MATHEMATICS

The Department of Mathematics offers courses leading to either a Bachelor of Arts (BA) degree in mathematics or a minor in mathematics. Students who choose to major in mathematics choose from one of five tracks for the major:

- **Comprehensive track:** The comprehensive track emphasizes theoretical mathematics and is aimed at students seeking a general background in mathematics or intending to pursue graduate work in mathematics.
- **Applicable track:** The applicable track is aimed at students seeking a background in applied and/or applicable mathematics.
- **Secondary education track:** The secondary education track is designed to align with the Colorado licensure requirements for mathematics secondary education and the university does offer a program for obtaining secondary education mathematics teaching licensure.
- **Computational track:** The computational track is designed for students with an interest in the intersection of mathematics and computer science.
- **Statistics track:** The statistics track is designed for students seeking a background in statistics and/or data science.

Course code for this program is MATH.

Bachelor's Degree

- Mathematics - Bachelor of Arts (BA) (https://catalog.colorado.edu/undergraduate/colleges-schools/arts-sciences/programs-study/mathematics/mathematics-bachelor-arts-ba/)

Minor

- Mathematics - Minor (https://catalog.colorado.edu/undergraduate/colleges-schools/arts-sciences/programs-study/mathematics/mathematics-minor/)

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; PhD, University of Washington Seattle

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

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

Bronstein, Albert (https://experts.colorado.edu/display/fisid_154916/)
Teaching Assistant Professor; PhD, University of Kentucky

Brown, Gordon E.
Professor Emeritus

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

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

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

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

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

Englander, Janos (https://experts.colorado.edu/display/fisid_147333/)
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

Grulke, Boo (https://experts.colorado.edu/display/fisid_144824/)
Teaching Assistant Professor; DEd, University of Florida

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

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

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)

Luh, Kyle (https://experts.colorado.edu/display/fisid_166949/)
Assistant Professor; PhD, Yale University

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/)
Teaching Associate Professor; PhD, University of Colorado Boulder

Mayr, Peter (https://experts.colorado.edu/display/fisid_155858/)
Associate 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/)
Associate Professor; PhD, University of California, Davis

Orosz Hunziker, Flor (https://experts.colorado.edu/display/fisid_167648/)
Assistant Professor; PhD, Yale University

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/)
Teaching Assistant Professor; PhD, University of Northern Colorado

Schmidt, Wolfgang
Professor Emeritus

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

Stalvey, Harrison Edward (https://experts.colorado.edu/display/fisid_158325/)
Teaching Assistant Professor; PhD, Georgia State University

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

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

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

Timmer, Joseph (https://experts.colorado.edu/display/fisid_156565/)
Teaching Associate Professor; PhD, University of Southern California

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

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

Webb, David C. (https://experts.colorado.edu/display/fisid_141204/)
Associate Professor; PhD, University of Wisconsin–Madison

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

Wolkowisky, Jay H.
Professor Emeritus

Courses

MATH 1005 (3) Introduction to College Mathematics
Introductory level mathematics course which presents a college level introduction to algebraic functions and their applications. Only offered through the Student Academic Service Center.
Equivalent - Duplicate Degree Credit Not Granted: MATH 1011
Additional Information: MAPS Course: Mathematics

MATH 1011 (3) College Algebra
Covers simplifying algebraic expressions, factoring, linear and quadratic equations, inequalities, exponentials, logarithms, functions, graphs and systems of equations. Department enforced prerequisite: one year high school algebra.
Equivalent - Duplicate Degree Credit Not Granted: MATH 1005
Additional Information: Arts Sci Core Curr: Quant Reasn Mathmat Skills
Arts Sci Gen Ed: Quantitative Reasoning Math
MAPS Course: Mathematics

MATH 1012 (3) Quantitative Reasoning and Mathematical Skills
Promotes mathematical literacy among liberal arts students. Teaches basic mathematics, logic, and problem-solving skills in the context of higher level mathematics, science, technology, and/or society. This is not a traditional math class, but is designed to stimulate interest in and appreciation of mathematics and quantitative reasoning as valuable tools for comprehending the world in which we live.
Equivalent - Duplicate Degree Credit Not Granted: MATH 1112
Additional Information: GT Pathways: GT-MA1 - Mathematics
Arts Sci Core Curr: Quant Reasn Mathmat Skills
Arts Sci Gen Ed: Quantitative Reasoning Math
MAPS Course: Mathematics

MATH 1021 (3) College Trigonometry
Covers trigonometric functions, identities, solutions of triangles, addition and multiple angle formulas, inverse and trigonometric functions and laws of sines and cosines. Department enforced prerequisite: MATH 1011 (minimum grade C-) or 1 1/2 years of high school algebra and 1 year of high school geometry.
Equivalent - Duplicate Degree Credit Not Granted: APPM 1235 or MATH 1150

MATH 1071 (3) Finite Mathematics for Social Science and Business
Discusses systems of linear equations and introduces matrices, linear programming, and probability.
Requisites: Requires prerequisite course of MATH 1011 (minimum grade C-) or a score of 46% or greater on an ALEKS math exam taken in 2016 or earlier.
Additional Information: Arts Sci Core Curr: Quant Reasn Mathmat Skills
Arts Sci Gen Ed: Quantitative Reasoning Math

MATH 1081 (3) Calculus for Social Science and Business
Covers differential and integral calculus of algebraic, logarithmic and exponential functions. For more information about the math placement referred to in the "Enrollment Requirements", contact your academic advisor.
Equivalent - Duplicate Degree Credit Not Granted: APPM 1345 or APPM 1350 or ECON 1088 or MATH 1300 or MATH 1310 or MATH 1330
Requisites: Requires prerequisite course of ECON 1078 or MATH 1011 or MATH 1071 or MATH 1150 or MATH 1160 (minimum grade C-) or an ALEKS math exam taken in 2016 or earlier, or placement into pre-calculus based on your admission data and/or CU Boulder coursework.
Additional Information: Arts Sci Core Curr: Quant Reasn Mathmat Skills
Arts Sci Gen Ed: Quantitative Reasoning Math

MATH 1110 (3) Mathematics for Elementary Educators 1
Includes a study of problem solving techniques in mathematics and the structure of number systems. Department enforced prereq., one year of high school algebra and one year of geometry. Department enforced restriction: restricted to prospective elementary teachers.
Additional Information: Arts Sci Core Curr: Quant Reasn Mathmat Skills
Arts Sci Gen Ed: Quantitative Reasoning Math

MATH 1112 (4) Mathematical Analysis in Business
Gives students experience with mathematical problem solving in real business contexts. Students will work with data and spreadsheets to build and analyze mathematical models. Themes of the course include applying logical operators to model business rules, interpreting data and using tables and graphs, finding break-even and optimal points, and addressing uncertainty and forecasting
Equivalent - Duplicate Degree Credit Not Granted: MATH 1012
Additional Information: Arts Sci Core Curr: Quant Reasn Mathmat Skills
Arts Sci Gen Ed: Quantitative Reasoning Math
MAPS Course: Mathematics

MATH 1120 (3) Mathematics for Elementary Educators 2
Topics include geometry, measurement, probability, and statistics. Department enforced restriction: restricted to prospective elementary teachers.
Requisites: Requires prerequisite course of MATH 1110 (minimum grade C-).
Additional Information: Arts Sci Core Curr: Quant Reasn Mathmat Skills
Arts Sci Gen Ed: Quantitative Reasoning Math

MATH 1130 (3) Mathematics from the Visual Arts
Introduces mathematical concepts through the study of visual arts.
Additional Information: Arts Sci Core Curr: Quant Reasn Mathmat Skills
Arts Sci Gen Ed: Quantitative Reasoning Math

MATH 1150 (4) Precalculus Mathematics
Develops techniques and concepts prerequisite to calculus through the study of trigonometric, exponential, logarithmic, polynomial and other functions. For more information about the math placement referred to in the "Enrollment Requirements", please contact your academic advisor.
Equivalent - Duplicate Degree Credit Not Granted: APPM 1235 or MATH 1021
Requisites: Requires prerequisite course of MATH 1011 (minimum grade C-) or an ALEKS math exam taken in 2016 or earlier, or placement into pre-calculus based on your admissions data and/or CU Boulder coursework. Requires enrollment in corequisite course MATH 1151.
Additional Information: GT Pathways: GT-MA1 - Mathematics
Arts Sci Core Curr: Quant Reasn Mathmat Skills
Arts Sci Gen Ed: Quantitative Reasoning Math
MAPS Course: Mathematics

MATH 1151 (1) Precalculus Supplemental Lab
Provides students concurrently enrolled in MATH 1150 with supplemental instruction.
Requisites: Requires enrollment in corequisite course of MATH 1150.
Grading Basis: Letter Grade

MATH 1160 (3) Transition to Calculus (IBL): The Theory, Applications and Analysis of Functions
Examines the functions of calculus and how they can be used to model concrete problems and/or change. This is an intensive study of these functions through Inquiry-Based Learning. Each class will be designed so students will be actively engaged in learning the material in small groups. For more information about the math placement referred to in the "Enrollment Requirements", please contact your academic advisor.
Requisites: Requires an ALEKS math exam taken in 2016 or earlier, or placement into pre-calculus based on your admissions data and/or CU Boulder coursework.

MATH 1212 (3) Data and Models
Engages students in statistical and algebraic problem solving through modeling data and real world questions taken from the social and life sciences. The course will emphasize these skills and the mathematical background needed for a university level statistics course.
Equivalent - Duplicate Degree Credit Not Granted: MATH 1011
Grading Basis: Letter Grade
Additional Information: Arts Sci Core Curr: Quant Reasn Mathmat Skills
Arts Sci Gen Ed: Quantitative Reasoning Math
MAPS Course: Mathematics

MATH 1300 (5) Calculus 1
Topics include limits, derivatives of algebraic and transcendental functions, applications of the derivative, integration and applications of the definite integral. Students who have already earned college credit for calculus 1 are eligible to enroll in this course if they want to solidify their knowledge base in calculus 1. For more information about the math placement referred to in the "Enrollment Requirements", contact your academic advisor.
Equivalent - Duplicate Degree Credit Not Granted: APPM 1345 or APPM 1350 or ECON 1088 MATH 1081 or MATH 1310 or MATH 1330
Requisites: Requires prerequisite course of MATH 1011 and MATH 1021 or MATH 1150 or MATH 1160 or APPM 1235 (minimum grade C-) or an ALEKS math exam taken in 2016 or earlier, or placement into calculus based on your admissions data and/or CU Boulder coursework.
Additional Information: GT Pathways: GT-MA1 - Mathematics
Arts Sci Core Curr: Quant Reasn Mathmat Skills
Arts Sci Gen Ed: Quantitative Reasoning Math

MATH 1301 (1) Calculus 1 Supplemental Lab
Provides students concurrently enrolled in MATH 1300 with supplemental instruction.
Requisites: Requires corequisite course of MATH 1300.
Grading Basis: Letter Grade

MATH 1310 (5) Calculus for Life Sciences
Calculus concepts are developed through the analysis and modeling of complex systems, ranging from gene networks and cells to populations and ecosystems. Fundamental concepts of probability and statistics are also developed through the lens of calculus. MATH 1300 is similar, but a greater emphasis is placed on relevance and applications in biology and other life sciences. Students who have already earned college credit for calculus 1 are eligible to enroll in this course if they want to solidify their knowledge base in calculus 1. For more information about the math placement referred to in the "Enrollment Requirements", contact your academic advisor.
Equivalent - Duplicate Degree Credit Not Granted: APPM 1345 or APPM 1350 or ECON 1088 or MATH 1081 or MATH 1300 or MATH 1330
Requisites: Requires prerequisite course of APPM 1235 or MATH 1021 or MATH 1150 or MATH 1160 or MATH 1300 (minimum grade C-) or an ALEKS math exam taken in 2016 or earlier, or placement into calculus based on your admissions data and/r CU Boulder coursework.
Additional Information: GT Pathways: GT-MA1 - Mathematics
Arts Sci Core Curr: Quant Reasn Mathmat Skills
Arts Sci Gen Ed: Quantitative Reasoning Math

MATH 1330 (4) Calculus for Economics and the Social Sciences
A calculus course intended to meet the needs of social science and economics majors, including applications. Covers differential and integral calculus of algebraic, logarithmic and exponential functions and modeling. For more information about the math placement referred to in the "Enrollment Requirements", contact your academic advisor.
Equivalent - Duplicate Degree Credit Not Granted: APPM 1345 or APPM 1350 or ECON 1088 or MATH 1081 or MATH 1300 or MATH 1310
Requisites: Requires a prerequisite course of ECON 1078 or MATH 1011 or MATH 1071 or MATH 1150 or MATH 1160 (minimum grade C-) or an ALEKS math exam taken in 2016 or earlier, or placement into calculus based on your admissions data and/r CU Boulder coursework.
Additional Information: Arts Sci Core Curr: Quant Reasn Mathmat Skills
Arts Sci Gen Ed: Quantitative Reasoning Math

MATH 2001 (3) Introduction to Discrete Mathematics
Introduces the ideas of rigor and proof through an examination of basic set theory, existential and universal quantifiers, elementary counting, discrete probability, and additional topics.
Equivalent - Duplicate Degree Credit Not Granted: MATH 2002
Requisites: Requires prerequisite course of MATH 1300 or MATH 1310 or APPM 1345 or APPM 1350 (all minimum grade C-).

MATH 2002 (3) Number Systems: An Introduction to Higher Mathematics
Introduces the concepts of mathematical proofs using the construction of the real numbers from set theory. Topics include basic logic and set theory, equivalence relations and functions, Peano's axioms, construction of the integers, the rational numbers and axiomatic treatment of the real numbers.
Equivalent - Duplicate Degree Credit Not Granted: MATH 2001
Requisites: Requires prerequisite of MATH 1300 or MATH 1310 or APPM 1345 or APPM 1350 (all minimum grade C-).

MATH 2130 (3) Introduction to Linear Algebra for Non-Mathematics Majors
Examines basic properties of systems of linear equations, vector spaces, inner products, linear independence, dimension, linear transformations, matrices, determinants, eigenvalues, eigenvectors and diagonalization. Intended for students who do not plan to major in Mathematics. Formerly MATH 3130.
Equivalent - Duplicate Degree Credit Not Granted: MATH 2135 or APPM 3310
Requisites: Requires prerequisite course of MATH 2300 or APPM 1360 (minimum grade C-).

MATH 2135 (3) Introduction to Linear Algebra for Mathematics Majors
Examines basic properties of systems of linear equations, vector spaces, inner products, linear independence, dimension, linear transformations, matrices, determinants, eigenvalues, eigenvectors and diagonalization. Intended for students who plan to major in Mathematics. Formerly MATH 3135.
Equivalent - Duplicate Degree Credit Not Granted: MATH 2130 or APPM 3310
Requisites: Requires a prerequisite course of (MATH 2300 or APPM 1360) and (MATH 2001 or MATH 2002) (all minimum grade C-).

MATH 2300 (5) Calculus 2
Continuation of MATH 1300. Topics include transcendental functions, methods of integration, polar coordinates, differential equations, improper integrals, infinite sequences and series, Taylor polynomials and Taylor series. Department enforced prerequisite: MATH 1300 or MATH 1310 or APPM 1345 or APPM 1350 (minimum grade C-).
Equivalent - Duplicate Degree Credit Not Granted: APPM 1360
Requisites: Requires prerequisite course of MATH 1300 or MATH 1310 or APPM 1345 or APPM 1350 (minimum grade C-).

MATH 2380 (3) Mathematics for the Environment
An interdisciplinary course where environmental issues, such as climate change, global epidemics, pollution, population models and kinship relations of Australian Aborigines are studied with elementary mathematics (such as fuzzy logic). Similar techniques are applied to analyze other current events, such as surveillance, economic meltdowns, identity theft and media literacy. Department enforced prerequisite: proficiency in high school mathematics.
Additional Information: Arts Sci Core Curr: Quant Reasn Mathmat Skills
Arts Sci Gen Ed: Quantitative Reasoning Math

MATH 2400 (5) Calculus 3
Continuation of MATH 2300. Topics include vectors, three-dimensional analytic geometry, partial differentiation and multiple integrals, and vector analysis. Department enforced prerequisite: MATH 2300 or APPM 1360 (minimum grade C-).
Equivalent - Duplicate Degree Credit Not Granted: APPM 2350
Requisites: Requires prerequisite course of MATH 2300 or APPM 1360 (minimum grade C-).

MATH 2510 (3) Introduction to Statistics
Elementary statistical measures. Introduces statistical distributions, statistical inference, hypothesis testing and linear regression. Department enforced prerequisite: two years of high school algebra.
Additional Information: Arts Sci Core Curr: Quant Reasn Mathmat Skills
Arts Sci Gen Ed: Quantitative Reasoning Math
MAPS Course: Mathematics

MATH 3001 (3) Analysis 1
Provides a rigorous treatment of the basic results from elementary Calculus. Topics include the topology of the real line, sequences of numbers, continuous functions, differentiable functions and the Riemann integral.
Requisites: Requires prerequisite courses of (MATH 2001 or MATH 2002) and (MATH 2130 or MATH 3130 or MATH 2135 or MATH 3135) (all minimum grade C-).

MATH 3110 (3) Introduction to Theory of Numbers
Studies the set of integers, focusing on divisibility, congruences, arithmetic functions, sums of squares, quadratic residues and reciprocity, and elementary results on distributions of primes.
Requisites: Requires prerequisite of MATH 2001 or MATH 2002 (both minimum grade C-).

MATH 3120 (3) Functions and Modeling
Engages the students in daily projects and occasional in-class labs designed to strengthen and expand knowledge of the topics in secondary mathematics, focusing especially on topics from algebra, precalculus and calculus. Projects and labs involve the use of multiple representations, transformations, data analysis techniques and interconnections among ideas from geometry, algebra, probability and calculus.
Requisites: Requires prerequisite of MATH 2001 or MATH 2002 (both minimum grade C-).

MATH 3130 (3) Introduction to Linear Algebra
Examines basic properties of systems of linear equations, vector spaces, inner products, linear independence, dimension, linear transformations, matrices, determinants, eigenvalues, eigenvectors and diagonalization.
Equivalent - Duplicate Degree Credit Not Granted: MATH 3135 or APPM 3310
Requisites: Requires prerequisite course of MATH 2300 or APPM 1360 (minimum grade C-).

MATH 3135 (3) Honors Introduction to Linear Algebra
Examines basic properties of systems of linear equations, vector spaces, inner products, linear independence, dimension, linear transformations, matrices, determinants, eigenvalues, eigenvectors and diagonalization.
Equivalent - Duplicate Degree Credit Not Granted: MATH 3130 or APPM 3310
Requisites: Requires a prerequisite course of MATH 2300 or APPM 1360 and MATH 2001 (all minimum grade C-).

MATH 3140 (3) Abstract Algebra 1
Studies basic properties of algebraic structures with a heavy emphasis on groups. Other topics, time permitting, may include rings and fields.
Requisites: Requires prerequisite courses of (MATH 2001 or MATH 2002) and (MATH 2130 or MATH 3130 or MATH 2135 or MATH 3135) (all minimum grade C-).

MATH 3170 (3) Combinatorics 1
Covers basic methods and results in combinatorial theory. Includes enumeration methods, elementary properties of functions and relations, and graph theory. Emphasizes applications.
Requisites: Requires prerequisite of MATH 2001 or MATH 2002 (both minimum grade C-).

MATH 3210 (3) Euclidean and Non-Euclidean Geometry
Axiomatic systems; Euclid's presentation of the elements of geometry; Hilbert's axioms; neutral, Euclidean and non-Euclidean geometries and their models.
Requisites: Requires prerequisite courses of (MATH 2001 or MATH 2002) and (MATH 2130 or MATH 3130 or MATH 2135 or MATH 3135) (all minimum grade C-).

MATH 3430 (3) Ordinary Differential Equations
Involves an elementary systematic introduction to first-order scalar differential equations, nth order linear differential equations, and n-dimensional linear systems of first-order differential equations. Additional topics are chosen from equations with regular singular points, Laplace transforms, phase plane techniques, basic existence and uniqueness and numerical solutions. Formerly MATH 4430.
Requisites: Requires prerequisite courses of (MATH 2400 or APPM 2350) and (MATH 2130 or 3130 or MATH 2135 or 3135 or APPM 3310) (all minimum grade C-).

MATH 3450 (3) Introduction to Complex Variables
Theory of functions of one complex variable, including integrals, power series, residues, conformal mapping, and special functions. Formerly MATH 4450.
Requisites: Requires prerequisite courses of MATH 2400 or APPM 2350 (minimum grade C-).

MATH 3510 (3) Introduction to Probability and Statistics
Introduces the basic notions of Probability: random variables, expectation, conditioning, and the standard distributions (Binomial, Poisson, Exponential, Normal). This course also covers the Law of Large Numbers and Central Limit Theorem as they apply to statistical questions: sampling from a random distribution, estimation, and hypothesis testing.
Equivalent - Duplicate Degree Credit Not Granted: MATH 2510 or MATH 4510
Requisites: Requires a prerequisite course of (MATH 2300 or APPM 1360) and (MATH 2001 or MATH 2002) (all minimum grade C-).

MATH 3850 (1) Seminar in Guided Mathematics Instruction
Provides learning assistants with an opportunity to analyze assessment data for formative purposes and develop instructional plans as a result of these analyses. These formative assessment analyses will build on the literature in the learning sciences. Students gain direct experiences interacting with the tools of the trade, especially with actual assessment data and models of instruction. Restricted to learning assistants in Math.
Repeatable: Repeatable for up to 3.00 total credit hours.
Requisites: Requires a corequisite course of EDUC 4610.

MATH 4000 (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.
Equivalent - Duplicate Degree Credit Not Granted: MATH 5000
Requisites: Requires prerequisite courses of MATH 3001 or MATH 3140 or MATH 4730 (all minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Arts Humanities

MATH 4001 (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 5001
Requisites: Requires prerequisite course of MATH 3001 (minimum grade C-).

MATH 4120 (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.
Equivalent - Duplicate Degree Credit Not Granted: APPM 5120 and APPM 4120 and MATH 5120
Requisites: Requires prerequisite course of MATH 2130 or 3130 or MATH 2135 or 3135 or APPM 3310 (minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

MATH 4140 (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.
Equivalent - Duplicate Degree Credit Not Granted: MATH 5140
Requisites: Requires prerequisite course of MATH 3140 (minimum grade C-).

MATH 4200 (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 5200
Requisites: Requires prerequisite course of MATH 3001 (minimum grade C-).

MATH 4230 (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 5230
Requisites: Requires prerequisite courses of (MATH 2400 or APPM 2350) and (MATH 2001 or 2002) and (MATH 2130 or MATH 3130 or MATH 2135 or MATH 3135) (all minimum grade C-).

MATH 4240 (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 5240
Requisites: Requires prerequisite course of MATH 3001 (minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

MATH 4330 (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.
Equivalent - Duplicate Degree Credit Not Granted: MATH 5330
Requisites: Requires prerequisite course of MATH 3001 (minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

MATH 4440 (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.
Equivalent - Duplicate Degree Credit Not Granted: MATH 5440
Requisites: Requires prerequisite course of MATH 2130 or 3130 or MATH 2135 or 3135 (minimum grade C-).

MATH 4470 (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.
Equivalent - Duplicate Degree Credit Not Granted: MATH 5470
Requisites: Requires prerequisite courses of MATH 3430 (minimum grade C-).

MATH 4510 (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: APPM 3570 or ECEN 3810 or MATH 3510 MATH 5510
Requisites: Requires prerequisite courses of (MATH 2400 or APPM 2350) and (MATH 2130 or 3130 or MATH 2135 or 3135) (all minimum grade C-).

MATH 4520 (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.
Equivalent - Duplicate Degree Credit Not Granted: MATH 5520 and STAT 4520 and STAT 5520
Requisites: Requires prerequisite course of MATH 4510 or APPM 3570 (minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

MATH 4530 (3) Theoretical Foundations of Data Science
Introduces theoretical concepts from mathematics, statistics, and computer science required to understand and analyze data. Topics include randomized algorithms, machine learning, streaming, sketching, clustering, random matrices and graphs, graphical models and compressed sensing.
Requisites: Requires prerequisite courses of (MATH 2130 or MATH 2135) and MATH 4510 (minimum grade C-).

MATH 4540 (3) Introduction to Time Series
Studies basic properties, trend-based models, seasonal models, modeling and forecasting with ARIMA models, spectral analysis and frequency filtration.
Equivalent - Duplicate Degree Credit Not Granted: MATH 5540 and STAT 4540 and STAT 5540
Requisites: Requires prerequisite course of MATH 4520 or APPM 4520 (minimum grade C-).
Additional Information: Arts Sci Gen Ed: Distribution-Natural Sciences

MATH 4650 (3) Intermediate Numerical Analysis 1
Focuses on numerical solution of nonlinear equations, interpolation, methods in numerical integration, numerical solution of linear systems, and matrix eigenvalue problems. Stresses significant computer applications and software. Department enforced prerequisite: knowledge of a programming language.
Equivalent - Duplicate Degree Credit Not Granted: APPM 4650
Requisites: Requires a prerequisite course of MATH 3430 or APPM 2360 and APPM 3310 (minimum grade C-).

MATH 4730 (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 5730
Requisites: Requires prerequisite courses of MATH 3001 or MATH 3110 or MATH 3140 or MATH 3170 or MATH 3210 or MATH 3510 or MATH 4230 (all minimum grade C-).

MATH 4805 (1) Mathematical Teacher Training: Inclusive Pedagogy
Designed to train students to teach mathematics in an inclusive, multicultural environment. Students teach a math course within the McNeill Academic Program (Student Academic Services Center) meeting weekly with faculty and colleagues to learn to re-design curriculum, fine-tune pedagogical practices, create assessments, mentor undergraduate instructor assistants and create an inclusive classroom environment. Department enforced restriction: experience with college-level instruction.
Repeatable: Repeatable for up to 4.00 total credit hours.
Requisites: Restricted to students with 87-180 credits (Seniors) or graduate students only.

MATH 4810 (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 5810
Repeatable: Repeatable for up to 7.00 total credit hours.

MATH 4820 (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 5820
Requisites: Prerequisite courses of MATH 2001 or MATH 2002 and one of the following: MATH 3001, 3110, 3120, 3140, 3170, 3210, 3430, 3450, 3510, 3850, 4000, 4001, 4120, 4140, 4200, 4230, 4330, 4440, 4510, 4520, 4540, 4650, or 4660 (all min grade C-).
Recommended: completion of upper division Written Communication requirement.
Additional Information: Arts Sci Gen Ed: Distribution-Arts Humanities

MATH 4890 (1-3) Honors Independent Study
Offered for students doing a thesis for departmental honors.
Additional Information: Arts Sciences Honors Course

MATH 4900 (1-3) Independent Study
Repeatable: Repeatable for up to 6.00 total credit hours.