MATHEMATICS

PhD Program

The Department of Mathematics offers coursework and research leading to the PhD degree in mathematics. The department has a diversified graduate faculty with current areas of research in algebra, classical analysis, differential equations, geometry, harmonic analysis, logic and foundations, number theory, probability and stochastic processes and topology. For more information, see the Department of Mathematics (https://www.colorado.edu/math) website.

MA/MS Program

Students may obtain an MA/MS degree as either an undergraduate student through the concurrent bachelor's/master's degree program (see below) or as a graduate student.

As a rule, graduate students are admitted to the PhD program in mathematics and earn an MA or MS when they complete their PhD comprehensive exam. Students may choose to leave the program with MA/MS degree. Under certain circumstances, students can be admitted to the graduate program for a terminal MA/MS degree, in which case the prerequisites are the same as for the doctoral program.

Course code for this program is MATH.

Master's Degree

- Mathematics - Master of Arts (MA) (catalog.colorado.edu/graduate/colleges-schools/arts-sciences/programs-study/mathematics/mathematics-master-arts-ma)

Doctoral Degree

- Mathematics - Doctor of Philosophy (PhD) (catalog.colorado.edu/graduate/colleges-schools/arts-sciences/programs-study/mathematics/mathematics-doctor-philosophy-phd)

Faculty

While many faculty teach both undergraduate and graduate students, some instruct students at the undergraduate level only. For more information, contact the faculty member's home department.

Baggett, Lawrence W.
Professor Emeritus

Beaudry, Agnès (https://experts.colorado.edu/display/fisid_157677)
Assistant Professor; PhD, Northwestern University

Black, John (https://experts.colorado.edu/display/fisid_126540)
Associate Professor; PhD, University of California, Davis

Bronstein, Albert
Instructor; PhD, University of Kentucky

Brown, Gordon E.
Professor Emeritus

Casalaina-Martin, Sebastian Ben (https://experts.colorado.edu/display/fisid_145845)
Associate Professor; PhD, Columbia University

Clelland, Jeanne Nielsen (https://experts.colorado.edu/display/fisid_113103)
Associate Chair, Professor; PhD, Duke University

Clements, George F.
Professor Emeritus

Czubak, Magdalena (https://experts.colorado.edu/display/fisid_157955)
Assistant Professor; PhD, University of Texas at Austin

Deeley, Robin (https://www.colorado.edu/math/robin-deeley)
Assistant Professor; PhD, University of Victoria (Canada)

Elliott, Peter D. (https://experts.colorado.edu/display/fisid_105048)
Professor; PhD, University of Cambridge (England)

Ellis, Homer G.
Professor Emeritus

Englander, Janos (https://experts.colorado.edu/display/fisid_147333)
Associate Professor; PhD, Technion – Israel Institute of Technology

Farsi, Carla Emilia (https://experts.colorado.edu/display/fisid_101437)
Professor; PhD, University of Maryland, College Park

Fox, Jeffrey S. (https://experts.colorado.edu/display/fisid_105586)
Professor; PhD, University of California, Berkeley

Goodrich, Robert K.
Professor Emeritus

Gorokhovsky, Alexander (https://experts.colorado.edu/display/fisid_126279)
Professor; PhD, The Ohio State University

Grant, David R. (https://experts.colorado.edu/display/fisid_100868)
Professor; PhD, Massachusetts Institute of Technology

Green, Richard Mutegeki (https://experts.colorado.edu/display/fisid_129800)
Professor; MA, Oxford University (England)

Grochow, Joshua A. (https://experts.colorado.edu/display/fisid_158240)
Assistant Professor; PhD, University of Chicago

Gustafson, Karl E. (https://experts.colorado.edu/display/fisid_104877)
Professor; PhD, University of Maryland, College Park

Hermes, Henry G.
Professor Emeritus

Holley, Richard A.
Professor Emeritus

Ih, Su-Ion (https://experts.colorado.edu/display/fisid_141091)
Associate Professor; PhD, Brown University

Jesudason, Judith Packer (https://experts.colorado.edu/display/fisid_100338)
Professor; PhD, Harvard University

Jones, William B.
Professor Emeritus

Kearnes, Keith (https://experts.colorado.edu/display/fisid_118457)
Professor; PhD, University of California, Berkeley

Kuznetsov, Sergei Eugenievitch (https://experts.colorado.edu/display/fisid_113246)
Associate Professor, Associate Chair; DSc, Vilnius State University (Lithuania)

Lundell, Albert T.
Professor Emeritus

Macrae, Robert Eugene
Professor Emeritus

Malitz, Jerome I.
Professor Emeritus

Manley, Kevin W. (https://experts.colorado.edu/display/fisid_142342)
Instructor; PhD, University of Colorado Boulder

Mayr, Peter (https://experts.colorado.edu/display/fisid_155858)
Assistant Professor; PhD, Johannes Kepler Universität Linz (Austria)

Monk, James Donald
Professor Emeritus

Mycielski, Jan
Professor Emeritus

O'Rourke, Sean Daniel (https://experts.colorado.edu/display/fisid_154418)
Assistant Professor; PhD, University of California, Davis

Pflaum, Markus Josef (https://experts.colorado.edu/display/fisid_144979)
Professor; Dr habil, Humboldt University of Berlin (Germany)

Ramsay, Arlan
Professor Emeritus

Rearick, David F.
Professor Emeritus

Roberson, Lee Forrest (https://experts.colorado.edu/display/fisid_158380)
Instructor; PhD, University of Northern Colorado

Roth, Richard L.
Professor Emeritus

Sather, Duane P.
Professor Emeritus

Schmidt, Wolfgang
Professor Emeritus

Stade, Eric (https://experts.colorado.edu/display/fisid_100456)
Professor; PhD, Columbia University

Stange, Katherine E. (https://experts.colorado.edu/display/fisid_151508)
Associate Professor; PhD, Brown University

Struik, Ruth Rebekka
Professor Emerita

Szendrei, Agnes Erzsebet (https://experts.colorado.edu/display/fisid_130160)
Professor; DSc, Hungarian Academy of Sciences (Hungary)

Thiem, Franz Nathaniel (https://experts.colorado.edu/display/fisid_144618)
Associate Professor; PhD, University of Wisconsin–Madison

Timmer, Joseph (https://www.colorado.edu/math/joseph-timmer)
Instructor; PhD, University of Southern California

Tubbs, Robert (https://experts.colorado.edu/display/fisid_101761)
Associate Professor; PhD, Pennsylvania State University

Varanasi, Mahesh K. (https://experts.colorado.edu/display/fisid_103090)
Professor; PhD, Rice University

Vernerey, Divya E. (https://experts.colorado.edu/display/fisid_145131)
Instructor; PhD, Northwestern University

Walter, Martin E. (https://experts.colorado.edu/display/fisid_105263)
Professor; PhD, University of California, Irvine

Watts, Jordan A. (https://experts.colorado.edu/display/fisid_156585)
Visiting Assistant Professor

Wise, Jonathan (https://experts.colorado.edu/display/fisid_151516)
Assistant Professor; PhD, Brown University

Wolkowisky, Jay H.
Professor Emeritus

Courses

MATH 5000 (3) Foundations of Mathematics
Focuses on a complete deductive framework for mathematics and applies it to various areas. Presents Goedel's famous incompleteness theorem about the inherent limitations of mathematical systems. Uses idealized computers to investigate the capabilities and limitations of human and machine computation. Department enforced prerequisites: MATH 2130 and MATH 3140.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4000
Requisites: Restricted to graduate students only.

MATH 5001 (3) Analysis 2
Provides a rigorous treatment of infinite series, sequences of functions and an additional topic chosen by the instructor (for example, multivariable analysis, the Lebesgue integral or Fourier analysis).
Equivalent - Duplicate Degree Credit Not Granted: MATH 4001
Requisites: Restricted to graduate students only.

MATH 5030 (3) Intermediate Mathematical Physics 1
Surveys classical mathematical physics, starting with complex variable theory and finite dimensional vector spaces. Discusses topics in ordinary and partial differential equations, the special functions, boundary value problems, potential theory, and Fourier analysis. Department enforced prerequisite: MATH 4001. Instructor consent required for undergraduates.
Equivalent - Duplicate Degree Credit Not Granted: PHYS 5030
Requisites: Restricted to graduate students only.

MATH 5040 (3) Intermediate Mathematical Physics 2
Surveys classical mathematical physics, starting with complex variable theory and finite dimensional vector spaces. Discusses topics in ordinary and partial differential equations, the special functions, boundary value problems, potential theory and Fourier analysis. Department enforced prerequisite: MATH 5030.
Equivalent - Duplicate Degree Credit Not Granted: PHYS 5040
Requisites: Restricted to graduate students only.

MATH 5120 (3) Introduction to Operations Research
Studies linear and nonlinear programming, the simplex method, duality, sensitivity, transportation, and network flow problems, some constrained and unconstrained optimization theory, and the Kuhn-Tucker conditions, as time permits. Department enforced prerequisite: MATH 2130 or MATH 2135 or APPM 3310. Instructor consent required for undergraduates.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4120 and APPM 4120 and APPM 5120
Requisites: Restricted to graduate students only.

MATH 5140 (3) Abstract Algebra 2
Explores some topic that builds on material in MATH 3140. Possible topics include (but are not limited to) Galois theory, representation theory, advanced linear algebra or commutative algebra. Department enforced prerequisite: MATH 3140.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4140
Requisites: Restricted to graduate students only.

MATH 5150 (3) Linear Algebra
Highlights vector spaces, linear transformations, eigenvalues and eigenvectors, and canonical forms. Department enforced prerequisite: MATH 2130 or MATH 2135. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 5200 (3) Introduction to Topology
Introduces the basic concepts of point set topology. Includes topological spaces, metric spaces, homeomorphisms, connectedness and compactness.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4200

MATH 5230 (3) Differential Geometry of Curves and Surfaces
Introduces the modern differential geometry of plane curves, space curves, and surfaces in 3-dimensional space. Topics include the Frenet frame, curvature and torsion for space curves; Gauss and mean curvature for surfaces; Gauss and Codazzi equations, and the Gauss-Bonnet theorem.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4230
Requisites: Restricted to graduate students only.

MATH 5240 (3) Hilbert Spaces and the Mathematics of Quantum Mechanics
Provides an introduction to Hilbert spaces and their application in quantum mechanics. The primary goal is to prove and understand the so-called spectral theorem, which is crucial for the formulation of quantum mechanics. In addition, some examples from physics will be discussed, such as the quantum harmonic oscillator and the spectrum of the hydrogen atom.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4240
Requisites: Restricted to graduate students only.

MATH 5330 (3) Fourier Analysis
The notion of Fourier analysis, via series and integrals, of periodic and nonperiodic phenomena is central to many areas of mathematics. Develops the Fourier theory in depth and considers such special topics and applications as wavelets, Fast Fourier Transforms, seismology, digital signal processing, differential equations, and Fourier optics. Department enforced prerequisite: MATH 4001.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4330
Requisites: Restricted to graduate students only.

MATH 5430 (3) Ordinary Differential Equations
Introduces theory and applications of ordinary differential equations, including existence and uniqueness theorems, qualitative behavior, series solutions, and numerical methods, for scalar equations and systems. Department enforced prerequisites: MATH 2130 and MATH 3001. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 5440 (3) Mathematics of Coding and Cryptography
Gives an introduction, with proofs, to the algebra and number theory used in coding and cryptography. Basic problems of coding and cryptography are discussed; prepares students for the more advanced ECEN 5682.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4440
Requisites: Restricted to graduate students only.

MATH 5470 (3) Partial Differential Equations
Studies initial boundary and eigenvalue problems for the wave, heat and potential equations. Solution by separation of variables, Green's function, and variational methods. Department enforced prerequisite: MATH 3430 or MATH 5430. Instructor consent required for undergraduates.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4470
Requisites: Restricted to graduate students only.

MATH 5510 (3) Introduction to Probability Theory
Studies axioms, combinatorial analysis, independence and conditional probability, discrete and absolutely continuous distributions, expectation and distribution of functions of random variables, laws of large numbers, central limit theorems, and simple Markov chains if time permits.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4510
Requisites: Restricted to graduate students only.

MATH 5520 (3) Introduction to Mathematical Statistics
Examines point and confidence interval estimation. Principles of maximum likelihood, sufficiency, and completeness: tests of simple and composite hypotheses, linear models, and multiple regression analysis if time permits. Analyzes various distribution-free methods. Department enforced prerequisite: MATH 4510 or MATH 5510 or APPM 3570.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4520 and STAT 4520 and STAT 5520
Requisites: Restricted to graduate students only.

MATH 5540 (3) Introduction to Time Series
Studies basic properties, trend-based models, seasonal models, modeling and forecasting with ARIMA models, spectral analysis and frequency filtration. Department enforced prerequisite: MATH 4520 or MATH 5520 or APPM 4520 or APPM 5520.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4540 and STAT 4540 and STAT 5540
Requisites: Restricted to graduate students only.

MATH 5600 (3) Numerical Analysis 1
Solution of nonlinear algebraic equations, interpolation, approximation theory and numerical integration. Department enforced prerequisites: MATH 2130 or MATH 2135 or APPM 3310 and experience with a scientific programming language. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 5610 (3) Numerical Analysis 2
Solution of linear systems, eigenvalue problems, optimization problems, and ordinary and partial differential equations. Department enforced prerequisite: MATH 5600 or APPM 5600. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 5730 (3) Set Theory
Studies in detail the theory of cardinal and ordinal numbers, definition by recursion, the statement of the continuum hypothesis, simple cardinal arithmetic and other topics chosen by the instructor.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4730

MATH 5810 (1-3) Special Topics in Mathematics
Covers various topics not normally covered in the curriculum. Offered intermittently depending on student demand and availability of instructors.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4810
Repeatable: Repeatable for up to 7.00 total credit hours.
Requisites: Restricted to graduate students only.

MATH 5820 (3) History of Mathematical Ideas
Examines the evolution of a few mathematical concepts (e.g., number, geometric continuum, or proof), with an emphasis on the controversies surrounding these concepts. Begins with Ancient Greek mathematics and traces the development of mathematical concepts through the middle ages into the present.
Equivalent - Duplicate Degree Credit Not Granted: MATH 4820
Requisites: Restricted to graduate students only.
Recommended: Requisite completion of upper division Written Communication requirement.

MATH 5905 (1) Mathematics Teacher Training
Designed to train students to become effective teachers. Students teach a mathematics course, meeting weekly with faculty to discuss problems particular to the teaching of mathematics. Department enforced prerequisite: current employment as a teaching assistant.
Requisites: Restricted to graduate students only.

MATH 6000 (3) Model Theory
Proves the compactness theorem, showing the essential finiteness of logical implication. Proves many basic properties of theories, showing how the syntactic form of statements influences their behavior w.r.t., different models. Finally, studies properties of elements that cannot be stated by a single formula (the type of the element) and shows it can be used to characterize certain models.
Requisites: Restricted to graduate students only.

MATH 6010 (3) Computability Theory
Studies the computable and uncomputable. Shows that there are undecidable problems and from there builds up the theory of sets of natural numbers under Turing reducibility. Studies Turing reducibility, the arithmetical hierarchy, oracle constructions and end with the finite injury priority method. Department enforced prerequisite: MATH 6000.
Requisites: Restricted to graduate students only.

MATH 6110 (3) Introduction to Number Theory
Examines divisibility properties of integers, congruences, diophantine equations, arithmetic functions, quadratic residues, distribution of primes and algebraic number fields. Department enforced prerequisite: MATH 3140. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6130 (3) Algebra 1
Studies group theory and ring theory. Department enforced prerequisite: MATH 3140. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6140 (3) Algebra 2
Studies modules, fields and Galois theory. Department enforced prerequisite: MATH 6130. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6150 (3) Commutative Algebra
Introduces topics used in number theory and algebraic geometry, including radicals of ideals, exact sequences of modules, tensor products, Ext, Tor, localization, primary decomposition of ideals and Noetherian rings. Department enforced prerequisite: MATH 6140. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6170 (3) Algebraic Geometry
Introduces algebraic geometry, including affine and projective varieties, rational maps and morphisms and differentials and divisors. Additional topics might include Bezout's Theorem, the Riemann-Roch Theorem, elliptic curves, and sheaves and schemes. Department enforced prerequisite: MATH 6140. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6180 (3) Algebraic Number Theory
Introduces number fields and completions, norms, discriminants and differents, finiteness of the ideal class group, Dirichlet's unit theorem, decomposition of prime ideals in extension fields, decomposition and ramification groups. Department enforced prerequisites: MATH 6110 and MATH 6140. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6190 (3) Analytic Number Theory
Acquaints students with the Riemann Zeta-function and its meromorphic continuation, characters and Dirichlet series, Dirichlet's theorem on primes in arithmetic progressions, zero-free regions of the zeta function and the prime number theorem. Department enforced prerequisites: MATH 6110 and MATH 6350. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6210 (3) Introduction to Topology 1
Introduces elements of point-set topology and algebraic topology, including the fundamental group and elements of homology. Department enforced prerequisites: MATH 2130 and MATH 3140 and MATH 4001. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6220 (3) Introduction to Topology 2
Continuation of MATH 6210. Department enforced prerequisite: MATH 6210. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6230 (3) Introduction to Differential Geometry 1
Introduces topological and differential manifolds, vector bundles, differential forms, de Rham cohomology, integration, Riemannian metrics, connections and curvature. Department enforced prerequisites: MATH 2130 and MATH 4001. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6240 (3) Introduction to Differential Geometry 2
Continuation of MATH 6230. Department enforced prerequisite: MATH 6230. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6250 (3) Theory of Rings
Studies semi-simple Artinian rings, the Jacobson radical, group rings, representations of finite groups, central simple algebras, division rings and the Brauer group. Department enforced prerequisites: MATH 6130 and MATH 6140. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6260 (3) Geometry of Quantum Fields and Strings
Focuses on differential geometric techniques in quantum field and string theories. Topics include: spinors, Dirac operators, index theorem, anomalies, geometry of superspace, supersymmetric quantum mechanics and field theory and nonperturbative aspects in field and string theories. Department enforced prerequisites: MATH 6230 and MATH 6240 and PHYS 5250 and PHYS 7280. Instructor consent required for undergraduates.
Equivalent - Duplicate Degree Credit Not Granted: PHYS 6260
Requisites: Restricted to graduate students only.

MATH 6270 (3) Theory of Groups
Studies nilpotent and solvable groups, simple linear groups, multiply transitive groups, extensions and cohomology, representations and character theory, and the transfer and its applications. Department enforced prerequisites: MATH 6130 and MATH 6140. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6280 (3) Advanced Algebraic Topology
Covers homotopy theory, spectral sequences, vector bundles, characteristic classes, K-theory and applications to geometry and physics. Department enforced prerequisite: MATH 6220. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6290 (3) Homological Algebra
Studies categories and functors, abelian categories, chain complexes, derived functors, Tor and Ext, homological dimension, group homology and cohomology. If time permits, the instructor may choose to cover additional topics such as spectral sequences or Lie algebra homology and cohomology. Department enforced prerequisites: MATH 6130 and MATH 6140.
Requisites: Restricted to graduate students only.

MATH 6310 (3) Introduction to Real Analysis 1
Develops the theory of Lebesgue measure and the Lebesgue integral on the line, emphasizing the various notions of convergence and the standard convergence theorems. Applications are made to the classical L^p spaces. Department enforced prerequisite: MATH 4001. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6320 (3) Introduction to Real Analysis 2
Covers general metric spaces, the Baire Category Theorem, and general measure theory, including the Radon-Nikodym and Fubini theorems. Presents the general theory of differentiation on the real line and the Fundamental Theorem of Lebesgue Calculus. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.
Recommended: Prerequisite MATH 6310.

MATH 6350 (3) Functions of a Complex Variable 1
Focuses on complex numbers and the complex plane. Includes Cauchy-Riemann equations, complex integration, Cauchy integral theory, infinite series and products, and residue theory. Department enforced prerequisite: MATH 4001. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6360 (3) Functions of a Complex Variable 2
Focuses on conformal mapping, analytic continuation, singularities and elementary special functions. Department enforced prerequisite: MATH 6350. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6534 (3) Topics in Mathematical Probability
Offers selected topics in probability such as sums of independent random variables, notions of convergence, characteristic functions, Central Limit Theorem, random walk, conditioning and martingales, Markov chains and Brownian motion. Department enforced prerequisite: MATH 6310. Instructor consent required for undergraduates
Requisites: Restricted to graduate students only.

MATH 6550 (3) Introduction to Stochastic Processes
Systematic study of Markov chains and some of the simpler Markov processes, including renewal theory, limit theorems for Markov chains, branching processes, queuing theory, birth and death processes, and Brownian motion. Applications to physical and biological sciences. Department enforced prerequisite: MATH 4001 or MATH 4510 or APPM 3570 or APPM 4560. Instructor consent required for undergraduates.
Equivalent - Duplicate Degree Credit Not Granted: APPM 6550
Requisites: Restricted to graduate students only.

MATH 6730 (3) Set Theory
Presents cardinal and ordinal arithmetic, and basic combinatorial concepts, including stationary sets, generalization of Ramsey's theorem, and ultrafilters, consisting of the axiom of choice and the generalized continuum hypothesis. Department enforced prerequisites: MATH 4000 or MATH 5000 and MATH 4730 or MATH 5730. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6740 (3) Forcing
Presents independence of the axiom of choice and the continuum hypothesis, Souslin's hypothesis and other applications of the method of forcing. Introduces the theory of large cardinals. Department enforced prerequisite: MATH 6730. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 6900 (1-3) Independent Study
Instructor consent required for undergraduates.
Repeatable: Repeatable for up to 6.00 total credit hours.
Requisites: Restricted to graduate students only.

MATH 6940 (1) Master's Candidate for Degree
This course is for students preparing for the no-thesis option for a master's degree. The content is set by the students' advisors.
Requisites: Restricted to graduate students only.
Grading Basis: Pass/Fail

MATH 6950 (1-6) Master's Thesis

MATH 8114 (3) Topics in Number Theory
May include the theory of automorphic forms, elliptic curves, or any of a variety of advanced topics in analytic and algebraic number theory. Department enforced prerequisite: MATH 6110. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 8174 (3) Topics in Algebra I
Department enforced prerequisites: MATH 6130 and MATH 6140. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 8234 (3) Topics in Differential Geometry
Presents advanced topics in Differential Geometry, such as index theory, partial differential equations on manifolds, exterior differential systems, and Cartan's methods.
Repeatable: Repeatable for up to 12.00 total credit hours. Allows multiple enrollment in term.
Requisites: Requires prerequisite courses of MATH 6230 and MATH 6310 (minimum grade D-). Restricted to graduate students only. Instructor consent required for undergraduates.

MATH 8250 (3) Mathematical Theory of Relativity 1
Focuses on Maxwell equations, Lorentz force, Minkowski space-time, Lorentz, Poincare, and conformal groups,metric manifolds, covariant differentiation, Einstein space-time, cosmologies, and unified field theories. Instructor consent required.
Requisites: Restricted to graduate students only.

MATH 8304 (3) Topics in Analysis 1
Presents advanced topics in analysis including Lie groups, Banach algebras, operator theory, ergodic theory, representation theory, etc. Department enforced prerequisites: MATH 8330 and MATH 8340. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 8330 (3) Functional Analysis 1
Introduces such topics as Banach spaces (Hahn-Banach theorem, open mapping theorem, etc.), operator theory (compact operators and integral equations and spectral theorem for bounded self-adjoint operators) and Banach algebras (the Gelfand theory). Department enforced prerequisites: MATH 6310 and MATH 6320. Instructor consent required for undergraduates. See also MATH 8340.
Requisites: Restricted to graduate students only.

MATH 8340 (3) Functional Analysis 2
Introduces such topics as Banach spaces (Hahn-Banach theorem, open mapping theorem, etc.), operator theory (compact operators and integral equations and spectral theorem for bounded self-adjoint operators) and Banach algebras (the Gelfand theory). Department enforced prerequisite: MATH 8330. Instructor consent required for undergraduates. See also MATH 8330.
Requisites: Restricted to graduate students only.

MATH 8370 (3) Harmonic Analysis 1
Examines trigonometric series, periodic functions, diophantine approximation and Fourier series. Also covers Bohr and Stepanoff almost periodic functions, positive definite functions and the L^1 and L^2 theory of the Fourier integral. Applications to group theory and differential equations. Department enforced prerequisites: MATH 5150 and MATH 6320. Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.

MATH 8714 (3) Topics in Logic 1 and 2
Requisites: Restricted to graduate students only.

MATH 8815 (1-3) Ulam Seminar
Repeatable: Repeatable for up to 3.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to graduate students only.

MATH 8900 (1-3) Independent Study
Instructor consent required for undergraduates.
Repeatable: Repeatable for up to 6.00 total credit hours.
Requisites: Restricted to graduate students only.

MATH 8990 (1-10) Doctoral Dissertation
All doctoral students must register for not fewer than 30 hours of dissertation credit as part of the requirements for the degree. For a detailed discussion of doctoral dissertation credit, refer to the Graduate School portion of the catalog.
Requisites: Restricted to graduate students only.