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), predicting how financial markets will behave (requiring probability/statistics, analysis and optimization), and understanding how liquids flow around solids (requiring computational methods and analysis).

Our programs focus on four areas of modern applied mathematics: applied analysis, computational mathematics, discrete applied mathematics, and stochastics. More detailed descriptions of these areas follow.

### Degrees Offered
- Master of Applied Mathematics
- Master of Science in Applied Mathematics
- Doctor of Philosophy in Applied Mathematics
- With the Department of Computer Science: Master of Data Science
- With the Stuart School of Business: Master of Mathematical Finance

### 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 at IIT are primarily in four areas of modern applied mathematics: applied analysis, computational mathematics, discrete applied mathematics, and stochastics. These areas are briefly described in the following subsections; faculty with primary and secondary interests.

#### Applied Analysis
Applied analysis is one of the foundations for interdisciplinary applied mathematics. The principles of (functional) analysis are applied to such areas as partial differential equations, dynamical systems, and numerical analysis.

The basic framework, concepts, and techniques of modern mathematical analysis are essential for modeling, analysis, and simulation of complicated phenomena in engineering and science. Applying the ideas and methods of modern mathematical analysis to such problems has been a thoroughly interdisciplinary effort.

Research and teaching within the applied analysis group at IIT concentrates on development and application of new techniques for investigating numerous phenomena in engineering and science. In particular, members of the group do research in nonlinear dynamics, approximation theory, numerical analysis, fluid dynamics, materials science, viscoelastic and polymeric fluid flows, biological science, quantum mechanics and electro-dynamics, solid mechanics, financial engineering, and other disciplines.

Primary interests: Bielecki, Duan, Lubin
Secondary interests: Cialenco, Fasshauer, S. Li, X. Li, Nair, Rempfer, Tier
**Applied Mathematics**

**Computational Mathematics**

The use of computation/simulation as a third alternative to theory and experimentation is now common practice in many branches of science and engineering. Many scientific problems that were previously inaccessible have seen tremendous progress from the use of computation (e.g., many-body simulations in physics and chemistry, simulation of semi-conductors, etc.). Researchers and scientists in these areas must have a sound training in the fundamentals of computational mathematics and become proficient in the use (and development) of new algorithms and analytical techniques as they apply to modern computational environments.

Research and teaching within the computational mathematics group at IIT concentrates on basic numerical analysis, as well as development of new computational methods used in the study and solution of problems in the applied sciences and engineering. In particular, members of the group do research on complexity theory, the finite element method, meshfree methods, multiscale and multilevel methods, Monte Carlo and quasi-Monte Carlo methods, numerical methods for deterministic and stochastic ordinary and partial differential equations, computational fluid dynamics, computational materials science, computer-aided geometric design, and parallel computation.

Primary interests: Fasshauer, Hickernell, S. Li, X. Li, Tier
Secondary interests: Duan, Petrovic, Rempfer

**Discrete Applied Mathematics**

Discrete applied mathematics is a fairly young branch of mathematics and is concerned with using combinatorics, graph theory, optimization, and portions of theoretical computer science to attack problems in engineering, as well as the hard and soft sciences.

Research interests in the discrete applied mathematics group at IIT are in discrete methods in computational and mathematical biology, intersection graphs and their applications, discrete location theory, voting theory applied to data analysis, graph drawing, random geometric graphs, communication networks, coding theory, low discrepancy sequences, algorithm design, and analysis.

Primary interests: Ellis, Kaul, Pelsmajer, Reingold
Secondary interests: Hickernell, Kang, Petrovic, Weening

**Stochastics**

Stochastics at IIT includes traditional statistics (the methods of data analysis and inference) and probability (the modeling of uncertainty and randomness). However, also included are other areas where stochastic methods have been becoming more important in recent years such as finite and infinite dimensional stochastic processes, stochastic integration, stochastic dynamics, stochastic partial differential equations, probabilistic methods for analysis, mathematical finance and discrete mathematics, computational methods for stochastic systems, etc.

The current research and teaching interests in the stochastic analysis group at IIT include asymptotics in statistics, experimental design, computational statistics, stochastic calculus and probability theory, stochastic dynamical systems, stochastic control, stochastic partial differential equations, and statistical decision theory.

Primary interests: Adler, Bielecki, Cialenco, Duan, Hickernell, Kang, Petrovic, Tier
Secondary interests: Ellis, Kaul
Faculty

Adler, Andre, Associate Professor. B.S., State University of New York-Binghamton; M.S., Purdue University; Ph.D., University of Florida. Asymptotics in statistics, probability, and statistical inference.


Choi, Sou-Cheng, Research Assistant Professor. B.Sc., M.Sc., National University of Singapore; Ph.D., Stanford University.

Cialenco, Igor, Associate Professor. B.S., Ph.D., Moldova State University; M.S., Ph.D., University of Southern California. Stochastic processes, stochastic partial differential equations(PDEs), statistical inference for stochastic PDEs, application of stochastic PDEs to mathematical finance, operator theory, spectral analysis of non-selfadjoint operators.

Duan, Jinqiao (Jeffrey), Professor. B.S., Wuhan University (China); M.S., University of Massachusetts-Amherst; Ph.D., Cornell University. Stochastic dynamical systems; stochastic partial differential equations; nonlinear dynamical systems; modeling, analysis, simulation and prediction of random, complex and multiscale phenomena in engineering and science (geophysical and environmental systems, etc).

Ellis, Robert B., Associate Professor. B.S., M.S., Virginia Tech; Ph.D., University of California-San Diego. Combinatorics, spectral, random and algebraic graph theory, probabilistic methods, coding theory, and combinatorial algorithms.

Erickson, John F., Senior Lecturer. B.S., M.S., University of Illinois-Chicago; M.S., Northeastern Illinois University; Ph.D., Illinois Institute of Technology.

Fasshauer, Gregory, Professor, Associate Chair, and Director of Undergraduate Studies, Department of Applied Mathematics. Diplom, Universitat Stuttgart (Germany); M.A., Ph.D., Vanderbilt University. Approximation theory, numerical analysis, meshfree methods with applications to multivariate scattered data approximation and the solution of partial differential equations. Computer-aided geometric design and bivariate splines.

Góralczyk, Adam, Research Assistant Professor. M.Sc., Warsaw School of Economics; Ph.D., University of California, San Diego. Mathematical finance, stochastic analysis, probability and random processes, computational finance.

Hickernell, Fred J., Professor and Chairman. B.A., Pomona College; Ph.D., Massachusetts Institute of Technology. Computational mathematics, numerical approximation of integrals and functions, Monte Carlo and quasi-Monte Carlo methods, low discrepancy analysis, information-based complexity theory, design of laboratory and computer experiments, computational finance.

Kang, Lulu, Assistant Professor. B.S., Nanjing University (China); Ph.D., Georgia Institute of Technology. Non-parametric statistical modeling, Bayesian experimental design, computer experiments, engineering statistics.

Kaul, Hemanshu, Associate Professor. B.Sc., St. Stephen’s College (India); M.Sc., Indian Institute of Technology (India); Ph.D., University of Illinois, Urbana-Champaign. Graph theory and combinatorics, discrete optimization and operations research, probabilistic models and methods in discrete mathematics.

Li, Shuwang, Associate Professor. B.E., Tong Ji University (China); M.S., Ph.D., University of Minnesota. Computational mathematics and modeling of biosystems, numerical analysis, methods for interface problems in Fluids, Biology and Materials.

Li, Xiaofan, Professor, Director of Graduate Studies in the Department of Applied Mathematics, and Associate Vice Provost for Graduate Admission. B.A., Zhejiang University (China); M.A., Ph.D., University of California-Los Angeles. Computational fluid dynamics, computational materials science, boundary integral method, moving-boundary value problems, suspension of particles, phase transformation in materials science.

Lubin, Arthur, Associate Professor. B.S., Michigan State University; M.A., Ph.D., University of Wisconsin. Commuting contractions in Hilbert space, spectral theory, models for analytic functions, linear system theory.

Maslanka, David, Senior Lecturer. B.A., St. Xavier University; M.S., Ph.D., Illinois Institute of Technology.

Nair, Sudhakar E., Professor of Mechanical and Aerospace Engineering and Applied Mathematics. B.Sc., Regional Engineering College (India); M.E., Indian Institute of Science; Ph.D., University of California-San Diego. Solid mechanics, stress analysis of composite and inelastic material, dynamics of cable, fracture mechanics and wave propagation theory.
Applied Mathematics

Faculty (continued)

Nieweglowski, Mariusz, Visiting Assistant Professor. M.S., Ph.D., Warsaw University of Technology (Poland). Stochastic analysis and financial mathematics.

Pelsmajer, Michael J., Associate Professor. B.A., Williams College; M.S., Ph.D., University of Illinois, Urbana- Champaign. Discrete Applied Mathematics: Graph theory, combinatorics, communication networks, algorithms and complexity.

Petrovic, Sonja., Assistant Professor. B.Sc. University of Tennessee at Chattanooga; Ph.D. University of Kentucky. Algebraic statistics (algebra, geometry, and combinatorics for statistical models), computational algebraic geometry, applications to social networks, and computational biology (phylogenetics).

Rempfer, Dietmar, Professor of Mechanical and Aerospace Engineering and Applied Mathematics, and Associate Dean, Armour College of Engineering. M.S., Ph.D., Universität Stuttgart (Germany). Fluid mechanics, especially theoretical studies of transitional and turbulent shear flows in open systems, numerical fluid mechanics, modeling for environmental and urban fluid mechanics, coherent structures in turbulent flows, control of transitional and turbulent wall layers, nonlinear dynamical systems.

Tier, Charles, Senior Lecturer. Ph.D. Courant Institute, New York University. Asymptotic and singular perturbation methods, applied stochastic modeling, mathematical biology, queueing models, computational finance.

Weening, Fred, Senior Lecturer. B.S., Carnegie-Mellon University; Ph.D. University of California-San Diego. Complex analysis, combinatorics.

Admission Requirements

Cumulative undergraduate GPA minimum: 3.0/4.0
GRE score minimum:
M.A.S. and M.S.: 304 (quantitative + verbal) 2.5 (analytical writing)
Before 2011: 1100 (quantitative + verbal)
Ph.D.: 304 (quantitative + verbal) 3.0 (analytical writing)
Before 2011: 1100 (quantitative + verbal)
TOEFL minimum: 80/213/550 (internet/computer/paper based test scores)
At least two letters of recommendation

Admission to the professional master’s program in Mathematical Finance requires a bachelor’s degree in mathematics, engineering, or equivalent, with a minimum cumulative GPA of 3.0/4.0. TOEFL scores (if required) must have a minimum score of 100/250 (internet/computer-based test score). A professional statement of goals/objectives (2 pages) and a curriculum vitae must be submitted. Three letters of recommendation are required (at least two must be from academia, the third may be from industry). An interview may also be required.

Typically, admitted students score at least 156 on the quantitative portion of the GRE and at least 3.0 on the analytical writing portion. However, 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, including grades in mathematics courses, letters of recommendation, and the student’s overall record of achievements.

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.

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

32 credit hours

The Master of Applied Mathematics program at IIT is a non-thesis professional master’s degree program that provides graduates with mathematics training for technology-based jobs in business, industry, or government. Graduates develop state-of-the-art skills in modeling, analysis, and computation needed to solve real-world problems. The program requires students to learn writing and communication skills along with teamwork and project management skills. The program can typically be completed in 15 months, with three regular term semesters and one summer semester.

Core Courses

Applied Mathematics and Computational Science Core
MATH 475 Probability
OR
MATH 563 Mathematical Statistics

MATH 522 Mathematical Modeling
MATH 577 Computational Mathematics I

Business and Professional Core
SCI 522 Public Engagement for Scientists
CHEM 511 Project Management: Business Principles

Capstone Professional Experience
MATH 523 Case Studies and Project Design in Applied Mathematics
OR
MATH 592 Internship in Applied Mathematics

MATH 594 Professional Master’s Project

Elective Courses

Advanced Computation
MATH 489 Partial Differential Equations
MATH 565 Monte Carlo Methods in Finance
MATH 578 Computational Mathematics II
MATH 581 Finite Element Method
MATH 589 Numerical Methods for Partial Differential Equations
CS 595 Topics in Computer Science
MSF 526 Computational Finance

Stochastic Modeling and Analysis
MATH 481 Introduction to Stochastic Processes
MATH 485 Introduction to Mathematical Finance
MATH 542 Stochastic Processes
MATH 548 Mathematical Finance I
MATH 582 Mathematical Finance II

Statistical and Data Analytics
MATH 563 Mathematical Statistics
MATH 564 Applied Statistics
MATH 565 Monte Carlo Methods in Finance
MATH 567 Advanced Design of Experiments

Discrete Mathematics and Optimization
MATH 535 Optimization I
MATH 553 Discrete Applied Mathematics I
MATH 554 Discrete Applied Mathematics II

Degree Requirements
All IIT Graduate College requirements must be satisfied. Specific departmental requirements follow.

Credit Requirements
The student must complete 32 credit hours and maintain a 3.0/4.0 GPA. There are 23 hours of required, core courses. Nine hours of electives from each of four areas selected in consultation with, and approval of, the Program Director are required. The program may include, at most, nine hours at the 400-level.

Capstone Professional Experience
The capstone consists of a six-hour course in case studies and project management or an internship in applied mathematics.

Master’s Project
The project, which is three credit hours of MATH 594, is conducted under the supervision of a faculty member or an industrial partner.

Course Substitutions and Prerequisites
Course substitutions and needed prerequisite courses may be permitted, subject to the approval of the Program Director.
Master of Data Science
Collaborative Program with the Department of Computer Science

33 credit hours

This Professional Master’s degree program consists of 33 credit hours of coursework, including a practicum, in data science. The program is designed primarily for those with previous degrees or experience in computer science, statistics, mathematics, natural sciences, or business, who are interested in preparing for a career as a data science professional in business and industry. Enrolled full-time, the program can be completed in a year, including one summer.

Admission Requirements
A Bachelor’s degree from an accredited university with a minimum cumulative GPA of at least 3.0/4.0. Combined verbal and quantitative GRE examination score of at least 304 and an analytic writing score of at least 3.0, for the post-October 2002 test. The GRE requirement is waived for students with a bachelor’s degree from an accredited college or university in the United States with a cumulative GPA of at least 3.0/4.0.

Prerequisites include knowledge of a high level programming language at the level of CS 201 (Java or C/C++ programming is required), a data structures course at the level of CS 331, experience with database programming at the level of CS 425, linear algebra at the level of MATH 332, and probability and statistics at the level of MATH 474. Information on these courses is available in this catalog.

Students with insufficient background in computer science and/or mathematics will be required to take the relevant prerequisite courses and earn at least a B grade in each. These prerequisite courses do not count toward the 33 credit hour requirement.

Program Requirements
Coursework includes 18 credit hours of required core courses and 6 credit hours of CSP/MATH 572 Data Science Practicum. At least 9 credit hours must be taken of 500-level CS or CSP courses and 9 credit hours of 500-level MATH courses, not including the CSP/MATH 572 Data Science Practicum. Students must also take one semester of CSP/MATH 570 Data Science Seminar.

Data Science Core Courses
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>COM 523</td>
<td>Communicating Science</td>
</tr>
<tr>
<td>CS 587</td>
<td>Software Project Management</td>
</tr>
<tr>
<td>CS 584</td>
<td>Machine Learning</td>
</tr>
<tr>
<td>MATH 569</td>
<td>Statistical Learning</td>
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<tr>
<td>OR</td>
<td></td>
</tr>
<tr>
<td>CS 525</td>
<td>Advanced Database Organization</td>
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<tr>
<td>OR</td>
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<tr>
<td>CS 554</td>
<td>Data-Intensive Computing</td>
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<tr>
<td>MATH 564</td>
<td>Applied Statistics</td>
</tr>
<tr>
<td>MATH 571</td>
<td>Data Preparation and Analysis</td>
</tr>
</tbody>
</table>

Data Science Electives

Computational Fundamentals
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>CS 425</td>
<td>Database Organization</td>
</tr>
<tr>
<td>CS 450</td>
<td>Operating System</td>
</tr>
<tr>
<td>CS 535</td>
<td>Design and Analysis of Algorithms</td>
</tr>
<tr>
<td>CS 546</td>
<td>Parallel and Distributed Processing</td>
</tr>
<tr>
<td>CS 553</td>
<td>Cloud Computing</td>
</tr>
<tr>
<td>CS 589</td>
<td>Software Testing and Analysis</td>
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</tbody>
</table>

Computer Science Applications
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>CS 512</td>
<td>Topics in Computer Vision</td>
</tr>
<tr>
<td>CS 529</td>
<td>Information Retrieval</td>
</tr>
<tr>
<td>CS 556</td>
<td>Cyber-Physical Systems: Languages and Systems</td>
</tr>
<tr>
<td>CS 557</td>
<td>Cyber-Physical Systems: Networking and Algorithms</td>
</tr>
<tr>
<td>CS 583</td>
<td>Probabilistic Graphical Models</td>
</tr>
<tr>
<td>CS 585</td>
<td>Natural Language Processing</td>
</tr>
</tbody>
</table>

Mathematics, Probability, and Statistics
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 532</td>
<td>Linear Algebra</td>
</tr>
<tr>
<td>MATH 540</td>
<td>Probability</td>
</tr>
<tr>
<td>MATH 542</td>
<td>Stochastic Processes</td>
</tr>
<tr>
<td>MATH 565</td>
<td>Monte Carlo Methods in Finance</td>
</tr>
<tr>
<td>MATH 567</td>
<td>Advanced Design of Experiments</td>
</tr>
<tr>
<td>MATH 574</td>
<td>Bayesian Computational Statistics</td>
</tr>
</tbody>
</table>

Mathematical and Scientific Computing
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 577</td>
<td>Computational Mathematics I</td>
</tr>
<tr>
<td>MATH 578</td>
<td>Computational Mathematics II</td>
</tr>
<tr>
<td>MATH 590</td>
<td>Meshfree Methods</td>
</tr>
<tr>
<td>PHYS 440</td>
<td>Computational Physics</td>
</tr>
</tbody>
</table>
Master of Mathematical Finance
Collaborative Program with the Stuart School of Business

33 credit hours

The objective of the MMF program is to provide individuals interested in pursuing careers in financial risk management with advanced education in theoretical, computational, and business aspects of relevant quantitative methodologies. This is a collaborative program between the Stuart School of Business (SSB) and the Applied Mathematics Department (AM) and as such, it gives students the chance to benefit from the strength of both units. Students are required to complete a total of 11 semester courses, including eight core courses and three elective courses.

Core Courses
- MSF 505 Futures, OPT, and OTC Derivatives
- MSF 526 Computational Finance
- MSF 575 C++ with Financial Markets
- MATH 542 Stochastic Processes
- MATH 548 Mathematical Finance I
- MATH 565 Monte Carlo Methods in Finance
- MATH 582 Mathematical Finance II
- MATH 586 Theory and Practice of Fixed Income Modeling

Elective Courses from the Department of Applied Mathematics
- CS 522 Data Mining
- MATH 512 Partial Differential Equations
- MATH 522 Mathematical Modeling
- MATH 540 Probability
- MATH 543 Stochastic Analysis
- MATH 544 Stochastic Dynamics
- MATH 545 Stochastic Partial Differential Equations
- MATH 546 Introduction to Time Series
- MATH 566 Multivariate Analysis
- MATH 567 Advanced Design of Experiments
- MATH 569 Statistical Learning
- MATH 577 Computational Mathematics I
- MATH 578 Computational Mathematics II
- MATH 579 Complexity of Numerical Problems
- MATH 587 Theory and Practice of Modeling Risk and Credit Derivatives
- MATH 589 Numerical Methods for Partial Differential Equations
- MATH 590 Meshfree Methods

Elective Courses from the Stuart School
- MSF 524 Models for Derivatives
- MSF 525 Term Structure Modeling and Interest Rate Derivatives
- MSF 545 Structured Fixed Income Portfolios
- MSF 546 Quantitative Investment Strategies
- MSF 554 Market Risk Management
- MSF 555 Credit Risk Management
- MSF 564 Financial Theory
- MSF 565 International Finance Theory
- MSF 566 Time Series Analysis
- MSF 567 Bayesian Econometrics
- MSF 574 .NET and Database Management
- MSF 576 OOP and Algorithmic Trading Systems
- MSF 577 High Frequency Finance
- MSF 584 Equity and Equity Derivatives Trading
- MSF 585 FOREX and Fixed Income Strategies

Core Requirement
All Mathematical Finance students must complete the eight core classes unless they have obtained written permission from their academic advisor to substitute an alternative class for a core class.

Course Substitutions
To the extent that students have completed commensurate coursework or professional experience, substitutions to the required curriculum may be permitted, with the approval of the academic advisor.

Electives
At least one elective must be taken in Finance and at least one elective must be taken in Math from the elective options listed above.

Free Electives
One graduate level elective may be taken from outside the courses prescribed above, provided that it is consistent with the MMF program objectives and has been approved by the Program Director prior to the student’s registration.

Students may also transfer up to two classes from a graduate program at another accredited university if the student has not used the classes to satisfy the requirements for a degree at the previous university. Additional classes may be transferred with the permission of the Program Director.

Prerequisite Courses
Some students may be required to take prerequisite courses in mathematics, statistics, or computer programming before being admitted to a graduate course.
Master of Science in Applied Mathematics

32 credit hours
Comprehensive exam

The M.S. degree program provides a broad background in the fundamentals of the advanced mathematics that is applied to solve problems in other fields. The goal is to prepare students for careers in industry and for the doctoral program.

Required Credit Hours
Required courses 12 hours
Research/thesis 5-8 hours
Elective courses 12-20 hours

Required Courses
The colloquium/seminar course MATH 593 (must take it at least twice with satisfactory grade), and at least two of the basic sequences in the four core areas of study:

- **Applied Analysis**
  - MATH 500  Applied Analysis I
  - MATH 501  Applied Analysis II

- **Discrete Applied Mathematics**
  - MATH 553  Discrete Applied Mathematics I
  - MATH 554  Discrete Applied Mathematics II

- **Computational Mathematics**
  - MATH 577  Computational Mathematics I
  - MATH 578  Computational Mathematics II

- **Stochastics**
  - MATH 540  Probability

  AND one of the following:
  - MATH 543  Stochastic Analysis
  - MATH 544  Stochastic Dynamics
  - MATH 545  Stochastic Partial Differential Equations

Elective Courses
The remaining courses in each student’s program are selected in consultation with, and approval of, the Director of Graduate Studies. The program may include at most three courses at the 400-level and at most two courses outside the department.

Comprehensive Examination
The comprehensive examination requirement is fulfilled by a master’s thesis (5 to 8 credit hours of MATH 591), under the supervision of a faculty member, or by passing written tests in two of the four core areas of study.
Doctor of Philosophy in Applied Mathematics

84 credit hours beyond the bachelor’s degree
Qualifying exam
Comprehensive exam
Dissertation and Defense

Required Credit Hours (if entering with a bachelor’s degree)
Required courses 18 hours
Research/dissertation 24-32 hours
Elective courses 34-42 hours

Required Credit Hours (if entering with a master’s degree)
Required courses 18 hours
Research/dissertation 24-32 hours
Elective courses: 2-10 hours

The Ph.D. program provides advanced education through coursework (including independent study) and original, creative research in order to prepare students for careers in industrial research and academia. The program requires a total of 84 credit hours (approximately 52 for students entering with a master’s degree).

The qualifying examination requirement is fulfilled by passing written tests in three of the four core areas of study listed under the M.S. degree. The areas are chosen by the student and the qualifying exam must be completed within the first five semesters of study. The written tests will be offered twice every year, one in the early Fall (September) and the other in early Spring (January or February). The tests are given in each area separately and students can take the tests in one, two, or three areas each time. The comprehensive examination consists of an oral examination based on the student’s research proposal. The exam aims to ensure that the student has the background to carry out successful research in his/her chosen area and the proposed research has sufficient scholarly merit. Exceptions to these general rules require approval by the departmental Graduate Studies Committee.

Besides the courses in the core areas of study, the remaining courses in the program are selected in consultation with the student’s academic advisor. The program may include at most three MATH courses at the 400-level. The program requires the student take the colloquium/seminar course MATH 593 at least six times with satisfactory grade. The program must include at least three (but no more than five) courses in an area of concentration outside of the department, as approved by the director of graduate studies; these may include 400-level courses.

The dissertation (thesis) is expected to contain a distinct and substantial, original, and publishable contribution to the field of study. The credit hours devoted to thesis research (MATH 691) must total between 24 and 32. An oral examination in defense of the thesis constitutes completion of the degree.
Course Descriptions

MATH 400  
Real Analysis  
Real numbers, continuous functions; differentiation and Riemann integration. Functions defined by series. Prerequisite(s): [(MATH 251)] (3-0-3)

MATH 402  
Complex Analysis  
Analytic functions, conformal mapping, contour integration, series expansions, singularities and residues, and applications. Intended as a first course in the subject for students in the physical sciences and engineering. Prerequisite(s): [(MATH 251)] (3-0-3)

MATH 405  
Introduction to Iteration & Chaos  
Functional iteration and orbits, periodic points and Sharkovsky's cycle theorem, chaos and dynamical systems of dimensions one and two. Julia sets and fractals, physical implications. Prerequisite(s): [(MATH 251, MATH 252, and MATH 332) OR (MATH 251, MATH 252, and MATH 333)] (3-0-3)

MATH 410  
Number Theory  
Divisibility, congruencies, distribution of prime numbers, functions of number theory, diophantine equations, applications to encryption methods. Prerequisite(s): [(MATH 230)] (3-0-3)

MATH 420  
Geometry  
The course is focused on selected topics related to fundamental concepts and methods of Euclidean geometry in two and three dimensions and their applications with emphasis on various problem-solving strategies, geometric proof, visualization, and interrelation of different areas of mathematics. Prerequisite: Permission of instructor. (3-0-3)

MATH 425  
Statistical Methods  
Concepts and methods of gathering, describing and analyzing data including basic 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 students in education or the social sciences. This course does not count for graduation in any mathematics programs. Credit not given for both MATH 425 and MATH 476. Course does not satisfy graduation requirements for Applied Mathematics majors. (3-0-3)

MATH 426  
Statistical Tools for Engineers  
Descriptive statistics and graphs, probability distributions, random sampling, independence, significance tests, design of experiments, regression, time-series analysis, statistical process control, introduction to multivariate analysis. Same as CHE 426. Credit not given for both Math 426 and CHE 426 Course does not satisfy graduation requirements for Applied Mathematics majors. Requires sophomore standing. (3-0-3)

MATH 430  
Applied Algebra  
Relations; modular arithmetic; group theory; symmetry, permutation, cyclic, and abelian groups; group structure; subgroups, cosets, homomorphisms, classifications theorems; rings and fields. Applications to crystallography, cryptography, and check-digit schemes. Prerequisite(s): [(MATH 250) OR (MATH 332)] (3-0-3)

MATH 431  
Applied Algebra II  
Ring homomorphisms; factorization and reducibility in polynomial rings; integral domains; vector spaces; fields and their extensions. As time permits, application to one or more of the following: Frieze and crystallographic groups, Cayley digraphs, and coding theory. Prerequisite(s): [(MATH 430)] (3-0-3)

MATH 435  
Linear Optimization  
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 granted for both MATH 435 and MATH 535. Prerequisite(s): [(MATH 230)] (3-0-3)

MATH 453  
Combinatorics  
Permutations and combinations; pigeonhole principle; inclusion-exclusion principle; recurrence relations and generating functions; enumeration under group action. Prerequisite(s): [(MATH 230)] (3-0-3)

MATH 454  
Graph Theory & Applications  
Graph theory is the study of systems of points with some of the pairs of points joined by lines. Sample topics include: paths, cycles and trees; adjacency and connectivity; directed graphs; Hamiltonian and Eulerian graphs and digraphs; intersection graphs. Applications to the sciences (computer, life, physical, social) and engineering will be introduced throughout the course. Credit will not be granted for both MATH 454 and MATH 553. Prerequisite(s): [(MATH 230 and MATH 251) OR (MATH 230 and MATH 252)] (3-0-3)

MATH 461  
Fourier Series & Boundary-Value Problems  
Fourier series and integrals. The Laplace, heat, and wave equations: Solutions by separation of variables. D'Alembert's solution of the wave equation. Boundary-value problems. Prerequisite(s): [(MATH 251 and MATH 252)] (3-0-3)

MATH 474  
Probability & Statistics  
Elementary probability theory including discrete and continuous distributions, sampling, estimation, confidence intervals, hypothesis testing, and linear regression. Credit not granted for both MATH 474 and MATH 475. Course does not satisfy graduation requirements for Applied Mathematics majors. Prerequisite(s): [(MATH 251)] (3-0-3)
MATH 475
Probability
Elementary probability theory; combinatorics; random variables; discrete and continuous distributions; joint distributions and moments; transformations and convolution; basic theorems; simulation. Credit not granted for both MATH 474 and MATH 475.
Prerequisite(s): [(MATH 251)]
(3-0-3)

MATH 476
Statistics
Estimation theory; hypothesis tests; confidence intervals; goodness-of-fit tests; correlation and linear regression; analysis of variance; nonparametric methods.
Prerequisite(s): [(MATH 475)]
(3-0-3)

MATH 477
Numerical Linear Algebra
Fundamentals of matrix theory; least squares problems; computer arithmetic; conditioning and stability; direct and iterative methods for linear systems; eigenvalue problems. Credit may not be granted for both MATH 477 and MATH 577.
Prerequisite(s): [(MATH 350)]
(3-0-3)

MATH 478
Numerical Methods for Differential Equations
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 for ordinary differential equations by shooting method, finite differences and spectral methods. Credit may not be granted for both MATH 478 and MATH 578.
Prerequisite(s): [(MATH 350)]
(3-0-3)

MATH 481
Introduction to Stochastic Processes
This is an introductory, undergraduate course in stochastic processes. Its purpose is to introduce students to a range of stochastic processes which are used as modeling tools in diverse fields of applications, especially in risk management applications for finance and insurance. The course covers basic classes of stochastic processes: Markov chains and martingales in discrete time; Brownian motion; and Poisson process. It also presents some aspects of stochastic calculus.
Prerequisite(s): [(MATH 332 and MATH 475) OR (MATH 333 and MATH 475)]
(3-0-3)

MATH 483
Design & Analysis of Experiments
Review of elementary probability and statistics; analysis of variance for design of experiments; estimation of parameters; confidence intervals for various linear combinations of the parameters; selection of sample sizes; various plots of residuals; block designs; Latin squares; one, two, and 2k factorial designs; nested and cross factor designs; regression; nonparametric techniques.
Prerequisite(s): [(MATH 476)]
(3-0-3)

MATH 484
Regression & Forecasting
Simple linear regression; multiple linear regression; least squares estimates of parameters; hypothesis testing and confidence intervals in linear regression models; testing of models, data analysis, and appropriateness of models; linear time series models; moving average, autoregressive and/or ARIMA models; estimation, data analysis, and forecasting with time series models; forecasting errors and confidence intervals. Credit may not be granted for both MATH 484 and MATH 564.
Prerequisite(s): [(MATH 474) OR (MATH 476)]
(3-0-3)

MATH 485
Introduction to Mathematical Finance
This is an introductory course in mathematical finance. Technical difficulty of the subject is kept at a minimum while the major ideas and concepts underlying modern mathematical finance and financial engineering are explained and illustrated. The course covers the binomial model for stock prices and touches on continuous time models and the Black-Scholes formula.
Prerequisite(s): [(MATH 475)]
(3-0-3)

MATH 486
Mathematical Modeling I
The course provides a systematic approach to modeling and analysis of physical processes. For specific applications, relevant differential equations are derived from basic principles – for example, from conservation laws and constitutive equations. Dimensional analysis and scaling are introduced to prepare a model for analysis. Analytic solution techniques, such as integral transforms and similarity variable techniques, or approximate methods, such as asymptotic and perturbation methods, are presented and applied to the models. A broad range of applications from areas such as physics, engineering, biology, and chemistry are studied. Credit may not be granted for both MATH 486 and MATH 522.
Prerequisite(s): [(MATH 461)]
(3-0-3)

MATH 487
Mathematical Modeling II
The formulation of mathematical models, solution of mathematical equations, interpretation of results. Selected topics from queuing theory and financial derivatives.
Prerequisite(s): [(MATH 252)]
(3-0-3)

MATH 488
Ordinary Differential Equations & Dynamical Systems
Boundary-value problems and Sturm-Liouville theory; linear system theory via eigenvalues and eigenvectors; Floquet theory; nonlinear systems: critical points, linearization, stability concepts, index theory, phase portrait analysis, limit cycles, and stable and unstable manifolds; bifurcation; and chaotic dynamics.
Prerequisite(s): [(MATH 251 and MATH 252)]
(3-0-3)

MATH 489
Partial Differential Equations
First-order equations, characteristics. Classification of second-order equations. Laplace’s equation; potential theory. Green’s function, maximum principles. The wave equation: characteristics, general solution. The heat equation: use of integral transforms.
Prerequisite(s): [(MATH 461)]
(3-0-3)
MATH 491  
**Reading & Research**  
Independent reading and research.  
(Credit: Variable)

MATH 497  
**Special Problems**  
Special problems.  
(Credit: Variable)

MATH 500  
**Applied Analysis I**  
Metric and Normed Spaces; Continuous Functions; Contraction Mapping Theorem; Topological Spaces; Banach Spaces; Hilbert Spaces; Eigenfunction Expansion.  
Prerequisite(s): [(MATH 400)]  
(3-0-3)

MATH 501  
**Applied Analysis II**  
Bounded Linear Operators on a Hilbert Space; Spectrum of Bounded Linear Operators; Linear Differential Operators and Green’s Functions; Distributions and the Fourier Transform; Measure Theory, Lebesgue Integral and Function Spaces; Differential Calculus and Variational Methods.  
Prerequisite(s): [(MATH 500)]  
(3-0-3)

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) OR (MATH 489)]  
(3-0-3)

MATH 515  
**Ordinary Differential Equations & 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.  
Prerequisite(s): [(MATH 252)]  
(3-0-3)

MATH 519  
**Complex Analysis**  
Analytic functions, contour integration, singularities, series, conformal mapping, analytic continuation, multivalued functions.  
Prerequisite(s): [(MATH 402)]  
(3-0-3)

MATH 522  
**Mathematical Modeling**  
The course provides a systematic approach to modeling and analysis of physical processes. For specific applications, relevant differential equations are derived from basic principles – for example, from conservation laws and constitutive equations. Dimensional analysis and scaling are introduced to prepare a model for analysis. Analytic solution techniques, such as integral transforms and similarity variable techniques, or approximate methods, such as asymptotic and perturbation methods, are presented and applied to the models. A broad range of applications from areas such as physics, engineering, biology, and chemistry are studied. Credit may not be granted for both MATH 486 and MATH 522.  
Prerequisite(s): [(MATH 461)]  
(3-0-3)

MATH 523  
**Case Studies & 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): [(CHEM 511 and MATH 522)]  
(6-0-6)

MATH 525  
**Statistical Models & 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.  
(3-0-3)

MATH 530  
**Algebra**  
Axiomatic treatment of groups, rings and fields, ideals and homomorphisms; field extensions, modules over rings.  
Prerequisite(s): [(MATH 332) OR (MATH 430)]  
(3-0-3)

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)]  
(3-0-3)
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)]
(3-0-3)

MATH 540
Probability
Random events and variables, probability distributions, sequences of random variables, limit theorems, conditional expectations, and martingales.
Prerequisite(s): [(MATH 400)] AND [(MATH 475)]
(3-0-3)

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. Credit may not be granted for Math 481 and Math 542.
Prerequisite(s): [(MATH 332) OR (MATH 333)]
(3-0-3)

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 Itô 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)]
(3-0-3)

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 540)]
(3-0-3)

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) OR (MATH 543) OR (MATH 544)]
(3-0-3)

MATH 546
Introduction to Time Series
Properties of stationary, random processes; standard discrete parameter models, autoregressive, moving average, harmonic; standard continuous parameter models. Spectral analysis of stationary processes, relationship between the spectral density function and the autocorrelation function; spectral representation of some stationary processes; linear transformations and filters. Introduction to estimation in the time and frequency domains.
Prerequisite(s): [(ECE 511) OR (MATH 475)]
(3-0-3)

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. Credit may not be granted for Math 485 and Math 548.
Prerequisite(s): [(MATH 474) OR (MATH 475)]
(3-0-3)

MATH 550
Topology
Topological spaces, continuous mappings and homeomorphisms, metric spaces and metrizability, connectedness and compactness, homotopy theory.
Prerequisite(s): [(MATH 556)]
(3-0-3)

MATH 553
Discrete Applied Mathematics I
Graph theory is the study of systems of points with some of the pairs of points joined by lines. Sample topics include: paths, cycles, and trees; adjacency and connectivity; directed graphs; Hamiltonian and Eulerian graphs and digraphs; intersection graphs. Applications to the sciences (computer, life, physical, social) and engineering will be introduced throughout the course. This course runs concurrently with Math 454 but projects and homework are at the graduate level. Credit will not be granted for both Math 454 and Math 553.
Prerequisite(s): [(MATH 453)]
(3-0-3)
MATH 554
Discrete Applied Mathematics II
Graduate level treatment of applied combinatorics; posets: product and dimension, lattices, extremal set theory and symmetric chain decomposition; combinatorial designs: block designs, Latin Squares, finite fields, block designs and Steiner systems, finite projective planes; coding theory: error-correcting codes, Hamming and sphere bounds, linear codes, codes from liar games and adaptive coding.
Prerequisite(s): [(MATH 453) OR (MATH 454) OR (MATH 553)]
(3-0-3)

MATH 555
Tensor Analysis
Development of the calculus of tensors with applications to differential geometry and the formulation of the fundamental equations in various fields.
Prerequisite(s): [(MATH 332 and MATH 400)]
(3-0-3)

MATH 556
Metric Spaces
Point-set theory, compactness, completeness, connectedness, total boundedness, density, category, uniform continuity and convergence, Stone-Weierstrass theorem, fixed point theorems.
Prerequisite(s): [(MATH 400)]
(3-0-3)

MATH 557
Probabilistic Methods in Combinatorics
Graduate level introduction to probabilistic methods, including linearity of expectation, the deletion method, the second moment method and the Lovasz Local Lemma. Many examples from classical results and recent research in combinatorics will be included throughout, including from Ramsey Theory, random graphs, coding theory and number theory.
(3-0-3)

MATH 563
Mathematical Statistics
Theory of sampling distributions; interval and point estimation, sufficient statistics, order statistics, hypothesis testing, correlation and linear regression; analysis of variance; non-parametric methods. Credit given only for one of MATH 425, MATH 476, MATH 525, or MATH 563.
Prerequisite(s): [(MATH 475) OR (MATH 540)]
(3-0-3)

MATH 564
Applied Statistics
Simple linear regression; multiple linear regression; least squares estimates of parameters; hypothesis testing and confidence intervals in linear regression models; testing of models, data analysis, and appropriateness of models; linear time series models; moving average, autoregressive and/or ARIMA models; estimation, data analysis, and forecasting with time series models; forecasting errors and confidence intervals. Credit may not be granted for both MATH 484 and MATH 564.
Prerequisite(s): [(MATH 474) OR (MATH 476) OR (MATH 563)]
(3-0-3)

MATH 565
Monte Carlo Methods in Finance
In addition to the theoretical constructs in financial mathematics, there are also a range of computational/simulation techniques that allow for the numerical evaluation of a wide range of financial securities. This course will introduce the student to some such simulation techniques, known as Monte Carlo methods, with focus on applications in financial risk management. Monte Carlo and Quasi Monte Carlo techniques are computational sampling methods which track the behavior of the underlying securities in an option or portfolio and determine the derivative’s value by taking the expected value of the discounted payoffs at maturity. Recent developments with parallel programming techniques and computer clusters have made these methods widespread in the finance industry.
Prerequisite(s): [(MATH 474)]
(3-0-3)

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, MATH 563, and MATH 564)]
(3-0-3)

MATH 567
Advanced Design of Experiments
Various type of designs for laboratory and computer experiments, including fractional factorial designs, optimal designs and space filling designs.
Prerequisite(s): [(MATH 474) OR (MATH 476)]
(3-0-3)

MATH 568
Topics in Statistics
Categorical data analysis, contingency tables, log-linear models, nonparametric methods, sampling techniques.
Prerequisite(s): [(MATH 563)]
(3-0-3)

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 350)] AND [(MATH 474) OR (MATH 475)]
(3-0-3)

MATH 570
Data Science Seminar
Various research topics on data science are presented in this seminar. Permission is required from the instructor or department. Open only to Data Science majors.
(1-0-0)
MATH 571
Data Preparation & 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. Open only to Data Science majors.
Prerequisite(s): [(CSP 570*) OR (MATH 570*)] An asterisk (*) designates a course which may be taken concurrently. (3-0-3)

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. Open only to Data Science majors.
Prerequisite(s): [(CS 584) OR (MATH 569)] AND [(SCI 511)] AND [(CSP 571) OR (MATH 571)] AND [(SCI 522)] (3-3-6)

MATH 573
Reliable Mathematical Software
Many mathematical problems cannot be solved analytically or by hand in a reasonable amount of time; so, turn to mathematical software to solve these problems. Popular examples of general-purpose mathematical software include Mathematica, MATLAB, the NAG Library, and R. Researchers often find themselves writing mathematical software to demonstrate their new ideas or using mathematical software written by others to solve their applications. This course covers the ingredients that go into 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.
(1-0-0)

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.
(3-0-3)

MATH 577
Computational Mathematics I
Fundamentals of matrix theory; least squares problems; computer arithmetic, conditioning and stability; direct and iterative methods for linear systems; eigenvalue problems. 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)] (3-0-3)
## Applied Mathematics

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 587</td>
<td>Theory &amp; Practice of Modeling Risk &amp; Credit Derivatives</td>
<td>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)] (3-0-3)</td>
</tr>
<tr>
<td>MATH 589</td>
<td>Numerical Methods for Partial Differential Equations</td>
<td>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 MATH 489 or consent of instructor. Prerequisite(s): [(MATH 350 and MATH 489)] (3-0-3)</td>
</tr>
<tr>
<td>MATH 590</td>
<td>Meshfree Methods</td>
<td>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. (3-0-3)</td>
</tr>
<tr>
<td>MATH 591</td>
<td>Research &amp; Thesis M.S.</td>
<td>Prerequisite: Instructor permission required. (Credit: Variable)</td>
</tr>
<tr>
<td>MATH 592</td>
<td>Internship in Applied Mathematics</td>
<td>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. (0-0-6)</td>
</tr>
<tr>
<td>MATH 593</td>
<td>Seminar in Applied Mathematics</td>
<td>Current research topics presented in the department colloquia and seminars. (1-0-0)</td>
</tr>
<tr>
<td>MATH 594</td>
<td>Professional Master’s Project</td>
<td>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)</td>
</tr>
<tr>
<td>MATH 597</td>
<td>Reading &amp; Special Projects</td>
<td>(Credit: Variable)</td>
</tr>
<tr>
<td>MATH 599</td>
<td>TA Training</td>
<td>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. (1-0-0)</td>
</tr>
<tr>
<td>MATH 601</td>
<td>Advanced Topics in Combinatorics</td>
<td>Course content is variable and reflects current research in combinatorics. Prerequisite(s): [(MATH 554)] (3-0-3)</td>
</tr>
<tr>
<td>MATH 602</td>
<td>Advanced Topics in Graph Theory</td>
<td>Course content is variable and reflects current research in graph theory. Prerequisite(s): [(MATH 554)] (3-0-3)</td>
</tr>
<tr>
<td>MATH 603</td>
<td>Advanced Topics in Computational Mathematics</td>
<td>Course content is variable and reflects current research in computational mathematics. Prerequisite(s): [(MATH 578)] (3-0-3)</td>
</tr>
<tr>
<td>MATH 604</td>
<td>Advanced Topics in Applied Analysis</td>
<td>Course content is variable and reflects current research in applied analysis. Prerequisite(s): [(MATH 501)] (3-0-3)</td>
</tr>
<tr>
<td>MATH 605</td>
<td>Advanced Topics in Stochastics</td>
<td>Course content is variable and reflects current research in stochastic. Prerequisite(s): [(MATH 544)] (3-0-3)</td>
</tr>
<tr>
<td>MATH 691</td>
<td>Research &amp; Thesis Ph.D.</td>
<td>(Credit: Variable)</td>
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</tbody>
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