

# MATHEMATICS (MATH)

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## MATH 1483 Mathematical Functions and Their Uses (A)

**Prerequisites:** An acceptable placement score - see placement.okstate.edu.

**Description:** Analysis of functions and their graphs from the viewpoint of rates of change. Linear, exponential, logarithmic and other functions. Applications to the natural sciences, agriculture, business and the social sciences.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**General Education and other Course Attributes:** Analytical & Quant Thought

**Additional Fees:** MATH Corequisite Lab fee of \$90 applies.

## MATH 1493 Applications of Modern Mathematics (A)

**Prerequisites:** An acceptable placement score (see placement.okstate.edu).

**Description:** Introduction to contemporary applications of discrete mathematics. Topics from management science, statistics, coding and information theory, social choice and decision making, geometry and growth.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**General Education and other Course Attributes:** Analytical & Quant Thought

## MATH 1513 College Algebra (A)

**Prerequisites:** An acceptable placement score (see placement.okstate.edu). Two years of high school algebra recommended.

**Description:** Quadratic equations, functions and graphs, inequalities, systems of equations, exponential and logarithmic functions, theory of equations, sequences, permutations and combinations. Combined credit toward a degree for MATH 1513, MATH 1613 and MATH 1715 limited to six hours.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**General Education and other Course Attributes:** Analytical & Quant Thought

**Additional Fees:** MATH Corequisite Lab fee of \$90 applies.

## MATH 1583 Applied Geometry and Trigonometry (A)

**Prerequisites:** A grade of "C" or better in one of MATH 1483 or MATH 1513, or an acceptable placement score (see placement.okstate.edu).

**Description:** Geometry, trigonometry, and their applications to technology and design. Not intended for calculus-bound students.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**General Education and other Course Attributes:** Analytical & Quant Thought

## MATH 1613 Trigonometry (A)

**Prerequisites:** MATH 1513 with grade of "C" or better or an acceptable placement score (see placement.okstate.edu).

**Description:** Trigonometric functions, solution of triangles and applications to physical sciences. Combined credit toward a degree for MATH 1513, MATH 1613 and MATH 1715 limited to six hours.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**General Education and other Course Attributes:** Analytical & Quant Thought

## MATH 1715 Precalculus (A)

**Prerequisites:** An acceptable placement score (see http://placement.okstate.edu). One year of high school geometry and two years of high school algebra recommended.

**Description:** Includes an integrated treatment of topics from College Algebra and Trigonometry. Combined credit toward a degree for MATH 1513, MATH 1613 and MATH 1715 limited to six hours. Satisfies the six hour general education Analytical and Quantitative Thought requirement.

**Credit hours:** 5

**Contact hours:** Lecture: 5 Contact: 5

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**General Education and other Course Attributes:** Analytical & Quant Thought

**MATH 1813 Preparation for Calculus (A)**

**Prerequisites:** MATH 1513 with grade of "C" or better or an acceptable placement score (see placement.okstate.edu).

**Description:** A conceptual approach to the algebra and trigonometry needed for calculus. Trigonometry from the perspective of the unit circle and right triangles, behavior of trigonometric functions, and basic identities. Functions arising in calculus and the notion of an inverse function, especially in the context of trigonometric, logarithmic, and exponential functions. Rates of change and the limiting process. Combined credit toward a degree for MATH 1513, MATH 1613, and MATH 1813 limited to six hours. May not be used for degree credit with MATH 1715.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**General Education and other Course Attributes:** Analytical & Quant Thought

**Additional Fees:** MATH Corequisite Lab fee of \$90 applies.

**MATH 1910 Special Studies**

**Prerequisites:** Consent of instructor.

**Description:** Special subjects in mathematics. Offered for variable credit, 1-3 credit hours, maximum of 3 credit hours.

**Credit hours:** 1-3

**Contact hours:** Contact: 1-3 Other: 1-3

**Levels:** Undergraduate

**Schedule types:** Independent Study

**Department/School:** Mathematics

**MATH 2103 Business Calculus (A)**

**Prerequisites:** A grade of "C" or better in one of MATH 1483 or MATH 1513 or MATH 1715 or MATH 1813, or an acceptable placement score (see <http://placement.okstate.edu>).

**Description:** An introduction to calculus in the context of applications to business. Previously offered as MATH 2713.

**Credit hours:** 3

**Contact hours:** Lecture: 2 Contact: 3 Other: 1

**Levels:** Undergraduate

**Schedule types:** Discussion, Combined lecture & discussion, Lecture

**Department/School:** Mathematics

**General Education and other Course Attributes:** Analytical & Quant Thought

**MATH 2123 Calculus for Technology Programs I (A)**

**Prerequisites:** MATH 1613 with a grade of "C" or better, or MATH 1715 with a grade of "C" or better, or MATH 1813 with a grade of "C" or better, or an acceptable placement score (see placement.okstate.edu).

**Description:** First semester of a terminal sequence in calculus for students in the School of Technology. Functions and graphs, differentiation and integration with applications. Previously offered as MATH 2373.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**General Education and other Course Attributes:** Analytical & Quant Thought

**MATH 2133 Calculus for Technology Programs II (A)**

**Prerequisites:** A grade of "C" or better in MATH 2123 or in MATH 2144.

**Description:** Second semester of a terminal sequence in calculus for students in the School of Technology. Calculus of trigonometric, exponential and logarithmic functions and applications to physical problems. Previously offered as MATH 2383.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**General Education and other Course Attributes:** Analytical & Quant Thought

**MATH 2144 Calculus I (A)**

**Prerequisites:** MATH 1613 with grade of "C" or better, or MATH 1715 with grade of "C" or better, or MATH 1813 with grade of "C" or better, or an acceptable placement score (see placement.okstate.edu).

**Description:** An introduction to derivatives, integrals and their applications. Previously offered as MATH 2145 and MATH 2265.

**Credit hours:** 4

**Contact hours:** Lecture: 4 Contact: 4

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**General Education and other Course Attributes:** Analytical & Quant Thought

**Additional Fees:** MATH Corequisite Lab fee of \$90 applies.

**MATH 2153 Calculus II (A)**

**Prerequisites:** MATH 2144 with grade of "C" or better.

**Description:** A continuation of MATH 2144, including techniques of integration, series and their applications, parametric equations, and polar coordinates. Previously offered as MATH 2155, MATH 2163, and MATH 2365.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**General Education and other Course Attributes:** Analytical & Quant Thought

**MATH 2163 Calculus III**

**Prerequisites:** MATH 2153 with grade of "C" or better.

**Description:** A continuation of MATH 2153, including differential and integral calculus of functions of several variables and an introduction to vector analysis.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 2233 Differential Equations****Prerequisites:** MATH 2153 with grade of "C" or better.**Description:** Methods of solution of ordinary differential equations with applications. First order equations, linear equations of higher order, series solutions and Laplace transforms. Combined credit toward a degree for MATH 2233, MATH 3013, and MATH 3263 limited to six hours. Previously offered as MATH 2613.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Undergraduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 2890 Honors Experience in Math****Prerequisites:** Honors College participation and concurrent enrollment in a designated MATH course.**Description:** A supplemental Honors experience in mathematics to partner concurrently with designated MATH course(s). This course adds a different intellectual dimension to the designated course(s). Offered for fixed credit, 1 credit hour, maximum of 6 credit hours.**Credit hours:** 1**Contact hours:** Lecture: 1 Contact: 1**Levels:** Undergraduate**Schedule types:** Lecture**Department/School:** Mathematics**General Education and other Course Attributes:** Honors Credit**MATH 2900 Undergraduate Research****Prerequisites:** Consent of instructor.**Description:** A guided program of independent reading and research under the direction of a faculty member. Offered for variable credit, 1-3 credit hours, maximum of 3 credit hours.**Credit hours:** 1-3**Contact hours:** Contact: 1-3 Other: 1-3**Levels:** Undergraduate**Schedule types:** Independent Study**Department/School:** Mathematics**MATH 2910 Special Studies****Prerequisites:** Consent of instructor.**Description:** Special subjects in mathematics. Offered for variable credit. 1-3 credit hours, maximum of 6 credit hours.**Credit hours:** 1-3**Contact hours:** Contact: 1-3 Other: 1-3**Levels:** Undergraduate**Schedule types:** Independent Study**Department/School:** Mathematics**MATH 3013 Linear Algebra (A)****Prerequisites:** MATH 2153 with a grade of "C" or better.**Description:** Algebra and geometry of finite-dimensional linear spaces, linear transformations, algebra of matrices, eigenvalues and eigenvectors. Combined credit toward a degree for MATH 2233, MATH 3013 and MATH 3263 limited to six hours.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Undergraduate**Schedule types:** Lecture**Department/School:** Mathematics**General Education and other Course Attributes:** Analytical & Quant Thought**MATH 3263 Linear Algebra and Differential Equations****Prerequisites:** MATH 2153 with a grade of "C" or better.**Description:** An integrated treatment of linear algebra and differential equations. Combined credit toward a degree for MATH 2233, MATH 3013, and MATH 3263 limited to six hours. Previously offered as MATH 3623.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Undergraduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 3303 Advanced Perspectives on Secondary Mathematics****Prerequisites:** MATH 2153 with grade of "C" or better.**Description:** A conceptually rigorous treatment of topics in secondary mathematics including functions, rates of change, and modeling with linear, exponential, logarithmic, and trigonometric functions. Emphasis on articulating ideas and developing pre-service teachers' ability to teach for understanding. No credit towards the MATH minor.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Undergraduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 3403 Geometric Structures for Early Childhood and Elementary Teachers****Prerequisites:** MATH 1483 or MATH 1493 or MATH 1513.**Description:** Foundations of geometry for prospective early childhood and elementary educators. Linear and angular measure, polygons and polyhedra, similarity and congruence, geometric constructions, motion and transformations. Class format may emphasize student investigation and discovery, discussion and presentation, and working with mathematical tools. This course, together with MATH 3603, prepares students for SMED 3153 and SMED 4153 and/or HDFS 3223. Previously offered as MATH 3733.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Undergraduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 3583 Introduction to Mathematical Modeling****Prerequisites:** MATH 2153 and MATH 3013 with grades of "C" or better.**Description:** A project-based introduction to the core methods used in mathematical modeling: model building, computation and simulation, model verification, interpretation, and refinement. Students conduct inquiries to create and analyze mathematical models to solve problems in various scientific or business contexts, using approaches that may include discrete or continuous models, dynamical systems, stochastic processes, empirical modeling, and others. Written reports and oral presentation of solutions required. May not be used for degree credit with MATH 4583.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Undergraduate**Schedule types:** Lecture**Department/School:** Mathematics

**MATH 3603 Mathematical Structures for Early Childhood and Elementary Teachers****Prerequisites:** MATH 1483 or MATH 1493 or MATH 1513.**Description:** Foundations of mathematics and number concepts for prospective early childhood and elementary educators. Problem solving, logic, set theory, functions and relations, number systems, number theory, rational numbers, decimals and fractions, exponentiation, probability, and applications. Class format may emphasize student investigation and discovery, discussion and presentation, and working with mathematical tools. Together with MATH 3403, it prepares students for SMED 3153 and SMED 4153 and/or HDFS 3223. Previously offered as MATH 3723.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Undergraduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 3613 Introduction to Abstract Algebra****Prerequisites:** MATH 3013 with a grade of "C" or better.**Description:** An introduction to mathematical reasoning including logical structure of statements, quantifiers, basic set theory and techniques of proof. Elementary number theory including divisors and prime factorization, the Euclidean algorithm, and modular arithmetic. Introduction to rings, integral domains, fields, and polynomial rings. Previously offered as MATH 3113.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Undergraduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 3890 Advanced Honors Experience in Mathematics****Prerequisites:** Honors College participation and concurrent enrollment in a designated MATH course.**Description:** A supplemental Honors experience in mathematics to partner concurrently with designated upper-division MATH course(s). This course adds a different intellectual dimension to the designated course(s). Offered for fixed credit, 1 credit hour, maximum of 6 credit hours.**Credit hours:** 1**Contact hours:** Lecture: 1 Contact: 1**Levels:** Undergraduate**Schedule types:** Lecture**Department/School:** Mathematics**General Education and other Course Attributes:** Honors Credit**MATH 3910 Special Studies****Prerequisites:** Consent of instructor.**Description:** Special subjects in mathematics. Offered for variable credit, 1-3 credit hours, maximum of 3 credit hours.**Credit hours:** 1-3**Contact hours:** Contact: 1-3 Other: 1-3**Levels:** Undergraduate**Schedule types:** Independent Study**Department/School:** Mathematics**MATH 3933 Introduction to Mathematical Research****Prerequisites:** MATH 3013 with grade of "C" or better; MATH 3613 with grade of "C" or better recommended.**Description:** A project-based introduction to the core methods used in mathematical research: computation, pattern recognition, conjecture, proof, and generalization. Students conduct inquiries in various mathematical areas to be selected from number theory, combinatorics, game theory, and others. Calculation and computer experimentation will be used to gather data and facilitate recognition of patterns. Written reports and oral presentation of solutions required.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Undergraduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 4003 Mathematical Logic and Computability****Prerequisites:** MATH 3613 or PHIL 3003 or consent of instructor.**Description:** The basic metatheorems of first order logic: soundness, completeness, compactness, Lowenheim-Skolem theorem, undecidability of first order logic, Godel's incompleteness theorem. Enumerability, diagonalization, formal systems, standard and nonstandard models, Godel numberings, Turing machines, recursive functions, and evidence for Church's thesis. Same course as PHIL 4003.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Undergraduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 4013 Calculus of Several Variables****Prerequisites:** MATH 2163 and MATH 3013 with grades of "C" or better.**Description:** Differential and integral calculus of functions of several variables, vector analysis, Stokes' Theorem, Green's Theorem and applications. May not be used for degree credit with MATH 5063.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Undergraduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 4023 Introduction to Analysis****Prerequisites:** MATH 2153 and MATH 3613 with grades of "C" or better, or consent of instructor.**Description:** An introduction to analysis of functions of one real variable emphasizing the reading and writing of mathematical proof. Basic logic, set theory, functions and relations, cardinality of sets. Structure of the real numbers, completeness, open and closed sets, compact sets. Convergence of sequences bounded and monotone sequences, subsequences. Limits of functions, continuity. May not be used for degree credit with MATH 5073.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Undergraduate**Schedule types:** Lecture**Department/School:** Mathematics

**MATH 4033 History of Mathematics**

**Prerequisites:** MATH 2153 with a grade of "C" or better.

**Description:** Historical development of mathematical ideas and methods relating to concepts of number, geometry, algebra, and other areas, from the time of the ancient Greeks through major developments in the Renaissance and 17th and 18th centuries, with a brief survey of later developments. Includes contributions from diverse cultures and individuals, and influences from astronomy and physics. The emphasis in the course will be on replicating historical techniques and relating them to contemporary practice. The course provides future secondary and college teachers with a foundation for incorporating historical perspectives in their lessons. May not be used for degree credit with MATH 5033.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4063 Advanced Linear Algebra**

**Prerequisites:** MATH 3013 and MATH 3613 with grades of "C" or better; grades of "B" or better recommended.

**Description:** A rigorous treatment of vector spaces, linear transformations, determinants, orthogonal and unitary transformations, canonical forms, bilinear and hermitian forms, and dual spaces. Honors and regular sections are offered and meet with MATH 5023. May not be used for degree credit with MATH 5023.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4083 Intermediate Analysis**

**Prerequisites:** MATH 4023 with grade of "C" or better.

**Description:** Continuation of MATH 4023. Review of limits and continuity. Properties of continuous functions, uniform continuity, the derivative, the Mean Value Theorem. The Riemann integral, the Fundamental Theorem of Calculus. Infinite series, power series, pointwise and uniform convergence of series of functions. May not be used for degree credit with MATH 5083.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4143 Advanced Calculus I**

**Prerequisites:** MATH 2163, MATH 3013, and MATH 4023 with grades of "C" or better; grades of "B" or better recommended.

**Description:** A rigorous treatment of calculus for functions of one and several variables. Elementary topology of Euclidean and metric spaces, continuity and uniform continuity, differentiation and integration in one variable. Honors and regular sections are offered and meet with MATH 5043. May not be used for degree credit with MATH 5043.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4153 Advanced Calculus II**

**Prerequisites:** MATH 4143 with grade of "C" or better; grade of "B" or better recommended.

**Description:** Continuation of MATH 4143. A rigorous treatment of sequences and series of functions, uniform convergence, and differentiation and integration of vector-valued functions. Honors and regular sections are offered and meet with MATH 5053. May not be used for degree credit with MATH 5053.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4233 Intermediate Differential Equations**

**Prerequisites:** MATH 2233 and MATH 3013 with grades of "C" or better.

**Description:** Systems of differential equations, series solutions, special functions, elementary partial differential equations, Sturm-Liouville problems, stability and applications. Previously offered as MATH 4653. May not be used for degree credit with MATH 5203.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4263 Introduction to Partial Differential Equations**

**Prerequisites:** MATH 2163 and MATH 2233 and MATH 3013 with grades of "C" or better.

**Description:** Solution of the standard partial differential equations (Laplace's equation, transport equation, heat equation, wave equation) by separation of variables and transform methods, including eigenfunction expansions, Fourier and Laplace transform. Boundary value problems, Sturm-Liouville theory, orthogonality, Fourier, Bessel, and Legendre series, spherical harmonics. May not be used for degree credit with MATH 5263.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4283 Complex Variables**

**Prerequisites:** MATH 2163 with a grade of "C" or better.

**Description:** Properties of complex numbers, analytic functions of a complex variable, contour integrals, Cauchy's Integral Theorem, power series and Laurent series, residues and poles, conformal mapping, and applications. Previously offered as MATH 4673. May not be used for degree credit with MATH 5273.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4343 Introduction to Topology**

**Prerequisites:** MATH 4023 with a grade of "C" or better.

**Description:** Topological spaces, basic point-set topology, introduction to surfaces and three-manifolds, introduction to knot theory, applications. May not be used for degree credit with MATH 5343.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics



**MATH 4403 Geometry**

**Prerequisites:** MATH 3013 and MATH 3613 with grades of "C" or better.

**Description:** A rigorous and thorough development of plane geometry including lines, triangles, and circles. Congruence of figures using rigid motions and similarity using dilations. Construction of geometric figures. Additional topics may include non-Euclidean geometries and higher dimensional geometry. Previously offered as MATH 4043.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4423 Geometry and Algorithms in Three-Dimensional Modeling**

**Prerequisites:** MATH 2163 and MATH 3013 and (CS 1103 or CS 1113 or ENGR 1412) with grades of "C" or better.

**Description:** A project-based introduction to 3D computer-aided design tools from a mathematical perspective. Students will learn some of the mathematical background behind computer representation and manipulation of 3D geometry and will apply their knowledge, via both graphical user and programming interfaces, to design and 3D-print models visualizing mathematical concepts. Written reports and oral presentation required. May not be used for degree credit with MATH 5423.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4453 Mathematical Interest Theory**

**Prerequisites:** MATH 2153 and MATH 2233 with grades of "C" or better.

**Description:** Fundamental concepts of financial mathematics including simple and compound interest, inflation, yield rates, and equations of value for annuities, stocks, bonds, and other financial instruments. Determining equivalent measures of interest, determining yield rates, estimating rates of return, amortization. Useful in preparing for the actuarial FM exam. May not be used for degree credit with MATH 5453.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4513 Introduction to Numerical Analysis**

**Prerequisites:** MATH 2233 and MATH 3013 with grades of "C" or better and knowledge of programming, or consent of instructor.

**Description:** Computer arithmetic and round-off errors, numerical solution to nonlinear equations, interpolation, numerical differentiation and integration, numerical solutions to ordinary differential equations, error analysis for numerical solutions and approximations. Additional topics may include direct and iterative solutions for linear systems for equations. Same course as CS 4513. May not be used for degree credit with MATH 5513.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4553 Introduction to Optimization**

**Prerequisites:** MATH 2163 and MATH 3013 with grades of "C" or better.

**Description:** A survey of optimization theory and methods for functions of several variables. Unconstrained optimization, gradient methods. Linear programming, simplex method, duality. Nonlinear constrained optimization. May not be used for degree credit with MATH 5503.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4590 Professional Practice in Mathematics**

**Prerequisites:** Declared major in mathematics and consent of instructor.

**Description:** Internship or practicum experience applying mathematical principles to solve problems encountered during employment or an internship in business, industry, or government. Written and oral reports may be required. Offered for variable credit, 1-3 credit hours, maximum of 3 credit hours.

**Credit hours:** 1-3

**Contact hours:** Contact: 1-3 Other: 1-3

**Levels:** Undergraduate

**Schedule types:** Independent Study

**Department/School:** Mathematics

**MATH 4603 Intermediate Abstract Algebra**

**Prerequisites:** MATH 3613 with grade of "C" or better.

**Description:** Introduction to groups, subgroups, homomorphisms, quotient groups. Theory of field extensions and automorphisms, introduction to Galois theory.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4613 Abstract Algebra I**

**Prerequisites:** MATH 3613 with grade of "C" or better; grade of "B" or better recommended.

**Description:** A rigorous treatment of group theory including subgroups and quotient groups, isomorphism and homomorphism, structure theory, group actions, and the Sylow theorems. Introduction to rings, ideals, and homomorphisms. Honors and regular sections are offered and meet with MATH 5003. May not be used for degree credit with MATH 5003.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4623 Abstract Algebra II**

**Prerequisites:** MATH 4613 with grade of "C" or better; grade of "B" or better recommended.

**Description:** Continuation of MATH 4613. A rigorous treatment of ring theory including ideals, homomorphism, unique factorization domains, principal ideal domains, modules and vector spaces. Field theory and Galois theory. Honors and regular sections are offered and meet with MATH 5013. May not be used for degree credit with MATH 5013.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4663 Combinatorics**

**Prerequisites:** MATH 3013 with a grade of "C" or better.

**Description:** Introduction to graph theory and network theory, counting techniques, generating functions, recurrence relations, and difference equations. Previously offered as MATH 4273. May not be used for degree credit with MATH 5673.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4713 Number Theory**

**Prerequisites:** MATH 3613 with a grade of "C" or better.

**Description:** Divisibility of integers, congruencies, quadratic residues, distribution of primes, continued fractions and the theory of ideals. Previously offered as MATH 4243. May not be used for degree credit with MATH 5713.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4753 Introduction to Cryptography**

**Prerequisites:** MATH 3013 and (MATH 3613 or CS 3653) with grades of "C" or better.

**Description:** Classical and modern techniques for transmitting and managing information in the presence of eavesdroppers or adversaries and the mathematical principles on which they are based. Symmetric and asymmetric ciphers such as RSA and public key cryptography. Modular arithmetic, the factoring problem, and the discrete logarithm problem. May not be used for degree credit with MATH 5753.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4813 Groups and Representations**

**Prerequisites:** MATH 3013 and MATH 3613 with grades of "C" or better, or consent of instructor.

**Description:** An introduction to groups, group actions, symmetry groups, representations and characters. Further topics may include infinite symmetry groups, applications to chemistry and physics, finite isometry groups and geometry. May not be used for degree credit with MATH 5803.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4900 Undergraduate Research**

**Prerequisites:** Consent of instructor.

**Description:** A guided program of independent reading and research under the direction of a faculty member. Offered for variable credit, 1-3 credit hours, maximum of 6 credit hours.

**Credit hours:** 1-3

**Contact hours:** Contact: 1-3 Other: 1-3

**Levels:** Undergraduate

**Schedule types:** Independent Study

**Department/School:** Mathematics

**MATH 4910 Special Studies**

**Prerequisites:** Consent of instructor.

**Description:** Special subjects in mathematics. Offered for variable credit, 1-3 credit hours, maximum of 9 credit hours.

**Credit hours:** 1-3

**Contact hours:** Contact: 1-3 Other: 1-3

**Levels:** Undergraduate

**Schedule types:** Independent Study

**Department/School:** Mathematics

**MATH 4950 Problem Solving Seminar**

**Prerequisites:** MATH 2153 with a grade of "C" or better.

**Description:** The general process of problem solving. Selected problem-solving techniques. Applications to challenging problems from all areas of mathematics. Offered for variable credit, 1-3 credit hours, maximum of 3 credit hours.

**Credit hours:** 1-3

**Contact hours:** Lecture: 1-3 Contact: 1-3

**Levels:** Undergraduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 4963 Preparation for Senior Thesis**

**Prerequisites:** Consent of instructor, junior or senior standing.

**Description:** A guided program of independent reading and research under the direction of a faculty member. This course may serve as the first part of a two-semester senior thesis or senior honors thesis experience.

**Credit hours:** 3

**Contact hours:** Contact: 3 Other: 3

**Levels:** Undergraduate

**Schedule types:** Independent Study

**Department/School:** Mathematics

**MATH 4973 Senior Thesis**

**Prerequisites:** Consent of instructor, senior standing.

**Description:** A guided program of independent reading and research under the direction of a faculty member. The project culminates in an oral presentation, and a written report also approved by a second faculty reader.

**Credit hours:** 3

**Contact hours:** Contact: 3 Other: 3

**Levels:** Undergraduate

**Schedule types:** Independent Study

**Department/School:** Mathematics

**MATH 4993 Senior Honors Thesis**

**Prerequisites:** Consent of instructor, senior standing, and Honors Program participation.

**Description:** A guided program of independent reading and research under the direction of a faculty member. The project culminates in an oral presentation, and a written report also approved by a second faculty reader. Required for graduation with Departmental honors in mathematics.

**Credit hours:** 3

**Contact hours:** Contact: 3 Other: 3

**Levels:** Undergraduate

**Schedule types:** Independent Study

**Department/School:** Mathematics

**General Education and other Course Attributes:** Honors Credit

**MATH 5000 Master's Research and Thesis****Prerequisites:** Consent of advisory committee.**Description:** Directed reading and research culminating in the master's report or master's thesis. Offered for variable credit, 1-6 credit hours, maximum of 6 credit hours.**Credit hours:** 1-6**Contact hours:** Contact: 1-6 Other: 1-6**Levels:** Graduate**Schedule types:** Independent Study**Department/School:** Mathematics**MATH 5003 Abstract Algebra I****Prerequisites:** MATH 3613 with grade of "C" or better; grade of "B" or better recommended.**Description:** A rigorous treatment of group theory including subgroups and quotient groups, isomorphism and homomorphism, structure theory, group actions, and the Sylow theorems. Introduction to rings, ideals, and homomorphisms. Meets with MATH 4613. May not be used for degree credit with MATH 4613.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 5010 Seminar in Mathematics****Prerequisites:** Consent of instructor.**Description:** Topics in mathematics. Offered for variable credit, 1-3 credit hours, maximum of 12 credit hours.**Credit hours:** 1-3**Contact hours:** Contact: 1-3 Other: 1-3**Levels:** Graduate**Schedule types:** Independent Study**Department/School:** Mathematics**MATH 5013 Abstract Algebra II****Prerequisites:** A grade of "C" or better in one of MATH 4613 or MATH 5003; grade of "B" or better recommended.**Description:** Continuation of MATH 5003. A rigorous treatment of ring theory including ideals, homomorphism, unique factorization domains, principal ideal domains, modules and vector spaces. Field theory and Galois theory. Meets with MATH 4623. May not be used for degree credit with MATH 4623.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 5023 Advanced Linear Algebra****Prerequisites:** MATH 3013 and MATH 3613 with grades of "C" or better; grades of "B" or better recommended.**Description:** A rigorous treatment of vector spaces, linear transformations, determinants, orthogonal and unitary transformations, canonical forms, bilinear and Hermitian forms, and dual spaces. Meets with MATH 4063. May not be used for degree credit with MATH 4063.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 5033 History of Mathematics****Prerequisites:** MATH 2153 with a grade of "C" or better.**Description:** Historical development of mathematical ideas and methods relating to concepts of number, geometry, algebra, and other areas, from the time of the ancient Greeks through major developments in the Renaissance and 17th and 18th centuries, with a brief survey of later developments. Includes contributions from diverse cultures and individuals, and influences from astronomy and physics. The emphasis in the course will be on replicating historical techniques and relating them to contemporary practice. The course provides future secondary and college teachers with a foundation for incorporating historical perspectives in their lessons. May not be used for degree credit with MATH 4033.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 5043 Advanced Calculus I****Prerequisites:** MATH 2163, MATH 3013, and MATH 4023 with grades of "C" or better; grades of "B" or better recommended.**Description:** A rigorous treatment of calculus for functions of one and several variables. Elementary topology of Euclidean and metric spaces, continuity and uniform continuity, differentiation and integration in one variable. Meets with MATH 4143. May not be used for degree credit with MATH 4143.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 5053 Advanced Calculus II****Prerequisites:** A grade of "C" or better in one of MATH 4143 or MATH 5043; grade of "B" or better recommended.**Description:** Continuation of MATH 5043. A rigorous treatment of sequences and series of functions, uniform convergence, and differentiation and integration of vector-valued functions. Meets with MATH 4153. May not be used for degree credit with MATH 4153.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 5063 Calculus of Several Variables****Prerequisites:** MATH 2163 and MATH 3013 with grades of "C" or better.**Description:** Differential and integral calculus of functions of several variables, vector analysis, Stokes' Theorem, Green's Theorem and applications. May not be used for degree credit with MATH 4013.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics



**MATH 5073 Introduction to Analysis**

**Prerequisites:** MATH 2153 and MATH 3613 with grades of "C" or better, or consent of instructor.

**Description:** An introduction to analysis of functions of one real variable emphasizing the reading and writing of mathematical proof. Basic logic, set theory, functions and relations, cardinality of sets. Structure of the real numbers, completeness, open and closed sets, compact sets. Convergence of sequences bounded and monotone sequences, subsequences. Limits of functions, continuity. May not be used for degree credit with MATH 4023.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5083 Intermediate Analysis**

**Prerequisites:** MATH 4023 with grade of "C" or better.

**Description:** Continuation of MATH 4023. Review of limits and continuity. Properties of continuous functions, uniform continuity, the derivative, the Mean Value Theorem. The Riemann integral, the Fundamental Theorem of Calculus. Infinite series, power series, pointwise and uniform convergence of series of functions. May not be used for degree credit with MATH 4083.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5133 Stochastic Processes**

**Prerequisites:** MATH 2233, MATH 3013 and STAT 5123.

**Description:** Definition of stochastic processes, probability structure, mean and covariance function, the set of sample functions, stationary processes and their spectral analysis, renewal processes, counting analysis, discrete and continuous Markov chains, birth and death processes, exponential model, queuing theory. Same course as IEM 5133 & STAT 5133.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5143 Real Analysis I**

**Prerequisites:** MATH 4153 or MATH 5053.

**Description:** Measure theory, measurable functions, integration and differentiation of functions.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5153 Real Analysis II**

**Prerequisites:** MATH 5143.

**Description:** Differentiation with respect to measures. Aspects of point set topology: nets, locally compact spaces, product spaces. Elementary functional analysis: Hahn-Banach, uniform boundedness, open mapping theorems, weak topologies, Hilbert spaces. Riesz representation theorems: duals of Lebesgue spaces and spaces of continuous functions. Other topics may include: elements of Fourier analysis, distribution theory, Stone-Weierstrass theorem.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5193 Differentiable Manifolds**

**Prerequisites:** MATH 4153 or MATH 5053; recommended MATH 4343 or MATH 5303.

**Description:** Differentiable manifolds and maps, tangent vectors, vector fields, integral curves, submanifolds, differential forms, and integration. Additional topics may be selected from: flows, Lie derivatives, the Frobenius theorem, structures defined by differential forms, vector bundles and de Rham theory.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5203 Intermediate Differential Equations**

**Prerequisites:** MATH 2233 and MATH 3013 with grades of "C" or better.

**Description:** Systems of differential equations, series solutions, special functions, elementary partial differential equations, Sturm-Liouville problems, stability and applications. Previously offered as MATH 4653. May not be used for degree credit with MATH 4233.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5213 Fourier Analysis and Wavelets**

**Prerequisites:** MATH 4013 or MATH 4023.

**Description:** Orthogonal series expansions, Fourier series and integrals and boundary value problems. Haar wavelets and multiresolution analysis. Applications.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5233 Partial Differential Equations**

**Prerequisites:** MATH 4013, MATH 4143 and MATH 4233 or consent of instructor.

**Description:** Representation formulas for solutions of transport equation, Laplace's equation, heat equation and wave equation, mean value theorems, maximum principle, Green's functions, characteristics, eigenvalue problems, separation of variables, transform methods, variational methods, general theory of first order equations.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5243 Ordinary Differential Equations**

**Prerequisites:** MATH 4143 or MATH 5043; MATH 4233; MATH 5023.

**Description:** Banach space, contraction mapping principle, existence and uniqueness theorems, linear systems, higher-order linear equations, boundary value and eigenvalue problems, stability and asymptotic behavior, attractors, Gronwall's inequality, Liapunov method.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5253 Advanced Ordinary Differential Equations**

**Prerequisites:** MATH 5243.

**Description:** Selected topics in ordinary differential equations.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5263 Introduction to Partial Differential Equations**

**Prerequisites:** MATH 2163 and MATH 2233 and MATH 3013 with grades of "C" or better.

**Description:** Solution of the standard partial differential equations (Laplace's equation, transport equation, heat equation, wave equation) by separation of variables and transform methods, including eigenfunction expansions, Fourier and Laplace transform. Boundary value problems, Sturm-Liouville theory, orthogonality, Fourier, Bessel, and Legendre series, spherical harmonics. May not be used for degree credit with MATH 4263.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5273 Complex Variables**

**Prerequisites:** MATH 2163 with a grade of "C" or better.

**Description:** Properties of complex numbers, analytic functions of a complex variable, contour integrals, Cauchy's Integral Theorem, power series and Laurent series, residues and poles, conformal mapping, and applications. Previously offered as MATH 4673. May not be used for degree credit with MATH 4283.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5283 Complex Analysis I**

**Prerequisites:** MATH 4153 or MATH 5053.

**Description:** Basic topology of the plane, functions of a complex variable, analytic functions, transformations, infinite series, integration and conformal mapping.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5293 Complex Analysis II**

**Prerequisites:** MATH 5283.

**Description:** Riemann Mapping Theorem, meromorphic functions, analytic continuation, Dirichlet problem, and entire functions.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5303 General Topology**

**Prerequisites:** MATH 4143 or MATH 5043 or consent of instructor.

**Description:** Basic properties of topological spaces and continuous functions, including connectedness, compactness, and separation and countability axioms. Metric, product, and quotient spaces, Urysohn lemma, and Tietze extension theorem.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5313 Geometric Topology**

**Prerequisites:** MATH 4613 or MATH 5003, MATH 5303.

**Description:** Manifolds, complexes, the fundamental group, covering spaces, combinatorial group theory, the Seifert-Van Kampen theorem, and related topics.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5343 Introduction to Topology**

**Prerequisites:** MATH 4023 with a grade of "C" or better.

**Description:** Topological spaces, basic point-set topology, introduction to surfaces and three-manifolds, introduction to knot theory, applications. May not be used for degree credit with MATH 4343.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5413 Differential Geometry**

**Prerequisites:** MATH 4013 or MATH 4143 or MATH 5043.

**Description:** Differential manifolds, vector fields, differential forms, connections, Riemannian metrics, geodesics, completeness, curvature, and related topics.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5423 Geometry and Algorithms in Three-Dimensional Modeling**

**Prerequisites:** MATH 2163 and MATH 3013 and (CS 1113 or ENGR 1412) with grades of "C" or better.

**Description:** A project-based introduction to 3D computer-aided design tools from a mathematical perspective. Students will learn some of the mathematical background behind computer representation and manipulation of 3D geometry and will apply their knowledge, via both graphical user and programming interfaces, to design and 3D-print models visualizing mathematical concepts. Written reports and oral presentation required. May not be used for degree credit with MATH 4423.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5453 Mathematical Interest Theory**

**Prerequisites:** MATH 2153 and MATH 2233 with grades of "C" or better.

**Description:** Fundamental concepts of financial mathematics including simple and compound interest, inflation, yield rates, and equations of value for annuities, stocks, bonds, and other financial instruments. Determining equivalent measures of interest, determining yield rates, estimating rates of return, amortization. Useful in preparing for the actuarial FM exam. May not be used for degree credit with MATH 4453.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5473 Financial Calculus**

**Prerequisites:** MATH 4143 or MATH 5043, STAT 4203 or consent of instructor.

**Description:** Introduction to derivative pricing and market derivatives. Introduction to the Ito-Doebelin calculus and martingales; the martingale properties of Brownian motion, the Black-Scholes-Merton theory as a simple, special case of martingale pricing, market models of modern fixed income pricing. Insurance, hedging, and options.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5503 Introduction to Optimization**

**Prerequisites:** MATH 2163 and MATH 3013 with grades of "C" or better.

**Description:** A survey of optimization theory and methods for functions of several variables. Unconstrained optimization, gradient methods. Linear programming, simplex method, duality. Nonlinear constrained optimization. May not be used for degree credit with MATH 4553.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5513 Introduction to Numerical Analysis**

**Prerequisites:** MATH 2233 and MATH 3013 with grades of "C" or better and knowledge of programming, or consent of instructor.

**Description:** Computer arithmetic and round-off errors, numerical solution to nonlinear equations, interpolation, numerical differentiation and integration, numerical solutions to ordinary differential equations, error analysis for numerical solutions and approximations. Additional topics may include direct and iterative solutions for linear systems of equations. May not be used for degree credit with MATH 4513 or CS 4513.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5543 Numerical Analysis for Differential Equations**

**Prerequisites:** MATH 4233, MATH 4513 or CS 4513.

**Description:** Advanced machine computing, algorithms, analysis of truncation and rounding errors, convergence and stability applied to discrete variables, finite elements, and spectral methods in ordinary and partial differential equations.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5553 Numerical Analysis for Linear Algebra**

**Prerequisites:** MATH 3013, and MATH 4513 or CS 4513.

**Description:** Advanced machine computing, algorithms, analysis of rounding errors, condition, convergence, and stability applied to direct and iterative solution of linear systems of equations, linear least squares problems, and algebraic eigenvalue problems, including LU and QR factorization, conjugate gradients, QR algorithm, and Lanczos method.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5563 Finite Element Methods for Partial Differential Equations**

**Prerequisites:** MATH 4023; MATH 4263; and MATH 4513 or CS 4513 or equivalent. MATH 4143 or MATH 5043 preferred.

**Description:** Theory and practice of finite element methods, including elliptic boundary value problems, weak formulations, the Ritz-Galerkin method, conforming and non-conforming finite elements, error estimates, and numerical experiments.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5580 Case Studies in Applied Mathematics**

**Prerequisites:** MATH 2233, MATH 4013, and knowledge of computer programming.

**Description:** Selected mathematical problems from industry. Independent problem-solving, oral presentation of solutions, and technical report writing. Seminar-style format. Offered for variable credit, 1-3 credit hours, maximum of 6 credit hours.

**Credit hours:** 1-3

**Contact hours:** Contact: 1-3 Other: 1-3

**Levels:** Graduate

**Schedule types:** Independent Study

**Department/School:** Mathematics

**MATH 5593 Methods of Applied Mathematics**

**Prerequisites:** MATH 2233, MATH 4013, and knowledge of computer programming.

**Description:** Continuous and discrete techniques in modern applied mathematics. Positive definite matrices, eigenvalues and dynamical systems, discrete and continuous equilibrium equations, least squares estimation and the Kalman filter, potential flow, calculus of variations, network flows, and combinatorics.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5613 Algebra I**

**Prerequisites:** MATH 4613 or MATH 5003.

**Description:** A rigorous treatment of classical results in group theory, ring theory, and field theory.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5623 Algebra II**

**Prerequisites:** MATH 5613.

**Description:** A rigorous treatment of classical results in module theory, multilinear algebra, and representation theory.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5673 Combinatorics**

**Prerequisites:** MATH 3013 with a grade of "C" or better.

**Description:** Introduction to graph theory and network theory, counting techniques, generating functions, recurrence relations, and difference equations. May not be used for degree credit with MATH 4663.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5713 Number Theory**

**Prerequisites:** MATH 3613 with a grade of "C" or better.

**Description:** Divisibility of integers, congruencies, quadratic residues, distribution of primes, continued fractions and the theory of ideals. May not be used for degree credit with MATH 4713.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5753 Introduction to Cryptography**

**Prerequisites:** MATH 3013 and (MATH 3613 or CS 3653) with grades of "C" or better.

**Description:** Classical and modern techniques for transmitting and managing information in the presence of eavesdroppers or adversaries and the mathematical principles on which they are based. Symmetric and asymmetric ciphers such as RSA and public key cryptography. Modular arithmetic, the factoring problem, and the discrete logarithm problem. May not be used for degree credit with MATH 4753.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5803 Groups and Representations**

**Prerequisites:** MATH 3013 and MATH 3613 with grades of "C" or better, or consent of instructor.

**Description:** An introduction to groups, group actions, symmetry groups, representations and characters. Further topics may include infinite symmetry groups, applications to chemistry and physics, finite isometry groups and geometry. May not be used for degree credit with MATH 4813.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5903 Seminar and Practicum in the Teaching of College Mathematics**

**Prerequisites:** Graduate standing in mathematics or consent of instructor.

**Description:** Foundations of college mathematics teaching, including lecturing, grading and exam preparation. Adapting classroom activities to better serve different types of learners. Current trends in mathematics education such as calculus reform, cooperative learning, and technology in the classroom. Previously offered as MATH 5902.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 5913 Introduction to Research in Mathematics Education**

**Prerequisites:** MATH 3613 or MATH 4023 or equivalent.

**Description:** Examination and critique of research in mathematics education. A comparative study of research design, analysis, and reporting of both qualitative and quantitative research.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 6000 Doctoral Research and Dissertation****Prerequisites:** Consent of advisory committee.**Description:** Directed reading and research culminating in the PhD or EdD thesis. Offered for variable credit, 1-9 credit hours, maximum of 24 credit hours.**Credit hours:** 1-9**Contact hours:** Contact: 1-9 Other: 1-9**Levels:** Graduate**Schedule types:** Independent Study**Department/School:** Mathematics**MATH 6010 Advanced Seminar in Mathematics****Prerequisites:** Consent of instructor and student's advisory committee.**Description:** Directed reading on advanced topics in mathematics. Offered for variable credit, 1-3 credit hours, maximum of 12 credit hours.**Credit hours:** 1-3**Contact hours:** Contact: 1-3 Other: 1-3**Levels:** Graduate**Schedule types:** Independent Study**Department/School:** Mathematics**MATH 6090 Doctoral Research Project****Prerequisites:** Consent of advisory committee.**Description:** Directed reading and research culminating in preliminary doctoral research project. Offered for variable credit, 1-6 credit hours, maximum of 6 credit hours.**Credit hours:** 1-6**Contact hours:** Contact: 1-6 Other: 1-6**Levels:** Graduate**Schedule types:** Independent Study**Department/School:** Mathematics**MATH 6143 Functional Analysis I****Prerequisites:** MATH 4613 or MATH 5003 or MATH 5023, MATH 5153, MATH 5303.**Description:** Theory of topological vector spaces including metrizability, consequences of completeness, Banach spaces, weak topologies, and convexity.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 6213 Harmonic Analysis****Prerequisites:** MATH 5153, MATH 5283.**Description:** Classical results giving connections among the size of a harmonic or analytic function on a complex domain, the existence and smoothness of its boundary values, and behavior of the Fourier series; selected extensions, related topics and applications.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 6233 Advanced Partial Differential Equations****Prerequisites:** MATH 5233 or consent of instructor.**Description:** Schwarz class, tempered distributions, basic linear functional analysis, Holder spaces, Sobolev spaces, spaces involving time, Sobolev inequalities, existence and regularity theory of second-order elliptic, parabolic, and hyperbolic equations, semigroup theory.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 6263 Potential Theory****Prerequisites:** MATH 5153 and MATH 5283.**Description:** Subharmonic and superharmonic functions, potentials, energy problems (including problems with external fields), equilibrium measures, capacities, Dirichlet problems, regularity, Green functions, harmonic measures, conformal mappings, and applications.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 6283 Several Complex Variables****Prerequisites:** MATH 5283.**Description:** Elements of function theory of several complex variables, including extension phenomena, domains of holomorphy, notions of convexity, holomorphic maps, and complex analytic varieties.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 6290 Topics in Analysis****Prerequisites:** Consent of instructor.**Description:** Advanced topics in analysis. Offered for variable credit, 1-3 credit hours, maximum of 9 credit hours.**Credit hours:** 1-3**Contact hours:** Contact: 1-3 Other: 1-3**Levels:** Graduate**Schedule types:** Independent Study**Department/School:** Mathematics**MATH 6323 Algebraic Topology I****Prerequisites:** MATH 5313.**Description:** Chain complexes, homology and cohomology groups, the Eilenberg-Steenrod axioms, Mayer-Vietoris sequences, universal coefficient theorems, the Eilenberg-Zilber theorem and Kunneth formulas, cup and cap products, and duality in manifolds.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics



**MATH 6390 Topics in Topology****Prerequisites:** Consent of instructor.**Description:** Advanced topics in topology. Offered for variable credit, 1-3 credit hours, maximum of 9 credit hours.**Credit hours:** 1-3**Contact hours:** Contact: 1-3 Other: 1-3**Levels:** Graduate**Schedule types:** Independent Study**Department/School:** Mathematics**MATH 6433 Algebraic Geometry****Prerequisites:** MATH 5623.**Description:** Affine and projective varieties, dimension, algebraic curves, divisors and Riemann-Roch theorem for curves.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 6453 Complex Geometry****Prerequisites:** MATH 5283.**Description:** Complex manifolds, analytic sheaves, differential forms, Dolbeault cohomology, Hodge theory, line bundles, divisors, Kodaira embedding, and vanishing.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 6490 Topics in Geometry****Prerequisites:** Consent of instructor.**Description:** Advanced topics in geometry. Offered for variable credit, 1-3 credit hours, maximum of 9 credit hours.**Credit hours:** 1-3**Contact hours:** Contact: 1-3 Other: 1-3**Levels:** Graduate**Schedule types:** Independent Study**Department/School:** Mathematics**MATH 6513 Theoretical Numerical Analysis****Prerequisites:** MATH 5153, MATH 5543 or CS 5543, and MATH 5553 or CS 5553.**Description:** An advanced theoretical treatment based on function spaces and operator theory of algorithms for machine computing and analysis of errors.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 6590 Topics in Applied Mathematics****Prerequisites:** Consent of instructor.**Description:** Advanced topics in applied mathematics. Offered for variable credit, 1-3 credit hours, maximum of 9 credit hours.**Credit hours:** 1-3**Contact hours:** Contact: 1-3 Other: 1-3**Levels:** Graduate**Schedule types:** Independent Study**Department/School:** Mathematics**MATH 6613 Commutative Algebra****Prerequisites:** MATH 5623.**Description:** Commutative rings, exactness properties of modules, tensor products, integral dependence, chain conditions, completions, filtrations, local rings, dimension theory, and flatness.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 6623 Homological Algebra****Prerequisites:** MATH 5623.**Description:** Closed and projective classes, resolution and derived functors, adjoint theorem, construction of projective classes in the categories of groups, rings and modules; categories, Abelian categories.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 6690 Topics in Algebra****Prerequisites:** Consent of instructor.**Description:** Advanced topics in algebra. Offered for variable credit, 1-3 credit hours, maximum of 9 credit hours.**Credit hours:** 1-3**Contact hours:** Contact: 1-3 Other: 1-3**Levels:** Graduate**Schedule types:** Independent Study**Department/School:** Mathematics**MATH 6713 Analytic Number Theory****Prerequisites:** MATH 4283 or MATH 5283.**Description:** Arithmetic functions, Zeta and L functions, distribution of primes and introduction to modular forms.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 6723 Algebraic Number Theory****Prerequisites:** MATH 5013 or MATH 5623.**Description:** Number fields, ideal theory, units, decomposition of primes, quadratic and cyclotomic fields, introduction to local fields.**Credit hours:** 3**Contact hours:** Lecture: 3 Contact: 3**Levels:** Graduate**Schedule types:** Lecture**Department/School:** Mathematics**MATH 6790 Topics in Number Theory****Prerequisites:** Consent of instructor.**Description:** Advanced topics in number theory. Offered for variable credit, 1-3 credit hours, maximum of 9 credit hours.**Credit hours:** 1-3**Contact hours:** Contact: 1-3 Other: 1-3**Levels:** Graduate**Schedule types:** Independent Study**Department/School:** Mathematics

**MATH 6813 Lie Groups and Representations**

**Prerequisites:** MATH 4153 or MATH 5053, MATH 4613 or MATH 5003, MATH 5303.

**Description:** Differentiable manifolds, vector fields, Lie groups, exponential map, homogeneous spaces, representations of compact Lie groups, and maximal tori.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 6823 Lie Algebras**

**Prerequisites:** MATH 5013 and MATH 5023.

**Description:** Matrix groups, Lie algebras, root systems, structure of semisimple Lie algebras, universal enveloping algebra, and representations of lie algebras.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 6890 Topics in Representation Theory**

**Prerequisites:** Consent of instructor.

**Description:** Advanced topics in representation theory. Offered for variable credit, 1-3 credit hours, maximum of 9 credit hours.

**Credit hours:** 1-3

**Contact hours:** Contact: 1-3 Other: 1-3

**Levels:** Graduate

**Schedule types:** Independent Study

**Department/School:** Mathematics

**MATH 6923 Research in Undergraduate Mathematics Education**

**Prerequisites:** MATH 5913.

**Description:** Continuation of MATH 5913 with an emphasis on design of research in undergraduate mathematics education. Development of research questions, review of the literature, data collection and analysis, development and evaluation of research proposals, reporting research results.

**Credit hours:** 3

**Contact hours:** Lecture: 3 Contact: 3

**Levels:** Graduate

**Schedule types:** Lecture

**Department/School:** Mathematics

**MATH 6990 Topics in Collegiate Mathematics Education**

**Prerequisites:** Consent of instructor.

**Description:** Advanced topics in collegiate mathematics education. Offered for variable credit, 1-3 credit hours, maximum of 9 credit hours.

**Credit hours:** 1-3

**Contact hours:** Contact: 1-3 Other: 1-3

**Levels:** Graduate

**Schedule types:** Independent Study

**Department/School:** Mathematics