APPLIED MATHEMATICS

Applied mathematics graduates have the expertise and mathematical sophistication necessary to make contributions in a wide variety of fields, including scientific computation, actuarial science, financial modeling and most areas of science and engineering that have a mathematical basis.

A professional applied mathematician may work with engineers, scientists, programmers and other specialists. The curriculum at CU Boulder is designed to have the breadth for such an interdisciplinary career.

Course offerings at the undergraduate level focus on providing students with mathematical tools, problem-solving strategies and expertise useful in science and engineering. To fulfill requirements, a concentrated area of engineering courses (or approved natural science courses) must be completed. The college has formulated several recommended options within the discipline.

The Department of Applied Mathematics offers a BS degree in applied mathematics through the College of Engineering & Applied Science. The BS degree is designed to prepare graduates for exciting and diverse professional careers, and for graduate study in a wide variety of disciplines. A minor in applied mathematics (catalog.colorado.edu/undergraduate/colleges-schools/arts-sciences/programs-study/applied-mathematics/) and a minor in statistics (catalog.colorado.edu/undergraduate/colleges-schools/arts-sciences/programs-study/applied-mathematics/statistics-minor/) are offered through the College of Arts & Sciences.

The objectives of the Department of Applied Mathematics at CU Boulder are summarized below:

- provide undergraduate and graduate students with high-quality education and training in applied mathematics, and prepare them for careers in industry, laboratories and the academic professions;
- offer and monitor degree programs leading to BS, MS and PhD degrees in applied mathematics;
- nourish and maintain a professional environment in which excellence in teaching, learning, scholarship and creativity are of central importance;
- assure teaching and research expertise in a number of key areas of applied mathematics, including the methodology of applied mathematics, computational mathematics and algorithms, industrial applications, mathematical biology, applied probability and statistics.

Courses at the undergraduate level provide training in a broad range of mathematical techniques and problem-solving strategies. These courses teach the concepts and methods central to applications of linear algebra, ordinary and partial differential equations, numerical analysis, probability and statistics, complex variables and nonlinear dynamics. Since applied mathematicians often are involved in interdisciplinary work, the BS degree requires an in-depth knowledge of some area of science or engineering where mathematics is used. This knowledge prepares graduates to successfully communicate and cooperate with engineers and scientists. The BS degree also requires knowledge of a programming language and skill in using the computer.

Course code for this program is APPM.

Desired Outcomes

The undergraduate degree in applied mathematics emphasizes knowledge and awareness of:

- differential and integral calculus in one and several variables;
- vector spaces and matrix algebra;
- ordinary and partial differential equations;
- at least one programming language;
- at least one application software package in either mathematics or statistics;
- methods of complex variables as used in applications; and
- numerical solutions of linear and nonlinear problems.

In addition, students completing a degree in applied mathematics acquire:

- an in-depth knowledge of an area of application (an engineering discipline or a natural science field or one of the quantitative areas of business and economics);
- knowledge of problem-formulation, problem-solving and modeling techniques, and strategies central to applications; and
- the ability to communicate analytic arguments clearly and concisely in oral and written forms.

Bachelor's Degree

- Applied Mathematics - Bachelor of Science (BSAM) (catalog.colorado.edu/undergraduate/colleges-schools/engineering-applied-science/programs-study/applied-mathematics/applied-mathematics-bachelor-science-bsam/)

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/)
Professor; PhD, Massachusetts Institute of Technology

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

Bebernes, Jerrold
Professor Emeritus

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

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

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

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

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

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

Corcoran, Jem (https://experts.colorado.edu/display/fisid_118142/)
Associate Professor; 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, Senior Instructor; 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; PhD, University of Uppsala (Sweden)

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

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

Gunzburger, Max D.
Artist in Residence; PhD, New York University

Hoefer, Mark (https://experts.colorado.edu/display/fisid_154264/)
Associate 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

Kish, Jonathan
Instructor; PhD, University of Colorado Boulder

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

Law, Judith
Instructor; PhD, The University of Maryland, College Park

Li, Congming
Professor Emeritus

Lindsey, Daniel Seneca
Lecturer; PhD, University of California, Irvine

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
Visiting Professor

McCormick, Steven
Professor Emeritus

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

Meyer, Francois Georges
Professor; PhD, INRIA (France)

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

Onyejekwe, Osita Eluemuno (https://experts.colorado.edu/display/fisid_164235/)
Instructor; PhD, Florida Institute of Technology

Oscamou, Maribeth B. (https://experts.colorado.edu/display/fisid_159794/)
Instructor; MS, University of Colorado Boulder

Raissi, Maziar
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

Rumanov, Igor E.
Lecturer; PhD, Moscow Institute of Physics and Technology

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

Thaler, Eric R. (https://experts.colorado.edu/display/fisid_155505/)
Instructor; 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/)
Senior Instructor; PhD, Colorado School of Mines

Courses

APPM 1235 (4) Pre-Calculus for Engineers
Prepares students for the challenging content and pace of the calculus sequence required for all engineering majors. Covers algebra, trigonometry and selected topics in analytical geometry. Prepares students for the calculus courses offered for engineering students. Requires students to engage in rigorous work sessions as they review topics that they must be comfortable with to pursue engineering course work. Structured to accustom students to the pace and culture of learning encountered in engineering math courses. For more information about the math placement referred to in the "Enrollment Requirements", please contact your academic advisor. Formerly GEEN 1235.
Equivalent - Duplicate Degree Credit Not Granted: MATH 1021 or MATH 1150
Requisites: Requires an ALEKS math exam taken in 2016 or earlier, or placement into pre-calculus based on your admissions data and/or CU Boulder coursework.

APPM 1236 (1) Precalculus Work Group
Develops and enhances problem solving skills for students enrolled in APPM 1235. Course is conducted in a collaborative learning environment with students working in groups under the guide of a facilitator.
Requisites: Requires enrollment in corequisite course of APPM 1235.
Grading Basis: Pass/Fail

APPM 1340 (4) Calculus 1 with Algebra, Part A
Studies selected topics in analytical geometry and calculus: rates of change of functions, limits, derivatives and their applications. This course and APPM 1345 together are equivalent to APPM 1350. The sequence of this course and APPM 1345 is specifically designed for students whose manipulative skills in the techniques of high school algebra and precalculus may be inadequate for APPM 1350. For more information about the math placement referred to in the "Enrollment Requirements", please contact your academic advisor.
Requisites: Requires prerequisite course of APPM 1235 or MATH 1021 or MATH 1150 or MATH 1160 (minimum grade C-) or an ALEKS math exam taken in 2016 or earlier, or placement into pre-calculus based on your admissions data and/or CU Boulder coursework.
Additional Information: Arts Sci Gen Ed: Quantitative Reasoning Math

APPM 1345 (4) Calculus 1 with Algebra, Part B
Continuation of APPM 1340. Studies selected topics in calculus: derivatives and their applications, integration, differentiation and integration of transcendental functions. Algebraic and trigonometric topics are studied throughout, as needed.
Equivalent - Duplicate Degree Credit Not Granted: APPM 1350 or ECON 1088 or MATH 1081 or MATH 1300 or MATH 1310 or MATH 1330
Requisites: Requires prerequisite course of APPM 1340 (minimum grade C-).

APPM 1350 (4) Calculus 1 for Engineers
Topics in analytical geometry and calculus including limits, rates of change of functions, derivatives and integrals of algebraic and transcendental functions, applications of differentiations and integration. Students who have already earned college credit for calculus 1 are eligible to enroll in this course if they want to solidify their knowledge base in calculus 1. For more information about the math placement referred to in the "Enrollment Requirements", contact your academic advisor.
Equivalent - Duplicate Degree Credit Not Granted: APPM 1345 or ECON 1088 or MATH 1081 or MATH 1300 or MATH 1310 or MATH 1330
Requisites: Requires prerequisite course of APPM 1235 or MATH 1021 or MATH 1150 or MATH 1160 or MATH 1300 (minimum grade C-) or an ALEKS math exam taken in 2016 or earlier, or placement into calculus based on your admissions data and/or CU Boulder coursework.
Additional Information: GT Pathways: GT-MA1 - Mathematics
Arts Sci Core Curr: Quant Reasn Mathmat Skills
Arts Sci Gen Ed: Quantitative Reasoning Math

APPM 1351 (1) Calculus 1 Work Group
Provides problem-solving assistance to students enrolled in APPM 1350. Student groups work in collaborative learning environment. Student participation is essential.
Repeatable: Repeatable for up to 2.00 total credit hours.
Requisites: Requires enrollment in corequisite course of APPM 1350 or APPM 1345.
Grading Basis: Pass/Fail

APPM 1360 (4) Calculus 2 for Engineers
Continuation of APPM 1350. Focuses on applications of the definite integral, methods of integration, improper integrals, Taylor's theorem, and infinite series.
Equivalent - Duplicate Degree Credit Not Granted: MATH 2300
Requisites: Requires prerequisite course of APPM 1345 or APPM 1350 or MATH 1300 (minimum grade C-).

APPM 1361 (1) Calculus 2 Work Group
Provides problem solving assistance for students enrolled in APPM 1360. Conducted in a collaborative learning environment. Student work groups solve calculus problems with assistance of facilitator.
Requisites: Requires enrollment in corequisite course of APPM 1360.
Grading Basis: Pass/Fail

APPM 1390 (1) A Game for Calculus
Coaches students to implement study strategies geared specifically toward APPM Calculus in a structured, supportive, small group environment. Department consent required.
Repeatable: Repeatable for up to 3.00 total credit hours.

APPM 1650 (4) Python for Mathematical and Statistical Applications
Uses Python to teach the fundamentals of computer programming with an emphasis on mathematical and statistical applications. Topics will include data types, data structures, iteration, visualization, and simulations. Techniques covered will be applicable to many scientific and technical fields. No prior programming experience is required.
Requisites: Requires prerequisite or corequisite courses of APPM 1350 or APPM 1345 or MATH 1300 or MATH 1310 (all minimum grade C-).

APPM 2340 (4) Calculus 3 for Statistics and Data Science
Covers vectors and vector analysis, partial derivatives and the multivariable Taylor theorem, and multiple integrals. Introduces matrices and statistical applications.
Requisites: Requires prerequisite courses APPM 1360 or MATH 2300 (both minimum grade C-).

APPM 2350 (4) Calculus 3 for Engineers
Covers multivariable calculus, vector analysis, and theorems of Gauss, Green, and Stokes.
Equivalent - Duplicate Degree Credit Not Granted: MATH 2400
Requisites: Requires prerequisite course of APPM 1360 or MATH 2300 (minimum grade C-).

APPM 2351 (1) Calculus 3 Work Group
Provides problem solving assistance to students enrolled in APPM 2350. Conducted in a collaborative learning environment. Student work groups solve calculus problems with the assistance of a facilitator.
Requisites: Requires enrollment in corequisite course of APPM 2350.
Grading Basis: Pass/Fail

APPM 2360 (4) Introduction to Differential Equations with Linear Algebra
Introduces ordinary differential equations, systems of linear equations, matrices, determinants, vector spaces, linear transformations, and systems of linear differential equations.
Equivalent - Duplicate Degree Credit Not Granted: both MATH 2130 and MATH 3430
Requisites: Requires prerequisite course of APPM 1360 or MATH 2300 (minimum grade C-).

APPM 2450 (1) Calculus 3 Computer Lab
Selected topics in analytic geometry and calculus with a focus on symbolic computation using Mathematica.
Requisites: Requires a corequisite course of APPM 2350.
Grading Basis: Pass/Fail

APPM 2460 (1) Differential Equations Computer Lab
Selected topics in differential equations and linear algebra with a focus on symbolic computation using MATLAB.
Requisites: Requires enrollment in a corequisite course of APPM 2360.
Grading Basis: Pass/Fail

APPM 2720 (1-3) Open Topics in Lower Division Applied Mathematics
Provides a vehicle for the development and presentation of new topics that are accessible to lower division Applied Mathematics students. These topics have the potential to be incorporated into the core APPM curriculum.
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Requisites: Requires prerequisite course of APPM 1350 or MATH 1300 (minimum grade C-).
Grading Basis: Letter Grade

APPM 2750 (4) Java: Training, Mathematical Algorithms, and Mobile Apps
Preparatory course for Java programming. Provides necessary background for Java language: basic object-oriented concepts, analysis, and design. Learn to create Java applets, applications and mobile apps, create graphic context, and identify the key features of Java foundation classes as well as other Java-related technology. Material is taught in the context of mathematical algorithms from calculus. Department enforced requisite, knowledge of a programming language.
Requisites: Requires prerequisite course of APPM 1350 or MATH 1300 (minimum grade C-).

APPM 3010 (3) Chaos in Dynamical Systems
Introduces undergraduate students to chaotic dynamical systems. Topics include smooth and discrete dynamical systems, bifurcation theory, chaotic attractors, fractals, Lyapunov exponents, synchronization and networks of dynamical systems. Applications to engineering, biology and physics will be discussed.
Requisites: Requires prerequisite course of APPM 2360 or MATH 3430 (minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

APPM 3050 (3) Scientific Computing in Matlab
Topics covered include: approximations in computing, computer arithmetic, interpolation, matrix computations, nonlinear equations, optimization, and initial-value problems with emphasis on the computational cost, efficiency, and accuracy of algorithms. The problem sets are application-oriented with examples taken from orbital mechanics, physics, genetics, and fluid dynamics.
Requisites: Requires prerequisite course of APPM 2360 or MATH 3430 (minimum grade C-).

APPM 3170 (3) Discrete Applied Mathematics
Introduces students to ideas and techniques from discrete mathematics that are widely used in science and engineering. Mathematical definitions and proofs are emphasized. Topics include formal logic notation, proof methods; set theory, relations; induction, well-ordering; algorithms, growth of functions and complexity; integer congruences; basic and advanced counting techniques, recurrences and elementary graph theory. Other selected topics may also be covered.
Requisites: Requires a prerequisite of APPM 1360 or MATH 2300 (all minimum grade C-).

APPM 3310 (3) Matrix Methods and Applications
Introduces linear algebra and matrices with an emphasis on applications, including methods to solve systems of linear algebraic and linear ordinary differential equations. Discusses vector space concepts, decomposition theorems, and eigenvalue problems.
Equivalent - Duplicate Degree Credit Not Granted: MATH 2130 and MATH 2135
Requisites: Requires prerequisite course of APPM 2350 or APPM 2360 or MATH 2400 (minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

APPM 3350 (3) Advanced Engineering Calculus
Extends the treatment of engineering mathematics beyond the topics covered in Calculus 3 and differential equations. Topics include non-dimensionalization, elementary asymptotics and perturbation theory, Reynold's transport theorem and extensions of Leibnitz's rule, as applied to continuum conservation equations, Hamiltonian formulations, Legendre and Laplace transforms, special functions and their orthogonality properties.
Requisites: Requires prerequisite course of APPM 2350 or MATH 2400 and APPM 2360 (all minimum grade C-).

APPM 3570 (3) Applied Probability
Studies axioms, counting formulas, conditional probability, independence, random variables, continuous and discrete distribution, expectation, joint distributions, moment generating functions, law of large numbers and the central limit theorem.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 3810 or MATH 4510 STAT 3100
Requisites: Requires a prerequisite or corequisite course of APPM 2350 or MATH 2400 (prereq minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

APPM 4120 (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 5120 and MATH 4120 and MATH 5120
Requisites: Requires a prerequisite course of APPM 3310 or MATH 2130 or MATH 2135 (minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

APPM 4320 (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 5320
Requisites: Requires prerequisite courses of APPM 2360 and APPM 3310 (all minimum grade C-).
Grading Basis: Letter Grade

APPM 4350 (3) Methods in Applied Mathematics: Fourier Series and Boundary Value Problems
Reviews ordinary differential equations, including solutions by Fourier series. Physical derivation of the classical linear partial differential equations (heat, wave, and Laplace equations). Solution of these equations via separation of variables, with Fourier series, Fourier integrals, and more general eigenfunction expansions.
Equivalent - Duplicate Degree Credit Not Granted: APPM 5350
Requisites: Requires prerequisite courses of APPM 2350 or MATH 2400 and APPM 2360 (all minimum grade C-) and a prerequisite or corequisite course of APPM 3310 or MATH 3130 or MATH 3135 (prereq minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

APPM 4360 (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.
Equivalent - Duplicate Degree Credit Not Granted: APPM 5360
Requisites: Requires prerequisite courses of APPM 2350 or MATH 2400 and APPM 2360 (all minimum grade C-) and a prerequisite or corequisite course of APPM 3310 or MATH 3130 or MATH 3135 (prereq minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

APPM 4370 (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 5370
Requisites: Requires prerequisite courses of APPM 2360 and APPM 3310 (all minimum grade C-).
Recommended: Prerequisite APPM 3570/STAT 3100, STAT 2600 or CSCI 3022.
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

APPM 4380 (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.
Equivalent - Duplicate Degree Credit Not Granted: APPM 5380
Requisites: Requires prerequisite courses of APPM 2350 or MATH 2400 and APPM 2360 (all minimum grade C-).
Recommended: Prerequisites APPM 3310 and APPM 4350 and APPM 4650.
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

APPM 4390 (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.
Equivalent - Duplicate Degree Credit Not Granted: APPM 5390
Requisites: Requires prerequisite courses of APPM 2360 and APPM 3310 or MATH 3130 or MATH 3135 (all minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

APPM 4440 (3) Undergraduate Applied Analysis 1
Provides a rigorous treatment of topics covered in Calculus 1 and 2. Topics include convergent sequences; continuous functions; differentiable functions; Darboux sums, Riemann sums, and integration; Taylor and power series and sequences of functions.
Requisites: Requires prerequisite courses of APPM 2350 or MATH 2400 and APPM 2360 (all minimum grade C-) and a prerequisite or corequisite course of APPM 3310 or MATH 3130 or MATH 3135 (prereq minimum grade C-).

APPM 4450 (3) Undergraduate Applied Analysis 2
Continuation of APPM 4440. Study of multidimensional analysis including n-dimensional Euclidean space, continuity and uniform continuity of functions of several variables, differentiation, linear and nonlinear approximation, inverse function and implicit function theorems, and a short introduction to metric spaces.
Requisites: Requires prerequisite course of APPM 4440 or MATH 3001 (minimum grade C-).

APPM 4490 (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.
Requisites: Requires prerequisite course of APPM 4440 (minimum grade C-).
Recommended: Prerequisite CSCI 5622 (minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

APPM 4510 (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 5510, STAT 4250 and STAT 5250
Requisites: Requires prerequisite courses of APPM 3310 and APPM 3570 or STAT 3100 or MATH 4510 (all minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

APPM 4515 (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 5515
Requisites: Requires prerequisite courses of APPM 3310 and APPM 3570 (minimum grade C-).

APPM 4530 (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 5530, STAT 4230 and STAT 5230
Requisites: Requires prerequisite courses of APPM 3310 and APPM 3570, or STAT 3100, or MATH 4510 (all minimum grade C-).

APPM 4560 (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 STAT 4100
Requisites: Requires prerequisite courses of APPM 3570 or STAT 3100 or MATH 4510 (all minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

APPM 4565 (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 5565
Requisites: Requires prerequisite APPM 3570 or MATH 4510 (both minimum grade C).

APPM 4570 (3) Statistical Methods
Covers basic statistical concepts with accompanying introduction to the R programming language. Topics include discrete and continuous probability laws, random variables, expectation and variance, central limit theorem, testing hypothesis and confidence intervals, linear regression analysis, simulations for validation of statistical methods and applications of methods in R.
Equivalent - Duplicate Degree Credit Not Granted: APPM 5570
Requisites: Requires prerequisite course of APPM 1360 or MATH 2300 (minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

APPM 4590 (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.
Equivalent - Duplicate Degree Credit Not Granted: APPM 5590
Requisites: Requires prerequisite course of APPM 4520 or APPM 4570 or MATH 4520 (minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

APPM 4650 (3) Intermediate Numerical Analysis 1
Focuses on numerical solution of nonlinear equations, interpolation, methods in numerical integration, numerical solution of linear systems, and matrix eigenvalue problems. Stresses significant computer applications and software. Department enforced prerequisite: knowledge of a programming language.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4650
Requisites: Requires a prerequisite course of MATH 3430 or APPM 2360 and APPM 3310 (minimum grade C-).

APPM 4660 (3) Intermediate Numerical Analysis 2
Continuation of APPM 4650. Examines numerical solution of initial-value problems and two-point boundary-value problems for ordinary differential equations. Also looks at numerical methods for solving partial differential equations. Department enforced prerequisite: knowledge of a programming language.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4660
Requisites: Requires prerequisite course of APPM 4650 or MATH 4650 (minimum grade C-).

APPM 4720 (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 5720
Repeatable: Repeatable for up to 15.00 total credit hours. Allows multiple enrollment in term.

APPM 4840 (1-3) Reading and Research in Applied Mathematics
Introduces undergraduate students to the research foci of the Department of Applied Mathematics. Department enforced prerequisite: variable depending on the topic.
Repeatable: Repeatable for up to 9.00 total credit hours.

APPM 4950 (1-3) Seminar in Applied Mathematics
Introduces undergraduate students to the research foci of the program in applied mathematics. It is also designed to be a capstone experience for the program's majors. Department enforced prerequisite: variable depending on the topic.
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.

STAT 2600 (4) Introduction to Data Science
Introduces students to importing, tidying, exploring, visualizing, summarizing, and modeling data and then communicating the results of these analyses to answer relevant questions and make decisions. Students will learn how to program in R using reproducible workflows. During weekly lab sessions students will collaborate with their teammates to pose and answer questions using real-world datasets.
Requisites: Requires prerequisite of APPM 1350 or MATH 1300 (both require minimum grade C-).
Grading Basis: Letter Grade

STAT 3100 (3) Applied Probability
Studies axioms, counting formulas, conditional probability, independence, random variables, continuous and discrete distribution, expectation, joint distributions, moment generating functions, law of large numbers and the central limit theorem.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 3810 or MATH 4510 APPM 3570
Requisites: Requires a prerequisite or corequisite course of APPM 2350 or MATH 2400 (prereq minimum grade C-).

STAT 3400 (3) Applied Regression
Introduces methods, theory, and applications of linear statistical models, covering topics such as estimation, residual diagnostics, goodness of fit, transformations, and various strategies for variable selection and model comparison. Examples will be demonstrated using statistical programming language R.
Requisites: Requires prerequisite STAT 2600 and STAT 3100 or MATH 4510 (all minimum grade C-). Requires corequisite APPM 3310.
Grading Basis: Letter Grade

STAT 4000 (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 5000
Requisites: Requires prerequisite APPM 1360 or MATH 2300 (both minimum grade C-).
Grading Basis: Letter Grade

STAT 4010 (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 5010
Requisites: Requires prerequisite STAT 4000 (minimum grade C-).
Grading Basis: Letter Grade

STAT 4100 (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 and APPM 5560
Requisites: Requires prerequisite courses of APPM 3570 or STAT 3100 or MATH 4510 (all minimum grade C-).

STAT 4230 (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 5230
Requisites: Requires prerequisite courses of APPM 3310 and APPM 3570, or STAT 3100, or MATH 4510 (all minimum grade C-).

STAT 4250 (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 5510, APPM 4510 and STAT 5250
Requisites: Requires prerequisite courses of APPM 3310 and APPM 3570 or STAT 3100 or MATH 4510 (all minimum grade C-).

STAT 4400 (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.
Requisites: Requires prerequisite STAT 3400 and (STAT 4520 or STAT 5010) (all minimum grade C-).
Grading Basis: Letter Grade

STAT 4430 (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 5430
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

STAT 4520 (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.
Equivalent - Duplicate Degree Credit Not Granted: STAT 5520 and MATH 4520 and MATH 5520
Requisites: Requires prerequisites APPM 3570 or STAT 3100 or MATH 4510 (all minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

STAT 4540 (3) Introduction to Time Series
Studies basic properties, trend-based models, seasonal models modeling and forecasting with ARIMA models, spectral analysis and frequency filtration.
Equivalent - Duplicate Degree Credit Not Granted: STAT 5540 and MATH 4540 and MATH 5540
Requisites: Requires prerequisite course of APPM 4520 or STAT 4520 or MATH 4520 (minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

STAT 4610 (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 5610
Requisites: Requires prerequisite course of STAT 3400 (minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

STAT 4630 (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 5630
Requisites: Requires prerequisite courses of (APPM 4560 or STAT 4100) and STAT 3400 and (STAT 4520 or MATH 4520) (minimum grade C-).
Recommended: Prerequisite prior programming experience.

STAT 4680 (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 5680
Requisites: Requires a prerequisite course of STAT 4520 or MATH 4520 (minimum grade C-).
Grading Basis: Letter Grade
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

STAT 4690 (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 5690
Requisites: Requires prerequisite course of STAT 4680 or STAT 5680 (minimum grade C-).
Grading Basis: Letter Grade
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

STAT 4700 (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 5700
Requisites: Requires prerequisites STAT 4520 or STAT 3400 or STAT 4000 (all minimum grade C-).
Grading Basis: Letter Grade