MATHEMATICS (MATH-GA)

MATH-GA 1002 Multivariable Analysis (3 Credits)
Typically offered Spring
Differentiation and integration for vector-valued functions of one and several variables: curves, surfaces, manifolds, inverse and implicit function theorems, integration of differential forms on manifolds, Stokes' theorem, applications.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 1410 Intro to Math Analysis I (3 Credits)
Typically offered Fall
Rigorous treatment of limits and continuity. Riemann integral. Taylor series. Absolute and uniform convergence. Elements of ordinary and partial differential equations. Functions of several variables and their derivatives. The implicit function theorem, optimization, and Lagrange multipliers. Theorems of Gauss, Stokes, and Green. Fourier series and integrals
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 1420 Intro to Math Analy II (3 Credits)
Typically offered Spring
Rigorous treatment of limits and continuity. Riemann integral. Taylor series. Absolute and uniform convergence. Elements of ordinary and partial differential equations. Functions of several variables and their derivatives. The implicit function theorem, optimization, and Lagrange multipliers. Theorems of Gauss, Stokes, and Green. Fourier series and integrals
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2010 Numerical Methods I (3 Credits)
Typically offered Fall
This course is part of a two-course series meant to introduce graduate students in mathematics to the fundamentals of numerical mathematics (but any Ph.D. student seriously interested in applied mathematics should take it). It will be a demanding course covering a broad range of topics. There will be extensive homework assignments involving a mix of theory and computational experiments, and an in-class final. Topics covered in the class include floating-point arithmetic, solving large linear systems, eigenvalue problems, interpolation and quadrature (approximation theory), nonlinear systems of equations, linear and nonlinear least squares, nonlinear optimization, and Fourier transforms. This course will not cover differential equations, which form the core of the second part of this series, Numerical Methods II.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2011 Adv Tpcs in Numerical Analysis: (3 Credits)
Typically offered Fall
Recent topics: Monte Carlo methods; approximation theory and practice; fast algorithms; high performance computing; finite element methods; the immersed boundary methods for fluid-structure interaction; numerical optimization.
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2012 Adv Tpcs in Numerical Analysis: (3 Credits)
Typically offered Spring
Recent topics: Monte Carlo methods; approximation theory and practice; fast algorithms; high performance computing; finite element methods; the immersed boundary methods for fluid-structure interaction; numerical optimization.
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2020 Numerical Methods II (3 Credits)
Typically offered Spring
This course is focused on numerical methods for solving ordinary and partial differential equations, and will include topics such as: numerical approximation theory, orthogonal polynomials, the Fast Fourier Transform, finite differences, spectral methods, 2-point boundary value problems, elliptic PDEs and integral equations, high-order quadrature techniques, and fast structured matrix computations.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2041 Computing in Finance (3 Credits)
Typically offered Fall
An integrated introduction to software skills and their applications in finance including trading, research, hedging, and portfolio management. Students develop object-oriented software, gaining skill in effective problem solving and the proper use of data structures and algorithms while working with real financial models using historical and market data.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2043 Scientific Computing (3 Credits)
Typically offered Fall
Methods for numerical applications in the physical and biological sciences, engineerMethods for numerical applications in the physical and biological sciences, engineering, and finance. Basic principles and algorithms; specific problems from various application areas; use of standard software packages.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2045 Nonlinear Problems in Finance: Models and Computational Methods (3 Credits)
Typically offered Fall
Computational methods for calibrating models; valuing, hedging, and optimizing portfolios; and assessing risk. Approaches include finite difference methods, Monte Carlo simulation, and fast-Fourier-transform-based methods.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2046 Advanced Statistical Inference and Machine Learning (3 Credits)
Typically offered Fall
A rigorous background in Bayesian statistics geared towards applications in finance, including decision theory and the Bayesian approach to modeling, inference, point estimation, and forecasting, sufficient statistics, exponential families and conjugate priors, and the posterior predictive density. A detailed treatment of multivariate regression including Bayesian regression, variable selection techniques, multilevel/hierarchical regression models, and generalized linear models (GLMs). Inference for classical time-series models, state estimation and parameter learning in Hidden Markov Models (HMMs) including the Kalman filter, the Baum-Welch algorithm and more generally, Bayesian networks and belief propagation. Solution techniques including Markov Chain Monte Carlo methods, Gibbs Sampling, the EM algorithm, and variational mean field. Real world examples drawn from finance to include stochastic volatility models, portfolio optimization with transaction costs, risk models, and multivariate forecasting.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2047 Trends in Financial Data Science (3 Credits)
This is a full semester course focusing on practical aspects of alternative data, machine learning and data science in quantitative finance. Homework and hands-on projects form an integral part of the course, where students get to explore real-world datasets and software. The course begins with an overview of the field, its technological and mathematical foundations, paying special attention to differences between data science in finance and other industries. We review the software that will be used throughout the course. We examine the basic problems of supervised and unsupervised machine learning, and learn the link between regression and conditioning. Then we deepen our understanding of the main challenge in data science – the curse of dimensionality – as well as the basic trade-off of variance (model parsimony) vs. bias (model flexibility). Demonstrations are given for real world data sets and basic data acquisition techniques such as web scraping and the merging of data sets. As homework each student is assigned to take part in downloading, cleaning, and testing data in a common repository, to be used at later stages in the class. We examine linear and quadratic methods in regression, classification and unsupervised learning. We build a BARRA-style implicit risk-factor model and examine predictive models for county-level real estate, economic and demographic data, and macroeconomic data. We then take a dive into PCA, ICA and clustering methods to develop global macro indicators and estimate stable correlation matrices for equities. In many real-life problems, one needs to do SVD on a matrix with missing values. Common applications include noisy image-recognition and recommendation systems. We discuss the Expectation Maximization algorithm, the L1-regularized Compressed Sensing algorithm, and a naïve gradient search algorithm. The rest of the course focuses on non-linear or high-dimensional supervised learning problems. First, kernel smoothing and kernel regression methods are introduced as a way to tackle non-linear problems in low dimensions in a nearly model-free way. Then we proceed to generalize the kernel regression method in the Bayesian Regression framework of Gaussian Fields, and for classification as we introduce Support Vector Machines, Random Forest regression, Neural Nets and Universal Function Approximators.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2048 Scientific Computing in Finance (3 Credits)
Typically offered Spring
This is a version of the course Scientific Computing (MATH-GA 2043) designed for applications in quantitative finance. It covers software and algorithmic tools necessary to practical numerical calculation for modern quantitative finance. Specific material includes IEEE arithmetic, sources of error in scientific computing, numerical linear algebra (emphasizing PCA/SVD and conditioning), interpolation and curve building with application to bootstrapping, optimization methods, Monte Carlo methods, and the solution of differential equations.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2049 Alternative Data in Quantitative Finance (1.5 Credits)
This half-semester elective course examines techniques dealing with the challenges of the alternative data ecosystem in quantitative and fundamental investment processes. We will address the quantitative tools and technique for alternative data including identifier mapping, stable panel creation, dataset evaluation and sensitive information extraction. We will go through the quantitative process of transferring raw data into investment data and tradable signals using text mining, time series analysis and machine learning. It is important that students taking this course have working experience with Python Stack. We will analyze real-world datasets and model them in Python using techniques from statistics, quantitative finance and machine learning.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2070 Data Science & Data-Driven Modeling (1.5 Credits)
Typically offered Fall
This is a half-semester course covering practical aspects of econometrics/statistics and data science/machine learning in an integrated and unified way as they are applied in the financial industry. We examine statistical inference for linear models, supervised learning (Lasso, ridge and elastic-net), and unsupervised learning (PCA- and SVD-based) machine learning techniques, applying these to solve common problems in finance. In addition, we cover model selection via cross-validation; manipulating, merging and cleaning large datasets in Python; and web-scraping of publicly available data.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2071 Machine Learning & Computational Statistics (1.5 Credits)
Typically offered Spring
This half-semester course (a natural sequel to the course "MATH-GA 2070 Data Science & Data-Driven Modeling") examines techniques in machine learning and computational statistics in a unified way as they are used in the financial industry. We cover supervised learning (regression and classification using linear and nonlinear models), specifically examining splines and kernel smoothers, bagging and boosting approaches; and how to evaluate and compare the performance of these machine learning models. Cross-validation and bootstrapping are important techniques from the standard machine learning toolkit, but these need to be modified when used on many financial and alternative datasets. In addition, we discuss random forests and provide an introduction to neural networks. Hands-on homework forms an integral part of the course, where we analyze real-world datasets and model them in Python using the machine learning techniques discussed in the lectures.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2080 Computational Statistics (3 Credits)
Computation plays a central role in modern statistics and machine learning. This course aims to cover topics needed to develop a broad working knowledge of modern computational statistics. We seek to develop a practical understanding of how and why existing methods work, enabling effective use of modern statistical methods. Achieving these goals requires familiarity with diverse topics in statistical computing, computational statistics, computer science, and numerical analysis. Specific topics include: intro to numerical linear algebra, regression and Gaussian processes, Newton's method and optimization, numerical integration, random variable generation, Markov chain Monte Carlo (MCMC) and variance reduction, the Bootstrap, density estimation, and an introduction to modern methods in machine learning (neural networks and deep learning).
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2110 Linear Algebra I (3 Credits)
Typically offered Fall and Spring
Linear spaces and mappings. Matrices and linear equations. Eigenvalues and eigenvectors. Jordan form. Special classes of matrices, spectral theory.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2111 Linear Algebra (3 Credits)
Typically offered Fall
Linear operators. Spectral theory. Duality theorems. Euclidean and symplectic structure. Matrix valued functions. Matrix inequalities. Convexity.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2120 Linear Algebra II (3 Credits)
Typically offered Spring and Summer
Linear spaces and mappings. Matrices and linear equations. Eigenvalues and eigenvectors. Jordan form. Special classes of matrices, spectral theory.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2130 Algebra I (3 Credits)
Typically offered Fall
Basic concepts including groups, rings, modules, polynomial rings, field theory, and Galois theory.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2140 Algebra II (3 Credits)
Typically offered Spring
Basic concepts including groups, rings, modules, polynomial rings, field theory, and Galois theory.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2210 Introduction to Number Theory I (3 Credits)
Typically offered Spring
Introduction to the elementary methods of number theory. Topics: arithmetic functions, congruences, the prime number theorem, primes in arithmetic progression, quadratic reciprocity, the arithmetic of quadratic fields.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2310 Topology I (3 Credits)
Typically offered Fall
Survey of point-set topology. Funda-mental groups, homotopy, covering spaces. Singular homology, calculation of homology groups, applications. Homology and cohomology of manifolds. Poincar? duality. Vector bundles. De Rham cohomology and differential forms.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2320 Topology II (3 Credits)
Typically offered Spring
Survey of point-set topology. Funda-mental groups, homotopy, covering spaces. Singular homology, calculation of homSurvey of point-set topology. Funda-mental groups, homotopy, covering spaces. Singular homology, calculation of homology groups, applications. Homology and cohomology of manifolds. Poincar? duality. Vector bundles. De Rham cohomology and differential forms.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2333 Adv Tpcs in Topology: (3 Credits)
Typically offered Fall
Recent topics: concentration measures; characteristic classes and applications; toric varieties and their applications; vector bundles and characteristic classes.
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2350 Differential Geometry I (3 Credits)
Typically offered Fall
Theory of curves and surfaces. Riemannian geometry: manifolds, differential forms, and integration. Covariant derivatives and curvature. Differential geometry in the large. Curvature, geodesics, Jacobi fields, comparison theorems, and Gauss-Bonnet theorem.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2360 Differential Geometry II (3 Credits)
Typically offered Spring
Theory of curves and surfaces. Riemannian geometry: manifolds, differential forms, and integration. Covariant derivatives and curvature. Differential geometry in the large. Curvature, geodesics, Jacobi fields, comparison theorems, and Gauss-Bonnet theorem.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2400 Adv Tpcs in Geometry: (3 Credits)
Typically offered Fall
Recent topics: Geometric nonlinear analysis; geometries of scalar curvature; high dimensional expanders and Ramanujan complexes, randomness and complexity.
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2410 Adv Tpcs in Geometry: (3 Credits)
Typically offered Spring
Recent topics: Geometric nonlinear analysis; geometries of scalar curvature; high dimensional expanders and Ramanujan complexes, randomness and complexity.
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2420 Advanced Topics (1.5 Credits)
Advanced topics in mathematics
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2430 Real Variables I (3 Credits)
Typically offered Fall
Basics of the theory of measure and integration, elements of Banach spaces. Metric spaces, Ascoli-Arzela theorem, Radon-Nikodym theorem, Fourier transform, distributions. Sobolev spaces and imbedding theorems. Geometric measure theory, harmonic analysis, functional analysis. Measure theory and convergence theorems.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2440 Real Variables II (3 Credits)
Typically offered not typically offered
Basics of Functional Analysis. Rearrangement Inequalities. Basics of Fourier Analysis. Distributions. Sobolev Spaces. BV Functions. Interpolation. Maximal Function.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2450 Complex Variables I (3 Credits)
Typically offered Fall
Analytic functions. Cauchy?s theorem and its many consequences. Fractional linear transformations and conformal mappings. Introduction to Riemann surfaces. The Riemann mapping theorems. Entire functions. Special functions.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2451 Complex Variables (3 Credits)
Typically offered Fall
Complex numbers, the complex plane. Power series, differentiability of convergent power series. Cauchy-Riemann equations, harmonic functions. Conformal maComplex numbers, the complex plane. Power series, differentiability of convergent power series. Cauchy-Riemann equations, harmonic functions. Conformal mapping, linear fractional transformation. Integration, Cauchy integral theorem, Cauchy integral formula. Morera?s theorem. Taylor series, residue calculus. Maximum modulus theorem. Poisson formula. Liouville theorem. Rouche?s theorem. Weierstrass and Mittag-Leffler representation theorems. Singularities of analytic functions, poles, branch points, essential singularities, branch points. Analytic continuation, monodromy theorem, Schwarz reflection principle. Compactness of families of uniformly bounded analytic functions. Integral representations of special functions. Distribution of function values of entire functions.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2460 Complex Variables II (3 Credits)
Typically offered Spring
Analytic functions. Cauchy?s theorem and its many consequences. Fractional linear transformations and conformal mappings. Introduction to Riemann surfaces. The Riemann mapping theorems. Entire functions. Special functions.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2470 Ordinary Diff Equatns I (3 Credits)
Typically offered Spring
Existence, uniqueness, and continuous dependence. Linear ODE. Stability of equilibria. Floquet theory. Poincar?-Bendixson theorem. Additional topics may include bifurcation theory, Hamiltonian mechanics, and singular ODE in the complex plane.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2490 Introduction to Partial Differential Equations (3 Credits)
Typically offered Fall
First-order equations. Cauchy-Kowalewsky theorem. Constant-coefficient, second-order equations: Laplace?s, heat, and wave equations. Explicit representation formulas and qualitative methods, such as the maximum principle. Nonlinear equations, e.g., Burger?s and minimal surface equations.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2500 Partial Differential Equations (3 Credits)
Typically offered Spring
Local existence theory: Cauchy-Kowalewsky theorem. Laplaces equation, harmonic functions, maximum principle, single and double layer potential. Fourier transform and distributions. Sobolev spaces. Elliptic boundary value problems. The Cauchy problem for the heat equation, wave equation. Local well posedness for semilinear Cauchy problems.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2510 Advanced PDEs (3 Credits)
Elliptic regularity: Harmonic functions and Harnack Inequality: Liouville's theorem, removable singularity, Harnack convergence theorems. Cacciopolli inequality and some of its consequences. De Giorgi-Nash Theory. Hyperbolic equations: Local existence and regularity of nonlinear problems, conserved quantities, vector fields method. Further topics, such as variational methods, homogenization, dispersive PDEs
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2550 Functional Analysis I (3 Credits)
Typically offered Fall and Spring
Banach spaces. Functionals and operators. Principle of uniform boundedness and closed graph theorem. Completely continuous mappings. Invariant subspaces. Linear operators, spectral theorem for self-adjoint operators. Hilbert- Schmidt operators. Semigroups. Fixed-point theorem. Applications.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2563 Harmonic Analysis (3 Credits)
Typically offered Fall and Spring
Hardy-Littlewood maximal functions and Marcinkiewicz integrals, singular integrals. Fourier series and Fourier integrals. Interpolation theorems. Applications in partial differential equations.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2610 Adv Tpcs in Pde: (3 Credits)
Typically offered Fall
Recent topics: extreme problems for elliptic eigenvalues; dynamics of the nonlinear Schroedinger equation; resonances in PDE; optimal transportation; viscosity solutions of PDE; fluid equations; math theory of water waves and nonlinear dispersive waves; wave turbulence; formation of singularities for compressible Euler shocks; geometric variational problems
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2620 Adv Tpcs in Pde: (3 Credits)
Typically offered Spring
Recent topics: extreme problems for elliptic eigenvalues; dynamics of the nonlinear Schroedinger equation; resonances in PDE; optimal transportation; viscosity solutions of PDE; fluid equations; math theory of water waves and nonlinear dispersive waves; wave turbulence; formation of singularities for compressible Euler shocks; geometric variational problems
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2650 Adv Tpcs in Analysis: (3 Credits)
Typically offered Fall
Recent topics: random matrices; regularity theorem for free boundary problems; elliptic functions, sampling and quantization; Sobolev spaces and interpolation; differentiable dynamical systems; Riemann-Hilbert theory
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2660 Adv Tpcs in Analysis: (3 Credits)
Typically offered Spring
Recent topics: random matrices; regularity theorem for free boundary problems; elliptic functions, sampling and quantization; Sobolev spaces and interpolation; differentiable dynamical systems; Riemann-Hilbert theory
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2701 Methods of Applied Mathematics (3 Credits)
Typically offered Fall
Convergent and divergent asymptotic series. Asymptotic expansion of integrals: steepest descents, Laplace principle, Watson?s lemma, and methods of stationary phase. Regular and singular perturbations of differential equations, the WKB method, boundary-layer theory, matched asymptotic expansions, and multiple-scale analysis. Rayleigh-Schr?dinger perturbatioConvergent and divergent asymptotic series. Asymptotic expansion of integrals: steepest descents, Laplace principle, Watson?s lemma, and methods of stationary phase. Regular and singular perturbations of differential equations, the WKB method, boundary-layer theory, matched asymptotic expansions, and multiple-scale analysis. Rayleigh-Schr?dinger perturbation theory for linear eigenvalue problems, summation of series, Pade approximation, averaging methods, renormalization groups, weakly nonlinear waves, and geometric optics.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2702 Fluid Dynamics (3 Credits)
Typically offered Fall
Conservation of mass, momentum, and energy. Eulerian and Lagrangian formulations. Basic theory of inviscid incompressible and barotropic fluids. Kinematics and dynamics of vorticity and circulation. Special solutions to the Euler equations: potential flows, rotational flows, conformal mapping methods. The Navier-Stokes equations and special solutions thereof. Boundary layer theory. Boundary conditions. The Stokes equations.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2704 Applied Stochastic Analysis (3 Credits)
Typically offered Spring
This class will introduce the major topics in stochastic analysis from an applied mathematics perspective. Topics to be covered include Markov chains, stochastic processes, stochastic differential equations, numerical algorithms, and asymptotics. It will pay particular attention to the connection between stochastic processes and PDEs, as well as to physical principles and applications. The class will attempt to strike a balance between rigour and heuristic arguments: it will assume that students have some familiarity with measure theory and analysis and will make occasional reference to these, but many results will be derived through other arguments.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2707 Time Series Analysis & Statistical Arbitrage (3 Credits)
Typically offered Fall
An introduction to econometric aspects of financial markets, focusing on the observation and quantification of volatility and on practical strategies for statistical arbitrage.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2708 Algorithmic Trading & Quantitative Strategies (3 Credits)
Typically offered Spring
Development of a quantitative investment and trading framework: mechanics of trading in the financial markets, some typical trading strategies, modelDevelopment of a quantitative investment and trading framework: mechanics of trading in the financial markets, some typical trading strategies, modeling of high- frequency data; transaction costs and market impact models, portfolio construction and robust optimization, and optimal betting and execution strategies; simulation techniques, back-testing strategies, and performance measurement. Use of advanced econometric tools and model risk mitigation techniques throughout the course.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2710 Mechanics I (3 Credits)
Typically offered Spring
Newtonian mechanics. Lagrangian and Hamiltonian mechanics. Integrable systems. Billiards. Method of averaging. KAM theory. Melnikov method.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2711 Machine Learning and Computational Statistics (3 Credits)

Typically offered Fall of even numbered years

This full-semester course integrates key elements of econometrics, data science, and machine learning in a financial context. Students will learn to model financial data using statistical techniques and computational methods while gaining hands-on experience with Python-based tools. The course emphasizes: # Financial Econometrics & Statistical Inference: Understanding linear regression frameworks, hypothesis testing, and model selection. # Supervised Learning: Implementing regression and classification models, optimizing performance through cross-validation and regularization. # Unsupervised Learning: Applying dimensionality reduction techniques such as PCA and SVD. # Machine Learning in Finance: Exploring algorithmic trading, risk modeling, and portfolio optimization using advanced methods like boosting, bagging, and deep learning. # Data Manipulation & Web Scraping: Handling real-world financial data, including structured and alternative datasets, using Python. Hands-on assignments will reinforce theoretical concepts, ensuring students gain practical experience in implementing machine learning techniques for financial applications.

Grading: GSAS Graded

Repeatable for additional credit: No

MATH-GA 2722 Fixed Income: Bonds, Securitized Products, and Derivatives (3 Credits)

Typically offered Fall of even numbered years

The first half of the course provides a hands-on exploration of fixed-income markets, equipping students with the quantitative and strategic skills needed for roles in trading, risk management, and quantitative modeling. Students will develop pricing models for bonds, Residential Mortgages, and Mortgage-Backed Securities (MBS), analyzing market reactions, risk positioning, and hedging strategies. Key topics include interest rates, prepayments, credit spreads (OAS), and model risk. The course also covers structured credit products such as CLOs, CMBS, ABS, and CDOs, along with credit derivatives like CDX and CMBX, emphasizing modeling risks and lessons from the 2008 Financial Crisis. The second half of the course focuses on real-world applications in fixed-income and rate-derivatives markets, bridging the gap between theory and practice. Students will examine bonds, swaps, flow options, and structured products, gaining insight into how economic trade ideas translate into trading and risk management strategies. A problem-oriented approach reinforces intuition about product structuring, market dynamics, and the practical constraints faced by sell-side practitioners in an evolving financial landscape.

Grading: GSAS Graded

Repeatable for additional credit: No

MATH-GA 2747 Stochastic Calculus & Dynamic Asset Pricing (3 Credits)

Typically offered Fall of even numbered years

The goal of the first half of the semester of the course is for students to develop an understanding of the techniques of stochastic processes and stochastic calculus as it is applied in financial applications. We begin by constructing the Brownian motion (BM) and the Ito integral, studying their properties. Then we turn to Ito's lemma and Girsanov's theorem, covering several practical applications. Towards the end of the course, we study the linkage between SDEs and PDEs through the Feynman-Kac equation. In the second half of the semester, we turn to asset pricing and the trading of derivative securities using stochastic calculus techniques. Using tools and techniques from stochastic calculus, we cover (a) Black-Scholes-Merton option pricing; (b) the martingale approach to arbitrage pricing; (c) incomplete markets; and (d) the general option pricing formula using the change of numeraire technique. As an important example of incomplete markets, we discuss bond markets, interest rates and basic term-structure models such as Vasicek and Hull-White.

Grading: GSAS Graded

Repeatable for additional credit: No

MATH-GA 2751 Risk and Portfolio Management (3 Credits)

Typically offered Fall and Spring

A mathematically sophisticated introduction to the analysis of investments. Core topics include expected utility, risk and return, mean-variance analysis, equilibrium asset pricing models, and arbitrage pricing theory.

Grading: GSAS Graded

Repeatable for additional credit: No

MATH-GA 2752 Active Portfolio Management (3 Credits)

Typically offered Spring

Theoretical aspects of portfolio construction and optimization, focusing on advanced techniques in portfolio construction, addressing the extensions to traditional mean-variance optimization including robust optimization, dynamical programming and Bayesian choice. Econometric issues associated with portfolio optimization, including estimation of returns, covariance structure, predictability, and the necessary econometric techniques to succeed in portfolio management will be covered.

Grading: GSAS Graded

Repeatable for additional credit: No

MATH-GA 2753 Advanced Risk Management (3 Credits)

Typically offered Spring

Measuring and managing the risk of trading and investment positions: interest rate positions, vanilla options positions, and exotic options positions. The portfolio risk management technique of Value-at-Risk, stress testing, and credit risk modeling.

Grading: GSAS Graded

Repeatable for additional credit: No

MATH-GA 2755 Project & Presentation (3 Credits)

Typically offered Fall and Spring

Students in the M.S. in Mathematics in Finance program conduct research projects individually or in small groups under the supervision of finance professionals. The course culminates in oral and written presentations of the research results.

Grading: GSAS Graded

Repeatable for additional credit: No

MATH-GA 2762 Advanced Topics In Equity & Energy Derivatives (3 Credits)
Typically offered Fall of even numbered years
The course provides a comprehensive overview of commonly traded quantitative strategies in financial and energy markets, bridging concepts from quantitative finance and energy economics. Key topics include theories of storage, net hedging pressure, optimal hedging, and risk transfer equilibrium. Throughout the course, emphasis is placed on understanding the behavior of various market participants and designing trading strategies to monetize inefficiencies arising from their activities and hedging needs. Structural changes such as the financialization of energy commodities, cross-market spillovers, and linkages to other financial asset classes are discussed in detail. Trading strategies covered include traditional risk premia, volatility, correlation, and higher-order options Greeks, with a particular focus on equity derivatives instruments, including volatility and correlation modeling, exotic options, and structured products. Case studies and real market data are used to illustrate key concepts. Additionally, the course explores meta-mathematical topics such as the practical and regulatory aspects of setting up a hedge fund, offering a practitioner's perspective on advanced financial topics.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2781 Alternative Data, Cryptocurrencies & Blockchains (3 Credits)
Typically offered Fall of even numbered years
This full-semester elective course explores techniques for handling alternative data in quantitative and fundamental investment processes, alongside the technologies and concepts behind distributed ledger systems and crypto financial markets. Students will learn quantitative tools for alternative data, including identifier mapping, stable panel creation, dataset evaluation, and sensitive information extraction, using Python-based statistical and machine-learning techniques. Additionally, the course covers the structure of traditional banking and money creation, cryptographic principles, blockchain security challenges, and the mechanics of Bitcoin, Ethereum, and decentralized finance (DeFi). Real-world datasets, including blockchain data, will be analyzed to develop investment insights and tradable signals. Proficiency in Python and experience with the numpy/pandas/sci-kit-learn stack are essential.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2791 Financial Securities and Markets (3 Credits)
Typically offered Fall and Spring
A first course in derivatives valuation. Arbitrage, risk neutral pricing, binomial trees. Black-Scholes theory, early exercise, barriers, interest rate models, floors, caps, swaptions. Introduction to credit-based instruments.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2792 Continuous Time Finance (3 Credits)
Typically offered Fall and Spring
Advanced option pricing and hedging using continuous time models: the martingale approach to arbitrage pricing; interests rate models including the Heath-Jarrow-Morton approach and short rate models; the volatility smile/ skew and approaches to accounting for it.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2793 Dynamic Asset Pricing (1.5 Credits)
Typically offered Spring
This is an advanced course on asset pricing and trading of derivative securities. Using tools and techniques from stochastic calculus, we cover (1) Black-Scholes-Merton option pricing; (2) the martingale approach to arbitrage pricing; (3) incomplete markets; and (4) the general option pricing formula using the change of numeraire technique. As an important example of incomplete markets, we discuss bond markets, interest rates and basic term-structure models such as Vasicek and Hull-White. It is important that students taking this course have good working knowledge of calculus-based probability and stochastic calculus. Students should also have taken the course "Financial Securities and Markets" previously. In addition, we recommend an intermediate course on mathematical statistics or engineering statistics as an optional prerequisite for this class.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2798 Interest Rate & Fx Models (3 Credits)
Typically offered Spring
The course is divided into two parts. The first addresses the fixed-income models most frequently used in the finance industry, and their applications to the pricing and hedging of interest-based derivatives. The second part covers the foreign exchange derivatives markets, with a focus on vanilla options and first-generation (flow) exotics. Throughout both parts, the emphasis is on practical aspects of modeling, and the significance of the models for the valuation and risk management of widely-used derivative instruments
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2799 Modeling and Risk Management of bonds and Securitized Products (1.5 Credits)
Typically offered Spring
This half-semester course is designed for students interested in Fixed Income roles in front-office trading, market risk management, model development ("Quants", "Strats"), or model validation. We begin by modeling the cash flows of a generic bond, emphasizing how the bond reacts to changes in markets, how traders may position themselves given their views on the markets, and how risk managers think about the risks of a bond. We then focus on Mortgages, covering the fundamentals of Residential Mortgages, and Mortgage-Backed Securities. Students will build pricing models for mortgages, pass-throughs, sequentials and CMO's that generate cash flows and that take into account interest rates, prepayments and credit spreads (OAS). The goals are for students to develop: (1) an understanding of how to build these models and how assumptions create "model risk", and (2) a trader's and risk manager's intuition for how these instruments behave as markets change, and (3) a knowledge how to hedge these products. We will graph cash flows and changes in market values to enhance our intuition (e.g. in Excel, Python or by using another graphing tool). In the course we also review the structures of CLO's, Commercial Mortgage Backed Securities (CMBS), Auto Asset Backed Securities (ABS), Credit Card ABS, subprime mortgages and CDO's and credit derivatives such as CDX, CMBX and ABX. We discuss the modeling risks of these products and the drivers of the Financial Crisis of 2008. As time permits, we touch briefly on Peer-to-peer / MarketPlace Lending.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2800 Trading Energy Derivatives (1.5 Credits)
Typically offered Spring
The course provides a comprehensive overview of most commonly traded quantitative strategies in energy markets. The class bridges quantitative finance and energy economics covering theories of storage, net hedging pressure, optimal risk transfer, and derivatives pricing models. Throughout the course, the emphasis is placed on understanding the behavior of various market participants and trading strategies designed to monetize inefficiencies resulting from their activities and hedging needs. We discuss in detail recent structural changes related to financialization of energy commodities, crossmarket spillovers, and linkages to other financial asset classes. Trading strategies include traditional risk premia, volatility, correlation, and higher-order options Greeks. Examples and case studies are based on actual market episodes using real market data.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2801 Advanced Topics in Equity Derivatives (1.5 Credits)
Typically offered Spring
This half-semester course will give a practitioner's perspective on a variety of advanced topics with a particular focus on equity derivatives instruments, including volatility and correlation modeling and trading, and exotic options and structured products. Some meta-mathematical topics such as the practical and regulatory aspects of setting up a hedge fund will also be covered.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2802 Market Microstructure (1.5 Credits)
Typically offered not typically offered
This is a half-semester course covering topics of interest to both buy-side traders and sell-side execution quants. The course will provide a detailed look at how the trading process actually occurs and how to optimally interact with a continuous limit-order book market. We begin with a review of early models, which assume competitive suppliers of liquidity whose revenues, corresponding to the spread, reflect the costs they incur. We discuss the structure of modern electronic limit order book markets and exchanges, including queue priority mechanisms, order types and hidden liquidity. We examine technological solutions that facilitate trading such as matching engines, ECNs, dark pools, multiple venue problems and smart order routers. The second part of the course is dedicated pre-trade market impact estimation, post-trade slippage analysis, optimal execution strategies and dynamic no-arbitrage models. We cover Almgren-Chriss model for optimal execution, Gatheral's no-dynamic-arbitrage principle and the fundamental relationship between the average response of the market price to traded quantity, and properties of the decay of market impact. Homework assignments will supplement the topics discussed in lecture. Some coding in Java will be required and students will learn to write their own simple limit-order-book simulator and analyze real NYSE TAQ data.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2803 Fixed Income Derivatives: Models and Strategies in Practice (1.5 Credits)
This half-semester class focuses on the practical workings of the fixed-income and rates-derivatives markets. The course content is motivated by a representative set of real-world trading, investment, and hedging objectives. Each situation will be examined from the ground level and its risk and reward attributes will be identified. This will enable the students to understand the link from the underlying market views to the applicable product set and the tools for managing the position once it is implemented. Common threads among products – structural or model-based – will be emphasized. We plan on covering bonds, swaps, flow options, semi-exotics, and some structured products. A problem-oriented holistic view of the rate-derivatives market is a natural way to understand the line from product creation to modeling, marketing, trading, and hedging. The instructors hope to convey their intuition about both the power and limitations of models and show how sell-side practitioners manage these constraints in the context of changes in market backdrop, customer demands, and trading parameters.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2804 Credit Analytics: Bonds, Loans and Derivatives (1.5 Credits)
This half-semester course introduces the institutional market for bonds and loans subject to default risk and develops concepts and quantitative frameworks useful for modeling the valuation and risk management of such fixed income instruments and their associated derivatives. Emphasis will be put on theoretical arbitrage restrictions on the relative value between related instruments and practical applications in hedging, especially with credit derivatives. Some attention will be paid to market convention and related terminology, both to ensure proper interpretation of market data and to prepare students for careers in the field. We will draw on the fundamental theory of derivatives valuation in complete markets and the probabilistic representation of the associated valuation operator. As required, this will be extended to incomplete markets in the context of doubly stochastic jump-diffusion processes. Specific models will be introduced, both as examples of the underlying theory and as tools that can be (and are) used to make trading and portfolio management decisions in real world markets.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2805 Trends in Sell-Side Modeling: XVA, Capital and Credit Derivatives (3 Credits)
This class explores technical and regulatory aspects of counterparty credit risk, with an emphasis on model building and computational methods. The first part of the class will provide technical foundation, including the mathematical tools needed to define and compute valuation adjustments such as CVA and DVA. The second part of the class will move from pricing to regulation, with an emphasis on the computational aspects of regulatory credit risk capital under Basel 3. A variety of highly topical subjects will be discussed during the course, including: funding costs, XVA metrics, initial margin, credit risk mitigation, central clearing, and balance sheet management. Students will get to build a realistic computer system for counterparty risk management of collateralized fixed income portfolios, and will be exposed to modern frameworks for interest rate simulation and capital management.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2830 Adv Tpcs in Applied Math (3 Credits)
Typically offered Fall
Recent topics: optimization and data analysis; quantifying uncertainties in complex turbulence systems; physics and mathematics of active matter; information theory and predictability; fast analysis based algorithms; stochastic modeling in finance.
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2840 Adv Tpcs in Applied Math (3 Credits)
Typically offered Spring
Recent topics: optimization and data analysis; quantifying uncertainties in complex turbulence systems; physics and mathematics of active matter; information theory and predictability; fast analysis based algorithms; stochastic modeling in finance.
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2851 Adv Tpcs in Math Biology (3 Credits)
Typically offered Fall
Recent topics: problems in cellular, molecular and neural biology; PDE in biology; math models of primitive organisms.
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2852 Adv Tpcs in Math Biology (3 Credits)
Typically offered occasionally
Recent topics: problems in cellular, molecular and neural biology; PDE in biology; math models of primitive organisms.
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2855 Adv Tpcs in Math Physiology (3 Credits)
Typically offered Fall
Lecture course on the formulation and analysis of differential equation models for neuronal ensembles and neuronal computations. Topics include neuronal rhythms, motor pattern generators, perceptual dynamics, decision-making, etc.
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2856 Adv Tpcs in Math Physiology (3 Credits)
Typically offered all terms
Recent topics: math aspects of neurophysiology; physiological control mechanisms; cardiac mechanisms and electrophysiology; nonlinear dynamics of neuronal systems neuronal networks
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2862 Adv Tpcs Fluid Dynamics (3 Credits)
Typically offered Spring
Recent topics: plasma physics; hydrodynamic stability; computational fluids; dynamics of complex and biological fluids; atomic modeling and computation.
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2901 Essentials of Probability (3 Credits)
Typically offered Fall, Spring, and Summer terms
Probability as a tool in computer science, finance, statistics, and the natural and social sciences. Independence. Random variables and their distributions. Conditional probability. Laws of large numbers. Central limit theorem. Random walk, Markov chains, and Brownian motion. Selected applications.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2902 Stochastic Calculus (3 Credits)
Typically offered Fall, Spring, and Summer terms
An application-oriented introduction to those aspects of diffusion processes most relevant to finance. Topics include Markov chains; Brownian motion; stochastic differential equations; the Ito calculus; the forward and backward Kolmogorov equations; and Girsanov?s theorem.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2903 Stochastic Calculus (1.5 Credits)
Typically offered Spring
Review of basic probability and useful tools. Bernoulli trials and random walk. Law of large numbers and central limit theorem. Conditional expectation and martingales. Brownian motion and its simplest properties. Diffusion in general: forward and backward Kolmogorov equations, stochastic differential equations and the Ito calculus. Feynman-Kac and Cameron-Martin Formulas
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2911 Probability Theory I (3 Credits)
Typically offered Fall
The classical limit theorems: laws of large numbers, central limit theorem, iterated logarithm, arcsine law. Further topics: large deviation theory, martingales, Birkhoff?s ergodic theorem, Markov chains, Shannon?s theory of information, infinitely divisible and stable laws, Poisson processes, and Brownian motion. Applications.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2912 Probability Theory II (3 Credits)
Typically offered Spring
The course is targeted at Mathematics PhD students. Stochastic processes in continuous time. Brownian motion. Poisson process. Processes with independent increments. Stationary processes. Semi-martingales. Markov processes and the associated semi-groups. Connections with PDEs. Stochastic differential equations. Convergence of processes.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 2931 Adv Tpcs in Probability: (3 Credits)
Typically offered all terms
Recent topics: Gaussian fields and extrema of the Gaussian free field; random matrices; Markov chain analysis; statistical mechanics and the Riemann hypothesis; Schramm Loewner evolution.
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2932 Adv Tpcs Probability II (3 Credits)
Typically offered Spring
Recent topics: Gaussian fields and extrema of the Gaussian free field; random matrices; Markov chain analysis; statistical mechanics and the Riemann hypothesis; Schramm Loewner evolution.
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 2962 Mathematical Statistics (3 Credits)
Typically offered not typically offered
Principles and methods of statistical inference. Topics: large sample theory, minimum variance unbiased estimates, method of maximum likelihood, sufficient statistics, Neyman-Pearson theory of hypothesis testing, confidence intervals, regression, nonparametric methods.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 3001 Geophys Fluid Dynamics (3 Credits)
Typically offered Fall
This course serves as an introduction to the fundamentals of geophysical fluid dynamics. No prior knowledge of fluid dynamics is assumed, but the course moves quickly into the subtopic of rapidly rotating, stratified flows. Topics covered include (but are not limited to) the advective derivative, momentum conservation and continuity, the rotating Navier-Stokes equations and non-dimensional parameters, equations of state and thermodynamics of Newtonian fluids, atmospheric and oceanic basic states, the fundamental balances (thermal wind, geostrophic and hydrostatic), the rotating shallow water model, vorticity and potential vorticity, inertia-gravity waves, geostrophic adjustment, the quasi-geostrophic approximation and other small-Rossby number limits, Rossby waves, baroclinic and barotropic instabilities, Rayleigh and Charney-Stern theorems, and geostrophic turbulence. Students are assigned biweekly homework assignments and some computer exercises, and are expected to complete a final project or exam.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 3003 Ocean Dynamics (3 Credits)
Typically offered Spring term of odd numbered years
The goal of this course is to introduce students to modern dynamical oceanography, with a focus on mathematical models for observed phenomena. The lectures cover the observed structure of the ocean, the thermodynamics of seawater, the equations of motion for rotating-stratified flow, and the most useful approximations thereof: the primitive, planetary geostrophic, and quasi-geostrophic equations. The lectures demonstrate how these approximations can be used to understand boundary layers, wind-driven circulation, buoyancy-driven circulation, oceanic waves (Rossby, Kelvin, and inertia-gravity), potential vorticity dynamics, theories for the observed upper-ocean stratification (the thermocline), and for the abyssal circulation. Students should have some knowledge in geophysical fluid dynamics before taking this course. Throughout the lectures, the interplay between observational, theoretical, and modeling approaches to problems in oceanography are highlighted.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 3004 Atmosphere Dynamics (3 Credits)
Typically offered Spring term of even numbered years
This course offers a general overview of the physical processes that determine the state of the Earth's atmosphere. The focus is to describe the main features of the planetary circulation and to explain how they arise as a dynamical response of the atmosphere to different external forcings such as solar radiation or topography. Students should have some knowledge in geophysical fluid dynamics before taking this course. Topics covered include solar forcing, the mean-state of the atmosphere, Hadley and monsoonal circulations, dynamics of the mid-latitude stormtracks, energetics, zonally asymmetric circulations, equatorial dynamics, and the interaction between moist convection and large-scale flow. Students are assigned bi-weekly homework assignments and some computer exercises, and are expected to complete a final project or exam.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 3006 Data-Driven Climate Science (3 Credits)
Typically offered Fall of even numbered years
This course explores the application of data-driven techniques in climate science, focusing on statistical methods, machine learning, and data assimilation. Students will learn how to analyze large climate datasets, extract meaningful patterns, and develop predictive models. Through hands-on exercises, we will cover topics such as observational data processing, feature selection, and neural networks for climate prediction. The course is designed for students with an interest in leveraging data science to address key challenges in climate research.
Grading: GSAS Graded
Repeatable for additional credit: No

MATH-GA 3010 Advanced Topics in AOS: (3 Credits)
Typically offered Fall
The purpose of this course is to introduce students to the instrumentation used in collecting basic data of the Earth's atmosphere, oceans, and cryosphere. Most of our fundamental knowledge of the Earth's physical environment has been gained from observations taken over the last few decades, using a wide variety of observational techniques ranging from in situ observations at the sea floor to remote sensing satellites at high altitudes in the atmosphere. In this course the student is introduced to basic meteorological instrumentation using a hands-on approach with equipment on a rooftop and basic oceanographic instrumentation deployed in the nearby Hudson estuary. To help understand and reinforce the underlying theoretical concepts of geophysical fluid dynamics as presented in other course work, the students operate a laboratory turntable and perform experiments that demonstrate the roles of rotation and stratification in atmospheric and oceanic circulations on a wide range of spatial and temporal scales. Students complete an individually assigned laboratory experiment project.
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 3011 Adv Top in Atmosphere (3 Credits)
Typically offered Spring
The goal of this course is to introduce students to the fundamental principles underlying climate dynamics and change. The course is primarily lecture oriented but with a numerical laboratory component. Lectures focus on introducing the main concepts of atmosphere/ocean dynamics while a limited set of numerical experiments reinforce the material presented in the lectures. Classical models in climate dynamics are presented, in additional discussion on more recent advances. Topics include radiative convective equilibrium, energy balance, and simple stochastic climate models. Throughout the lectures, the interplay between observational, theoretical, and modeling approaches toward the understanding of climate dynamics is highlighted. The laboratory component involves a technical introduction and a series of numerical experiments with the models that also forms part of the assignments. Assignments also explore the theoretical basis for the models studied.
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 3771 Independent Study (1-3 Credits)
Typically offered Fall and Summer terms
Supervised reading and/or research with a faculty member on a topic selected by the student and faculty
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 3772 Independent Study (1-3 Credits)
Typically offered Spring and Summer
Supervised reading and/or research with a faculty member on a topic selected by the student and faculty
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 3773 Independent Study (1-3 Credits)
Typically offered occasionally
Supervised reading and/or research with a faculty member on a topic selected by the student and faculty
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 3774 Independent Study (1-3 Credits)
Typically offered occasionally
Supervised reading and/or research with a faculty member on a topic selected by the student and faculty
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 3775 Advanced Practical Training (3 Credits)
Typically offered Fall, Spring, and Summer terms
Students in the doctoral program in mathematics gain experience with practical uses of advanced mathematical tools, through relevant activity in a corporate, laboratory, or similar environment. This opportunity may be available to MS students; decisions are made on a case-by-case basis
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 3881 Master's Thesis Research (2 Credits)
Typically offered Fall, Spring, and Summer terms
Under the supersvision of a faculty member and approved by the department, students will conduct research and write a paper that must be approved by faculty
Grading: GSAS Pass/Fail
Repeatable for additional credit: Yes

MATH-GA 3991 Research (3 Credits)
Typically offered Fall
Open only to students who have passed the oral preliminary examination for the Ph.D. degree
Grading: GSAS Pass/Fail
Repeatable for additional credit: Yes

MATH-GA 3992 PhD Research (3 Credits)
Typically offered Spring
Open only to students who have passed the oral preliminary examination for the Ph.D. degree
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 3993 Research (3 Credits)
Typically offered Fall
Open only to students who have passed the oral preliminary examination for the Ph.D. degree
Grading: GSAS Pass/Fail
Repeatable for additional credit: Yes

MATH-GA 3994 PhD Research (3 Credits)
Typically offered Spring
Open only to students who have passed the oral preliminary examination for the Ph.D. degree
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 3995 Research (3 Credits)
Typically offered Fall
Open only to students who have passed the oral preliminary examination for the Ph.D. degree
Grading: GSAS Pass/Fail
Repeatable for additional credit: Yes

MATH-GA 3996 PhD Research (3 Credits)
Typically offered Fall
Open only to students who have passed the oral preliminary examination for the Ph.D. degree
Grading: GSAS Graded
Repeatable for additional credit: Yes

MATH-GA 3997 Research (3 Credits)
Typically offered Fall
Open only to students who have passed the oral preliminary examination for the Ph.D. degree
Grading: GSAS Pass/Fail
Repeatable for additional credit: Yes

MATH-GA 3998 PhD Research (3 Credits)
Typically offered Spring
Open only to students who have passed the oral preliminary examination for the Ph.D. degree
Grading: GSAS Graded
Repeatable for additional credit: Yes