APPLIED MATHEMATICS

John T. Rettaliata Engineering Center, Suite 208
10 W. 32nd St.
Chicago, IL 60616
312.567.8980
amath@iit.edu
iit.edu/applied-mathematics

Chair
Chun Liu

Associate Chair and Director of Undergraduate Studies
Kiah Wah Ong

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

Applied mathematics is the mathematics that is created in response to problems in science, engineering, and society. Applied mathematicians work on a wide variety of topics such as how to construct methods for multi-criteria decision making (requiring discrete mathematics and statistics), predicting how the financial markets will behave (requiring probability/statistics, analysis, optimization), analyzing how liquid flows around solids, and how ions move in biological environments (requiring expertise in computational methods and analysis). Students with an applied mathematics background are prepared for careers in the insurance industry, electronics and computer manufacturers, logistics companies, pharmaceutical firms, and more. An applied mathematics background also prepares students for continuing on the academic path, in graduate programs in pure and applied mathematics, statistics, data science, and financial mathematics.

Our graduates work in financial and insurance companies as analysts, computer and IT companies as programmers and hardware developers, and in many different fields as researchers, as well as in academia. They have gone to excellent graduate schools in mathematics (pure, applied, and financial), statistics, physics, design, accounting, and M.B.A. programs. Students have the flexibility to assemble a portfolio of courses that will satisfy both intellectual needs and career preparation. There is a wide variety of courses offered, with strengths in contemporary topics in applied mathematics: stochastic analysis (including mathematical finance), applied analysis, computational mathematics, discrete mathematics, and statistics.

The department offers two degree programs, a B.S. in Applied Mathematics and a B.S. in Statistics. A minor is required, which gives students an area of focus where mathematics or statistics may be applied. With a minor in computer science, business, or one of the engineering areas, for example, the student will be well prepared to enter the job market in business or government.

If desired, students can select a specialization (taking electives appropriate for different career paths) or double major in another subject such as computer science or physics. There is also the option of a co-terminal degree, where a student graduates with a B.S. and a master's degree at the same time, in as little as five years.

Degree Programs

- Bachelor of Science in Applied Mathematics
- Bachelor of Science in Data Science
- Bachelor of Science in Statistics

Co-Terminal Options

The Department of Applied Mathematics also offers the following co-terminal degrees, which enables a student to simultaneously complete both an undergraduate and graduate degree in as few as five years:

- Bachelor of Science in Applied Mathematics/Master of Science in Applied Mathematics
- Bachelor of Science in Applied Mathematics/Master of Computer Science
- Bachelor of Science in Applied Mathematics/Master of Science in Computer Science
- Bachelor of Science in Applied Mathematics/Master of Data Science
- Bachelor of Science in Applied Mathematics/Master of Mathematical Finance

These co-terminal degrees allow students to gain greater knowledge in specialized areas while, in most cases, completing a smaller number of credit hours with increased scheduling flexibility. For more information, please visit the Department of Applied Mathematics website (science.iit.edu/applied-mathematics/programs).

Minors

- Minor in Applied Mathematics
- Minor in Computational Mathematics
- Minor in Data Science
- Minor in Statistics

Course Descriptions

DS 100
Introduction to the Profession
Introduces students to data science as a profession, as currently practiced and continuing to develop. Presents various elements of the data science life cycle at an introductory level, culminating with a start-to-finish data analysis project. Includes guest lectures from data science practitioners and faculty. Explores real-world examples of ethical issues, bias, and privacy in data science. Survey careers in data science and familiarize students with elements of career development.
Lecture: 3 **Lab:** 0 **Credits:** 3

DS 151
Introduction to Data Science
This course introduces the critical concepts and skills in statistical inference, machine learning, and computer programming, through hands-on analysis of real-world datasets from various fields.
Lecture: 3 **Lab:** 0 **Credits:** 3

DS 251
Mathematical Foundations for Data Science I
This course introduces the critical mathematical foundation knowledge for data science. Specifically, this course covers the basic topics on linear algebra and discrete math that are most relevant to the data science major.
Prerequisite(s): MATH 251
Lecture: 3 **Lab:** 0 **Credits:** 3

DS 261
Ethics and Privacy in Data Science
This course introduces the critical concepts and skills of ethics and privacy in data science, as well as hands-on implementation of important algorithms. It will cover important concepts of bias and privacy, and the computational strategies to ensure fairness and privacy in a variety of emerging data science applications. The course provided hands-on experience in collecting, analyzing, and modeling data for tackling ethical issues.
Lecture: 3 **Lab:** 0 **Credits:** 3

DS 351
Mathematical Foundations for Data Science II
This course introduces mathematical tools from optimization, differential equations, and numerical analysis etc. that are relevant to the data science major.
Prerequisite(s): DS 251
Lecture: 3 **Lab:** 0 **Credits:** 3

DS 451
Data Science Life Cycle
This course is designed to educate the data science students in the typical project life-cycle stages required in the data science professions. Stages of a data science project from start to finish such as obtaining data, exploring data, determining what questions the data can answer, exploratory analysis, ethical impacts analysis and mitigation, hypothesis (re-)formulation, in-depth analysis, validation, and reporting, are presented.
Prerequisite(s): DS 251 or MATH 484 or CS 484 or CS 422
Lecture: 3 **Lab:** 0 **Credits:** 3

DS 472
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 the 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): DS 451 or CSP 571
Credit: Variable

MATH 100
Introduction to the Profession
Introduces the student to the scope of mathematics as a profession, develops a sense of mathematical curiosity and problem solving skills, identifies and reinforces the student's career choices, and provides a mechanism for regular academic advising. Provides integration with other first-year courses. Introduces applications of mathematics to areas such as engineering, physics, computer science, and finance. Emphasis is placed on the development of teamwork skills.
Lecture: 3 **Lab:** 0 **Credits:** 3
Satisfies: Communications (C)

MATH 119
Geometry for Architects
Basic Euclidean and analytic geometry in two and three dimensions; trigonometry. Equations of lines, circles and conic sections; resolution of triangles; polar coordinates. Equations of planes, lines, quadratic surfaces. Applications. This course does not count toward business, computer science, engineering, mathematics, or natural science degree programs.
Lecture: 3 **Lab:** 1 **Credits:** 3

MATH 122
Introduction to Calculus
Basic concepts of calculus of a single variable; limits, continuity, derivatives, and integrals. Applications. This course does not count toward any business, computer science, engineering, mathematics, or natural science degree programs.
Prerequisite(s): MATH 119
Lecture: 3 **Lab:** 1 **Credits:** 3

MATH 130
Thinking Mathematically
This course allows students to discover, explore, and apply modern mathematical ideas. Emphasis is placed on using sound reasoning skills, visualizing mathematical concepts, and communicating mathematical ideas effectively. Classroom discussion and group work on challenging problems are central to the course. Topics from probability, statistics, logic, number theory, graph theory, combinatorics, chaos theory, the concept of infinity, and geometry may be included. This course does not count toward any computer science, engineering, mathematics, or natural science degree programs.
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 131
Mathematics for Sustainability
The course provides students with the mathematical background and quantitative reasoning skills necessary to engage as informed citizens in discussions of sustainability related to climate change, resources, pollution, recycling, economic change, and similar matters of public interest. Introduces mathematical modeling techniques with examples related to environmental and economic sustainability. Emphasis is placed on quantitative reasoning, visualization of mathematical concepts and effective communication, both verbally and textually, through writing projects that require quantitative evidence to support an argument, classroom activities, and group work. Topics range from probability, statistics, decision theory, graph theory, physics, modeling, and algebra.
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 147
College Algebra
This course is an in-depth study of the properties of the set of real numbers; operations with exponents (integer and rational), radicals, and logarithms; simplifying polynomials and rational expressions; and solving equations, inequalities, and systems of equations.
Lecture: 4 **Lab:** 0 **Credits:** 4

MATH 148
Preparation for Calculus
Review of algebra and analytic geometry. Functions, limits, derivatives. Trigonometry, trigonometric functions and their derivatives. Inverse functions, inverse trigonometric functions and their derivatives. Exponential and logarithmic functions. This course does not count toward any mathematics requirements in business, computer science, engineering, mathematics, or natural science degree programs.
Prerequisite(s): MATH 147 with min. grade of C
Lecture: 4 **Lab:** 0 **Credits:** 4

MATH 151
Calculus I
Analytic geometry. Functions and their graphs. Limits and continuity. Derivatives of algebraic and trigonometric functions. Applications of the derivative. Introduction to integrals and their applications.
Prerequisite(s): IIT Mathematics Placement score of 151 or MATH 145 with min. grade of C or MATH 148 with min. grade of C
Lecture: 4 **Lab:** 1 **Credits:** 5
Satisfies: Communications (C)

MATH 152
Calculus II
Transcendental functions and their calculus. Integration techniques. Applications of the integral. Indeterminate forms and improper integrals. Polar coordinates. Numerical series and power series expansions.
Prerequisite(s): MATH 149 with min. grade of C or MATH 151 with min. grade of C
Lecture: 4 **Lab:** 1 **Credits:** 5
Satisfies: Communications (C)

MATH 180
Fundamentals of Discrete Mathematics
Basic counting techniques, discrete probability, graph theory, algorithm complexity, logic and proofs, and other fundamental discrete topics. Required for students in the Bachelor of Information Technology and Management degree. This course does not count toward any computer science, engineering, mathematics, or natural science degree program. Credit will only be granted for one of MATH 180, MATH 230, and CS 330.
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 191
Business Calculus
This is an introduction to basic calculus with an emphasis on applications to business economics, management, information science, and related fields. Topics include relations and functions, limits, continuity, derivatives, techniques of differentiation, chain rule, applications of differentiation, antiderivatives, the definite integral, the fundamental theorem of calculus, and applications of integration.
Prerequisite(s): MATH 148
Lecture: 4 **Lab:** 0 **Credits:** 4

MATH 192
Finite Mathematics
Finite Mathematics contains a carefully selected set of topics in probability and linear algebra, topics that provide the foundation for understanding any future statistics course and many phenomena you may well encounter in your life. The probability portion in the first half of the course provides the basis of understanding chance. It culminates in a discussion of Bayes' formula which is useful for understanding medical testing, drug testing, and lie detector testing and for understanding public policy for the use of these tests. The second half covers basic linear algebra culminating in linear optimization techniques which are useful in applications from baking to business. The two topics are tied together at the end of the course through a brief introduction to Markov chains, a common elementary mathematical model in social science, business, and science.
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 225
Introductory Statistics
An introduction to statistics; data collection, description, visualization and analysis; basic probability; statistical reasoning and inference including hypothesis tests and confidence intervals: t-tests, chi-squared tests, ANOVA, correlation and regression.
Lecture: 3 **Lab:** 0 **Credits:** 3
Satisfies: Communications (C)

MATH 230
Introduction to Discrete Math
Sets, statements, and elementary symbolic logic; relations and digraphs; functions and sequences; mathematical induction; basic counting techniques and recurrence. Credit will not be granted for both CS 330 and MATH 230.
Lecture: 3 **Lab:** 0 **Credits:** 3
Satisfies: Communications (C)

MATH 251
Multivariate and Vector Calculus
Analytic geometry in three-dimensional space. Partial derivatives. Multiple integrals. Vector analysis. Applications.
Prerequisite(s): MATH 152
Lecture: 4 **Lab:** 1 **Credits:** 4

MATH 252
Introduction to Differential Equations
Linear differential equations of order one. Linear differential equations of higher order. Series solutions of linear DE. Laplace transforms and their use in solving linear DE. Introduction to matrices. Systems of linear differential equations.
Prerequisite(s): MATH 152
Lecture: 4 **Lab:** 0 **Credits:** 4

MATH 332
Elementary Linear Algebra
Systems of linear equations; matrix algebra, inverses, determinants, eigenvalues, and eigenvectors, diagonalization; vector spaces, basis, dimension, rank and nullity; inner product spaces, orthonormal bases; quadratic forms.
Prerequisite(s): MATH 251*, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 333
Matrix Algebra and Complex Variables
Vectors and matrices; matrix operations, transpose, rank, inverse; determinants; solution of linear systems; eigenvalues and eigenvectors. The complex plane; analytic functions; contour integrals; Laurent series expansions; singularities and residues.
Prerequisite(s): MATH 251
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 350
Introduction to Computational Mathematics
Study and design of mathematical models for the numerical solution of scientific problems. This includes numerical methods for the solution on linear and nonlinear systems, basic data fitting problems, and ordinary differential equations. Robustness, accuracy, and speed of convergence of algorithms will be investigated including the basics of computer arithmetic and round-off errors. Same as MMAE 350.
Prerequisite(s): (CS 104 or CS 105 or CS 115) and MATH 251 and MATH 252*, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 **Lab:** 0 **Credits:** 3
Satisfies: Communications (C)

MATH 374
Probability and Statistics for Electrical and Computer Engineers
This course focuses on the introductory treatment of probability theory including: axioms of probability, discrete and continuous random variables, random vectors, marginal, joint, conditional and cumulative probability distributions, moment generating functions, expectations, and correlations. Also covered are sums of random variables, central limit theorem, sample means, and parameter estimation. Furthermore, random processes and random signals are covered. Examples and applications are drawn from problems of importance to electrical and computer engineers. Credit only granted for one of MATH 374, MATH 474, and MATH 475.
Prerequisite(s): MATH 251
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 380
Introduction to Mathematical Modeling
This course provides an introduction to problem-driven (as opposed to method-driven) applications of mathematics with a focus on design and analysis of models using tools from all parts of mathematics.
Prerequisite(s): (CS 104 or CS 105 or CS 115) and MATH 251 and MATH 252* and MATH 332*, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 **Lab:** 0 **Credits:** 3
Satisfies: Communications (C)

MATH 400
Real Analysis
Real numbers, continuous functions; differentiation and Riemann integration. Functions defined by series.
Prerequisite(s): MATH 251 or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 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 or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 405
Introduction to Iteration and 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 and MATH 252 and MATH 332) or (MATH 252 and MATH 333 and MATH 251) or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 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 or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 420
Geometry
The course is focused on selected topics related to fundamental ideas and methods of Euclidean geometry, non-Euclidean geometry, and differential 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. Permission of the instructor is required.
Lecture: 3 **Lab:** 0 **Credits:** 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.
Lecture: 3 **Lab:** 0 **Credits:** 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.
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 430
Applied Algebra
Introduction to groups, homomorphisms, group actions, rings, field theory. Applications, including constructions with ruler and compass, solvability by radicals, error correcting codes.
Prerequisite(s): MATH 230 or MATH 332* or Graduate standing, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 **Lab:** 0 **Credits:** 3
Satisfies: Communications (C)

MATH 431
Computational Algebraic Geometry
Systems of polynomial equations and ideals in polynomial rings; solution sets of systems of equations and algebraic varieties in affine n-space; effective manipulation of ideals and varieties, algorithms for basic algebraic computations; Groebner bases; applications. Credit may not be granted for both MATH 431 and MATH 530.
Prerequisite(s): MATH 332 and MATH 230
Lecture: 3 **Lab:** 0 **Credits:** 3
Satisfies: Communications (C)

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 332
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 446
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
Lecture: 3 **Lab:** 0 **Credits:** 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 or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 454
Graph Theory and Applications
Directed and undirected graphs; paths, cycles, trees, Eulerian cycles, matchings and coverings, connectivity, Menger's Theorem, network flow, coloring, planarity, with applications to the sciences (computer, life, physical, social) and engineering.
Prerequisite(s): (MATH 230 and MATH 251) or (MATH 252 and MATH 230)
Lecture: 3 **Lab:** 0 **Credits:** 3
Satisfies: Communications (C)

MATH 461
Fourier Series and 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) or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 474
Probability and 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.
Prerequisite(s): MATH 251 or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 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 or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 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 or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 3
Satisfies: Communications (C)

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 or MMAE 350
Lecture: 3 **Lab:** 0 **Credits:** 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 or MMAE 350
Lecture: 3 **Lab:** 0 **Credits:** 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 475 and MATH 333)
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 483
Design and Analysis 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 476 or MATH 474
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 484
Regression
This course introduces the basic statistical regression model and design of experiments concepts. 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, design and analysis of single-factor experiments.
Prerequisite(s): MATH 474 with min. grade of C or (MATH 476 with min. grade of C and MATH 475 with min. grade of C)
Lecture: 3 **Lab:** 0 **Credits:** 3
Satisfies: Communications (C)

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
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 486
Mathematical Modeling I
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.
Prerequisite(s): MATH 251 and MATH 332 and MATH 252
Lecture: 3 **Lab:** 0 **Credits:** 3
Satisfies: Communications (C)

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 or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 488
Ordinary Differential Equations and 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 252 and MATH 251) or Graduate standing
Lecture: 3 **Lab:** 0 **Credits:** 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 252
Lecture: 3 **Lab:** 0 **Credits:** 3

MATH 491
Reading and Research
Independent reading and research. **Instructor permission required.**
Credit: Variable
Satisfies: Communications (C)

MATH 493
Summer Research and Independent Study
Students will conduct research work with advisers.
Lecture: 0 **Lab:** 0 **Credits:** 0

MATH 497
Special Problems
Special problems.
Credit: Variable
Satisfies: Communications (C)