APPLIED MATHEMATICS

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Chair
Chun Liu

Associate Chair and Director of Graduate Studies
Igor Cialenco

Faculty with Research Interests
For more information regarding faculty visit the Department of Applied Mathematics website.

The Department of Applied Mathematics puts mathematics to work solving problems in science, engineering, and society. Applied mathematicians investigate a wide variety of topics, such as how to construct methods for multi-criteria decision making (requiring discrete mathematics and statistics), analyzing the stochastic nature of financial markets (requiring probability/statistics, analysis, and optimization), understanding how liquids flow around solids, and how ions move in biological environments (requiring computational methods and analysis).

Research Facilities

The department provides students with office space equipped with computers and full access to the university's computer and library resources. The department also has a 128-core computer cluster for research purposes.

Research and Program Areas

The research and teaching foci of the Department of Applied Mathematics are primarily in five areas of modern applied mathematics: applied analysis, computational mathematics, discrete applied mathematics, statistics, and stochastics. These areas are briefly described in the following subsections, which also include the faculty with primary and secondary research interests in that area.

Applied Analysis

The applied analysis group studies mathematical problems arising from physical, chemical, geophysical, biophysical, and materials sciences. These problems are often described by time-dependent partial, ordinary, or integral differential equations, together with sophisticated boundary conditions, interface conditions, and external forcing. Nonlinear dynamical systems offer a geometrical and topological framework for detecting, understanding, and quantifying complex phenomena of these time-dependent differential equations. Partial differential equation theory allows us to correctly formulate well-posed problems and to examine behaviors of solutions, and thus also allows us to set the stage for efficient numerical simulations. Nonlocal equations arise from macroscopic modeling of stochastic dynamical systems with Lévy noise and from modeling long range interactions, and consequently give an understanding of anomalous diffusions.

Faculty with primary interests: Leslie, Liu, Lubin, Ong

Faculty with secondary interests: Bielecki, Cassel, Cialenco, Hickernell, S. Li, X. Li, Nadtochiy, Schieber

Computational Mathematics

Computer simulation is recognized as the third pillar of science, complementing theory and experiment. The computational mathematics research group designs and analyzes numerical algorithms and answers fundamental questions about the underlying physics. We construct and analyze algorithms for approximating functions and integration in high dimensions, and solving systems of polynomial equations. The emphasis is on meshfree methods, maximizing algorithm efficiency, avoiding catastrophic round-off error, overcoming the curse of dimensionality, and advancing adaptive computations to meet error tolerances. We develop accurate mathematical models and efficient numerical methods to investigate dynamics of interfaces. Our goal is to understand the underlying mechanisms that govern the process of pattern formation, i.e., growth and form. Examples include multi-phase flows in complex fluids, and vesicle deformation in bio-related applications such as drug delivery. We establish analytical and computational techniques for extracting effective dynamics from multiscale phenomena that are abundant in geophysical and biophysical systems.

Faculty with primary interests: Hickernell, S. Li, X. Li, Liu, Zhong

Faculty with secondary interests: Cassel, Ong, Petrovic, Schieber

Discrete Applied Mathematics

The discrete mathematics group studies theoretical, algorithmic, and computational problems in the fields of graph theory, discrete optimization, combinatorics, and algebraic geometry, with applications in biology, computer science, physics, management sciences, and engineering. Network science, with fundamental concepts from graph theory and computational techniques from discrete optimization, is widely applied to problems arising in transportation/communication, distribution, and security of resources and information. Combinatorial search incorporates graph theory, set systems, and algorithms to tackle information-theoretic questions in topics such as message transmission, data compression, and identification of defective samples in a population. Computational algebra joins tools from algebraic geometry with randomized algorithms from discrete geometry to develop methods to solve systems of polynomial equations arising in statistical inference and mathematical modeling.

Faculty with primary interests: Cheng, Ellis, Kaul, Pelsmajer, Petrovic, Stasi

Statistics

The statistics research group works on applied problems in several areas of statistics from the theoretical, methodological, and computational points of view. Design and analysis of experiments with complex structures are used to help scientists gain higher-quality information from their lab work. Monte Carlo methods inform decisions depending on an unknown future by generating and analyzing a myriad of plausible scenarios. Algebraic statistics integrates algebra, geometry, and combinatorics into statistical modeling to provide better-fitting models for non-traditional data. Statistical network modeling and uncertainty quantification allow us to detect when certain data structures are more commonly observed than by chance. Bayesian statistics uses prior beliefs to inform statistical inference.
We closely collaborate with scientists and engineers from many different disciplines such as mechanical, manufacturing, civil, and transportation engineering; social sciences; biology; neuroscience; business; and management.

Faculty with primary interests: Cheng, Cialenco, Hickernell, Petrovic, Stasi

Faculty with secondary interests: Bielecki, Ellis, Gong, Nadtochiy, Zhong

Stochastics

The research outcome of the stochastics group provides modeling tools for analysis, control, and numerical study of various stochastic systems that evolve in time and space, and are subject to randomness. Our study of structured dependence between stochastic processes helps to construct models of multivariate random dynamical systems with prescribed global structural features and prescribed marginal structural features. Random sequence comparison helps scientists to identify regions of similarity in the sequences of DNA, RNA, and proteins, or between strings in a natural language. Stochastic partial differential equations and stochastic dynamical systems serve as modeling tools for complex phenomena such as turbulent flows, climate change, and behavior of financial markets. Our research in the area of mathematical finance provides quantitative models of financial securities that allow pricing, hedging, and mitigating the risk of complex financial products.

Faculty with primary interests: Bielecki, Cialenco, Duan, Hickernell, Nadtochiy

Faculty with secondary interests: X. Li, Zhong

Admission Requirements

Minimum Cumulative Undergraduate GPA

- Master's/Master of Science: 3.0/4.0
- Ph.D.: 3.5/4.0

GRE Scores - Optional

Suggested GRE scores:

- Master's/Master of Science: 304 (quantitative + verbal), 2.5 (analytical writing)
- Ph.D.: 304 (quantitative + verbal), 3.0 (analytical writing)

Minimum TOEFL Scores

80/550 (internet-based/paper-based test scores)

The applicants are also required to submit:

- at least two letters of recommendation
- a professional statement written in essay format (up to two pages long) that includes discussion of the reasons for pursuing graduate study, the applicant's academic background, relevant professional experience or related accomplishments to date, and applicant's career goals
- a curriculum vitae

Admission to the Master of Science and the Ph.D. program normally requires a bachelor's degree in mathematics or applied mathematics. Candidates whose degree is in another field (for example, computer science, physics, or engineering) and whose background in mathematics is strong are also eligible for admission and are encouraged to apply. Candidates in the Ph.D. program must also have demonstrated the potential for conducting original research in applied mathematics. Students must remove deficiencies in essential undergraduate courses that are prerequisites for the degree program, in addition to fulfilling all other degree requirements.

For admission requirements of the individual degree, see the corresponding program's graduate catalog page.

Meeting the minimum or typical GPA test score requirements does not guarantee admission. GPA and test scores are just two of several important factors considered for admission to the program.

The director of graduate studies serves as temporary academic adviser for newly admitted graduate students in the Master of Science and the Ph.D. programs until an appropriate faculty member is selected as the adviser. Students are responsible for following all departmental procedures, as well as the general requirements of the Graduate College.

Degrees Offered

- Master of Applied Mathematics
- Master of Financial Technology
- Master of Science in Applied Mathematics
- Doctor of Philosophy in Applied Mathematics

Joint Degree Programs

- Master of Data Science (with Computer Science)
- Master of Data Science: Coursera (with Computer Science)
- Master of Science in Computational Decision Sciences and Operations Research (with Computer Science)

Course Descriptions

MATH 500
Applied Analysis I
Measure Theory and Lebesgue Integration; Metric Spaces and Contraction Mapping Theorem, Normed Spaces; Banach Spaces; Hilbert Spaces.
Prerequisite(s): MATH 400 with min. grade of C or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 501
Applied Analysis II
Bounded Linear Operators on a Hilbert Space; Spectrum of Bounded Linear Operators; Fourier Series; Linear Differential Operators and Green's Functions; Distributions and the Fourier Transform; Differential Calculus and Variational Methods.
Prerequisite(s): MATH 500 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 512
Partial Differential Equations
Basic model equations describing wave propagation, diffusion and potential functions; characteristics, Fourier transform, Green function, and eigenfunction expansions; elementary theory of partial differential equations; Sobolev spaces; linear elliptic equations; energy methods; semigroup methods; applications to partial differential equations from engineering and science.
Prerequisite(s): MATH 461 with min. grade of C or MATH 489 with min. grade of C or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 515
Ordinary Differential Equations and Dynamical Systems
Basic theory of systems of ordinary differential equations; equilibrium solutions, linearization and stability; phase portraits analysis; stable unstable and center manifolds; periodic orbits, homoclinic and heteroclinic orbits; bifurcations and chaos; nonautonomous dynamics; and numerical simulation of nonlinear dynamics.
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 519
Complex Analysis
Analytic functions, contour integration, singularities, series, conformal mapping, analytic continuation, multivalued functions.
Prerequisite(s): MATH 402 with min. grade of C or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 522
Mathematical Modeling
The course provides a systematic approach to modeling applications from areas such as physics and chemistry, engineering, biology, and business (operations research). The mathematical models lead to discrete or continuous processes that may be deterministic or stochastic. Dimensional analysis and scaling are introduced to prepare a model for study. Analytic and computational tools from a broad range of applied mathematics will be used to obtain information about the models. The mathematical results will be compared to physical data to assess the usefulness of the models. Credit may not be granted for both MATH 486 and MATH 522.
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 523
Case Studies and Project Design in Applied Mathematics
The goal of the course is for students to learn how to use applied mathematics methods and skills to analyze real-world problems and to communicate their results in a non-academic setting. Students will work in groups of 2 or 3 to study and analyze problems and then provide useful information to a potential client. The time distribution is flexible and includes discussions of problems, presentation of needed background material and the required reports, and presentations by the teams. Several small projects will be examined and reported on.
Prerequisite(s): MATH 522
Credit: Variable

MATH 525
Statistical Models and Methods
Concepts and methods of gathering, describing and analyzing data including statistical reasoning, basic probability, sampling, hypothesis testing, confidence intervals, correlation, regression, forecasting, and nonparametric statistics. No knowledge of calculus is assumed. This course is useful for graduate students in education or the social sciences. This course does not count for graduation in any mathematics program. Credit given only for one of the following: MATH 425, MATH 476, or MATH 525.
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 527
Machine Learning in Finance: From Theory to Practice
The purpose of this course is to introduce students to the theory and application of supervised and reinforcement learning to big data problems in finance. This course emphasizes the various mathematical frameworks for applying machine learning in quantitative finance, such as quantitative risk modeling with kernel learning and optimal investment with reinforcement learning. Neural networks are used to implement many of these mathematical frameworks in finance using real market data.
Prerequisite(s): MATH 475
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 530
Applied and Computational Algebra
Basics of computation with systems of polynomial equations, ideals in polynomial rings; solving systems of equations by Groebner bases; introduction to elimination theory; algebraic varieties in affine n-space; Zariski topology; dimension, degree, their computation and theoretical consequences.
Prerequisite(s): MATH 532 with min. grade of C or MATH 332 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 532
Linear Algebra
Matrix algebra, vector spaces, norms, inner products and orthogonality, determinants, linear transformations, eigenvalues and eigenvectors, Cayley-Hamilton theorem, matrix factorizations (LU, QR, SVD).
Prerequisite(s): MATH 332 with min. grade of C or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 535
Optimization I
Introduction to both theoretical and algorithmic aspects of linear optimization: geometry of linear programs, simplex method, anticycling, duality theory and dual simplex method, sensitivity analysis, large scale optimization via Dantzig-Wolfe decomposition and Benders decomposition, interior point methods, network flow problems, integer programming. Credit may not be given for both MATH 435 and MATH 535.
Prerequisite(s): MATH 332 with min. grade of C or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 540
Probability
Random events and variables, probability distributions, sequences of random variables, limit theorems, conditional expectations, and martingales.
Prerequisite(s): MATH 475 with min. grade of C and (MATH 400 with min. grade of C or Graduate standing)
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 542
Stochastic Processes
This is an introductory course in stochastic processes. Its purpose is to introduce students into a range of stochastic processes, which are used as modeling tools in diverse field of applications, especially in the business applications. The course introduces the most fundamental ideas in the area of modeling and analysis of real World phenomena in terms of stochastic processes. The course covers different classes of Markov processes: discrete and continuous-time Markov chains, Brownian motion, and diffusion processes. It also presents some aspects of stochastic calculus with emphasis on the application to financial modeling and financial engineering.
Prerequisite(s): (MATH 332 with min. grade of C or MATH 333 with min. grade of C or Graduate standing) and (MATH 475 with min. grade of C or Graduate standing)
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 543
Stochastic Analysis
This course will introduce the student to modern finite dimensional stochastic analysis and its applications. The topics will include: a) an overview of modern theory of stochastic processes, with focus on semimartingales and their characteristics, b) stochastic calculus for semimartingales, including Ito formula and stochastic integration with respect to semimartingales, c) stochastic differential equations (SDE's) driven by semimartingales, with focus on stochastic SDE's driven by Levy processes, d) absolutely continuous changes of measures for semimartingales, e) some selected applications.
Prerequisite(s): MATH 540 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 544
Stochastic Dynamics
This course is about modeling, analysis, simulation and prediction of dynamical behavior of complex systems under random influences. The mathematical models for such systems are in the form of stochastic differential equations. It is especially appropriate for graduate students who would like to use stochastic methods in their research, or to learn these methods for long term career development. Topics include white noise and colored noise, stochastic differential equations, random dynamical systems, numerical simulation, and applications to scientific, engineering and other areas.
Prerequisite(s): MATH 474 or MATH 475 with min. grade of B
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 545
Stochastic Partial Differential Equations
This course introduces various methods for understanding solutions and dynamical behaviors of stochastic partial differential equations arising from mathematical modeling in science, engineering, and other areas. It is designed for graduate students who would like to use stochastic methods in their research or to learn such methods for long term career development. Topics include the following: Random variables; Brownian motion and stochastic calculus in Hilbert spaces; Stochastic heat equation; Stochastic wave equation; Analytical and approximation techniques; Stochastic numerical simulations via Matlab; and applications to science, engineering, and other areas.
Prerequisite(s): MATH 540 with min. grade of C or MATH 543 with min. grade of C or MATH 544 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 546
Introduction to Time Series
This course introduces the basic time series analysis and forecasting methods. Topics include stationary processes, ARMA models, spectral analysis, model and forecasting using ARMA models, nonstationary and seasonal time series models, multivariate time series, state-space models, and forecasting techniques.
Prerequisite(s): MATH 475 with min. grade of C or ECE 511 with min. grade of C or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 548
Mathematical Finance I
This is an introductory course in mathematical finance. Technical difficulty of the subject is kept at a minimum by considering a discrete time framework. Nevertheless, the major ideas and concepts underlying modern mathematical finance and financial engineering are explained and illustrated.
Prerequisite(s): MATH 474 with min. grade of C or MATH 475 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 550
Topology
Topological spaces, continuous mappings and homeomorphisms, metric spaces and metrizability, connectedness and compactness, homotopy theory.
Prerequisite(s): MATH 556 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 553
Discrete Applied Mathematics I
Graph Theory is the study of mathematical structures underlying the ubiquitous network models occurring in computer science, machine learning and optimization, electrical and computer engineering, physics, chemistry, and social networks. This graduate-level introduction to graph theory lays a rigorous foundation in graph theory through existential and algorithmic problems, structural and extremal results, and applications to science and engineering. Topics include trees, matchings, connectivity, planarity, and coloring. Credit will not be granted for both MATH 553 and MATH 454.
Prerequisite(s): MATH 410 or MATH 430 or MATH 453
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 554
Modern Methods in Discrete Applied Mathematics
A graduate-level course that introduces students in applied mathematics, computer science, natural sciences, and engineering, to the application of modern tools and techniques from various fields of mathematics to existential and algorithmic problems arising in discrete applied math. Probabilistic methods, entropy, linear algebra methods, Combinatorial Nullstellensatz, and Markov chain Monte Carlo, are applied to fundamental problems like Ramsey-type problems, intersecting families of sets, extremal problems on graphs and hypergraphs, optimization on discrete structures, sampling and counting discrete objects, etc.
Prerequisite(s): MATH 454 with min. grade of C or MATH 553 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 561
Algebraic and Geometric Methods in Statistics
Algebraic structures are present in a broad variety of statistical contexts, involving both parametric and non-parametric statistical models for continuous and discrete random variables. A broad range of algebraic tools is used to better understand model structure, improve statistical inference, and explore new classes of models. The course offers an overview of fundamental theoretical constructions relevant to some of the more popular recent applications in the field: exact conditional test for discrete data, likelihood geometry, parameter identifiability and model selection, network models with applications to social sciences and neuroscience, and phylogenetics and tree-based evolutionary models in biology.
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 563
Mathematical Statistics
Theory of sampling distributions; principles of data reduction; interval and point estimation, sufficient statistics, order statistics, hypothesis testing, correlation and linear regression; introduction to linear models.
Prerequisite(s): MATH 474 with min. grade of C or MATH 475 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 564
Regression
This course introduces the basic statistical regression models. Topics include simple linear regression, multiple linear regression, least square estimates of parameters; hypothesis testing and confidence intervals in linear regression, testing of models, data analysis and appropriateness of models, generalized linear models. Students are expected to use software packages (R, Python, etc.) to analyze real data. Credit may not be granted for both MATH 484 and MATH 564. (3-0-3)
Prerequisite(s): MATH 474 with min. grade of C or MATH 476 with min. grade of C or MATH 563 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 565
Monte Carlo Methods
This course teaches students Monte Carlo simulation techniques, focusing on applications in financial risk management, uncertainty quantification, and Bayesian inference. These sampling methods are used to compute the expected values, quantiles, and densities. Advanced techniques, such as Quasi-Monte Carlo methods and Markov chain Monte Carlo, are covered.
Prerequisite(s): MATH 474 or MATH 475
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 566
Multivariate Analysis
Random vectors, sample geometry and random sampling, generalized variance, multivariate normal and Wishart distributions, estimation of mean vector, confidence region, Hotelling's T-square, covariance, principal components, factor analysis, discrimination, clustering.
Prerequisite(s): MATH 532 with min. grade of C and MATH 564 with min. grade of C and MATH 563 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 567
Advanced Design of Experiments
Basic concepts for experimental design; introductory regression analysis; experiments with a single factor; experiments with more than one factor; full factorial experiments at two levels; fractional factorial design at two levels; full and fractional factorial design at three levels and at mixed levels; response surface methodology; introduction to computer experiments and space-filling design.
Prerequisite(s): MATH 474 with min. grade of C or MATH 476 with min. grade of C or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 568
Topics in Statistics
Categorical data analysis, contingency tables, log-linear models, nonparametric methods, sampling techniques.
Prerequisite(s): MATH 563 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 569
Statistical Learning
The wealth of observational and experimental data available provides great opportunities for us to learn more about our world. This course teaches modern statistical methods for learning from data, such as regression, classification, kernel methods, and support vector machines.
Prerequisite(s): (MATH 474 with min. grade of C or MATH 475 with min. grade of C or Graduate standing) and (MATH 350 with min. grade of C or Graduate standing)
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 571
Data Preparation and Analysis
This course surveys industrial and scientific applications of data analytics with case studies including exploration of ethical issues. Students will learn how to prepare data for analysis, perform exploratory data analysis, and develop meaningful data visualizations. They will work with a variety of real world data sets and learn how to prepare data sets for analysis by cleaning and reformatting. Students will also learn to apply a variety of different data exploration techniques including summary statistics and visualization methods.
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 572
Data Science Practicum
In this project-oriented course, students will work in small groups to solve real-world data analysis problems and communicate their results. Innovation and clarity of presentation will be key elements of evaluation. Students will have an option to do this as an independent data analytics internship with an industry partner.
Prerequisite(s): SCI 522 with min. grade of C and (CSP 571 with min. grade of C or MATH 571 with min. grade of C)
Lecture: 3 **Lab:** 3 **Credits:** 6

MATH 573
Reliable Mathematical Software
Many mathematical or statistical problems cannot be solved analytically or by hand in a reasonable amount of time, in which case we turn to mathematical software to solve these problems. Popular examples of general-purpose mathematical software include Python, MATLAB, R, Mathematica, Fortran, and the NAG Library. Researchers often find themselves writing mathematical software to demonstrate their new ideas, or using mathematical software written by others to solve their applications. Recently, the emergence of generative AI tools such as Generative Pre-trained Transformer (GPT) and Copilot can also assist in the prototyping of mathematical software. This course covers the ingredients as well as emerging opportunities and challenges in producing mathematical software that is efficient, robust, and trustworthy. Students will write their own packages or parts of packages to practice the principles of reliable mathematical software.
Lecture: 1 **Lab:** 0 **Credits:** 1

MATH 574
Bayesian Computational Statistics
Rigorous introduction to the theory of Bayesian statistical inference and data analysis including prior and posterior distributions, Bayesian estimation and testing, Bayesian computation theories and methods, and implementation of Bayesian computation methods using popular statistical software.
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 575
Statistical Analysis of Financial Data
The objective of this course is to introduce students to modern data analysis used in the financial industry, and to provide students with the necessary statistical toolkit to analyze and extract information from financial data. An important part of the course is the implementation of those statistical methods via Python/R, using real market data.
Prerequisite(s): MATH 474
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 577
Computational Mathematics I
Fundamentals of matrix theory; least squares problems; computer arithmetic, conditioning and stability; direct and iterative methods for linear systems; nonlinear systems. Credit may not be granted for both Math 577 and Math 477. Prerequisite: An undergraduate numerical course, such as MATH 350 or instructor permission.
Prerequisite(s): MATH 350 with min. grade of C or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 578
Computational Mathematics II
Polynomial interpolation; numerical integration; numerical solution of initial value problems for ordinary differential equations by single and multi-step methods, Runge-Kutta, Predictor-Corrector; numerical solution of boundary value problems, and eigenvalue problems. Credit may not be granted for both MATH 578 and MATH 478.
Prerequisite(s): MATH 350 with min. grade of C or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 581
Finite Element Method
Various elements, error estimates, discontinuous Galerkin methods, methods for solving system of linear equations including multigrid. Applications.
Prerequisite(s): MATH 350 with min. grade of C or MATH 489 with min. grade of C or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 582
Mathematical Finance II
This course is a continuation of Math 485/548. It introduces the student to modern continuous time mathematical finance. The major objective of the course is to present main mathematical methodologies and models underlying the area of financial engineering, and, in particular, those that provide a formal analytical basis for valuation and hedging of financial securities.
Prerequisite(s): (MATH 485 with min. grade of C or MATH 548 with min. grade of C) and (MATH 481 with min. grade of C or MATH 542 with min. grade of C)
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 583
Wealth management and robo-advising
This course covers fundamental concepts from modern wealth management industry and design of robo-advising systems. The course builds upon Modern Portfolio Theory, CAPM and their dynamic counterparts. A significant part of the course is dedicated to analysis, modeling and practical implementation of a robo-advising system using Python and real-market data.
Prerequisite(s): MATH 474 or MATH 475
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 584
Mathematical Methods for Algorithmic Trading
This course is concerned with the design and implementation of trading strategies. In particular, it covers the mean-variance portfolio selection problem, utility maximization, pairs trading, market making, and optimal liquidation. The analysis includes such important features as: the construction and usage of predictive signals, finding a tradeoff between risk and return, accounting for transaction costs and market impact. The available mathematical tools and models are presented in each case, and they include: methods for solving constrained optimization problems, stochastic control and dynamic programming principle, time-series analysis. An important part of the course is the implementation of trading algorithms via Python, using real market data. (3-0-3)
Prerequisite(s): (MATH 481 with min. grade of C or MATH 542 with min. grade of C or MATH 543 with min. grade of C or MATH 475 with min. grade of C or MATH 474 with min. grade of C or MATH 540 with min. grade of C) and (MATH 484* or MATH 546* with min. grade of C or MATH 563* with min. grade of C or MATH 564* with min. grade of C or MATH 476* or MATH 446* or MATH 426*), An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 585
Decentralized Financial Engineering
Decentralized finance (DeFI) is one of the fastest growing areas of finance and relies on blockchains, such as Ethereum, to provide decentralized applications for financial services. The purpose of this course is to equip students with engineering knowledge of DeFI markets and the ability to create models of token behaviour (tokenomics) and market microstructure in addition to gain familiarity with the tooling for implementing smart contracts.
Prerequisite(s): MATH 584 and MATH 474
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 586
Theory and Practice of Fixed Income Modeling
The course covers basics of the modern interest rate modeling and fixed income asset pricing. The main goal is to develop a practical understanding of the core methods and approaches used in practice to model interest rates and to price and hedge interest rate contingent securities. The emphasis of the course is practical rather than purely theoretical. A fundamental objective of the course is to enable the students to gain a hands-on familiarity with and understanding of the modern approaches used in practice to model interest rate markets.
Prerequisite(s): (MATH 481* with min. grade of C or MATH 542 with min. grade of C) and (MATH 485 with min. grade of C or MATH 548 with min. grade of C), An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 587
Theory and Practice of Modeling Risk and Credit Derivatives
This is an advanced course in the theory and practice of credit risk and credit derivatives. Students will get acquainted with structural and reduced form approaches to mathematical modeling of credit risk. Various aspects of valuation and hedging of defaultable claims will be presented. In addition, valuation and hedging of vanilla credit derivatives, such as credit default swaps, as well as vanilla credit basket derivatives, such as collateralized credit obligations, will be discussed.
Prerequisite(s): MATH 582 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 588
Advanced Quantitative Risk Management
This is an advanced course on quantitative risk management. The major concepts and ideas from the modern risk management will be explained and illustrated. The course builds upon general theory of risk measures and performance measures and addresses the current regulatory requirements for market participants.
Prerequisite(s): MATH 548 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 589
Numerical Methods for Partial Differential Equations
This course introduces numerical methods, especially the finite difference method for solving different types of partial differential equations. The main numerical issues such as convergence and stability will be discussed. It also includes introduction to the finite volume method, finite element method and spectral method. Prerequisite: An undergraduate numerical course such as MATH 350 and a PDE course such as MATH 461 or MATH 489 or consent of instructor.
Prerequisite(s): (MATH 350 or Graduate standing) and (MATH 461 or MATH 489)
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 590
Meshfree Methods
Fundamentals of multivariate meshfree radial basis function and moving least squares methods; applications to multivariate interpolation and least squares approximation problems; applications to the numerical solution of partial differential equations; implementation in Matlab.
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 591
Research and Thesis M.S.
Prerequisite: Instructor permission required.
Credit: Variable

MATH 592
Internship in Applied Mathematics
The course is for students in the Master of Applied Mathematics program who have an approved summer internship at an outside organization. This course can be used in place of Math 523 subject to the approval of the director of the program.
Credit: Variable

MATH 593
Seminar in Applied Mathematics
Current research topics presented in the department colloquia and seminars.
Lecture: 1 **Lab:** 0 **Credits:** 0

MATH 594
Professional Master's Project
The course is part of the capstone experience for students in the Master of Applied Mathematics program. Students will work in groups of 2 or 3 to study and analyze a real-world problem.
Credit: Variable

MATH 597
Reading and Special Projects
Independent study as a reading course or master's project with a faculty member in Mathematics. Letter grading. May be taken more than once. Instructor permission required.
Credit: Variable

MATH 599
TA Training
This course provides the foundation of how to teach mathematics in the context of introductory undergraduate courses. The course is designed to encourage participation and cooperation among the graduate students, to help them prepare for a career in academia, and to help convey the many components of effective teaching.
Lecture: 1 **Lab:** 0 **Credits:** 0

MATH 601
Advanced Topics in Combinatorics
Course content is variable and reflects current research in combinatorics.
Prerequisite(s): MATH 554 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 602
Advanced Topics in Graph Theory
Course content is variable and reflects current research in graph theory.
Prerequisite(s): MATH 554 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 603
Advanced Topics in Computational Mathematics
Course content is variable and reflects current research in computational mathematics.
Prerequisite(s): MATH 578 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 604
Advanced Topics in Applied Analysis
Course content is variable and reflects current research in applied analysis.
Prerequisite(s): MATH 501 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 605
Advanced Topics in Stochastics
Course content is variable and reflects current research in stochastic.
Prerequisite(s): MATH 544 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 691
Research and Thesis Ph.D.
(Credit: Variable)
Credit: Variable

MATH 764
Linear Regression
This is an introductory course on regression analysis. Topics include simple and multiple linear regression models, least square estimates of parameters, hypothesis testing, and confidence intervals. Students are expected to use software packages like R to analyze data.
Lecture: 1 **Lab:** 0 **Credits:** 1

MATH 765
Model Diagnostics and Remedial Measures
In this course, we will examine the situation when the assumptions of the regression model have been violated and how to remediate them.
Lecture: 1 **Lab:** 0 **Credits:** 1

MATH 766
Variable Selection, Model Validation, and Nonlinear Regression
In this course, we will examine the variable selection procedures, logistic regression and generalized linear model.
Lecture: 1 **Lab:** 0 **Credits:** 1

SCI 511
Project Management
Successful project management links the basic metrics of schedule adherence, budget adherence, and project quality. But, it also includes the 'people components' of customer satisfaction and effective management of people whether it is leading a project team or successfully building relationships with co-workers. Through course lectures, assigned readings, and case studies, the basic components of leading, defining, planning, organizing, controlling, and closing a project will be discussed. Such topics include project definition, team building, budgeting, scheduling, risk management and control, evaluation, and project closeout.
Lecture: 3 **Lab:** 0 **Credits:** 3

SCI 522
Public Engagement for Scientists
This course presents strategies for scientists to use when engaging a variety of audiences with scientific information. Students will learn to communicate their knowledge through correspondence, formal reports, and presentations. Students will practice document preparation using report appropriate formatting, style, and graphics. Written assignments, discussion questions, and communication exercises will provide students with a better understanding of the relationship between scientists and their audiences whether in the workplace, laboratory, etc.
Lecture: 3 **Lab:** 0 **Credits:** 3

SCI 595
Ethics for the Health Professions
Lectures and discussion relating to ethics relating to the health professions. This course exposes students to current ethical and social issues surrounding health care, including health care provider and patient interactions and institutional considerations using case study examples.
Lecture: 1 **Lab:** 0 **Credits:** 1

STAT 514
Applied Computational Statistics for Analytics
Generating actionable insights from data relies heavily on proper usage of analytics. The foundation of this process consists of two key ingredients: fundamental statistical concepts and corresponding computational tools. This course covers the topics from statistics and programming necessary to understand how such concepts come about, why the algorithms work the way they do, and how to use these in practice. The emphasis is on implementing the foundational procedures in industry-standard programming languages.
Lecture: 3 **Lab:** 0 **Credits:** 3