APPLIED MATHEMATICS

The Department of Applied Mathematics in the College of Arts and Sciences offers courses that focus on providing students with the mathematical tools and problem-solving strategies that are useful in science and engineering. The department 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.

The undergraduate Bachelor of Science degree (catalog.colorado.edu/undergraduate/colleges-schools/engineering-applied-science/programs-study/applied-mathematics) is offered through the College of Engineering and Applied Science.

Course code for this program is APPM.

Computational Mathematics

The study of computational mathematics has grown rapidly in recent years and has allowed scientists and engineers to answer questions and to develop insights not possible just a decade or two ago. Modern computational methods require in-depth knowledge of a variety of mathematical subjects including 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 high level of computer literacy and to gain a substantial knowledge of operating systems and hardware. Computational mathematics courses include the study of computational linear algebra, optimization, numerical solution of ordinary and partial differential equations, solution of nonlinear equations and advanced seminars in wavelet and multisolution analysis and in multigrid methods, radial basis functions and algorithm design and development, more generally.

Mathematical Biosciences

Advances in our ability to quantitatively study biological phenomena have provided a number of exciting opportunities for applied mathematicians. The careful modeling, analysis and simulation of these systems using the standard and state-of-the-art tools of applied mathematics has led to novel and non-intuitive insights into biology. Furthermore, 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). For students interested in pursuing research in mathematical biology, good preparatory classes would include differential equations, advanced calculus, numerical analysis and probability and statistics, as well as supplemental courses in the appropriate biological, biomedical or bioengineering fields. Research areas at CU encompass immunology, virology, bacteriology, population genetics and cardiac nonlinear dynamics. Specifically, current topics of interest include model selection and control of in vivo HIV pathogenesis dynamics, modeling of intracellular calcium dynamics, the analysis of heart rhythm instabilities, the role of aggregation and fragmentation in bacteremia and bacterial pneumonia, inverse problems arising in the use of population genetics and bioinformatics to identify geographic features and the analysis of patterns in biological sequences such as DNA and RNA.

Dynamical Systems and Nonlinear Phenomena

In recent years, there has been an explosion of interest in the study of nonlinear waves and dynamical systems with analytical results, often motivated by the use of computers. The faculty in the Department of Applied Mathematics are actively and intensively involved in this growing field. Research areas include qualitative analysis and computational dynamics, conservative and dissipative systems, bifurcation theory, the onset and development of chaos, wavelets and multisolution analysis, integrable systems, solitons, cellular automata, analytic dynamics, pattern formation and symmetry, synchronization, dynamics on networks, fluid dynamics, transport and mixing and the study of nonlinear phenomena arising from the interactions of many interconnected dynamical units. Department courses in this field include dynamical systems, nonlinear wave motion and many advanced seminars. Suitable background courses are analysis, computation and methods in applied mathematics. Valuable supplemental courses include mechanics and fluid dynamics.

Physical Applied Mathematics

Physical applied mathematics is a term that 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 an in-depth understanding of the underlying applications area, and usually requires knowledge and experience in numerical computation. The department has approximately 40 affiliated faculty who can direct thesis research in areas such as atmospheric and fluid dynamics, theoretical physics, plasma physics, genetic structure, parallel computation, etc. The department’s course requirements are designed to provide students with a foundation for their study (analysis and computation). The department also requires supplemental courses in one of the sciences or engineering fields necessary for thesis research in physical applied mathematics.

Statistics and Applied Probability

Almost all natural phenomena in the technological, biological, physical and social sciences have random components with complex levels of interactions, part stochastic, part deterministic. Applied probability is the application of probabilistic and analytic methods to model, understand and predict the behavior of real-life problems that involve random elements. Statistics is the science of using data that typically arise from the randomness inherent in nature to gain new knowledge. Areas of current interest by applied math and their affiliated faculty include optimization of stochastic networks; the study of stochastic processes, and stochastic differential equations in hydrology and telecommunications; probabilistic models, nonparametric regression methods, shrinkage estimation, gene expression microarray data analysis, false discovery rate control, classification methods and statistical tests based on these models, in genetics and RNA sequencing; and extreme value theory in estimation of maximal wind speeds. Appropriate course work includes analysis, stochastic processes, simulation techniques and mathematical statistics, as well as background courses in one of the sciences or engineering fields in which one intends to do research.

For details on the range of courses and research opportunities available through the Department of Applied Mathematics, visit www.colorado.edu/amath.
The undergraduate Bachelor of Science degree (catalog.colorado.edu/undergraduate/colleges-schools/engineering-applied-science/programs-study/applied-mathematics/applied-mathematics-bachelor-science-bs/#text) is offered through the College of Engineering and Applied Science.

Minors
- Applied Mathematics - Minor (catalog.colorado.edu/undergraduate/colleges-schools/arts-sciences/programs-study/applied-mathematics/applied-mathematics-minor)
- Statistics - Minor (catalog.colorado.edu/undergraduate/colleges-schools/arts-sciences/programs-study/applied-mathematics/statistics-minor)

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
Associate Professor; PhD, Royal Institute of Technology, Stockholm, 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 at Raleigh

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

Cox, Murray William (https://experts.colorado.edu/display/fisid_153192)
Instructor; PhD, Texas AM 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)
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, Univ of Uppsala (Sweden)

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

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; BBA, National Taiwan University

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

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

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

Li, Congming (https://experts.colorado.edu/display/fisid_10647)
Professor; PhD, New York University

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

Lyles, Danielle
Instructor; PhD, Cornell University, Ithaca, NY, USA

Manteuffel, Thomas A (https://experts.colorado.edu/display/fisid_102137)
Professor Emeritus; PhD, University of Illinois at Urbana-Champaign

McCormick, Steven
Professor Emeritus

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

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

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

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

Zaharatos, Brian R (https://experts.colorado.edu/display/fisid_156225)
Instructor; MS, Colorado School of Mines
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 coursework. 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: Restricted to College of Engineering or Pre-Engineering Arts and Sciences majors only. Requires 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.

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 Core Curr: Quant Reasn Mathmat Skills

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 differentiation 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: Arts Sci Core Curr: Quant Reasn Mathmat Skills

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 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 2360 (4) Introduction to Differential Equations with Linear Algebra
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 prerequisite, 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-).

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 congruencies; basic and advanced counting techniques, recurrences and elementary graph theory. Other selected topics may also be covered.
Requisites: Requires a prerequisite or corequisite course of APPM 2350 or APPM 2360 or MATH 2400 (prereq 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-).

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, Reynolds' 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
Requisites: Requires prerequisite course of APPM 2350 or MATH 2400 (prereq minimum grade C-).

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 3130 or MATH 3135 (minimum grade C-).

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-).

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-).

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.

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-).

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 4500 (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: APPM 5500  
Requisites: Requires a prerequisite course of APPM 4520 (minimum grade C).  
Grading Basis: Letter Grade  

APPM 4505 (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: APPM 5505  
Requisites: Requires prerequisite course of APPM 4500 or APPM 5500 (minimum grade C).  
Grading Basis: Letter Grade  

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  
Requisites: Requires prerequisite courses of APPM 3310 and APPM 3570 (all minimum grade C).  
Grading Basis: Letter Grade  

APPM 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: APPM 5520 and MATH 4520 and MATH 5520  
Requisites: Requires prerequisite course of APPM 3570 or MATH 4510 (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  
Requisites: Requires prerequisite courses of APPM 3570 and APPM 3310 (all minimum grade C). Requires prerequisite or corequisite course of APPM 4350 (minimum grade C).  
Grading Basis: Letter Grade  

APPM 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: APPM 5540 and MATH 4540 and MATH 5540  
Requisites: Requires prerequisite course of APPM 4520 or MATH 4520 (minimum grade C).  
Grading Basis: Letter Grade  

APPM 4550 (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: APPM 5550  
Requisites: Requires prerequisite course of APPM 4520 or APPM 5520 or MATH 4520 or MATH 5520 (minimum grade C).  
Grading Basis: Letter Grade  

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  
Requisites: Requires prerequisite course of APPM 3570 or MATH 4510 (minimum grade C).  
Grading Basis: Letter Grade  

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).  

APPM 4580 (3) Introduction to Statistical Learning  
Consists of applications and methods of statistical learning. Covers multiple linear regression, classification, regularization, splines, tree-based methods, support vector machines and unsupervised learning.  
Equivalent - Duplicate Degree Credit Not Granted: APPM 5580  
Requisites: Requires prerequisite course of APPM 4570 or APPM 5570 (minimum grade C).
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-).

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 6.00 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.