Mathematics

The Department of Mathematics offers graduate programs of study leading to the M.S. degree in Mathematics or the Ph.D. in Applied Mathematics.

The master’s program aims to give students the background to use mathematics in a variety of ways. We train students in mathematical rigor. This provides training in the ability to analyze and solve problems in all walks of life. We also emphasize the development of communication skills of our students (in the classes they take as well as in the classes they teach). Therefore the M.S. program prepares students not only for a career in secondary or junior college level teaching but provides also a very good preparation for students who go into business, industry, or government. In the past our students have been very successful in obtaining employment. Of course, the M.S. program will also prepare students who wish to pursue a Ph.D. in Mathematics but whose undergraduate education did not provide them with a sufficient background in advanced mathematics to directly enter a Ph.D. program.

The PhD program in Applied Mathematics prepares students interested in an academic career in a college or university as well as students interested in a career in business, industry, or government.

Mathematics

Prospective students that want to apply for admission have to provide academic records, three letters of recommendation, a CV, an Essay, and scores of the Graduate Record Examination (GRE), General Test. There are more requirements for international students. UAB charges an application fee, for details please see the admissions page of the Graduate School. The Graduate School requires that all applications are submitted online here via the TargetX application portal, required recommendation letters must also be submitted using this application portal.

Degree Offered M.S.
Director Dr. Ioulia Karpechina
Phone 205-934-2154
E-mail karpeshi@uab.edu
Website http://www.uab.edu/cas/mathematics

Program Information

Mathematics has always been divided into a pure and an applied branch. However, these have never been strictly separated. The M.S. program in mathematics stresses the interconnection between pure mathematics and its diverse applications.

Areas of Specialization

The student must choose a primary and a secondary specialization from a list of areas determined by the expertise of the faculty. As soon as the student is ready to choose specialization areas, he or she should contact the mathematics graduate program advisor. Courses offered to meet degree requirements must be approved by the mathematics graduate program advisor and the mathematics graduate program director.

Deadline for Entry Term(s) Each semester
Deadline for All Application Materials to be in the Graduate School Office Six weeks before term begins
Number of Evaluation Forms Required Three
Entrance Tests GRE (TOEFL and TWE also required for international applicants whose native language is not English)

Additional Information

For detailed information, contact Dr. Ioulia Karpechina, Mathematics Graduate Program Director, UAB Department of Mathematics, UH 4005, 1402 10th Avenue South, Birmingham, Alabama 35294-1241.

Telephone 205-934-2154
E-mail karpeshi@uab.edu
Web http://www.uab.edu/cas/mathematics/

Master of Science in Mathematics

The program requires a total of 30 semester hours where each grade must be an A or B and at least 24 hours must be at the 600-level or above. MA 540, MA 541, and courses below MA 520 cannot be counted towards degree requirements. All students, whether following Plan I or Plan II, must choose a primary and secondary area of specialization as indicated below.

Plan I - 30 hours

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>Primary Area of Specialization (choose 9 hours) and Secondary Area of Specialization (choose 6 hours):</td>
<td>15</td>
</tr>
<tr>
<td>Algebra</td>
<td></td>
</tr>
<tr>
<td>MA 534</td>
<td>Algebra I: Linear</td>
</tr>
<tr>
<td>MA 535</td>
<td>Algebra II: Modern</td>
</tr>
<tr>
<td>MA 631</td>
<td>Linear Algebra</td>
</tr>
<tr>
<td>MA 632</td>
<td>Abstract Algebra</td>
</tr>
<tr>
<td>MA 637</td>
<td>Graph Theory and Combinatorics</td>
</tr>
<tr>
<td>MA 660</td>
<td>Numerical Linear Algebra</td>
</tr>
<tr>
<td>Analysis</td>
<td></td>
</tr>
<tr>
<td>MA 544</td>
<td>Vector Analysis</td>
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<tr>
<td>MA 545</td>
<td>Complex Analysis</td>
</tr>
<tr>
<td>MA 553</td>
<td>Transforms</td>
</tr>
<tr>
<td>MA 554</td>
<td>Intermediate Differential Equations</td>
</tr>
<tr>
<td>MA 555</td>
<td>Partial Differential Equations I</td>
</tr>
<tr>
<td>MA 556</td>
<td>Partial Differential Equations II</td>
</tr>
<tr>
<td>MA 611</td>
<td>Modeling with Partial Differential Equations</td>
</tr>
<tr>
<td>MA 562</td>
<td>Intro to Stochastic Differential Equations</td>
</tr>
<tr>
<td>MA 566</td>
<td>Introduction to Optimization</td>
</tr>
<tr>
<td>MA 642</td>
<td>Calculus of Several Variables</td>
</tr>
<tr>
<td>MA 645</td>
<td>Real Analysis I</td>
</tr>
<tr>
<td>MA 646</td>
<td>Real Analysis II</td>
</tr>
<tr>
<td>MA 648</td>
<td>Complex Analysis</td>
</tr>
<tr>
<td>MA 650</td>
<td>Differential Equations</td>
</tr>
<tr>
<td>MA 655</td>
<td>Partial Differential Equations</td>
</tr>
<tr>
<td>MA 661</td>
<td>Modeling With PDE</td>
</tr>
</tbody>
</table>
## Plan II - 30 hours

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Area of Specialization (choose 12 hours)</td>
<td></td>
</tr>
<tr>
<td>Secondary Area of Specialization (choose 6 hours)</td>
<td></td>
</tr>
<tr>
<td><strong>Total Hours</strong></td>
<td>30</td>
</tr>
</tbody>
</table>

### Algebra
- MA 534  Algebra I: Linear
- MA 535  Algebra II: Modern
- MA 631  Linear Algebra
- MA 632  Abstract Algebra
- MA 637  Graph Theory and Combinatorics
- MA 660  Numerical Linear Algebra

### Analysis
- MA 544  Vector Analysis
- MA 545  Complex Analysis
- MA 553  Transforms
- MA 554  Intermediate Differential Equations
- MA 555  Partial Differential Equations I
- MA 556  Partial Differential Equations II
- MA 561  Modeling with Partial Differential Equations
- MA 562  Intro to Stochastic Differential Equations
- MA 566  Introduction to Optimization
- MA 642  Calculus of Several Variables
- MA 645  Real Analysis I
- MA 646  Real Analysis II

### Numerical Analysis
- MA 560  Scientific Programming
- MA 567  Gas Dynamics
- MA 568  Numerical Analysis I
- MA 569  Numerical Analysis II
- MA 660  Numerical Linear Algebra
- MA 665  Partial Differential Equations: Finite Differential Methods
- MA 668  Numerical Analysis I
- MA 669  Numerical Analysis II

### Probability/Statistics
- MA 562  Intro to Stochastic Differential Equations
- MA 584  Mathematical Finance
- MA 585  Intro to Probability
- MA 586  Mathematical Statistics
- MA 587  Advanced Probability
- MA 588  Advanced Statistics
- MA 687  Advanced Probability
- MA 688  Advanced Statistics

### Topology
- MA 574  Intro to Topology I
- MA 575  Intro to Topology II
- MA 670  Topology I
- MA 671  Topology II

### Additional Hours
- 9 additional hours must be outside the primary area of specialization
- 9
- Total Hours

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### Plan II - 30 hours

**Requirements**

<table>
<thead>
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<th>Hours</th>
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### Additional Hours

- 3 additional hours can be chosen from the primary, secondary, or any other area
- 3

**Total Hours**

**30**

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### Applied Mathematics

Prospective students that want to apply for admission have to provide academic records, three letters of recommendation, a CV, an Essay, and scores of the Graduate Record Examination (GRE), General Test. There are more requirements for international students. UAB charges an application fee, for details please see the admissions page of the Graduate School. The Graduate School requires that all applications are submitted online here via the TargetX application portal, required recommendation letters must also be submitted using this application portal.

### Program Information

Mathematics has always been divided into a pure and an applied branch. However, these have never been strictly separated. The Ph.D. program in applied mathematics stresses the interconnection between pure mathematics and its diverse applications.

### Admission

Only students with a firm foundation in advanced calculus, algebra, and topology are considered for immediate admission to the Ph.D. program.
A student lacking this background will be considered for admission to
the M.S. program. Upon passing the qualifying examination, a student
may transfer to the Ph.D. program. We expect at least a B average in a
student's previous work and a score above 158 on each section of the
Graduate Record Examination General Test.

Program of Study

Each student in the Ph.D. program has to take the following steps:

• Passing the Joint Program Exam (JPE), also called the Qualifying
Exam. The Joint Program Examinations in Real Analysis and Linear
Algebra are given during two periods each year (one in May and one
in September). During each period a student may take one or both
of the exams but subject to the following restrictions: (1) either exam
may be attempted at most twice and (2) a student may participate in
exams during no more than three periods.

• Completing 54 semester hours of graduate courses. The grade
of each course has to be at least a B. The student's supervisory
committee and the Joint Program Committee must approve the
selection of courses. At least 18 hours must be in a major area
of concentration, selected so that the student will be prepared to
conduct research in an area of applied mathematics, while at least
12 hours have to be in a minor area of study, which is a subject
outside mathematics. No courses counted towards an MS degree
can be used. There are additional requirements by the UAB Graduate
School, see "Minimum Course Requirements" in the Graduate
Catalog.

• Passing a language or tool of research exam.

• Passing the Comprehensive Exam, which consists of a written part
and an oral part.

• Preparing a dissertation, which must be a genuine contribution to
mathematics.

• Passing the Final Examination (thesis defense).

Additional Information

For detailed information, contact Dr. Ioulia Karpechina, Mathematics
Graduate Program Director, UAB Department of Mathematics, UH 4005,
1402 10th Avenue South, Birmingham, Alabama 35294-1241.

Telephone: 205-934-2154
Web http://www.uab.edu/cas/mathematics/

Courses

MA 501. History of Mathematics I. 3 Hours.
Development of mathematical principles and ideas from a historical
viewpoint, and their cultural, educational and social significance; earliest
origins through Newton and Leibnitz.
Prerequisites: MA 125 [Min Grade: C] or MA 225 [Min Grade: C]

MA 502. History of Mathematics II. 3 Hours.
Development of mathematical principles and ideas from a historical
viewpoint, and their cultural, educational and social significance; Newton
and Leibnitz through early 20th century.
Prerequisites: MA 501 [Min Grade: B] or MA 311 [Min Grade: B]

MA 511. Integrating Mathematical Ideas. 3 Hours.
This course will integrate ideas from algebra, geometry, probability, and
statistics. Emphasis will be on using functions as mathematical models,
becoming fluent with multiple representations of functions, and choosing
the most appropriate representations for solving a specific problem.
Students will be expected to communicate mathematics verbally and in
writing through small group, whole group, and individual interactions.

MA 513. Mathematics for Elementary and Middle School Teachers. 3 Hours.
Problem solving experiences, inductive and deductive reasoning,
patterns and functions, some concepts and applications of geometry
for elementary and middle school teachers. Topics include linear and
quadratic relations and functions and some cubic and exponential
functions. Number sense with the rational number system including
fractions, decimals and percents will be developed in problem contexts.
An emphasis will be on developing algebraic thinking and reasoning.
Prerequisites: MA 513 [Min Grade: C] or MA 513 [Min Grade: C]

MA 514. Mathematics for Elementary and Middle School Teachers. 3 Hours.
Problem solving experiences, inductive reasoning, concepts and
applications of geometry and proportional reasoning for elementary
and middle school teachers. Topics include analysis of one, two and
three dimensional feature of real objects, ratio and proportionality,
similarity and congruence, linear, area, and volume measurement, and
the development of mathematically convincing arguments. An emphasis
will be on developing thinking and reasoning.
Prerequisites: MA 513 [Min Grade: C] or MA 513 [Min Grade: C]

MA 515. Probabilistic & Stat Reasoning. 3 Hours.
Descriptive and inferential statistics, probability, estimation, hypothesis
testing. Reasoning with probability and statistics is emphasized.
Prerequisites: MA 513 [Min Grade: C] or MA 513 [Min Grade: C]

MA 516. Numerical Reasoning. 3 Hours.
Develop understanding of number and improve numerical reasoning
skills specifically with regard to place value, number relationship that
build fluency with basis facts, and computational proficiency; developing
a deep understanding of numerous diverse computational algorithms;
mathematical models to represent fractions, decimals and percents,
equivalencies and operations with fractions, decimals and percents;
number theory including order of operations, counting as a big idea,
properties of number, primes and composites, perfect, abundant and
significant numbers, and figurate numbers; inductive and deductive
reasoning with number.
Prerequisites: MA 513 [Min Grade: C] or MA 513 [Min Grade: C]

MA 517. Extending Algebraic Reasoning. 3 Hours.
Extending Algebraic Reasoning. Extending algebraic and functional
reasoning to polynomials, rational, exponential, and logarithmic functions;
problem-solving involving transfer among representations (equation,
graph, table); proof via symbolic reasoning, contradiction, and algorithm;
interpretation of key points on graphs (intercepts, slope, extrema);
develop facility and efficiency in manipulating symbolic representations
with understanding; appropriate use of technology and approximate
versus exact solutions; functions as models.
Prerequisites: MA 513 [Min Grade: C] or MA 513 [Min Grade: C]

MA 519. Special Topics for Teachers. 1-4 Hour.
With permission of instructor, may be used as continuation of any of
MA 513 through 518. May be repeated for credit when topics vary.
Prerequisites: MA 125 [Min Grade: C] or MA 225 [Min Grade: C]
MA 534. Algebra I: Linear. 3 Hours.
Abstract vector spaces, subspaces, dimension, bases, linear transformation, matrix algebra, matrix representations of linear transformations, determinants.
Prerequisites: MA 124 [Min Grade: C] or MA 126 [Min Grade: C] or MA 226 [Min Grade: C]

MA 535. Algebra II: Modern. 3 Hours.
Rings, including the rings of integers and of polynomials, integral domains, fields and groups. Homomorphism, isomorphism. As time permits, Galois theory, semi-groups, quotient groups, models, or other areas of algebra may be included. Students present proofs from a list of pre-assigned theorems to the class. Logical correctness and proper mathematical proof-writing style are assessed.
Prerequisites: MA 434 [Min Grade: C] or MA 534 [Min Grade: C]

MA 540. Advanced Calculus I. 3 Hours.
Introduction to real numbers, sequences and series of real numbers; functions and continuity; differentiation. This course is taught as a do-it-yourself course and will meet for 4 hours per week.

MA 541. Advanced Calculus II. 3 Hours.
Integration; sequences and series of functions; uniform vs. pointwise convergence; some elementary and special functions. This course is taught as a do-it-yourself course and will meet 4 hours per week.
Prerequisites: MA 540 [Min Grade: C]

MA 544. Vector Analysis. 3 Hours.
Review and applications of multiple integrals, Jacobians and change of variables in multiple integrals; line and surface integrals; theorems of Green, Gauss, and Stokes with application to the physical sciences; computation in spherical and cylindrical coordinates.
Prerequisites: MA 227 [Min Grade: C]

MA 545. Complex Analysis. 3 Hours.
Analytic functions, complex integration and Cauchy's theorem, Taylor and Laurent series, calculus of residues and applications, conformal mappings.
Prerequisites: MA 227 [Min Grade: C]

MA 553. Fourier Analysis. 3 Hours.
Fourier series, including odd/even functions expansions, complex power series, generalized Fourier series. Convergence, applications to partial differential equations. Fourier transform: basic properties, inversion of the FT, windowing, relation to the Laplace transform. Applications to partial differential equations. Wavelets and signal processing basic functions, transforming wavelets, short time Fourier transform.
Prerequisites: MA 252 [Min Grade: C]

MA 554. Intermediate Differential Equations. 3 Hours.
Topics from among Frobenius series solutions, Sturm-Liouville systems, nonlinear equations, and stability theory.
Prerequisites: MA 252 [Min Grade: C]

MA 555. Partial Differential Equations I. 3 Hours.
Classification of second order partial differential equations; background on eigenfunction expansions and Fourier series; integrals and transforms; solution of the wave equation, reflection of waves; solution of the heat equation in bounded and unbounded media; Laplace's equations, Dirichlet and Neumann problems.
Prerequisites: MA 252 [Min Grade: C]

MA 556. Partial Differential Equations II. 3 Hours.
Classification of second order partial differential equations; background on eigenfunction expansions and Fourier series; integrals and transforms; solution of the wave equations, reflection of waves; solution of heat equation in bounded and unbounded media; Laplace's equations, Dirichlet and Neumann problems.
Prerequisites: MA 252 [Min Grade: C]

MA 560. Scientific Programming. 3 Hours.
Programming and mathematical problem solving using Matlab, Python, FORTRAN or C++. Emphasizes the systematic development of algorithms and numerical methods. Topics include computers, floating point arithmetic, iteration, functions, arrays, Matlab graphics, image processing, robotics, GNU/Linux operating system, solving linear systems and differential equation arising from practical situations, use of debuggers and other debugging techniques, and profiling; use of callable subroutine packages like LAPACK and differential equation routines; parallel programming. Assignments and projects are designed to give students a computational sense through complexity, dimension, inexact arithmetic, randomness, simulation and the role of approximation.
Prerequisites: MA 126 [Min Grade: C] or MA 226 [Min Grade: C]

MA 561. Modeling with Partial Differential Equations. 3 Hours.
Practical examples of partial differential equations; derivation of partial differential equations from physical laws; introduction to MATLAB and its PDE Tool-box, and COMSOL using practical examples; an overview of finite difference and finite element solution methods; specialized modeling projects in topics such as groundwater modeling, scattering of waves, medical and industrial imaging, continuum mechanics and deformation of solids, Fluid mechanics including the class boat race, financial derivative modeling, and acoustic and electromagnetic wave applications. Written project reports required for all homework assignments. Quantitative Literacy and Writing are significant components of this course.
Prerequisites: MA 252 [Min Grade: C]

MA 562. Intro to Stochastic Differential Equations. 3 Hours.
Brownian motion and Wiener processes, stochastic integrals and the Ito calculus, stochastic differential equations, and applications to financial modeling, including option pricing.
Prerequisites: MA 485 [Min Grade: C] or MA 585 [Min Grade: C]

MA 566. Introduction to Optimization. 3 Hours.
Optimization is important in many decision making problems in various areas like engineering, economics and machine learning. Optimization theory deals with finding the best solution(s) or variables of a given objective function. Recently, the area of optimization has received much attention due to the development of highly efficient computational methods for data analysis. The scope of this course covers linear algebra, unconstrained optimization, linear programming, and nonlinear constrained optimization. The topics include linear algebra, linear program, duality, network flows, simplex method, non-simplex method, gradient and conjugate methods, neural network, genetic algorithm and convex optimization. The course will also introduce optimization algorithms and codes via python and matlab.
Prerequisites: MA 126 [Min Grade: C] or MA 226 [Min Grade: C]

MA 567. Gas Dynamics. 3 Hours.
Euler's equations for inviscid flows, rotation and vorticity, Navier-Stokes.
Prerequisites: MA 252 [Min Grade: C] and MA 360 [Min Grade: C] or MA 560 [Min Grade: C]
MA 568. Numerical Analysis I. 3 Hours.
Programming for numerical calculations, round-off error, approximation and interpolation, numerical quadrature, and solution of ordinary differential equations. Practice on the computer.
Prerequisites: MA 525 [Min Grade: C] and MA 227 [Min Grade: C]

MA 569. Numerical Analysis II. 3 Hours.
Iterative solution of systems of nonlinear equations, evaluation of eigenvalues and eigenvectors of matrices, applications to simple partial differential equations, special topics in numerical linear algebra. Practice on the computer.
Prerequisites: MA 568 [Min Grade: C]

MA 570. Differential Geometry. 3 Hours.
Prerequisites: MA 126 [Min Grade: C] or MA 226 [Min Grade: C]

MA 572. Geometry I. 3 Hours.
The axiomatic method; Euclidean geometry including Euclidean constructions, basic analytic geometry, transformational geometry, and Klein's Erlangen Program. Students present proofs from a list of pre-assigned theorems to the class. Logical correctness and proper mathematical proof-writing style are assessed.
Prerequisites: MA 125 [Min Grade: C] or MA 225 [Min Grade: C]

MA 573. Geometry II. 3 Hours.
Analytical geometry, Birkhoff's axioms, and the complex plane; structure and representation of Euclidean isometries; plane symmetries; non-Euclidean (hyperbolic) geometry and non-Euclidean transformations; fractal geometry; algorithmic geometry. Course integrates intuition/exploration and proof/explanation. Project and report or oral presentation required.
Prerequisites: MA 472 [Min Grade: C] or MA 572 [Min Grade: C]

MA 574. Intro to Topology I. 3 Hours.
Separable metric spaces, basis and sub-basis, continuity, compactness, completeness, Baire category theorem, countable products, general topological spaces, Tychonov theorem.
Prerequisites: MA 126 [Min Grade: C] or MA 226 [Min Grade: C]

MA 575. Intro to Topology II. 3 Hours.
Separable metric spaces, basis and sub-basis, continuity, compactness, completeness, Baire category theorem, countable products, general topological spaces, Tychonov theorem.
Prerequisites: MA 574 [Min Grade: C]

MA 584. Mathematical Finance. 3 Hours.
Prerequisites: (MA 260 [Min Grade: C] or MA 434 [Min Grade: C] or MA 435 [Min Grade: C]) and (MA 485 [Min Grade: C] or MA 585 [Min Grade: C])

MA 585. Intro to Probability. 3 Hours.
Probability spaces, combinatorics, conditional probabilities and independence, Bayes rule, discrete and continuous distributions, mean value and variance, moment generation function, joint distributions, correlation, Central Limit Theorem, Law of Large Numbers, random walks, Poisson process.
Prerequisites: MA 227 [Min Grade: C] and MA 260 [Min Grade: C]

MA 586. Mathematical Statistics. 3 Hours.
Confidence intervals, hypothesis testing, analysis of variance and covariance, maximum likelihood estimates, linear regression, tests of fit, robust estimates and tests.
Prerequisites: MA 485 [Min Grade: C] or MA 585 [Min Grade: C]

MA 587. Advanced Probability. 3 Hours.
Foundation of probability, conditional probabilities, and independence, Bayes theorem, discrete and continuous distributions, joint distributions, conditional and marginal distributions, convolution, moments and moment generation function, multivariable normal distribution and sums of normal random variables, Markov chains.
Prerequisites: MA 485 [Min Grade: B] or MA 585 [Min Grade: B]

MA 588. Advanced Statistics. 3 Hours.
Parameter estimations, maximum likelihood estimation, sufficient statistic, hypothesis testing, Neyman-Pearson Lemma, p-value, Kolmogorov-Smirnov test, Anderson-Darling test, P-P plot, Q-Q plot, testing for distribution type, location and scale parameters, mean squared error.
Prerequisites: MA 485 [Min Grade: B] or MA 585 [Min Grade: B] or MA 587 [Min Grade: B] or MA 687 [Min Grade: B]

MA 590. Mathematics Seminar. 1-3 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 591. Mathematics Seminar. 1-3 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 592. Special Topics in Mathematics. 1-3 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 593. Special Topics in Mathematics. 1-3 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 594. Special Topics in Mathematics. 1-6 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 595. Special Topics in Mathematics. 1-6 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 596. Special Topics in Mathematics. 1-12 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.
MA 597. Special Topics in Mathematics. 1-12 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 598. Research in Mathematics. 1-12 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 599. Research in Mathematics. 1-12 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 610. Intro to Set Theory. 3 Hours.
Set theory, products, relations, orders and functions, cardinal and ordinal numbers, transfinite induction, axiom of choice, equivalent statements.

MA 631. Linear Algebra. 3 Hours.
Vector spaces and their bases; linear transformations; eigenvalues and eigenvectors; Jordan canonical form; multilinear algebra and determinants; norms and inner products.

MA 632. Abstract Algebra. 3 Hours.
Propositional and predicate logic; set, relations, and functions; the induction principle; Groups, in particular symmetry groups, permutations groups, and cyclic groups; cosets and quotient groups; group homomorphisms; rings, integral domains, and fields; ideals and rings homomorphisms; factorization; polynomial rings.
Prerequisites: MA 534 [Min Grade: B] or MA 631 [Min Grade: B]

MA 637. Graph Theory and Combinatorics. 3 Hours.
Topics covered include specialized terminology and notation; eulerian and hamiltonian graphs; matrices of graphs and information about graphs obtained from matrices; topological graph theory, including planarity theorems of Kuratowski, Whitney and MacLane and also embeddings of graphs in surfaces of higher genus and in nonorientable surfaces; Menger's theorem and network flows; the graph reconstruction problem; counting techniques, including the Pigeonhole Principle and the use of generating functions; Dilworth's theorem; Sperner's lemma; finite and infinite Ramsey theory; matching theory and the classical theorem of Philip Hall; and, if time permits, the Polya/Redfield theory of enumerations.

MA 642. Calculus of Several Variables. 3 Hours.
Functions of several variables; total and partial derivatives; the Implicit Function Theorem; integration of differential forms; Stokes's Theorem.
Prerequisites: MA 541 [Min Grade: B]

MA 645. Real Analysis I. 3 Hours.
Abstract measures and integration; positive Borel measures; Lp-spaces.
Prerequisites: MA 642 [Min Grade: B] and MA 670 [Min Grade: B]

MA 646. Real Analysis II. 3 Hours.
Complex measures and the Radon-Nikodym theorem; differentiation; integration on product spaces and Fubini's theorem.
Prerequisites: MA 645 [Min Grade: B]

MA 648. Complex Analysis. 3 Hours.
The algebraic and topological structure of the complex plane; analytic functions; Cauchy's integral theorem and integral formula; power series; elementary functions; and their Riemann surfaces; isolated singularities and residues; the Laurent expansion; the Riemann mapping theorem.
Prerequisites: MA 642 [Min Grade: B]

MA 650. Differential Equations. 3 Hours.
Separable, linear, and exact first order equations; existence and uniqueness theorems; continuous dependence of solutions on data and initial conditions; first order systems and higher order equations; stability for two-dimensional linear systems; higher order linear systems; boundary value problems; stability theory.
Prerequisites: MA 642 [Min Grade: B]

MA 655. Partial Differential Equations. 3 Hours.
This course covers first order partial differential equations, elliptic equations, parabolic equations, and hyperbolic equations.
Prerequisites: MA 642 [Min Grade: C] or MA 650 [Min Grade: C]

MA 660. Numerical Linear Algebra. 3 Hours.
Vector and matrix norms; the singular value decomposition; stability, condition numbers, and error analysis; QR factorization; least squares problems; computation of eigenvalues and eigenvectors; iterative methods.
Prerequisites: MA 631 [Min Grade: B]

MA 661. Modeling With PDE. 3 Hours.
Practical examples of partial differential equations; derivation of partial differential equations from physical laws; introduction to MATLAB and its PDE Toolbox, and other PDE packages such as FEMLAB using practical examples; brief discussion of finite difference and finite element solution methods; introduction to continuum mechanics and classical electrodynamics; parallel programming using MPI and the mathematics department Beowulf system; specialized modeling projects in topics such as groundwater modeling, scattering of waves, medical and industrial imaging, fluid mechanics, and acoustic and electromagnetic applications.

Review of difference methods for ordinary differential equations including Runge-Kutta, multi-step, adaptive step-sizing, and stiffness; finite difference versus finite element; elliptic boundary value problems; iterative solution methods, self-adjoint elliptic problems; parabolic equations including consistency, stability, and convergence, Crank-Nicolson method, method, method of lines; first order hyperbolic systems and characteristics Lax-Wendroff schemes, methods of lines for hyperbolic equations.
Prerequisites: MA 360 [Min Grade: C] or MA 560 [Min Grade: C] or MA 455 [Min Grade: C] or MA 555 [Min Grade: C]

MA 668. Numerical Analysis I. 3 Hours.
Prerequisites: MA 670 [Min Grade: B]

MA 669. Numerical Analysis II. 3 Hours.
Prerequisites: MA 668 [Min Grade: B]

MA 670. Topology I. 3 Hours.
Definition of topologies; closure; continuity; finite product topology; metric spaces; connectedness; completeness and compactness (in particular, in metric spaces).
Prerequisites: MA 631 [Min Grade: B] or MA 540 [Min Grade: B] or MA 440 [Min Grade: B]
MA 671. Topology II. 3 Hours.
Product topology; quotient spaces; countability and separation axioms; Tychonoff's theorem; homotopy; manifolds; partitions of unity.
Prerequisites: MA 670 [Min Grade: B]

MA 675. Differential Geometry. 3 Hours.
Local and global theory of curves and surfaces; Fenchel's theorem; the first and second fundamental forms; surface area; Bernstein's theorem; Gauss's theorem egregium; local intrinsic geometry of surfaces; Riemannian surfaces; Lie derivatives; covariant differentiation; geodesics; the Reimann curvature tensor; the second variation of arc length; selected topics in the global theory of surfaces.
Prerequisites: MA 642 [Min Grade: C]

MA 687. Advanced Probability. 3 Hours.
Foundation of probability, conditional probabilities, and independence, Bayes theorem, discrete and continuous distributions, joint distributions, conditional and marginal distributions, convolution, moments and moment generation function, multivariable normal distribution and sums of normal random variables, Markov chains.
Prerequisites: MA 485 [Min Grade: B] or MA 585 [Min Grade: B]

MA 688. Advanced Statistics. 3 Hours.
Parameter estimations, maximum likelihood estimation, sufficient statistic, hypothesis testing, Neyman-Pearson Lemma, p-value, Kolmogorov-Smirnov test, Anderson-Darling test, P-P plot, Q-Q plot, testing for distribution type, location and scale parameters, mean squared error.
Prerequisites: MA 585 [Min Grade: B] or MA 587 [Min Grade: B] or MA 687 [Min Grade: B]

MA 690. Mathematics Seminar. 1-3 Hour.
This course covers special topics in mathematics and the applications of the mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 691. Mathematics Seminar. 1-3 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 692. Special Topics in Mathematics. 1-3 Hour.
This course covers special topics in mathematics and the applications of the mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 693. Special Topics in Mathematics. 1-3 Hour.
This course covers special topics in mathematics and the applications of the mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 694. Special Topics in Mathematics. 1-6 Hour.
This course covers special topics in mathematics and the applications of the mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 695. Special Topics in Mathematics. 1-6 Hour.
This course covers special topics in mathematics and the applications of the mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 696. Special Topics in Mathematics. 1-12 Hour.
This course covers special topics in mathematics and the applications of the mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 697. Special Topics in Mathematics. 1-12 Hour.
This course covers special topics in mathematics and the applications of the mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 698. M Lev Non-Thesis Res. 1-12 Hour.
This course covers special topics in mathematics and the applications of the mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

This course covers special topics in mathematics and the applications of the mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 740. Advanced Complex Analysis. 3 Hours.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites: Having passed the Qualifying Exam or permission of instructor.

MA 745. Functional Analysis I. 3 Hours.
Normed and Banach spaces; inner product and Hilbert spaces; linear functionals and dual spaces; operators in Hilbert spaces; theory of unbounded sesquilinear forms; Hahn-Banach, open mapping and closed graph theorems; spectral theory.
Prerequisites: MA 646 [Min Grade: B]

MA 746. Functional Analysis II. 3 Hours.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 747. Linear Operators in Hilbert Space. 3 Hours.
Hilbert space; Bessel's inequality; Parseval's formula; bounded and unbounded linear operators; representation theorems; the Friedrichs extension; the spectral theorem for self-adjoint operators; spectral theory for Schrodinger operators.
Prerequisites: MA 646 [Min Grade: B]

MA 748. Fourier Transforms. 3 Hours.
Fourier transform and inverse transform to tempered distributions; applications to partial differential equations.
Prerequisites: MA 645 [Min Grade: B] and MA 655 [Min Grade: B]

MA 749. Theory of Distribution. 3 Hours.
Prerequisites: MA 645 [Min Grade: B]

MA 750. Advanced Ordinary Differential Equations. 3 Hours.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 753. Nonlinear Analysis. 3 Hours.
Selected topics including degree theory, bifurcation theory, and topological methods.
MA 755. Advanced Partial Differential Equations. 3 Hours.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.
Prerequisites: MA 645 [Min Grade: B]

MA 760. Dynamical Systems I. 3 Hours.
Continuous dynamical systems; limit sets; centers of attraction; recurrence; stable and wandering points; flow boxes, and monotone sequences in planar dynamical systems; Poincare-Bendixson theorem.

MA 761. Dynamical Systems II. 3 Hours.
Discrete dynamical systems; hyperbolicity; symbolic dynamics; chaos; homoclinic orbits; bifurcations; attractors (theory and examples).

MA 770. Continuum Theory. 3 Hours.
Pathology of compact connected metric spaces; inverse limits; boundary bumping theorem; Hahn-Mazurkiewicz theorem; composants; chainable and circle-like continua; irreducibility; separation; unicoherence; indecomposability.

MA 772. Complex Analytic Dynamics. 3 Hours.
Riemann surfaces; polynomial dynamics, rational functions and entire functions; fixed point theory; Mandelbrot set; Julia sets; prime ends; conformal mappings.

MA 774. Algebraic Topology. 3 Hours.
Covering spaces; introduction to homotopy theory; singular homology, cohomology.

MA 776. Advanced Differential Geometry. 3 Hours.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 781. Differential Topology I. 3 Hours.
A study of differentiable structures on manifolds, primarily from a global viewpoint: smooth mappings including diffeomorphisms, immersions and submersions; submanifolds and transversality.
Prerequisites: MA 645 [Min Grade: B] and MA 675 [Min Grade: B]

MA 782. Differential Topology II. 3 Hours.
A continuation of MA 781, with further applications such as Morse Theory.

MA 790. Mathematics Seminar. 1-3 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 791. Mathematics Seminar. 1-3 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 792. Special Topics in Mathematics. 1-3 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 793. Special Topics in Mathematics. 1-3 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 794. Special Topics in Mathematics. 1-6 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 795. Special Topics in Mathematics. 1-6 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 796. Special Topics in Mathematics. 1-12 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 797. Special Topics in Mathematics. 1-12 Hour.
This course covers special topics in mathematics and the applications of mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

MA 798. Non-Dissertation Research and Preparation for Comp. 1-12 Hour.
This course covers special topics in mathematics and the applications of the mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

This course covers special topics in mathematics and the applications of the mathematics. May be repeated for credit when topics vary. Prerequisites vary with topics.

Prerequisites: GAC Z