Mathematical Sciences

Master of Science in Applied Mathematics

This program is intended for students with a strong interest in Applied Mathematics. Applied Mathematics is the application of classical and modern mathematical techniques to the solution of practical problems in the physical and biological sciences and engineering. The applied mathematician develops and analyzes mathematical models of physical and biological phenomena and engineering systems, interprets solutions to mathematical problems and uses the results to identify relationships, patterns, and the effects of altering one or more variables or modeling assumptions. Many of the courses in the program illustrate how mathematics can be used to predict the behavior of physical, biological, and engineering systems.

The Master of Science in Applied Mathematics, with its areas of specialization in analysis, applied mathematics, computational methods, and mathematical biology is designed to serve the needs of students who may be interested in pursuing a doctoral degree in the mathematical, physical, or biological sciences. The program also strengthens the quantitative and analytical skills of students with a baccalaureate degree who are planning to work in industry, commerce, or education, as well as practicing engineers and others already employed in industry and commerce.

Admission Requirements

It is expected that students applying for admission will have an undergraduate education in mathematics, the physical or biological sciences, or engineering. For additional information, see the Admissions section of this catalog. An undergraduate GPA of at least 2.8 on a 4.0 scale or equivalent is normally required. GRE scores are required for those students applying for financial support, or if the most recent degree was earned at a school outside the United States. Applications are considered on a case-by-case basis.

Master of Science in Applied Statistics

The objective of the Master of Science in Applied Statistics is to prepare students for a wide range of professional activities as practicing statisticians in both academia and industry. A statistician develops and analyzes models of data-driven situations where uncertainty of the outcomes plays a major role, identifies statistical relationships among observable variables, forecasts probable future outcomes, and draws inferences about background parameters that impact the phenomenon of interest. Thus the program is designed to provide students with the comprehensive knowledge and technical skills that are needed for the planning, execution, and analysis of statistical studies. These statistical studies are increasingly used as advisory instruments for policy decisions in the corporate and other sectors of the economy.

The Master of Science in Applied Statistics program will serve the needs of students with a baccalaureate degree who are planning to work in industry, commerce, or education, as well as practicing engineers and others already employed in industry and commerce. The program also strengthens the analytical and quantitative skills of graduate students who may be interested in pursuing a doctoral degree in Applied Probability and Statistics, since it equips them with basic training in the foundations of statistics in preparation for further advanced studies and research.

Admission Requirements

Applicants must have a degree from an accredited institution with at least 12 credits in mathematics, including calculus. Students who do not meet these requirements may be admitted if they satisfy the university’s requirements for admission. An undergraduate GPA of at least 2.8 on a 4.0 scale or equivalent is normally required. GRE scores are required for those students applying for financial support, or if the most recent degree was earned at a school outside the United States. Applications are considered on a case-by-case basis.

Bridge Program: Students who do not satisfy the credit requirement in mathematics will be required to take a bridge program of six credits in appropriate mathematics courses. Such courses do not count towards a graduate degree.

Master of Science in Biostatistics

The Master of Science in Biostatistics will provide advanced graduate education and training to students interested in applying statistical methods to the health sciences in general and clinical studies in particular. It will focus on training students in quantitative methods that will prepare them for careers in the health, life sciences, and pharmaceutical areas. Graduates, upon satisfactory completion of the degree program, are expected to have acquired appropriate skills in data analysis and computing that are typically required in their profession. This program will address the growing demand for trained biostatisticians in these fields, especially in New Jersey.

Admission Requirements

Applicants must have a baccalaureate degree in Statistics, Mathematics, Sciences, or Engineering, with at least 12 credits in mathematics, including calculus and at least one upper division course in statistics. Applicants with other baccalaureate degrees will also be considered and may be subject to a suitable bridge program. An undergraduate GPA of at least 3.0 on a 4.0 scale or equivalent is required.

Bridge Program: Students who do not satisfy the credit requirement in mathematics will be required to take a suitable bridge program of appropriate mathematics/statistics courses. Such courses do not count towards the graduate degree.
Master of Science in Mathematical and Computational Finance

The M.S. in Mathematical and Computational Finance (MSMCF) at NJIT provides students with the mathematical and computational tools and with the understanding of financial instruments and markets needed to obtain positions as quantitative analysts in financial institutions including Wall Street investment firms.

The Applied Quantitative Finance Option is designed to combine strong technical knowledge with the professional skills required for senior positions in industry, including emphasis on collaborative projects, communication, and project management.

Who should enroll?

The Master of Science in Mathematical and Computational Finance provides students with the theoretical knowledge as well as the practical methods and skills needed to begin or enhance careers as quantitative analysts in the financial industry. Because of the evolving nature of financial markets and institutions, practitioners in this field must be ready to learn new ideas and methods across a broad range of disciplines including mathematics, statistics, computational science, finance, and economics. The program aims to provide the multidisciplinary foundations preparing quantitative analysts for this life-long development of skills and understanding. Students should have a mathematical background equivalent to that of a typical undergraduate major in the engineering, physical, or mathematical sciences.

Admission Requirements

Undergraduate courses in multivariable calculus, probability theory, statistical inference, linear algebra, and differential equations.

How can I find out more?

- Attend a graduate student open house (http://www.njit.edu/admissions/visit/graduateopenhouses.php).
- Request information from our Admissions Office (http://www.njit.edu/admissions/graduate).

Why Study Mathematical Finance at NJIT?

Quantitative finance is an established discipline within the financial, investment, banking, and insurance industries and increasingly critical in regulatory agencies. As the financial industry is highly concentrated around the New York City area, quantitative financial engineers are in high demand locally. Mathematical and computational tools are at the heart of these activities. Practitioners combine high-level analytical, computational and modeling skills with a thorough understanding of financial markets and instruments to assess value and risk. The Department of Mathematical Sciences at NJIT has national prominence in several fields of applied mathematics, and annually obtains research funding from national agencies including The National Science Foundation, the National Institutes of Health, the Howard Hughes Institute of Medical Research, the Office of Naval Research, and the Department of Energy. The department has a thriving doctoral program as well as masters programs in applied mathematics and applied statistics.

GRE or GMAT scores are required for those students applying for financial support, or if the most recent degree was earned at a school outside the United States. Applications are considered on a case-by-case basis. Required courses for the program are generally offered in the evenings and part-time study is possible.

Bridge Program: Students with a baccalaureate degree not fully covering the prerequisites listed above may be admitted and required by the department to take an individually-designed program of courses that may include undergraduate courses before proceeding to the graduate curriculum. Such courses do not count towards a graduate degree.

Doctor of Philosophy in Mathematical Sciences

The Doctor of Philosophy in Mathematical Sciences is offered in collaboration with the Department of Mathematics and Computer Science at Rutgers University-Newark. The doctoral program in Mathematical Sciences is designed to prepare students for a wide range of professional activities in science and engineering. Prospective students must choose one of the following tracks:

- Applied Mathematics
- Applied Probability and Statistics
- Pure Mathematics

The doctoral program reflects the research interests of the faculty and is focused on the development and use of mathematical tools for solving modern scientific, technological and industrial problems, and advancing the research knowledge and methodology in various fields of specialization.

The Applied Mathematics track emphasizes the applications of mathematical methods to the physical and biological sciences and engineering, including acoustics, electromagnetics, fluid dynamics, materials science, biology, and medicine. Mathematical modeling, asymptotic analysis, and scientific computing are emphasized. Students are expected to develop a broad range of capabilities both in mathematics and in an area of application.

The Applied Probability and Statistics track emphasizes directed instruction and independent research in areas that are specializations of the faculty. Current research interest areas of the faculty include applied probability, non-parametric statistics, and statistical reliability theory and applications.
The Pure Mathematics track offers research opportunities in many fields of specialization, including representation theory, number theory, low-dimensional topology, Riemann surfaces and Kleinian groups, geometric group theory, and 4-manifolds.

**Admission Requirements**

Admission to the program is based on a review of the applicant’s credentials and interests as expressed in academic transcripts, GRE scores, letters of recommendation, statement of interests, and TOEFL scores (for students whose native language is not English). Applicants with strong academic records whose abilities and interests complement the research of the faculty are sought. In general, applicants should have a bachelor’s or master’s degree in mathematics, an engineering discipline, or a branch of the natural sciences. Students choosing the Applied Mathematics track or the Applied Probability and Statistics track must fulfill the admissions requirements specified in the Admissions section of this catalog.

Students interested in either the Applied Mathematics track or the Applied Probability and Statistics track should apply to NJIT. Students interested in the Pure Mathematics track should apply to Rutgers-Newark.

**NJIT Faculty**

**A**

Afkhami, Shahriar Zakerzadeh, Associate Professor

Ahuwalia, Daljit Singh, Professor Emeritus

Andrushkiw, Roman, Professor Emeritus

**B**

Batson II, William Richard, Post Doctoral Fellow

Bechtold, John K., Professor

Blackmore, Denis L., Professor

Booty, Michael R., Professor

Bose, Amitabha K., Professor

Boubendir, Yassine, Associate Professor

Brown, Ronald Robert, University Lecturer

Bukiet, Bruce G., Associate Professor

**C**

Choi, Wooyoung, Professor

Cummings, Linda J., Professor

**D**

Dhar, Sunil K., Professor

Diekman, Casey O., Assistant Professor

Dios, Rose, Associate Professor

**F**

Fang, Yixin, Associate Professor

Froese, Brittany, Assistant Professor

**G**

Garfield, Ralph, Associate Professor Emeritus

Goodman, Roy H., Associate Professor

Guo, Wenge, Associate Professor
Hayes, Jimmy L., University Lecturer
Horntrop, David J., Associate Professor
Horwitz, Kenneth A., University Lecturer
Hunter, John, University Lecturer

Jiang, Shidong, Associate Professor

Kappraff, Jay M., Associate Professor
Kelly, Rudy, University Lecturer
Kondic, Lou, Professor
Kriegsmann, Gregory A., Distinguished Professor Emeritus

Loh, Ji Meng, Associate Professor
Luke, Jonathan H. C., Professor

Matveev, Victor V., Associate Professor
Michailopoulou, Zoi-Heleni, Professor
Milojevic, Petronije, Professor
Miura, Robert M., Distinguished Professor Emeritus
Mohebbi Forushani, Soroosh, University Lecturer
Moore, Richard O., Associate Professor
Muratov, Cyril B., Professor

Natarajan, Padma, University Lecturer

Perez, Manuel, Professor
Petropoulos, Peter G., Associate Professor
Plastock, Roy A., Associate Professor
Pole, Andrew, MSMCF Coordinator
Porus, Jonathan J, Math Tutoring Center Director
Potocki-Dui, Magdallena M., University Lecturer

Rappaport, Karen D., Senior University Lecturer
Ratnaswamy, Jeyakumaran, Senior University Lecturer
Rotstein, Horacio G., Professor
S
Shirokoff, David, Assistant Professor
Siegel, Michael S., Professor
Stickler, David, Professor Emeritus
Subramanian, Sundarraman, Associate Professor

T
Tavantzis, John, Professor Emeritus
Turc, Catalin C., Associate Professor

V
Voronka, Roman W., Professor Emeritus

W
Wang, Antai, Associate Professor

Y
Young, Yuan-Nan, Associate Professor

Z
Zaleski, Joseph, University Lecturer

Programs

• Applied Mathematics - M.S. (http://catalog.njit.edu/graduate/science-liberal-arts/mathematical-sciences/applied-mathematics-ms)
• Applied Statistics - M.S. (http://catalog.njit.edu/graduate/science-liberal-arts/mathematical-sciences/applied-statistics-ms)
• BioStatistics - M.S. (http://catalog.njit.edu/graduate/science-liberal-arts/mathematical-sciences/biostatistics-ms)
• Computational Biology - M.S. (http://catalog.njit.edu/graduate/science-liberal-arts/mathematical-sciences/computational-biology-ms)
• Mathematical and Computational Finance - M.S. (http://catalog.njit.edu/graduate/science-liberal-arts/mathematical-sciences/mathematical-computational-finance-ms)
• Mathematical Sciences - Ph.D. (http://catalog.njit.edu/graduate/science-liberal-arts/mathematical-sciences/phd)

Programs

• Applied Statistical Methods (http://catalog.njit.edu/graduate/science-liberal-arts/mathematical-sciences/applied-statistical-methods-cert)
• Biostatistics Essentials (http://catalog.njit.edu/graduate/science-liberal-arts/mathematical-sciences/biostatistics-essentials-cert)
• Quantitative Finance (http://catalog.njit.edu/graduate/science-liberal-arts/mathematical-sciences/quantitative-finance-cert)

Mathematical Sciences Courses

MATH 545. Introductory Mathematical Analysis. 3 credits, 3 contact hours.
Prerequisite: MATH 211 or MATH 213, and departmental approval. Rigorous treatment of the calculus of real-valued functions of one real variable: the real number system, epsilon-delta theory of limit, continuity, derivative, and the Riemann integral. The fundamental theory of calculus. Series and sequences including Taylor series and uniform convergence. The inverse and implicit function theorems.

MATH 546. Advanced Calculus. 3 credits, 3 contact hours.
Prerequisite: MATH 545 or MATH 480. Rigorous treatment of the calculus of real-valued functions of several real variables: the geometry and algebra of n-dimensional Euclidean space, limit, continuity, derivative, and the Riemann integral of functions of several variables, the inverse and implicit function theorems, series, including Taylor series, optimization problems, integration on curves and surfaces, the divergence and related theorems.

MATH 573. Intermediate Differential Equations. 3 credits, 3 contact hours.
Prerequisites: MATH 222, MATH 337, or departmental approval. Methods and applications for systems of ordinary differential equations: existence and uniqueness for solutions of ODEs, linear systems, stability analysis, phase plane and geometrical methods, Sturm-Liouville eigenvalue problems.
MATH 608. Partial Differential Equations for Finance. 3 credits, 3 contact hours.
This course presents the subject of partial differential equations (PDE's) with a strong emphasis on the PDE's arising in the study of stochastic processes and finance. The focus is on analytical and numerical methods for obtaining solutions in a form useful for solving problems in financial engineering. Topics include modeling with PDE's, classification of PDE's, analytical and numerical methods for PDE's and application to finance.

MATH 609. Projects in Mathematical and Computational Finance. 3 credits, 3 contact hours.
Prerequisites: MATH 604 Mathematical Finance, MATH 605 Stochastic Calculus, MATH 606 Term Structure Models, or permission of the instructor. This project course requires students to demonstrate attained mastery of the material studies in the prerequisite courses. Projects also extend students' knowledge of specific areas beyond that covered in earlier courses into areas such as particle filtering or optimization techniques for term structure model calibration. The aim is to broaden the students' classroom focus to the more unconstrained, open-ended and less well defined contexts that are frequently encountered in practice.

MATH 610. Graduate Research Methods. 3 credits, 0 contact hours.
Prerequisite: MATH 614, MATH 671, and MATH 690. Acquaints second-year graduate students with the techniques and vocabulary of a field in applied mathematics. Each student contacts a designated faculty member and is given several basic papers or books on a research topic of current interest. The student prepares two lectures on his/her topic to be given at the end of the semester. A sample list of active fields of research includes acoustics, electromagnetic theory, elasticity, fluid dynamics, combustion, and mathematical biology.

MATH 611. Numerical Methods for Computation. 3 credits, 3 contact hours.
MATH 613. Advanced Applied Mathematics I: Modeling. 3 credits, 3 contact hours.
Prerequisites: MATH 331 and MATH 337, or departmental approval. Concepts and strategies of mathematical modeling are developed by investigation of case studies in a selection of areas. Consistency of a model, nondimensionalization and scaling, regular and singular effects are discussed. Possible topics include continuum mechanics (heat and mass transfer, fluid dynamics, elasticity), vibrating strings, population dynamics, traffic flow, and the Sommerfeld problem.

MATH 614. Numerical Methods I. 3 credits, 3 contact hours.
Prerequisites: MATH 222, MATH 337, MATH 340, and proficiency in a computer language (FORTRAN, C, or C++), or departmental approval. Theory and techniques of scientific computation, with more emphasis on accuracy and rigor than MATH 611. Machine arithmetic. Numerical solution of a linear system and pivoting. Interpolation and quadrature. Iterative solution of nonlinear systems. Computation of eigenvalues and eigenvectors. Numerical solution of initial- and boundary-value problems for systems of ODEs. Applications. The class includes examples requiring student use of a computer.

MATH 615. Approaches to Quantitative Analysis in the Life Sciences. 3 credits, 3 contact hours.
A graduate seminar-style course based around case studies of common data analytic methods used in the life sciences. The case studies are designed to help students who are interested in applications of statistical thinking to biological sciences appreciate the scope of quantitative methods, their underlying concepts, assumptions and limitations. While the mathematics of specific methods are not covered, students of the course will get an understanding of the diverse approaches to statistical inference in the life sciences.

MATH 630. Linear Algebra and Applications. 3 credits, 3 contact hours.
Prerequisites: (This course is not intended for students in the Master's in Applied Mathematics program or in the doctoral program in Mathematical Sciences.) Math 211 or Math 213, and Math 222. Development of the concepts needed to study applications of linear algebra and matrix theory to science and engineering. Topics include linear systems of equations, matrix algebra, orthogonality, eigenvalues and eigenvectors, diagonalization, and matrix decomposition.

MATH 631. Linear Algebra. 3 credits, 3 contact hours.
Prerequisites: MATH 222 and MATH 337, or departmental approval. Similar in aim and content to MATH 630 but with more emphasis on mathematical rigor. Linear systems of equations, matrix algebra, linear spaces, orthogonality, eigenvalues and eigenvectors, diagonalization, and matrix decomposition. Applications.

MATH 635. Analytical Computational Neuroscience. 3 credits, 3 contact hours.
Prerequisites: MATH 211 or 213, MATH 337, and CS 113 or MATH 240, or departmental approval. This course will provide an intermediate-level mathematical and computational modeling background for small neuronal systems. Models of biophysical mechanisms of single and small networks of neurons are discussed. Topics include voltage-dependent channel gating mechanisms, the Hodgkin-Huxley model for membrane excitability, repetitive and burst firing, single- and multi-compartmental modeling, synaptic transmission, mathematical treatment of 2-cell inhibitory or excitatory networks. In this course, the students will be required to build computer models of neurons and networks and analyze these models using geometric singular-perturbation analysis and dynamical systems techniques.

MATH 636. Systems Computational Neuroscience. 3 credits, 3 contact hours.
Prerequisites: MATH 222 and MATH 337, or departmental approval. This course provides an introduction to the use of mathematical techniques applied to solve problems in biology. Models discussed fall into 3 categories: discrete, continuous, and spatially distributed. Biological topics discussed range from the subcellular molecular systems and cellular behavior to physiological problems, population biology and developmental biology.

MATH 637. Foundations of Mathematical Biology. 3 credits, 3 contact hours.
Prerequisites: MATH 222 and MATH 337, or departmental approval. This course covers mathematical and computational modeling of neuronal networks. Topics covered include central pattern generators, models of visual processes, models of learning and memory, neural coding and mathematics of neural networks, models of oscillations in sensory, thalamic and thalamo-cortical networks, neuronal wave propagation.

MATH 639. Mathematical Modeling II. 3 credits, 3 contact hours.
Continuation of MATH 613 (Advanced Applied Mathematics I, Modeling). Concepts and strategies of Mathematical modeling are developed by case studies in a selection of areas. Topics will be complementary to those presented in MATH 613, and include for example, the mathematical theory of elasticity and electromagnetism.

MATH 644. Regression Analysis Methods. 3 credits, 3 contact hours.

MATH 645. Analysis I. 3 credits, 3 contact hours.
Prerequisite: MATH 546 or departmental approval. Review and extension of the fundamental concepts of advanced calculus: the real number system, limit, continuity, differentiation, the Riemann integral, sequences and series. Point set topology in metric spaces. Uniform convergence and its applications.

MATH 646. Time Series Analysis. 3 credits, 3 contact hours.
Prerequisite: MATH 661 or departmental approval. Time series models, smoothing, trend and removal of seasonality. Naive forecasting models, stationarity and ARMA models. Estimation and forecasting for ARMA models. Estimation, model selection, and forecasting of nonseasonal and seasonal ARIMA models.
MATH 647. Time Series Analysis II. 3 credits, 3 contact hours.
Prerequisite: MATH 646. Continuation of MATH 646. Covers methods of time series analysis useful in engineering, the sciences, economics, and modern financial analysis. Topics include spectral analysis, transfer functions, multivariate models, state space models and Kalman filtering. Selected applications from topics such as intervention analysis, neural networks, process control, financial volatility analysis.

MATH 651. Methods of Applied Mathematics I. 3 credits, 3 contact hours.
Prerequisite: MATH 222 or departmental approval. A survey of mathematical methods for the solution of problems in the applied sciences and engineering. Topics include: ordinary differential equations and elementary partial differential equations. Fourier series, Fourier and Laplace transforms, and eigenfunction expansions.

MATH 654. Clinical Trials Design and Analysis. 3 credits, 3 contact hours.
Prerequisites: MATH 665 or equivalent with Departmental approval. Statistical methods and issues in the design of clinical trials and analysis of their data. Topic include clinical trial designs for phases 1-4, randomization principle and procedures, analysis of pharmacokinetic data for bioequivalence, multi-center trials, categorical data analysis, survival analysis, longitudinal data analysis, interim analysis, estimation of sample size and power, adjustment for multiplicity, evaluation of adverse events, and regulatory overview.

MATH 656. Complex Variables I. 3 credits, 3 contact hours.
Prerequisite: MATH 545 or MATH 645 or departmental approval. The theory and applications of analytic functions of one complex variable: elementary properties of complex numbers, analytic functions, elementary complex functions, conformal mapping, Cauchy integral formula, maximum modulus principle, Laurent series, classification of isolated singularities, residue theorem, and applications.

MATH 659. Survival Analysis. 3 credits, 3 contact hours.
Prerequisites: MATH 665 or equivalent with Departmental approval. Introduction to statistical methods for modeling time-to-event data in the presence of censoring and truncation, with emphasis on applications to the health sciences. Topics include survival and hazard functions, censoring and truncation, parametric and nonparametric models for survival data, competing-risks, regression models including Cox proportional hazards model and time-dependent covariates, one and two sample tests, and use of appropriate statistical software for computations.

MATH 660. Introduction to Statistical Computing with SAS and R. 3 credits, 3 contact hours.
Prerequisite: Basic knowledge in statistical concepts or instructor approval. This course will study SAS and R programming and emphasize the SAS and R data steps including getting data into the SAS and R environments, working and combining data using control flows, merge and subsets, etc. as well as learning to export data and to generate high resolution graphics. Several SAS and R statistical procedures or functions will also be discussed and illustrated. Finally, interactive statistical software JMP and Minitab are briefly introduced.

MATH 661. Applied Statistics. 3 credits, 3 contact hours.
Prerequisite: MATH 112. Role and purpose of applied statistics. Data visualization and use of statistical software used in course. Descriptive statistics, summary measures for quantitative and qualitative data, data displays. Modeling random behavior: elementary probability and some simple probability distribution models. Normal distribution. Computational statistical inference: confidence intervals and tests for means, variances, and proportions. Linear regression analysis and inference. Control charts for statistical quality control. Introduction to design of experiments and their analysis. MATH 661 and MATH 663 cannot both be used toward degree credits at NJIT.

MATH 662. Probability Distributions. 3 credits, 3 contact hours.
Prerequisite: MATH 341 or MATH 333, and departmental approval. Probability, conditional probability, random variables and distributions, independence, expectation, moment generating functions, useful parametric families of distributions, transformation of random variables, order statistics, sampling distributions under normality, the central limit theorem, convergence concepts and illustrative applications.

MATH 663. Introduction to Biostatistics. 3 credits, 3 contact hours.
Prerequisites: Undergraduate Calculus. Introduction to statistical techniques with emphasis on applications in health related sciences. This course will be accompanied by examples from biological, medical and clinical applications. Summarizing and displaying data; basic probability and inference; Bayes’ theorem and its application in diagnostic testing; estimation, confidence intervals, and hypothesis testing for means and proportions; contingency tables; regression and analysis of variance; logistic regression and survival analysis; basic epidemiologic tools; use of statistical software. Math 661 and Math 663 cannot both be used toward degree credits at NJIT.

MATH 664. Methods for Statistical Consulting. 3 credits, 3 contact hours.
Prerequisite: MATH 661 or departmental approval. Communicating with scientists in other disciplines. Statistical tools for consulting. Using statistical software such as JMP, SAS, and S-plus. Case studies which illustrate using statistical methodology and tools are presented by the instructor and guest speakers from academia and industry. Assignments based on case studies with use of statistical software is required.

MATH 665. Statistical Inference. 3 credits, 3 contact hours.
Prerequisite: MATH 662 or departmental approval. Review of sampling distributions. Data reduction principles: sufficiency and likelihood. Theory and methods of point estimation and hypothesis testing, interval estimation, nonparametric tests, introduction to linear models.

MATH 666. Simulation for Finance. 3 credits, 3 contact hours.
Covers the use of Monte Carlo stochastic simulation for finance applications. Topics include generation of various random variables and stochastic processes (e.g., point processes, Brownian motion, diffusions), simulation methods for estimating quantities of interest (e.g., option prices, probabilities, expected values, quantiles), input modeling, and variance-reduction techniques. Students will write computer programs in C++. Students cannot receive credit for both CS 661 and CS/MATH 666.
MATH 671. Asymptotic Methods I. 3 credits, 3 contact hours.
Prerequisite: MATH 645 or MATH 654, and MATH 656, or departmental approval. Asymptotic sequences and series. Use of asymptotic series. Regular and singular perturbation methods. Asymptotic methods for the solution of ODEs, including: boundary layer methods and asymptotic matching, multiple scales, the method of averaging, and simple WKB theory. Asymptotic expansion of integrals, including: Watson's lemma, stationary phase, Laplace's method, and the method of steepest descent.

MATH 672. Biomathematics I: Biological Waves and Oscillations. 3 credits, 3 contact hours.
Prerequisites: MATH 222, MATH 331, and MATH 337, or departmental approval. Models of wave propagation and oscillatory phenomena in nerve, muscle, and arteries: Hodgkin-Huxley theory of nerve conduction, synchronization of the cardiac pacemaker, conduction and rhythm abnormalities of the heart, excitation-contraction coupling, and calcium induced waves, wave propagation in elastic arteries, models of periodic human locomotion.

MATH 673. Biomathematics II: Pattern Formation in Biological Systems. 3 credits, 3 contact hours.
Prerequisites: MATH 222, MATH 331, and MATH 337, or departmental approval. Emergence of spatial and temporal order in biological and ecological systems: Hopf and Turing bifurcation in reaction-diffusion systems, how do zebras get their stripes, patterns on snake skins and butterfly wings, spatial organization in the visual cortex, symmetry breaking in hormonal interactions, how do the ovaries count. Basic techniques of mathematics are introduced and applied to significant biological phenomena that cannot be fully understood without their use.

MATH 675. Partial Differential Equations. 3 credits, 3 contact hours.

MATH 676. Advanced Ordinary Differential Equations. 3 credits, 3 contact hours.
Prerequisites: MATH 222, MATH 337, and MATH 545 or MATH 645. A rigorous treatment of the theory of systems of differential equations: existence and uniqueness of solutions, dependence on initial conditions and parameters. Linear systems, stability, and asymptotic behavior of solutions. Nonlinear systems, perturbation of periodic solutions, and geometric theory of systems of ODEs.

MATH 677. Calculus of Variations. 3 credits, 3 contact hours.
Prerequisite: MATH 545 or MATH 645 or departmental approval. Necessary conditions for existence of extrema. Variation of a functional, Euler's equation, constrained extrema, first integrals, Hamilton-Jacobi equation, quadratic functionals. Sufficient conditions for the existence of extrema. Applications to mechanics.

MATH 678. Stat Methods in Data Science. 3 credits, 3 contact hours.
Prerequisite: MATH 661 or MATH 663, or permission by instructor. This course introduces students to concepts in statistical methods used in data science, including data collection, data visualization and data analysis. Emphasis is on model building and statistical concepts related to data analysis methods. The course provides the basic foundational tools on which to pursue statistics, data analysis and data science in greater depth. Topics include sampling and experimental design, understanding the aims of a study, principles of data analysis, linear and logistic regression, resampling methods, and statistical learning methods. Students will use the R statistical software.

MATH 680. Advanced Statistical Learning. 3 credits, 3 contact hours.
Prerequisites: MATH 478 or MATH 678, or permission by instructor. This course builds on the material in MATH 478 or MATH 678 and serves as a second graduate course in data science with emphasis on statistics. It covers many topics in high dimensional data analysis, including LASSO, SCAD and other regularization procedures, sparse PCA, sparse k-means, and asymptotic theory for high dimensional models. This course will provide students with necessary theoretical and computational skills to understand, design, and implement modern statistical learning methods, including ensemble learning (bagging, random forest, and boosting). Students will use the R statistical software.

MATH 683. High Dimensional Stat Inferenc. 3 credits, 3 contact hours.
Prerequisite: MATH 665 or permission by instructor. This course introduces modern statistical inference theory and methods developed as a result of the influence of computing. The course covers statistical thinking, ideas and theory that underlie many of the statistical learning algorithms used in data science, such as bootstrap, EM algorithm, cross-validation, large-scale hypothesis test, false discovery rates, sparse modeling, support vector machines and ensemble learning.

MATH 687. Quantitative Analysis for Environmental Design Research. 3 credits, 3 contact hours.
Prerequisites: MATH 333 and departmental approval. Fundamental concepts in the theory of probability and statistics including descriptive data analysis, inferential statistics, sampling theory, linear regression and correlation, and analysis of variance. Also includes an introduction to linear programming and nonlinear models concluding with some discussion of optimization theory.

MATH 688. Mathematical and Statistical Methods in Materials Science. 3 credits, 3 contact hours.
Prerequisites: MATH 111, MATH 112 and (MATH 211 or MATH 213). The course introduces mathematical methods necessary for materials science with emphasis on practical applications. Topics include power series, complex numbers, linear algebra, partial differentiation, multiple integrals, vector analysis, Fourier series and transformation, ordinary and partial differential equations, functions of complex variables, probability, and statistics.

MATH 689. Advanced Applied Mathematics II: Ordinary Differential Equations. 3 credits, 3 contact hours.
Prerequisites: MATH 545 or MATH 645, MATH 613, and MATH 631. A practical and theoretical treatment of boundary-value problems for ordinary differential equations: generalized functions, Green's functions, spectral theory, variational principles, and allied numerical procedures. Examples will be drawn from applications in science and engineering.
MATH 690. Advanced Applied Mathematics III: Partial Differential Equations. 3 credits, 3 contact hours.
Prerequisite: MATH 689. A practical and theoretical treatment of initial- and boundary-value problems for partial differential equations: Green's functions, spectral theory, variational principles, transform methods, and allied numerical procedures. Examples will be drawn from applications in science and engineering.

MATH 691. Stochastic Processes with Applications. 3 credits, 3 contact hours.
Prerequisite: MATH 662. Renewal theory, renewal reward processes and applications. Homogeneous, non-homogeneous, and compound Poisson processes with illustrative applications. Introduction to Markov chains in discrete and continuous time with selected applications.

MATH 692. MSMCF Forum. 0 credits, 0 contact hours.
Forum comprises informal discussions and debates engaging students in the realities of living and working in the world, with a focus on economics and finance. These realities include broad awareness of contemporary events, ethical implications of decisions, proper implementation and use of models, the research process and the critical skills of communication. Forum meetings are designed to promote understanding and build experience in all these areas.

MATH 698. Sampling Theory. 3 credits, 3 contact hours.
Prerequisite: MATH 662. Role of sample surveys. Sampling from finite populations. Sampling designs, the Horowitz-Thompson estimator of the population mean. Different sampling methods, simple random sampling, stratified sampling, ratio and regression estimates, cluster sampling, systematic sampling.

MATH 699. Design and Analysis of Experiments. 3 credits, 3 contact hours.
Prerequisite: MATH 662. Statistically designed experiments and their importance in data analysis, industrial experiments. Role of randomization. Fixed and random effect models and ANOVA, block design, Latin square design, factorial and fractional factorial designs and their analysis.

MATH 700. Master's Project. 0 credits, 0 contact hours.
Prerequisites: Matriculation for the Master of Science in Applied Mathematics or in Applied Statistics and departmental approval. Work must be initiated with the approval of a faculty member, who will be the student's project advisor. Work of sufficient quality may qualify for extension into a master's thesis, see MATH 701.

MATH 700B. Master's Project. 3 credits, 3 contact hours.
Prerequisites: Matriculation for the Master of Science in Applied Mathematics or in Applied Statistics and departmental approval. Work must be initiated with the approval of a faculty member, who will be the student's project advisor. Work of sufficient quality may qualify for extension into a master's thesis, see MATH 701.

MATH 701. Master's Thesis. 0 credits, 0 contact hours.
Prerequisite: Matriculation for the master's degree and departmental approval. Students must register for a minimum of 3 credits per semester until completion. The work is carried out under the supervision of a designated member of the faculty.

MATH 707. Advanced Applied Mathematics IV: Special Topics. 3 credits, 3 contact hours.
Prerequisite: Departmental approval. A current research topic of interest to departmental faculty. Typical topics include: computational fluid dynamics, theoretical fluid dynamics, acoustics, wave propagation, dynamical systems, theoretical and numerical aspects of combustion, mathematical biology, and various topics in statistics.

MATH 712. Numerical Methods II. 3 credits, 3 contact hours.
Prerequisites: MATH 614, MATH 331 or departmental approval, and proficiency in a computer programming language (FORTRAN, C, or C++). Numerical methods for the solution of initial- and boundary-value problems for partial differential equations, with emphasis on finite difference methods. Consistency, stability, convergence, and implementation are considered.

MATH 713. Advanced Scientific Computing: Multi-Dimensional Finite-Difference Schemes and Spectral Methods. 3 credits, 3 contact hours.
Prerequisite: MATH 712 and proficiency in a computer programming language (FORTRAN, C, or C++). Derivation and analysis of finite difference schemes for systems of partial differential equations in two and three spatial dimensions and time. Issues pertaining to efficient implementation of algorithms and to stability of physical and numerical boundary conditions. Pseudo-spectral and spectral methods to solve partial differential equations. Approximation properties of Fourier and Chebychev series and techniques based on the Fast Fourier Transform (FFT) and on matrix multiplication to numerically compute partial derivatives. Time-discretization techniques suitable for use with pseudo-spectral and spectral methods. Model systems arising in wave propagation, fluid dynamics, and mathematical biology will be considered.

MATH 715. Mathematical Fluid Dynamics I. 3 credits, 3 contact hours.
Introduction to the basic ideas of fluid dynamics, with an emphasis on rigorous treatment of fundamentals and the mathematical developments and issues. The course focuses on the background and motivation for recent mathematical and numerical work on the Euler and Navier-Stokes equations, and presents a mathematically intensive investigation of various model equations of fluid dynamics (e.g., the Korteweg-de-Vries equations).

MATH 716. Mathematical Fluid Dynamics II. 3 credits, 0 contact hours.
Continuation of MATH 715. Further development of the ideas of fluid dynamics, with an emphasis on mathematical developments and issues. A selection of topics will be developed in some detail, for example: Stokes flow and low-Reynolds-number hydrodynamics; flow at high Reynolds number and boundary layers; shock waves and hyperbolic systems; dynamics of interfacial flows; hydrodynamic stability; rotating fluids.

MATH 717. Inverse Problems and Global Optimization. 3 credits, 3 contact hours.
Introduction to inverse problems and global optimization. Linear, quasi-linear, and nonlinear inverse problems are studied with emphasis on regularization techniques. Bayesian statistical approaches and Monte Carlo methods are introduced and discussed in the context of inverse problems. The mathematical foundations of simulated annealing, genetic algorithms, and TABU are presented.
MATH 720. Tensor Analysis. 3 credits, 3 contact hours.
Prerequisite: MATH 613 and MATH 631, or departmental approval. Review of vector analysis in general curvilinear coordinates. Algebra and differential calculus of tensors. Applications to differential geometry, analytical mechanics, and mechanics of continuous media. The choice of applications will be determined by the interests of the class.

MATH 722. Wave Propagation. 3 credits, 3 contact hours.

MATH 725. Independent Study I. 3 credits, 3 contact hours.

MATH 745. Analysis II. 3 credits, 3 contact hours.

MATH 756. Complex Variables II. 3 credits, 3 contact hours.
Prerequisite: MATH 656. Selected topics from: conformal mapping and applications of the Schwarz-Christoffel transformation, applications of calculus of residues, singularities, principle of the argument, Rouche's theorem, Mittag-Leffler's theorem, Casorati-Weierstrass theorem, analytic continuation, and applications, Schwarz reflection principle, monodromy theorem, Wiener-Hopf technique, asymptotic expansion of integrals; integral transform techniques, special functions.

MATH 761. Statistical Reliability Theory and Applications. 3 credits, 3 contact hours.
Prerequisite: MATH 662 or departmental approval. Survival distributions, failure rate and hazard functions, residual life. Common parametric families used in modeling life data. Introduction to nonparametric aging classes. Coherent structures, fault tree analysis, redundancy and standby systems, system availability, repairable systems, selected applications such as software reliability.

MATH 763. Generalized Linear Models. 3 credits, 3 contact hours.
Prerequisites: MATH 662 and MATH 665 or departmental approval. Theoretical and applied aspects of generalized linear models. Classical linear models, nonlinear regression models, and generalized estimating equations.

MATH 767. Fast Numerical Algorithms. 3 credits, 3 contact hours.
The course covers state-of-the-art, analysis-based, fast numerical algorithms for computing discrete summations/transforms and for solving differential/ integral equations. In particular, this course presents fast multiple methods and their descendants, including fast Fourier transform for nonequispaced data, fast Gauss transform, fast iterative solver and direct solver for elliptic boundary value problems.

MATH 768. Probability Theory. 3 credits, 3 contact hours.
Prerequisite: MATH 645 or departmental approval. Measure theoretic introduction to axiomatic probability. Probability measures on abstract spaces and integration. Random variables and distribution functions, independence, 0-1 laws, basic inequalities, modes of convergence and their interrelationships, Laplace-Stieltjes transforms and characteristic functions, weak and strong laws of large numbers, conditional expectation, discrete time martingales.

MATH 771. Asymptotic Methods II. 3 credits, 3 contact hours.
Prerequisite: MATH 671. Continuation of MATH 671. Asymptotic methods for the solution of PDEs, including: matched asymptotic expansions, multiple scales, the WKB method or geometrical optics, and near-field far-field expansions. Applications to elliptic, parabolic, and hyperbolic problems. Further topics in the asymptotic expansion of integrals and the WKB method. Emphasis on examples drawn from applications in science and engineering.

MATH 781. Asymptotic Methods I. 3 credits, 3 contact hours.

MATH 786. Large Sample Theory and Inference. 3 credits, 3 contact hours.

MATH 787. Non-Parametric Statistics. 3 credits, 3 contact hours.
Prerequisite: MATH 662. Wilcoxon signed-ranks test, Mann-Whitney U test, binomial sign test for single sample and two dependent samples, McNemar's test, Cochran Q test, Wilcoxon matched-pairs signed-ranks test, Kruskal-Wallis one-way analysis of variance, Friedman two-way analysis of variance, Siegel-Tukey test for equal variability, chi-squared goodness-of-fit test, test for homogeneity and independence, single-sample runs test and other tests of randomness, correlation tests: Spearman's rank-order correlation, coefficient and Kendall's tau, Kendall's coefficient of concordance, and Goodman and Kruskal's gamma, comparing power efficiency.

MATH 790. Doctoral Dissertation & Res. 0 credits, 0 contact hours.
Prerequisite: Excellent performance on the doctoral qualifying examination. A minimum of 36 credits is required of all candidates for the Ph.D. degree. Candidates must register for 6 to 12 credits per semester, to be determined by a designated dissertation advisor. After reaching 36 credits, students must continue to register for 3 credits each semester until degree completion.
MATH 790A. Doct Dissertation & Res. 1 credit, 1 contact hour.
Prerequisite: Excellent performance on the doctoral qualifying examination. A minimum of 36 credits is required of all candidates for the Ph.D. degree. Candidates must register for 6 to 12 credits per semester, to be determined by a designated dissertation advisor. After reaching 36 credits, students must continue to register for 3 credits each semester until degree completion.

MATH 790B. Doct Dissertation & Res. 3 credits, 3 contact hours.
Prerequisite: Excellent performance on the doctoral qualifying examination. A minimum of 36 credits is required of all candidates for the Ph.D. degree. Candidates must register for 6 to 12 credits per semester, to be determined by a designated dissertation advisor. After reaching 36 credits, students must continue to register for 3 credits each semester until degree completion.

MATH 790C. Doct Dissertation & Res. 6 credits, 3 contact hours.
Prerequisite: Excellent performance on the doctoral qualifying examination. A minimum of 36 credits is required of all candidates for the Ph.D. degree. Candidates must register for 6 to 12 credits per semester, to be determined by a designated dissertation advisor. After reaching 36 credits, students must continue to register for 3 credits each semester until degree completion.

MATH 790D. Doct Dissertation & Res. 9 credits, 3 contact hours.
Prerequisite: Excellent performance on the doctoral qualifying examination. A minimum of 36 credits is required of all candidates for the Ph.D. degree. Candidates must register for 6 to 12 credits per semester, to be determined by a designated dissertation advisor. After reaching 36 credits, students must continue to register for 3 credits each semester until degree completion.

MATH 790E. Doctoral Dissertation. 12 credits, 12 contact hours.
Prerequisite: Excellent performance on the doctoral qualifying examination. A minimum of 36 credits is required of all candidates for the Ph.D. degree. Candidates must register for 6 to 12 credits per semester, to be determined by a designated dissertation advisor. After reaching 36 credits, students must continue to register for 3 credits each semester until degree completion.

MATH 791. Graduate Seminar. 0 credits, 1 contact hour.
All master's and doctoral students receiving departmental or research-based awards must register for this course each semester.

MATH 792B. Pre Doctoral Research. 3 credits, 3 contact hours.

MATH 792D. Pre Doctoral Research. 9 credits, 9 contact hours.