MATHEMATICS (MATH)

Mathematics Graduate Courses

MATH 8016 INTRODUCTION TO THE THEORY OF RECURSIVE FUNCTIONS (3 credits)
This is a proof-oriented course presenting the foundations of Recursion Theory. We present the definition and properties of the class of primitive recursive functions, study the formal models of computation, and investigate partially computable functions, universal programs. We prove Rice's Theorem, the Recursion Theorem, develop the arithmetic hierarchy, demonstrate Post's theorem. Introduction to the formal theories of computability and complexity is also given. (Cross-listed with CSCI 4010, CSCI 8016, MATH 4010).
Prerequisite(s): MATH 2230 or MATH 2030 with a C- or better or CSCI 3660 with a C- or better or instructor's permission.

MATH 8036 MODERN ALGEBRA (3 credits)
Algebra is the study of mathematical manipulations that preserve something (like equality - when solving equations). The areas in which Algebra finds application are quite diverse, from Ancient Greek Geometry through to Modern Information Protection and Security (error correcting codes, data compression, and cryptography). This course begins with topics that should be familiar (such as ruler-and-compass constructions, and modular arithmetic) and builds upon this foundation through polynomial rings up to finite fields and basic group theory. (Cross-listed with MATH 4030).
Prerequisite(s): MATH 2230 with a C- or better or MATH 2030 with a C- or better

MATH 8050 ALGORITHMIC GRAPH THEORY (3 credits)
The overall of the goal is to introduce advanced concepts in graph theory, graph modeling, and graph algorithms and how they can be used to solve a wide range of problems in various application domains. The course introduces students to several applied path algorithms, clustering and partitioning techniques, network flow algorithms, and weighted matching algorithms. Other advanced concepts associated with complex networks include node centralities in graphs and community detection approaches. The course will also introduce students to key classes of graphs with a particular focus on the main classes of Perfect Graphs and their applications in scheduling, chip design, mobile computing, and Biomedical Informatics. (Cross-listed with CSCI 8050).
Prerequisite(s): CSCI 3320 or CSCI 8325 and MATH 4150 or MATH 8156 or permission of instructor. Not open to non-degree graduate students.

MATH 8056 LINEAR ALGEBRA (3 credits)
Linear algebra is extensively utilized in the mathematical modeling of many natural phenomena. Many scientific and engineering disciplines, such as data science, chemical engineering and biology, make extensive use of the theory and techniques commonly present in basic to advanced linear algebra courses. The goal of this course is to help students to grasp a solid theoretical understanding of vectors, vector spaces, inner product spaces, linear transformations, eigenvalues, canonical forms, complex vectors, matrices, and orthogonality. By going through the materials in a mathematically rigorous way, students will develop deeper and more accurate intuitions of the basic concepts in linear algebra. Consequently, the applications of linear algebra will become much more transparent. (Cross-listed with MATH 4050).
Prerequisite(s): MATH 2050 with a grade of C- or better; MATH 2030 or MATH 2230 or equivalent with a grade of C- or better; or permission

MATH 8060 ALGORITHMIC COMBINATORICS (3 credits)
This course includes classical combinatorial analysis graph theory, trees, network flow, matching theory, external problems, and block designs. (Cross-listed with CSCI 8060).
Prerequisite(s): MATH 3100, CSCI 3100, MATH 8105 or CSCI 8105 or instructor's permission.

MATH 8080 DESIGN AND ANALYSIS OF ALGORITHMS (3 credits)
The course provides students an understanding of advanced topics in algorithms. Main topics include: growth of functions, asymptotic notation, recurrences, divide and conquer, dynamic programming, greedy algorithms, graph algorithms, and the theory of NP-Completeness. (Cross-listed with CSCI 8080).
Prerequisite(s): CSCI 3320 or CSCI 8325 or equivalent. Not open to non-degree graduate students.

MATH 8105 APPLIED COMBINATORICS (3 credits)
Basic counting methods, generating functions, recurrence relations, principle of inclusion-exclusion. Polya's formula. Elements of graph theory, trees and searching network algorithms. (Cross-listed with CSCI 3100, CSCI 8105, MATH 3100).

MATH 8116 ABSTRACT ALGEBRA I (3 credits)
An introduction to group theory. Various classes of group are studied: symmetric groups, abelian, cyclic, and permutation groups. Basic tools are developed and used: subgroups, normal subgroups, cosets, the Lagrange theorem, group homomorphisms, quotient groups, direct products, and group actions on a set. The course culminates with the Sylow theorems in finite group theory. The theory is illustrated with examples from geometry, linear algebra, number theory, crystallography, and combinatorics. (Cross-listed with MATH 4110).
Prerequisite(s): MATH 4050/MATH 8056 with a C- or better or MATH 4560/MATH 8566 with a C- or better or permission of instructor

MATH 8126 ABSTRACT ALGEBRA II (3 credits)
An introduction to ring and field theory. Various classes of commutative rings are considered including polynomial rings, and the Gaussian integers. Examples of fields include finite fields and various extensions of the rational numbers. Concepts such as that of an ideal, integral domain, characteristic and extension field are studied. The course culminates with an introduction to Galois theory. Applications include the resolution of two classical problems: the impossibility of angle-trisection and the general insolvability of polynomial equations of degree 5 or higher. (Cross-listed with MATH 4120)
Prerequisite(s): MATH 4110/MATH 8116 with a C- or better or permission of instructor

MATH 8156 GRAPH THEORY & APPLICATIONS (3 credits)
Introduction to graph theory. Representations of graphs and graph isomorphism. Trees as a special case of graphs. Connectivity, covering, matching and coloring in graphs. Directed graphs and planar graphs. Applications of graph theory in several fields such as networks, social sciences, VLSI, chemistry and parallel processing. (Cross-listed with CSCI 4150, CSCI 8156, MATH 4150).
Prerequisite(s): MATH 2030 or permission of instructor.

MATH 8206 NUMERICAL ANALYSIS (3 credits)
This course involves solving nonlinear algebraic equations and systems of equations, interpolation and polynomial approximation, numerical differentiation and integration, numerical solutions to ordinary differential equations, analysis of algorithms and errors, and computational efficiency. (Cross-listed with CSCI 4200, CSCI 8206, MATH 4200).
Prerequisite(s): MATH 1970 and MATH 2050 and MATH 2350 with a C- or better or permission of instructor.

MATH 8235 INTRODUCTION TO ANALYSIS (3 credits)
This course provides a theoretical foundation for the concepts of elementary calculus. Topics include real number system, topology of the real line, limits, functions of one variable, continuity, differentiation. (Cross-listed with MATH 3230).
Prerequisite(s): MATH 1960 and MATH 2230 each with a grade of C- or better.

MATH 8236 MATHEMATICAL ANALYSIS I (3 credits)
Provides a theoretical foundation for the concepts of classical calculus. Topics include ordered fields, the real and complex number system, basic metric space topology, numerical sequences and series, limits and continuity in metric spaces, monotonic functions, differentiation, (functions of several variables included). (Cross-listed with MATH 4230).
Prerequisite(s): MATH 3230/MATH 8235 or equivalent with a grade of C- or better.

MATH 8246 MATHEMATICAL ANALYSIS II (3 credits)
Provides a theoretical foundation for the concepts of classical Calculus (vector calculus included). Topics include sequences and series of functions, uniform convergence, power series, Fourier series, multivariable real differential and integral calculus, the Implicit Function Theorem, integration of different forms, and the important formulas, connecting those integrals, due to: Green, Gauss, Riemann, and Ostrogradski. (Cross-listed with MATH 4240).
Prerequisite(s): MATH 4230/MATH 8236 with a grade of C- or better.

MATH 8250 PARTIAL DIFFERENTIAL EQUATIONS (3 credits)
Partial differential equations (PDEs) are fundamental in the application of mathematics to science and engineering. Topics to be covered will include: Linear and nonlinear first-order equations, classification of second-order linear equations, elliptic, hyperbolic and parabolic equations and boundary value problems, and Green's functions.
Prerequisite(s): MATH 1970, MATH 2350, or instructor's permission. MATH 4330/MATH 8336 is recommended, but not required.

MATH 8255 INTRODUCTION TO NUMERICAL METHODS (3 credits)
This course emphasizes the implementation of several numerical methods to problems that arise in science and engineering. It involves the application of the computer to solve mathematical problems using the following computational techniques: Taylor Series approximation, numerical differentiation, root-finding methods, interpolation, extrapolation, curve fitting, solution methods for matrix equations, numerical differentiation, numerical integration, and the solution of differential equations. (Cross-listed with MATH 3250).
Prerequisite(s): MATH 1960 and MATH 2050 with a C or better, or permission of instructor.

MATH 8276 COMPLEX ANALYSIS (3 credits)
This course is an introduction to the theory of functions of a complex variable, a fundamental area of mathematics with multiple applications to science and engineering. Topics include the field of complex numbers, complex differentiation, the complex contour integral and Cauchy's integral formula, Taylor expansions and analytic functions, conformal mapping and Riemann's conformal equivalence theorem, residue theory and Laurent series, harmonic functions, and applications. (Cross-listed with MATH 4270).
Prerequisite(s): MATH 3230/MATH 8235 with a grade of C- or better or permission of the instructor.

MATH 8306 DETERMINISTIC OPERATIONS RESEARCH MODELS (3 credits)
This is a survey course of deterministic operations research models and algorithms. Topics include linear programming, network programming, and integer programming. (Cross-listed with CSCI 4300, CSCI 8306, MATH 4300).
Prerequisite(s): MATH 2050 with a C- or better or permission of instructor.

MATH 8316 PROBABILISTIC OPERATIONS RESEARCH MODELS (3 credits)
This is a survey course of probabilistic operations, research models and algorithms. Topics include Markov chains, queueing theory, inventory models, forecasting, and simulation. (Cross-listed with CSCI 4310, CSCI 8316, MATH 4310).
Prerequisite(s): MATH 2050 and either MATH 4740 or MATH 8746 or STAT 3800 or STAT 8805 all with a C- or better or permission of instructor.

MATH 8326 COMPUTATIONAL OPERATIONS RESEARCH (3 credits)
Survey of computational methods used in the solution of operations research problems. Some topics may include scripting to guide optimization software, constraint programming, heuristics and metaheuristics for optimization, basic machine learning algorithms, and simulation. (Cross-listed with MATH 4320, CSCI 4320, CSCI 8326).
Prerequisite(s): MATH 3200 or CSCI 1620, and MATH 4300 each with a grade of C- or better or permission of instructor.

MATH 8336 INTRODUCTION TO PARTIAL DIFFERENTIAL EQUATIONS (3 credits)
This course introduces the basic methods of PDEs guided by applications in physics and engineering. The main topics to be covered include The Linear First order PDEs, Transport equations, Characteristics, Classification of PDEs, Separation of variables, Heat conduction, vibrating membranes, boundary value problems, Maximum principle, Sturm-Liouville problems, Fourier series, Fourier integrals, Harmonic functions, Legendre polynomials, Distributions, Green's functions. (Cross-listed with MATH 4330).
Prerequisite(s): MATH 1970 with a C- or better and MATH 2350 with a C- or better, or permission of instructor; MATH 2050 recommended, not required.

MATH 8356 ORDINARY DIFFERENTIAL EQUATIONS (3 credits)
This course covers the theory of initial-, boundary-, and eigenvalue problems, existence theorems, real and complex linear systems of differential equations, and stability theory. There will be a strong emphasis on methods for finding solutions of initial and boundary value problems and analyzing properties of these solutions for various ordinary differential equations. (Cross-listed with MATH 4350).
Prerequisite(s): MATH 1970 with a C- or better, MATH 2050 with a C- or better, and MATH 2350 with a C-, or better or instructor's permission.

MATH 8400 DYNAMICAL SYSTEMS AND CHAOS (3 credits)
Review of difference equations and differential equations, stability theory, periodic orbits, bifurcations, Lyapunov exponents, fractals, chaotic orbits, and chaotic attractors.
Prerequisite(s): Permission from Instructor (If you have a background that covers introduction to analysis, differential equations, linear algebra, and you are somewhat familiar with computer codes, it is easy to obtain permission.)

MATH 8406 THE FINITE ELEMENT METHOD (3 credits)
Introduction to finite elements methods for solving ordinary and partial differential equations. Theoretical foundations of finite element methods for boundary value problems, approximation by piecewise polynomial functions, variation formulation of partial differential equations, basic error estimates. The Rayleigh-Ritz-Galerkin method, convergence of approximations, time-dependent problems, error analysis, discretization and computer implementation, applications to problems in elasticity, heat transfer, and fluid mechanics. (Cross-listed with MATH 4400).
Prerequisite(s): MATH 1970, MATH 2050 and MATH 2350 all with a C- or better or instructor permission. MATH 3300/MATH 8305 and MATH 4330/MATH 8336 recommended. Students should be able to use a programming language (ie MATLAB) to complete computational assignments

MATH 8410 BOOLEAN NETWORKS (3 credits)
This course is focused on introduction to discrete dynamical networks, in particular logical networks, and their applications.
Prerequisite(s): MATH 1960 (Calculus II), MATH 2230 (proof writing skills), MATH 4740 or equivalent (basic probability theory), basic computer skills; or permission of the instructor.

MATH 8430 LINEAR PROGRAMMING (3 credits)
This course includes a complete development of theoretical and computational aspects of linear programming. Basic theoretical foundations covered include polyhedra, convexity, linear inequalities and duality. Advanced topics such as decomposition and column generation are covered. Both simplex methods and interior point methods are included.
Prerequisite(s): MATH 4300/MATH 8306

MATH 8440 NETWORK PROGRAMMING (3 credits)
A presentation of network flow models and optimization algorithms. Topics include pure, generalized, integer, and constrained network problems, plus special cases of each, including transportation, assignment, shortest-path, transshipment, and multicommodity.
Prerequisite(s): MATH 4300/MATH 8306

MATH 8456 INTRODUCTION TO MACHINE LEARNING AND DATA MINING (3 credits)
This is an introduction to machine learning and data mining which covers the following topics with an emphasis on mathematical and statistical analysis in supervised learning. Topics include machine learning workflow, evaluation metrics, validation approaches, classification models including logistic regression, decision tree, boosting, random forest, support vector machines, neural networks, Bayesian methods, etc. If time allows, text mining and unsupervised learning topics will also be introduced in the course. Statistical software will be used. (Cross-listed with MATH 4450, STAT 4450, STAT 8456)
Prerequisite(s): MATH 4740/8746 with a C- or better or STAT 3800/8805 with a C- or better or permission of instructor.

MATH 8460 INTEGER PROGRAMMING (3 credits)
Advanced study in mathematical programming with integer or mixed integer variables. Topics include integer programming, modeling, applications of integer programming, and exploration of solution algorithms based on linear programming and heuristic methods such as tabu search, simulated annealing, and genetic algorithms.
Prerequisite(s): MATH 4300/CSCI 4300/MATH 8306/CSCI 8306. Not open to non-degree graduate students.

MATH 8480 MULTI-AGENT SYSTEMS AND GAME THEORY (3 credits)
This course covers advanced topics in the area of coordination of distributed agent-based systems with a focus on computational aspects of game theory. The main topics covered in this course include distributed constraint satisfaction, distributed constraint optimization, and competitive and cooperative game theory. (Cross-listed with CSCI 8480).
Prerequisite(s): CSCI 4450 or CSCI 8456. Suggested background courses: CSCI 4480 or CSCI 8486; CSCI 8080. Not open to non-degree graduate students.

MATH 8500 NUMERICAL LINEAR ALGEBRA (3 credits)
Topics covered in this course include error propagation, solutions of nonlinear equations, solutions of linear and nonlinear systems by various schemes, matrix norms and conditioning, and computation of eigenvalues and eigenvectors. (Cross-listed with CSCI 8500).
Prerequisite(s): MATH 1960 and MATH 2050, or permission of instructor. Familiarity with computer programming is assumed.

MATH 8510 NUMERICAL DIFFERENTIAL EQUATIONS (3 credits)
Topics covered in this course include interpolation and approximations, numerical differentiation, numerical integration, and numerical solutions of ordinary and partial differential equations. (Cross-listed with CSCI 8510).
Prerequisite(s): MATH 1970, MATH 2350, or permission of instructor. Familiarity with computer programming is assumed.

MATH 8520 ADVANCED TOPICS IN OPERATIONS RESEARCH (3 credits)
Advanced treatment of a specific topic in the area of operations research not available in the regular curriculum. Topics, developed by individual faculty members, will reflect their special interests and expertise. The course may be repeated for credit as topics differ. (Cross-listed with CSCI 8520).
Prerequisite(s): MATH 4300 or MATH 8306 or CSCI 4300 or CSCI 8306 or permission of the instructor.

MATH 8566 NUMBER THEORY & CRYPTOGRAPHY (3 credits)
An overview of one of the many beautiful areas of mathematics and its modern application to secure communication. The course is ideal for any student who wants a taste of mathematics outside of, or in addition to, the calculus sequence. Topics to be covered include: prime numbers, congruences, perfect numbers, primitive roots, quadratic reciprocity, sums of squares, and Diophantine equations. Applications include error-correcting codes, symmetric and public key cryptography, secret sharing, and zero knowledge proofs. (Cross-listed with CSCI 4560, CSCI 8566, MATH 4560).
Prerequisite(s): MATH 2230 with a C- or better or MATH 2030 with a C- or better or CSCI 2030 with a C- or better or permission of instructor

MATH 8616 INTRODUCTION TO TOPOLOGY (3 credits)
This is a proof-oriented course presenting the foundations of topology. Metric spaces and general topological spaces are introduced. The course explores the properties of connectedness, compactness and completeness, and operations of Tychonoff product and hyperspace. (Cross-listed with MATH 4610).
Prerequisite(s): MATH 3230/8235 with a C- or better or permission of instructor.

MATH 8620 GENERAL TOPOLOGY (3 credits)
General topology has roots in geometry and analysis through the study of spaces, dimensions, and transformations. Its development was influenced by the parallel development of (axiomatic) set theory. This course introduces topological spaces from the point of view of separation axioms, countability axioms, compactifications, Baire property, and other completeness properties. Basic concepts of Descriptive Set Theory are also introduced.
Prerequisite(s): MATH 4610/8616 or permission of instructor.

MATH 8626 ITERATED FUNCTION SYSTEMS AND FRACTALS (3 credits)
This is a proof-oriented course presenting the foundations of fractal geometry. It introduces students to the beauty, magic, and applications of fractals and iterated function systems, with emphasis on the mathematics behind it all. Topics range from contractions on hyperspaces and their fixed points to fractal dimensions to Julia and Mandelbrot sets. (Cross-listed with MATH 4620).
Prerequisite(s): MATH 8616 with a C or better or permission of instructor.

MATH 8645 MODERN GEOMETRY (3 credits)
This course will study the modern foundations of Euclidean and Non-Euclidian Geometry. Included will be a study of the principles of axiomatic systems. Euclidean Geometry will be investigated using Hilbert's axioms for Euclidean geometry (or another equivalent Euclidean geometry axiom set). Hyperbolic geometry will be encountered through the models of Klein and Poincare. Neutral geometry with Lambert and Saccheri quadrilaterals will be studied. Finite geometries and projective geometries will also be explored. (Cross-listed with MATH 3640).
Prerequisite(s): MATH 2230 with a grade of C- or better.

MATH 8650 INTRODUCTION TO PROBABILITY MODELS (3 credits)
This is an introduction to probability modeling including Poisson Processes, Markov chains, birth-death processes, queueing models and renewal theory. Applications will be an important part of the course.
Prerequisite(s): MATH 4740/MATH 8746 or STAT 3800/STAT 8805 or permission of instructor.

MATH 8666 AUTOMATA, COMPUTABILITY, AND FORMAL LANGUAGES (3 credits)
This course presents a sampling of several important areas of theoretical computer science. Definition of formal models of computation and important properties of such models, including finite automata and Turing machines. Definition and important properties of formal grammars and their languages. Introduction to the formal theories of computability and complexity. (Cross-listed with CSCI 4660, CSCI 8666, MATH 4660).
Prerequisite(s): MATH 2030. Recommended: CSCI 3320/CSCI 8325.

MATH 8670 TOPICS IN PROBABILITY AND STATISTICS (3 credits)
Advanced treatment of a specific topic in the area of probability and/or statistics not available in the regular curriculum. Topics, developed by individual faculty members, will reflect their special interests and expertise. The course may be repeated for credit as topics differ. (Cross-listed with STAT 8670).
Prerequisite(s): MATH 4750/MATH 8756 or STAT 3800/STAT 8805 or permission from instructor

MATH 8720 RELIABILITY THEORY (3 credits)
This course covers the probabilistic and statistical aspects of reliability theory. Reliability theory is concerned with the probability that a component or system is successfully working over a given time period or at a specific time instance. (Cross-listed with STAT 8720).

MATH 8746 INTRODUCTION TO PROBABILITY AND STATISTICS I (3 credits)
A mathematical introduction to probability theory including the properties of probability; probability distributions; expected values and moments; specific discrete and continuous distributions; and transformations of random variables. (Cross-listed with MATH 4740).
Prerequisite(s): MATH 1970 and either MATH 2230 or MATH 2030 all with a grade of C- or better or permission of instructor.

MATH 8756 INTRODUCTION TO PROBABILITY AND STATISTICS II (3 credits)
Theory and methods of statistical inference including sampling distributions, estimators, estimation, and statistical hypotheses. (Cross-listed with MATH 4750).
Prerequisite(s): MATH 4740/MATH 8746 with a grade of C- or better.

MATH 8766 TOPICS IN APPLIED MATHEMATICS (3 credits)
Selection of such topics such as dynamical systems and chaos, Boolean networks, modeling of discrete or continuous systems, matrix theory, difference equations, information theory, discrete events simulation and other approved by Upper Curriculum Committee. (Cross-listed with MATH 4760).
Prerequisite(s): MATH 3100/CSCI 3100 with a grade of C- or better, or permission of instructor.

MATH 8855 HISTORY OF MATHEMATICS (3 credits)
An overview of the history of mathematics and famous mathematicians via studying and solving famous mathematical problems, exploring famous mathematical theorems, and studying the biographies of famous mathematicians. (Cross-listed with MATH 3850).
Prerequisite(s): MATH 1950 with a grade of C- or higher and one of either MATH 2230 or MTCH 2000 with a grade of C- or higher.

MATH 8956 TOPICS IN THEORETICAL MATHEMATICS (3 credits)
This course introduces students to a specialized subject matter in the areas of theoretical mathematics not covered in existing courses. The course may be repeated for different topics up to a maximum of six credit hours. The specific topics will vary, depending upon when the course is offered. One example of a course is Axiomatic Set Theory. (Cross-listed with MATH 4950).
Prerequisite(s): Permission of instructor.

MATH 8960 MASTER'S PROJECT (1-6 credits)
An applied project, designed and executed under the supervision of both a faculty and industry advisor. In the project the student will apply their mathematical and/or statistical skills to an applied problem. The student will present their results via a written report and oral presentation. (Cross-listed with STAT 8960).
Prerequisite(s): Permission of faculty advisor and graduate program chair. Not open to non-degree graduate students.

MATH 8970 INDEPENDENT GRADUATE STUDIES (1-3 credits)
Under this number a graduate student may pursue studies in an area that is not normally available to him/her in a formal course. The topics studied will be a graduate area in mathematics to be determined by the instructor.
Prerequisite(s): Permission of instructor and graduate classification.

MATH 8980 GRADUATE SEMINAR (3 credits)
A graduate seminar in mathematics offering coverage of advanced areas of mathematics. Topics to be covered by the course will vary in different semesters.
Prerequisite(s): Permission of the Instructor.

MATH 8990 THESIS (1-6 credits)
An independent research project, written under the supervision of a graduate adviser in the department of mathematics. Approval of the topic and the completed project by thesis committee is required.
Prerequisite(s): Approval of the topic and the completed project by thesis committee is required.

MATH 9110 ADVANCED TOPICS IN APPLIED MATHEMATICS (3 credits)
Advanced treatment of a specific topic in the area of applied mathematics not available in the regular curriculum. Topics, developed by individual faculty members, will reflect their special interests and expertise. The course may be repeated for credit as topics differ.
Prerequisite(s): Permission of instructor.

MATH 9230 THEORY OF FUNCTION OF REAL VARIABLES (3 credits)
A theoretical foundation for the concepts of measure theory and integration on a measure space as developed by Henry Leon Lebesgue (followed by others) starting the first decade of the 20th century including a comparison with Riemann's classical construction of integration theory known from classical calculus. Topics include: Real number system, convergence, continuity, bounded variation, differentiation, Lebesque-Stieltjes integration, abstract measure theory, and the Lp spaces.
Prerequisite(s): MATH 4230/MATH 8236 or permission of the instructor