

# MATHEMATICS

## Degree Programs Offered

- Mathematics, MA (<http://catalog.unomaha.edu/graduate/degree-programs-certificates-minors/mathematics/mathematics-ma/>)
- Mathematics, MS (<http://catalog.unomaha.edu/graduate/degree-programs-certificates-minors/mathematics/mathematics-ms/>)
- Mathematics, MAT (<http://catalog.unomaha.edu/graduate/degree-programs-certificates-minors/mathematics/mathematics-mat/>)

### 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)/Corequisite(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)/Corequisite(s):** MATH 2230 with a C- or better or MATH 2030 with a C- or better

### MATH 8050 ALGORITHMIC GRAPH THEORY (3 credits)

Review of the basic concepts of graph theory. Introduction to perfect graphs and their characterizations. Main classes of perfect graphs and their properties. Algorithms for main problems of perfect graphs. Applications of perfect graphs in several fields such as scheduling, VLSI and communication networks. (Cross-listed with CSCI 8050).

**Prerequisite(s)/Corequisite(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)/Corequisite(s):** MATH 2050; MATH 2030 or MATH 2230 or equivalent; 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)/Corequisite(s):** MATH 3100, CSCI 3100, MATH 8105 or CSCI 8105 or instructor's permission.

### MATH 8080 DESIGN AND ANALYSIS OF ALGORITHMS (3 credits)

The study of algorithms important in computer programming. Principles and underlying concepts of algorithm design, fundamental techniques of algorithm analysis, typical types of algorithms. Related topics such as algorithms and computer architecture. (Cross-listed with CSCI 8080).

**Prerequisite(s)/Corequisite(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. Poly'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)/Corequisite(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 insolubility of polynomial equations of degree 5 or higher. (Cross-listed with MATH 4120)

**Prerequisite(s)/Corequisite(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)/Corequisite(s):** MATH 2030 or permission of instructor.

### MATH 8235 INTRODUCTION TO ANALYSIS (3 credits)

Provides a theoretical foundation for the concepts of elementary calculus. Topics include the real number system, topology of the real line, limits, functions of one variable, continuity, differentiation, integration. (Cross-listed with MATH 3230).

**Prerequisite(s)/Corequisite(s):** MATH 1970, and MATH 2030 or MATH 2230 or equivalent.

### MATH 8236 MATHEMATICAL ANALYSIS I (3 credits)

Provides a theoretical foundation for the concepts of elementary calculus. Topics include ordered fields and the real number system, basic properties of complex numbers, metric space topology, sequences and series in  $\mathbb{R}^k$ , limits and continuity in a metric space, monotonic functions. (Cross-listed with MATH 4230).

**Prerequisite(s)/Corequisite(s):** MATH 3230/MATH 8235 or equivalent

### MATH 8246 MATHEMATICAL ANALYSIS II (3 credits)

Provides a theoretical foundation for the concepts of elementary calculus. Topics include differentiation and Riemann-Stieltjes Integration, sequences and series of functions, uniform convergence, power series, functions of several variables, Implicit Function Theorem. (Cross-listed with MATH 4240).

**Prerequisite(s)/Corequisite(s):** MATH 4230/MATH 8236

**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)/Corequisite(s):** MATH 1970, MATH 2350, or instructor's permission. MATH 4330/MATH 8336 is recommended, but not required.

**MATH 8276 COMPLEX VARIABLES (3 credits)**

Differentiation, integration and power series expansions of analytic functions, conformal mapping, residue calculus, and applications. (Cross-listed with MATH 4270).

**Prerequisite(s)/Corequisite(s):** MATH 3230/MATH 8235 or equivalent

**MATH 8305 NUMERICAL METHODS (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 3300, CSCI 8305, MATH 3300).

**Prerequisite(s)/Corequisite(s):** MATH 1960 with a C- or better or permission of 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)/Corequisite(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)/Corequisite(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. Topics include scripting to guide optimization software, metaheuristics for optimization, and basic machine learning algorithms. (Cross-listed with MATH 4320).

**Prerequisite(s)/Corequisite(s):** MATH 3200 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)/Corequisite(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)/Corequisite(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, Lyapunov exponents, fractals, chaos, state reconstruction from time series data.

**Prerequisite(s)/Corequisite(s):** Permission from Instructor

**MATH 8406 FINITE ELEMENT METHODS FOR SOLVING ORDINARY AND PARTIAL DIFFERENTIAL EQUATIONS (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)/Corequisite(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 3300/MATH 8305 and MATH 4330/MATH 8336 are recommended, but not required. Familiarity with MATLAB programming is assumed.

**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)/Corequisite(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)/Corequisite(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)/Corequisite(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: linear and nonlinear regression models, model selection and regularization methods, resampling methods, classification models, tree-based models, and unsupervised learning topics. If time allows, text mining and deep learning will also be introduced in the course. Statistical software will be used. (Cross-listed with MATH 4450, STAT 4450, STAT 8456)

**Prerequisite(s)/Corequisite(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, model creation, developing solution algorithms, and applications of integer programming.  
**Prerequisite(s)/Corequisite(s):** MATH 2030 or MATH 2230 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)/Corequisite(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)/Corequisite(s):** MATH 1960 and MATH 2050, or permission of instructor. Familiarity with computer programming is assumed.

**MATH 8505 SELECTED TOPICS IN MATHEMATICS (1-6 credits)**

This is a variable content course with selected topics in the mathematical sciences which may be of interest to students in other disciplines such as mathematics education, psychology and business. The course may be taken more than once for credit provided topics differ, with a maximum credit of nine hours. Mathematics majors may apply no more than three hours of MATH 3500 toward the minimum major requirements. MATH 8505 does not apply to M.A. or M.S. in mathematics. (Cross-listed with MATH 3500).

**Prerequisite(s)/Corequisite(s):** Permission of instructor

**MATH 8510 NUMERICAL ANALYSIS II (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)/Corequisite(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)/Corequisite(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)/Corequisite(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)/Corequisite(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)/Corequisite(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)/Corequisite(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-Euclidean 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)/Corequisite(s):** MATH 2230

**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)/Corequisite(s):** MATH 4740/MATH 8746, MATH 4760/MATH 8766/CSCI 4760/CSCI 8766, 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)/Corequisite(s):** MATH 2030. Recommended: CSCI 3320/CSCI 8325.

**MATH 8670 TOPICS IN PROBABILITY AND STATISTICS (3 credits)**

A variable topics course in probability and or statistics. Topics covered will include one or more of the following: reliability theory and applications in engineering and science, advanced probability and statistical models, theory of parametric estimation and applications, and advanced probability theory and application.

**Prerequisite(s)/Corequisite(s):** MATH 4740/MATH 8740 or STAT 3800/STAT 8800 or permission from instructor

**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).

**MATH 8756 INTRODUCTION TO PROBABILITY AND STATISTICS II (3 credits)**

Theory and methods of statistical inference including estimators, statistical hypotheses, multivariate estimation, chi-square tests, analysis of variance, and statistical software. (Cross-listed with MATH 4750).

**Prerequisite(s)/Corequisite(s):** MATH 4740/MATH 8746

**MATH 8766 TOPICS IN MODELING (3 credits)**

Selection of such topics as formulation and analysis of various models involving Markov chains, Markov processes (including birth and death processes), queues, cellular automata, difference and differential equations, chaotic systems and fractal geometries. (Cross-listed with CSCI 4760, CSCI 8766, MATH 4760).

**Prerequisite(s)/Corequisite(s):** MATH 2350 and MATH 4740 or MATH 8746.

**MATH 8850 ADVANCED AUTOMATA AND FORMAL LANGUAGES (3 credits)**

A continuation of MATH 4660/MATH 8666/CSCI 4660/CSCI 8666. The course will be an introduction to computational complexity. Topics that will be covered include space and time complexities of Turing Machines, deterministic versus non-deterministic machines, NP-Complete problems, alternating Turing machines, and concepts of reducibility. (Cross-listed with CSCI 8850).

**Prerequisite(s)/Corequisite(s):** Not open to non-degree graduate students.

**MATH 8855 HISTORY OF MATHEMATICS (3 credits)**

An overview of the historical development of mathematical concepts and methods. Brief biographies of major mathematicians, descriptions of the cultural context of selected major advances, and examples of the solution of problems using the knowledge and methods appropriate for each time period will be included. (Cross-listed with MATH 3850).

**Prerequisite(s)/Corequisite(s):** Students who enroll in this course should have completed MATH 1970 and MATH 2230 in order to have the minimum amount of mathematical background needed to appreciate the mathematical content of the course.

**MATH 8880 ADVANCED PLACEMENT INSTITUTE: CALCULUS (3 credits)**

A workshop for teachers planning to offer an advanced placement course in calculus. Objectives include increasing teacher competencies in single-variable calculus, discussion and study of AP calculus exams, implementations of AP courses in calculus, and development and presentation of projects for graduate credit. (This course will not count toward the M.A. or M.S. degrees in Mathematics.)

**Prerequisite(s)/Corequisite(s):** Graduate in mathematics or mathematics education.

**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)/Corequisite(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)/Corequisite(s):** Permission of instructor and graduate classification.

**MATH 8980 GRADUATE SEMINAR (1-3 credits)**

A graduate seminar in mathematics.

**MATH 8990 THESIS (1-6 credits)**

Master's Thesis.

**MATH 9110 ADVANCED TOPICS IN APPLIED MATHEMATICS (3 credits)****MATH 9230 THEORY OF FUNCTION OF REAL VARIABLES (3 credits)**

Real number system, convergence, continuity, bounded variation, differentiation, Lebesgue-Stieltjes integration, abstract measure theory, the  $L_p$  spaces.

**Prerequisite(s)/Corequisite(s):** MATH 4230/MATH 8236 and MATH 8240 or equivalent.