APPLIED MATHEMATICS

The Department of Applied Mathematics in the College of Arts and Sciences offers a range of courses and research opportunities in many areas, including computational mathematics, mathematical biology, nonlinear phenomena, physical applied mathematics, and probability and statistics. Each of these areas is described below.

Course codes for this program include APPM and STAT.

Computational Mathematics

Computational mathematics encompasses the techniques that allow practitioners to approximate quantities via a computer. These techniques are used to do a wide range of things including simulations of physical phenomena, reducing the cost of product design and providing the basis of machine learning. Some applications include weather forecasting, optimal design of materials and simulating flight paths of rockets. This field continues to grow as computational resources and needs of users change. The fast developments in this area have allowed mathematicians to answer questions and develop insights not possible only 20-30 years ago. Modern computational methods require an in-depth knowledge of a variety of mathematical subjects which include linear algebra, analysis, ordinary and partial differential equations, asymptotic analysis, elements of harmonic analysis and nonlinear equations.

Since computers are invaluable tools for an applied mathematician, students are expected to attain a highly professional level of computer literacy, to program in a language such as Python, know how to maintain a Git repository and understand the basics of parallel computing.

Computational mathematics courses include the study of numerical linear algebra, numerical integration, approximation of functions, optimization, numerical solution of ordinary and partial differential equations, and solution of nonlinear equations. There are two advanced seminars related to this topic: computational mathematics and optimization.

Mathematical Biosciences

Recent advances in our ability to quantitatively study biological phenomena have provided a tremendous number of exciting opportunities for applied mathematicians. The careful modeling, analysis and simulation of these systems using the standard tools of applied mathematics has led to novel and non-intuitive insights into biology.

Furthermore, a deeper understanding of the inherently complex and multiscale nature of biological systems, in many cases, requires the development of new mathematical tools, techniques and methodologies (a challenge to which applied mathematics is particularly well suited). Research areas in APPM encompass cell migration, ecology, infectious diseases, neuroscience, population genetics and social systems, as well as data-driven methods in biology. For more information, see the Mathematical Biology Group (http://mathbio.colorado.edu/) webpage.

Mathematical Geosciences

Mathematical geosciences encompass quantitative modeling, analysis and simulation of all aspects of the Earth system. Our faculty's research intersects a broad range of geosciences: from the geodynamo to ocean circulation, from computational methods for seismic imaging to the impacts of weather on epidemiology, from tsunamis to stochastic weather generators. The complex and multiscale nature of geophysical systems, in many cases, requires the development of new mathematical models and simulation strategies, a challenge to which applied mathematics is particularly well suited.

Appropriate coursework includes analysis and computation, probability and statistics, as well as background courses in one of the sciences or engineering fields in which one intends to do research.

Applied Nonlinear PDEs and Dynamics

The Applied Mathematics Department's research in nonlinear PDEs and dynamics is intrinsically interdisciplinary, i.e., involves the study of mathematical problems with direct physical application. Physically inspired research problems invariably lead to complex nonlinear phenomena so that, in addition to mathematical analysis, their solution requires a deep understanding of the underlying application area, and often requires knowledge and experience in numerical computation. The faculty in Applied Mathematics specializing in this area of research generally work on problems in nonlinear waves, dynamical systems, partial differential equations and applications. Topics of interest include wave motion, solitons and traveling waves, dispersive shock waves, integrable systems, pattern formation, qualitative structure and bifurcation theory, dynamics on networks and transport phenomena. Application areas include numerous areas of physics (fluid dynamics, condensed matter, optics, plasma), biology (neural systems, ecology) and sociology (crime, social networks).

Courses in this field include dynamical systems, nonlinear waves and many advanced seminar courses. Research talks in this field are regularly offered in the Dynamics Seminar and the Nonlinear Waves Seminar.

Suitable background coursework includes analysis, numerical analysis, partial differential equations, mathematical modeling and methods of applied mathematics.

Physical Applied Mathematics

Physical applied mathematics is a term which generally refers to the study of mathematical problems with direct physical application. This area of research is intrinsically interdisciplinary. In addition to mathematical analysis, it requires a deep understanding of the underlying applications area, and usually requires knowledge and experience in numerical computation.

The department's affiliated faculty have a wide variety of expertise in various areas of application, e.g. atmospheric and fluid dynamics, theoretical physics, plasma physics, genetic structure, etc. The course requirements of the Program are designed to provide students with a foundation for their study (analysis and computation).

The department also requires supplemental courses in one of the science or engineering fields which are needed to begin doing thesis research in physical applied mathematics.

See the Dispersive Hydrodynamics Lab (https://www.colorado.edu/amath/dispersive-hydrodynamics-lab/) page, APPM's own fluid dynamics laboratory.

Statistics and Data Science

Statistics and data science are the studies of empirical inquiry. Statistical science focuses on the development of data analytic methods that are ubiquitous and applicable in all sciences, as well as the theoretical underpinnings supporting such approaches. Data science focuses on the application of such methods to data problems, including development

of implementations and associated studies of computational aspects. Of chief importance is the role of interdisciplinary research to solve scientifically impactful problems, which often motivate the need for new statistical methodology. Faculty members working in statistics and data science cover a breadth of expertise and domain knowledge including Bayesian computation, epidemiology, statistical climatology, statistics for energy science, signal processing and image analysis, networks, machine learning for physical systems, uncertainty quantification as well as the study of collaborative research.

Appropriate coursework includes statistics, probability, computation and mathematical analysis as well as background courses in one of the sciences or engineering fields in which one intends to do research.

Stochastic Processes and Applications

The Stochastic Processes and Applications (SPA) research group aims to develop and apply probabilistic tools to model, predict and analyze randomness in real-life phenomena. As such, SPA encompasses various areas of both theoretical and applied probability, including Bayesian networks, computational biology, computational probability, discrete probability, mathematical finance, Markov processes, Markov chain Monte Carlo (MCMC) algorithms, optimal stopping, stochastic control, stochastic differential equations and random graphs.

For more information on courses and research opportunities, visit the Department of Applied Mathematics website (http://www.colorado.edu/amath/).

Master's Degrees

- Applied Mathematics - Master of Science (MS) (https://catalog.colorado.edu/graduate/colleges-schools/arts-sciences/programs-study/applied-mathematics/applied-mathematics-master-science-ms/)
- Applied Mathematics - Professional Master of Science (MSAM) (https://catalog.colorado.edu/graduate/colleges-schools/arts-sciences/programs-study/applied-mathematics/applied-mathematics-professional-master-science-msam/)

Doctoral Degree

- Applied Mathematics - Doctor of Philosophy (PhD) (https://catalog.colorado.edu/graduate/colleges-schools/arts-sciences/programs-study/applied-mathematics/applied-mathematics-doctor-philosophy-phd/)

Faculty

While many faculty teach both undergraduate and graduate students, some instruct students at the undergraduate level only. For more information, contact the faculty member's home department.

Ablowitz, Mark J. (https://experts.colorado.edu/display/fisid_100691/)
Distinguished Professor; PhD, Massachusetts Institute of Technology

Appelö, Daniel E. (https://experts.colorado.edu/display/fisid_159438/)
Assistant Professor Adjunct; PhD, KTH Royal Institute of Technology (Sweden)

Bebernes, Jerrold (https://experts.colorado.edu/display/fisid_103560/)
Professor Emeritus

Becker, Stephen R. (https://experts.colorado.edu/display/fisid_154263/)
Associate Professor; PhD, California Institute of Technology

Benim, W. Robert (https://experts.colorado.edu/display/fisid_167716/)
Assistant Teaching Professor

Beylkin, Gregory (https://experts.colorado.edu/display/fisid_100437/)
Professor; PhD, New York University

Bhat, Yermal Sujeet (https://experts.colorado.edu/display/fisid_146506/)
Associate Teaching Professor; PhD, University of Florida

Bortz, David Matthew (https://experts.colorado.edu/display/fisid_143348/)
Professor; PhD, North Carolina State University

Chang, Silva (https://experts.colorado.edu/display/fisid_145582/)
Teaching Professor; MS, Yale University

Corcoran, Jem (https://experts.colorado.edu/display/fisid_118142/)
Associate Professor Emeritus; PhD, Colorado State University

Curry, James H. (https://experts.colorado.edu/display/fisid_105730/)
Professor; PhD, University of California, Berkeley

Dougherty, Anne Margaret (https://experts.colorado.edu/display/fisid_101349/)
Associate Chair, Teaching Professor; PhD, University of Wisconsin–Madison

Dukic, Vanja (https://experts.colorado.edu/display/fisid_148718/)
Professor; PhD, Brown University

Easton, Robert
Professor Emeritus

Fornberg, Bengt (https://experts.colorado.edu/display/fisid_108048/)
Professor Emeritus; PhD, University of Uppsala (Sweden)

Gillman, Adrianna (https://experts.colorado.edu/display/fisid_165224/)
Associate Professor; PhD, University of Colorado Boulder

Grooms, Ian G. (https://experts.colorado.edu/display/fisid_155588/)
Associate Professor; PhD, University of Colorado Boulder

Gunzburger, Max D. (https://experts.colorado.edu/individual/fisid_163681/)
Artist in Residence, Professor Adjoint; PhD, New York University

Hoefer, Mark (https://experts.colorado.edu/display/fisid_154264/)
Professor; PhD, University of Colorado Boulder

Huang, Yu-Jui (https://experts.colorado.edu/display/fisid_157746/)
Assistant Professor; PhD, University of Michigan Ann Arbor

Julien, Keith (https://experts.colorado.edu/display/fisid_108913/)
Chair, Professor; PhD, University of Cambridge (England)

Kilpatrick, Zachary Peter (https://experts.colorado.edu/display/fisid_155782/)
Associate Professor; PhD, University of Utah

Kleiber, William Paul (https://experts.colorado.edu/display/fisid_151943/)
Associate Professor; PhD, University of Washington

Li, Congming
Professor Emeritus

Lladser, Manuel E. (https://experts.colorado.edu/display/fisid_134170/)
Associate Professor; PhD, The Ohio State University

Manteuffel, Thomas A.
Professor Emeritus

Martinsson, Per-Gunnar (https://experts.colorado.edu/individual/fisid_141180/)
Visiting Professor

McCormick, Steven
Professor Emeritus

Mcnamara, Rich (https://experts.colorado.edu/display/fisid_167770/)
Lecturer

Meiss, James D. (https://experts.colorado.edu/display/fisid_103702/)
Professor; PhD, University of California, Berkeley

Meyer, Francois Georges (https://experts.colorado.edu/individual/fisid_115559/)
Professor; PhD, INRIA (France)

Mitchell, Colin
Lecturer

Nixon, Sean (https://experts.colorado.edu/display/fisid_167600/)
Instructor

Norris, Jan Adam (https://experts.colorado.edu/display/fisid_101412/)
Teaching Professor; PhD, University of Colorado Boulder

Pruitt, Kris
Associate Teaching Professor

Raissi, Maziar (https://experts.colorado.edu/individual/fisid_165748/)
Assistant Professor; PhD, University of Maryland, College Park

Restrepo, Juan G. (https://experts.colorado.edu/display/fisid_145811/)
Associate Professor; PhD, University of Maryland, College Park

Rodriguez, Nancy (https://experts.colorado.edu/display/fisid_164028/)
Assistant Professor; PhD, University of California-Los Angeles

Segur, Harvey (https://experts.colorado.edu/display/fisid_102287/)
Professor Emeritus; PhD, University of California, Berkeley

Sharma, Manjul
Instructor

Thaler, Eric R. (https://experts.colorado.edu/display/fisid_155505/)
Associate Teaching Professor; PhD, University of Colorado Boulder

Vance, Eric (https://experts.colorado.edu/display/fisid_158342/)
Associate Professor; PhD, Duke University

Zaharatos, Brian R. (https://experts.colorado.edu/display/fisid_156225/)
Teaching Professor, Faculty Director; PhD, Colorado School of Mines

Courses

APPM 5120 (3) Introduction to Operations Research
Studies linear and nonlinear programming, the simplex method, duality, sensitivity, transportation and network flow problems, some constrained and unconstrained optimization theory, and the Kuhn-Tucker conditions, as time permits.
Equivalent - Duplicate Degree Credit Not Granted: APPM 4120 and MATH 4120 and MATH 5120
Requisites: Restricted to graduate students only.
Recommended: Prerequisites APPM 3310 OR MATH 2130 OR MATH 2135 or equivalent.

APPM 5320 (3) Introduction to Dynamics on Networks
Introduces modern approaches to model and analyze dynamical processes on complex networks. Many dynamical processes such as epidemic propagation, opinion formation, synchronization, and cascading processes take place on complex social or technological networks. This course will introduce the tools to understand the interplay between network structure and the outcome of these dynamical processes. Previously offered as a special topics course.
Equivalent - Duplicate Degree Credit Not Granted: APPM 4320
Requisites: Restricted to graduate students only.
Grading Basis: Letter Grade

APPM 5350 (3) Methods in Applied Mathematics: Fourier Series and Boundary Value Problems
Department enforced prerequsite courses: APPM 2350 or MATH 2400 and APPM 2360 and a prerequisite or corequisite course: APPM 3310 or MATH 2130 or MATH 2135.
Equivalent - Duplicate Degree Credit Not Granted: APPM 4350
Requisites: Restricted to graduate students only.

APPM 5360 (3) Methods in Applied Mathematics: Complex Variables and Applications
Introduces methods of complex variables, contour integration and theory of residues. Applications include solving partial differential equations by transform methods, Fourier and Laplace transforms and Reimann-Hilbert boundary-value problems, conformal mapping to ideal fluid flow and/or electrostatics. Department enforced prerequisites: APPM 2350 or MATH 2400 and APPM 2360 and a prerequisite or corequisite course of APPM 3310 or MATH 3130 or MATH 3135.
Equivalent - Duplicate Degree Credit Not Granted: APPM 4360
Requisites: Restricted to graduate students only.

APPM 5370 (3) Computational Neuroscience
Applies mathematical and computational methods to neuroscience. Techniques from linear algebra, differential equations, introductory dynamical systems, probability, stochastic processes, model validation, and machine learning will be learned and used. Neuroscience topics include neural spiking, network dynamics, probabilistic inference, learning, and plasticity. Will learn how the brain uses computational principles to enact decision making, vision, and memory. Recommended background includes linear algebra, differential equations, probability, and programming. Students will hone programming skills in MATLAB/Python and TensorFlow.
Equivalent - Duplicate Degree Credit Not Granted: APPM 4370
Requisites: Restricted to graduate students only.
Recommended: Prerequisites APPM 2360 and APPM 3310 and STAT 4000 or equivalent courses.

APPM 5380 (3) Modeling in Applied Mathematics
An exposition of a variety of mathematical models arising in the physical and biological sciences. Students' modeling projects are presented in class. Topics may include: GPS navigation, medical imaging, ocean waves, and computerized facial recognition. Department enforced prerequisites: APPM 2350 or MATH 2400 and APPM 2360.
Equivalent - Duplicate Degree Credit Not Granted: APPM 4380
Requisites: Restricted to graduate students only.
Recommended: Prerequisites APPM 3310 and APPM 4350 and APPM 4650.

APPM 5390 (3) Modeling in Mathematical Biology
Investigates how complex systems in biology can be studied using applied mathematics. Examines several case studies which include topics from microbiology, enzyme reaction kinetics, neuroscience, ecology, epidemiology, physiology and bioengineering. Department enforced prerequisites: APPM 2360 and APPM 3310 or MATH 2130 or MATH 2135 or instructor consent required.
Equivalent - Duplicate Degree Credit Not Granted: APPM 4390
Requisites: Restricted to graduate students only.

APPM 5430 (3) Methods in Applied Mathematics: Applications of Complex Variables
Reviews basic ideas of complex analysis, including solutions of ODEs and PDEs of physical interest via complex analysis; conformal mapping, including Schwarz-Christoffel transformations and generalizations; computational methods; Riemann-Hilbert problems; topics in asymptotic methods. Department enforced prerequisite: APPM 4360 or APPM 5360.
Requisites: Restricted to graduate students only.

APPM 5440 (3) Applied Analysis 1
Discusses the elements of basic real and complex analysis, Banach spaces, Lp spaces and many relevant inequalities. Includes applications of existence and uniqueness of solutions to various types of ordinary differential equations, partial differential equations, and integral equations. Department enforced prerequisites: APPM 4440 and APPM 4450.
Requisites: Restricted to graduate students only.

APPM 5450 (3) Applied Analysis 2
Continuation of APPM 5440. Department enforced prerequisite: APPM 5440.
Requisites: Restricted to graduate students only.

APPM 5460 (3) Methods in Applied Mathematics: Dynamical Systems and Differential Equations
Introduces the theory and applications of dynamical systems through solutions to differential equations. Covers existence and uniqueness theory, local stability properties, qualitative analysis, global phase portraits, perturbation theory and bifurcation theory. Special topics may include Melnikov methods, averaging methods, bifurcations to chaos and Hamiltonian systems. Department enforced prerequisites: APPM 2360 and APPM 3310 and APPM 4440.
Requisites: Restricted to graduate students only.

APPM 5470 (3) Methods of Applied Mathematics: Partial Differential and Integral Equations
Studies properties and solutions of partial differential equations. Covers methods of characteristics, well-posedness, wave, heat and Laplace equations, Green's functions and related integral equations. Department enforced prerequisites: APPM 4350 or MATH 4470 and APPM 4360 or MATH 3450.
Requisites: Restricted to graduate students only.

APPM 5480 (3) Methods of Applied Mathematics: Approximation Methods
Covers asymptotic evaluation of integrals (stationary phase and steepest descent), perturbation methods (regular and singular methods, and inner and outer expansions), multiple scale methods and applications to differential and integral equations. Department enforced prerequisite: APPM 5470.
Requisites: Restricted to graduate students only.

APPM 5490 (3) Theory of Machine Learning
Presents the underlying theory behind machine learning in proofs-based format. Answers fundamental questions about what learning means and what can be learned via formal models of statistical learning theory. Analyzes some important classes of machine learning methods. Specific topics may include the PAC framework, VC-dimension and Rademacher complexity.
Recommended: Prerequisites APPM 4440 and CSCI 5622.

APPM 5510 (3) Data Assimilation in High Dimensional Dynamical Systems
Develops and analyzes approximate methods of solving the Bayesian inverse problem for high-dimensional dynamical systems. After briefly reviewing mathematical foundations in probability and statistics, the course covers the Kalman filter, particle filters, variational methods and ensemble Kalman filters. The emphasis is on mathematical formulation and analysis of methods.
Equivalent - Duplicate Degree Credit Not Granted: APPM 4510, STAT 4250 and STAT 5250
Requisites: Restricted to graduate students only.

APPM 5515 (3) High-Dimensional Probability for Data Science
Provides students with an exposition of the most recent methods of high-dimensional probability for the analysis of high dimensional datasets. Applications include randomized algorithms and high-dimensional random models of datasets.
Equivalent - Duplicate Degree Credit Not Granted: APPM 4515
Recommended: Prerequisites APPM 3310 and APPM 3570, or equivalent.

APPM 5530 (3) Stochastic Analysis for Finance
Studies mathematical theories and techniques for modeling financial markets. Specific topics include the binomial model, risk neutral pricing, stochastic calculus, connection to partial differential equations and stochastic control theory.
Equivalent - Duplicate Degree Credit Not Granted: APPM 4530, STAT 5230 and STAT 4230
Requisites: Restricted to graduate students only.
Recommended: Prerequisite previous coursework equivalent to that of APPM 3310 and one of APPM 3570, STAT 3100 or MATH 4510; all with minimum grade of C-.

APPM 5560 (3) Markov Processes, Queues, and Monte Carlo Simulations
Brief review of conditional probability and expectation followed by a study of Markov chains, both discrete and continuous time, including Poisson point processes. Queuing theory, terminology and single queue systems are studied with some introduction to networks of queues. Uses Monte Carlo simulation of random variables throughout the semester to gain insight into the processes under study.
Equivalent - Duplicate Degree Credit Not Granted: APPM 4560, STAT 4100 and STAT 5100
Requisites: Restricted to graduate students only.

APPM 5565 (3) Random Graphs
Introduces mathematical techniques, including generating functions, the first- and second-moment method and Chernoff bounds to study the most fundamental properties of the Erdos-Renyl model and other celebrated random graph models such as preferential attachment, fixed degree distribution, and stochastic block models.
Equivalent - Duplicate Degree Credit Not Granted: APPM 4565
Requisites: Restricted to graduate students only.
Grading Basis: Letter Grade

APPM 5590 (3) Statistical Modeling
Introduces methods, theory and applications of statistical models, from linear models (simple and multiple linear regression), to hierarchical linear models. Topics such as estimation, residual diagnostics, goodness of fit, transformations, and various strategies for variable selection and model comparison will be discussed in depth. Examples and exercises will be demonstrated using statistical software. Department enforced prerequisite: APPM 4570 or APPM 4520 or MATH 4520 or instructor consent required.
Equivalent - Duplicate Degree Credit Not Granted: APPM 4590
Requisites: Restricted to graduate students only.
Grading Basis: Letter Grade

APPM 5600 (3) Numerical Analysis 1
Solution of nonlinear algebraic equations, interpolation, integration, approximation, and numerical linear algebra. Department enforced prerequisite: APPM 3310 or MATH 2130 and experience with a scientific programming language.
Requisites: Restricted to graduate students only.

APPM 5610 (3) Numerical Analysis 2
Numerical linear algebra, eigenvalue problems, optimization problems, and ordinary and partial differential equations. Department enforced prerequisite: APPM 5600 or MATH 5600.
Requisites: Restricted to graduate students only.

APPM 5620 (3) Numerical Linear Algebra
Develops and analyzes methods for the solution of square nonsingular linear systems, linear least squares problems, eigenvalue problems, and rank estimation. Direct and iterative methods are covered, as well as methods for dense and sparse problems. Requires solid background in linear algebra and proficiency with scientific computing.
Requisites: Restricted to graduate students only.

APPM 5650 (3) Randomized Algorithms
Investigates modern randomized methods that are used in scientific and numerical computing, in particular randomized matrix approximation methods. Other topics may include stochastic gradient methods and variance reduced versions, compressed sensing, and locality sensitive hashing.
Equivalent - Duplicate Degree Credit Not Granted: STAT 5650
Requisites: Restricted to graduate students only.
Recommended: Prerequisite APPM 4440 or equivalent.

APPM 5720 (1-3) Open Topics in Applied Mathematics
Provides a vehicle for the development and presentation of new topics that may be incorporated into the core courses in applied mathematics. Department enforced prerequisite: variable, depending on the topic, see instructor.
Equivalent - Duplicate Degree Credit Not Granted: APPM 4720
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to graduate students only.

APPM 6470 (3) Advanced Partial Differential Equations
Continuation of APPM 5470. Advanced study of the properties and solutions of elliptic, parabolic, and hyperbolic partial differential equations. Topics include the study of Sobolev spaces and variational methods as they relate to PDEs, and other topics as time permits. Department enforced prerequisite: APPM 5470.
Requisites: Restricted to graduate students only.

APPM 6520 (3) Mathematical Statistics
Emphasizes mathematical theory of statistics. Topics include distribution theory, estimation and testing of hypotheses, multivariate analysis, and nonparametric inference, all with emphasis on theory. Department enforced prerequisite: APPM 5520 or MATH 5520.
Requisites: Restricted to graduate students only.

APPM 6550 (3) Introduction to Stochastic Processes
Systematic study of Markov chains and some of the simpler Markov processes including renewal theory, limit theorems for Markov chains, branching processes, queuing theory, birth and death processes, and Brownian motion. Applications to physical and biological sciences. Department enforced prerequisite: MATH 4001 or MATH 4510 or APPM 3570 or APPM 4560 or instructor consent.
Equivalent - Duplicate Degree Credit Not Granted: MATH 6550
Requisites: Restricted to graduate students only.

APPM 6560 (3) Measure-Theoretic Probability
Introduces a series of fundamental concepts and results in probability theory, using rigorous measure-theoretic language. Provides a solid foundation for further studies and research in probability, stochastic processes, statistics, and data science.
Requisites: Restricted to graduate students only.
Recommended: Prerequisites Undergraduate analysis at the level of APPM 4440.

APPM 6570 (3) Stochastic Differential Equations
Devoted to a comprehensive investigation of stochastic differential equations, as well as their important applications in Finance, Physics, and Engineering. Consists of three main topics: stochastic integration, the theory of stochastic differential equations (SDEs), and applications of SDEs.
Recommended: Prerequisite APPM 6560 or MATH/APPM 6550.

APPM 6610 (3) Introduction to Numerical Partial Differential Equations
Covers finite difference, finite element, finite volume, pseudo-spectral, and spectral methods for elliptic, parabolic, and hyperbolic partial differential equations. Department enforced prerequisite: APPM 5600.
Requisites: Restricted to graduate students only.
Recommended: Prerequisite APPM 5610 or graduate numerical linear algebra.

APPM 6640 (3) Multigrid Methods
Develops a fundamental understanding of the principles and techniques of the multigrid methodology, which is a widely used numerical approach for solving many problems in such diverse areas as aerodynamics, astrophysics, chemistry, electromagnetics, hydrology, medical imaging, meteorology/oceanography, quantum mechanics, and statistical physics.
Requisites: Restricted to graduate students only.

APPM 6900 (1-6) Independent Study
Introduces graduate students to research foci of the Department of Applied Mathematics.
Requisites: Restricted to graduate students only.

APPM 6930 (1-3) Professional Master's Culminating Experience
Provides an opportunity for an Applied Mathematics Professional Master¿s student to complete their Culminating Experience (CE) project with an advisor. Before enrolling, the student is expected to have an advisor who has agreed to guide a proposed CE project.
Requisites: Restricted to Applied Mathematics professional master's degree (AMEN-MSAM) students only.
Grading Basis: Letter Grade

APPM 6940 (1) Master's Candidate for Degree
Requisites: Restricted to graduate students only.

APPM 6950 (1-6) Master's Thesis
Repeatable: Repeatable for up to 6.00 total credit hours.
Requisites: Restricted to graduate students only.

APPM 7100 (3) Mathematical Methods in Dynamical Systems
Covers dynamical systems defined by mappings and differential equations. Hamiltonian mechanics, action-angle variables, results from KAM and bifurcation theory, phase plane analysis, Melnikov theory, strange attractors, chaos, etc.
Requisites: Requires prerequisite course of APPM 5460 (minimum grade D-). Restricted to graduate students only.

APPM 7300 (3) Nonlinear Waves and Integrable Equations
Includes basic results associated with linear dispersive wave systems, first-order nonlinear wave equations, nonlinear dispersive wave equations, solitons, and the methods of the inverse scattering transform. Department enforced prerequisites: APPM 4350 and APPM 4360.
Requisites: Restricted to graduate students only.

APPM 7400 (1-3) Topics in Applied Mathematics
Provides a vehicle for the development and presentation of new topics with the potential of being incorporated into the core courses in applied mathematics.
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to graduate students only.

APPM 7900 (1-3) Independent Study
Introduces graduate students to research foci of the Department of Applied Mathematics.
Requisites: Restricted to graduate students only.

APPM 8000 (1) Colloquium in Applied Mathematics
Introduces graduate students to the major research foci of the Department of Applied Mathematics.
Requisites: Restricted to Applied Mathematics (APPM) graduate students only.

APPM 8100 (1) Seminar in Dynamical Systems
Introduces advanced topics and research in dynamical systems.
Requisites: Restricted to Applied Mathematics (APPM) graduate students only.

APPM 8300 (1-3) Nonlinear Waves Seminar
Introduces the core methods in the analysis of nonlinear partial differential and integral equations or systems to graduate students. Provides a vehicle for the development, presentation, and corporative research of new topics in PDE and analysis.
Requisites: Requires prerequisite course of APPM 5440 (minimum grade D-). Restricted to Applied Mathematics (APPM) graduate students only.

APPM 8400 (1) Mathematical Biology Seminar
Introduces advanced topics and research in mathematical and computational biology. Instructor consent required.
Requisites: Restricted to graduate students only.
Grading Basis: Letter Grade

APPM 8500 (1) Statistics, Optimization and Machine Learning Seminar
Research-level seminar that explores the mathematical foundations of machine learning, in particular how statistics and optimization give rise to well-founded and efficient algorithms.
Requisites: Restricted to graduate students only.
Grading Basis: Letter Grade

APPM 8600 (1) Seminar in Computational Mathematics
Introduces advanced topics and research in computational mathematics.
Requisites: Restricted to Applied Mathematics (APPM) graduate students only.

APPM 8700 (1) Mathematical Geosciences Seminar
Research-level seminar that explores applications of mathematical and statistical modeling, analysis, and computation in the geosciences. Provides a vehicle for the development, presentation, and dissemination of new topics in the mathematical geosciences. Formerly offered as a special topics course.
Repeatable: Repeatable for up to 3.00 total credit hours.
Requisites: Restricted to graduate students only.
Grading Basis: Letter Grade

APPM 8990 (1-10) Doctoral Dissertation
All doctoral students must register for no fewer than 30 hours of dissertation credit as part of the requirements for the degree. No more than 10 credit hours may be taken in any one semester.
Repeatable: Repeatable for up to 30.00 total credit hours.
Requisites: Restricted to graduate students only.

STAT 5000 (3) Statistical Methods and Application I
Introduces exploratory data analysis, probability theory, statistical inference, and data modeling. Topics include discrete and continuous probability distributions, expectation, laws of large numbers, central limit theorem, statistical parameter estimation, hypothesis testing, and regression analysis. Considerable emphasis on applications in the R programming language.
Equivalent - Duplicate Degree Credit Not Granted: STAT 4000
Requisites: Restricted to graduate students only.
Grading Basis: Letter Grade

STAT 5010 (3) Statistical Methods and Applications II
Expands upon statistical techniques introduced in STAT 4000. Topics include modern regression analysis, analysis of variance (ANOVA), experimental design, nonparametric methods, and an introduction to Bayesian data analysis. Considerable emphasis on application in the R programming language.
Equivalent - Duplicate Degree Credit Not Granted: STAT 4010
Requisites: Requires prerequisite STAT 5000 (minimum grade C-)
Grading Basis: Letter Grade

STAT 5100 (3) Markov Processes, Queues, and Monte Carlo Simulations
Brief review of conditional probability and expectation followed by a study of Markov chains, both discrete and continuous time, including Poisson point processes. Queuing theory, terminology and single queue systems are studied with some introduction to networks of queues. Uses Monte Carlo simulation of random variables throughout the semester to gain insight into the processes under study.
Equivalent - Duplicate Degree Credit Not Granted: APPM 5560 and APPM 4560
Requisites: Restricted to graduate students only.
Recommended: Prerequisite previous coursework equivalent to that of APPM 3570 or STAT 3100 or MATH 4510, with a minimum grade of C-.

STAT 5230 (3) Stochastic Analysis for Finance
Studies mathematical theories and techniques for modeling financial markets. Specific topics include the binomial model, risk neutral pricing, stochastic calculus, connection to partial differential equations and stochastic control theory.
Equivalent - Duplicate Degree Credit Not Granted: APPM 4530, APPM 5530 and STAT 4230
Requisites: Restricted to graduate students only.
Recommended: Prerequisite previous coursework equivalent to that of APPM 3310 and one of APPM 3570, STAT 3100 or MATH 4510; all with minimum grade of C-.

STAT 5250 (3) Data Assimilation in High Dimensional Dynamical Systems
Develops and analyzes approximate methods of solving the Bayesian inverse problem for high-dimensional dynamical systems. After briefly reviewing mathematical foundations in probability and statistics, the course covers the Kalman filter, particle filters, variational methods and ensemble Kalman filters. The emphasis is on mathematical formulation and analysis of methods.
Equivalent - Duplicate Degree Credit Not Granted: APPM 4510 and APPM 5510
Requisites: Restricted to Graduate, Graduate Nondegree and non sponsored students only.

STAT 5400 (3) Advanced Statistical Modeling
Introduces methods, theory and applications of modern statistical models, from linear to hierarchical linear models, to generalized hierarchical linear models, including hierarchical logistic and hierarchical count regression models. Topics such as estimation, residual diagnostics, goodness of fit, transformations, and various strategies for variable selection and model comparison will be discussed in depth. Examples will be demonstrated using statistical programming language R.
Equivalent - Duplicate Degree Credit Not Granted: STAT 4400
Requisites: Restricted to graduate students only.
Recommended: Prerequisite previous coursework equivalent to one of STAT 3400 or STAT 4010 or STAT 5010 and one of STAT 4520 or STAT 5520 or STAT 5530; all with a minimum grade of C-.
Grading Basis: Letter Grade

STAT 5430 (3) Spatial Statistics
Introduces the theory of spatial statistics with applications. Topics include basic theory for continuous stochastic processes, spatial prediction and kriging, simulation, geostatistical methods, likelihood and Bayesian approaches, spectral methods and an overview of modern topics such as nonstationary models, hierarchical modeling, multivariate processes, methods for large datasets and connections to spines.
Equivalent - Duplicate Degree Credit Not Granted: STAT 4430
Requisites: Restricted to graduate students only.
Recommended: Prerequisite previous coursework equivalent to one of STAT 3400 or STAT 4010 or STAT 5010 and one of STAT 4520 or STAT 5520 or STAT 5530; all with a minimum grade of C-.

STAT 5520 (3) Introduction to Mathematical Statistics
Examines point and confidence interval estimation. Principles of maximum likelihood, sufficiency, and completeness: tests of simple and composite hypotheses, linear models, and multiple regression analysis if time permits. Analyzes various distribution-free methods. Department enforced prerequisite: one semester calculus-based probability course, such as MATH 4510 or APPM 3570.
Equivalent - Duplicate Degree Credit Not Granted: STAT 4520 and MATH 4520 and MATH 5520
Requisites: Restricted to graduate students only.
Recommended: Prerequisite previous coursework equivalent to APPM 3570 or STAT 3100 or MATH 4510; minimum grade of C- for all.

STAT 5530 (3) Mathematical Statistics
Covers the theory of estimation, confidence intervals, hypothesis testing, and decision theory. In particular, it covers the material of APPM 5520 in greater depth, especially the topics of optimality and asymptotic approximation. Additional topics include M-estimation, minimax tests, the EM algorithm, and an introduction to Bayesian estimation and empirical likelihood techniques. Recommended Prerequisite is a one-semester calculus-based probability course such as MATH 4510 or APPM 3570.
Equivalent - Duplicate Degree Credit Not Granted: STAT 5520 or MATH 5520 or STAT 4520 or MATH 4520
Requisites: Restricted to graduate students only.

STAT 5540 (3) Introduction to Time Series
Studies basic properties, trend-based models, seasonal models modeling and forecasting with ARIMA models, spectral analysis and frequency filtration. Department enforced prerequisite: APPM 5520 or MATH 5520.
Equivalent - Duplicate Degree Credit Not Granted: STAT 4540 and MATH 4540 and MATH 5540
Requisites: Restricted to graduate students only.
Recommended: Prerequisite previous coursework equivalent to STAT 4520 or MATH 4520 or STAT 5520 or MATH 5520; minimum grade of C- for all.

STAT 5600 (3) Methods in Statistical Learning
Provides an introduction to methods in the field of statistical learning. Topics include a review of multiple regression, assessing model accuracy, classification, resampling methods, model selection and regularization, nonlinear regression, tree-based methods, support vector machines and unsupervised learning. Involves hands-on data analysis using the R programming language.
Requisites: Requires prerequisite course of STAT 5010 (minimum grade C-). Restricted to MS-DS students.

STAT 5610 (3) Statistical Learning
Consists of applications and methods of statistical learning. Reviews multiple linear regression and then covers classification, regularization, splines, tree-based methods, support vector machines, unsupervised learning and Gaussian process regression.
Equivalent - Duplicate Degree Credit Not Granted: STAT 4610
Requisites: Restricted to graduate students only.
Recommended: Prerequisite previous coursework equivalent to that of STAT 3400 or STAT 4010 or STAT 5010; minimum C- grade for all.

STAT 5630 (3) Computational Bayesian Statistics
Introduces Bayesian statistics, normal and non-normal approximation to likelihood and posteriors, the EM algorithm, data augmentation, and Markov Chain Monte Carlo (MCMC) methods. Additionally, introduces more advanced MCMC algorithms and requires significant statistical computing. Examples from a variety of areas, including biostatistics, environmental sciences, and engineering, will be given throughout the course.
Equivalent - Duplicate Degree Credit Not Granted: STAT 4630
Requisites: Requires prerequisite courses of (STAT 5520 or MATH 5520 or STAT 5530) and (APPM 5560 or STAT 5100 or APPM 6550 or MATH 6550) (all minimum grade C-).
Recommended: Prerequisite prior programming and basic statistical modeling experience is required.

STAT 5650 (3) Randomized Algorithms
Investigates modern randomized methods that are used in scientific and numerical computing, in particular randomized matrix approximation methods. Other topics may include stochastic gradient methods and variance reduced versions, compressed sensing, and locality sensitive hashing.
Equivalent - Duplicate Degree Credit Not Granted: APPM 5650
Requisites: Restricted to graduate students only.
Recommended: Prerequisite APPM 4440 or equivalent.

STAT 5680 (3) Statistical Collaboration
Educates and trains students to become effective interdisciplinary collaborators by developing the communication and collaboration skills necessary to apply technical statistics and data science skills to help domain experts answer research questions. Topics include structuring effective meetings and projects; communicating statistics to non-statisticians; using peer feedback, self-reflection and video analysis to improve collaboration skills; creating reproducible statistical workflows; working ethically.
Equivalent - Duplicate Degree Credit Not Granted: STAT 4680
Requisites: Restricted to graduate students only.
Recommended: Prerequisite undergraduate statistics courses equivalent to STAT 4400 (minimum grade C-) or STAT 4010 (minimum grade C-) or Instructor's approval.
Grading Basis: Letter Grade

STAT 5690 (2) Advanced Statistical Collaboration
Educates and trains students to become advanced interdisciplinary collaborators by developing and refining the communication, collaboration and technical statistics and data science skills necessary to collaborate with domain experts to answer research questions. Students work on multiple projects. Discussions center on technical skills necessary to solve research problems and video analysis to improve communication and collaboration skills.
Equivalent - Duplicate Degree Credit Not Granted: STAT 4690
Requisites: Requires prerequisite course of STAT 4680 or STAT 5680 (minimum grade C-). Restricted to graduate students only.
Grading Basis: Letter Grade

STAT 5700 (3) Philosophical and Ethical Issues in Statistics
Introduces students to philosophical issues that arise in statistical theory and practice. Topics include interpretations of probability, philosophical paradigms in statistics, inductive inference, causality, reproducible, and ethical issues arising in statistics and data analysis.
Equivalent - Duplicate Degree Credit Not Granted: STAT 4700
Requisites: Restricted to graduate students only.
Recommended: Prerequisite previous coursework equivalent to STAT 3400 or STAT 4000 or STAT 4520 or STAT 5000 or STAT 5520 or STAT 5530; minimum grade C- for all.
Grading Basis: Letter Grade