

# M - Mathematics

## M 005 Co-Req Support for M 105Q: 1 Credits (1 Lec)

(F, Sp) This co-requisite support course allows students who do not meet the prerequisites of M105Q to enroll in specific sections of M105Q. This course will provide an additional day of instruction and will present additional topics to support student success and understanding in M105Q. Course does not earn college-level credit.

## M 021 Co-Requisite Support for M121Q College Algebra: 2 Credits (2 Lec)

PREREQUISITE: M 090 or MPLEX 30 or ACT 21 or SAT 530 or 26 or old SAT 500 or M 065 A- or A. (F, Sp, Su) This course serves as a co-requisite for M121Q (College Algebra). Upon completing this course along with the co-requisite M121Q, students will be prepared to take M151Q or M161Q (depending on major). This course is intended to allow some students placing into developmental math an opportunity to enroll in M121Q while providing the additional time and support associated with developmental courses. Course does not earn college-level credit

## M 063 Foundations of Mathematics: 1 Credits (1 Lec)

COREQUISITE: This course will be linked to a M 090 Introductory Algebra Course with the same section number. (F, Sp) This instructor-taught course covers basic concepts relating to whole numbers, integers, fractions, decimals, percent and selected geometry topics. This course is to be taken during the same semester as M 090. The course is offered as a review and/or preparation for further studies in Mathematics. Offered by Gallatin College. Course does not earn college-level credit

## M 065 Pre-Algebra: 4 Credits (4 Lec)

This instructor-taught course covers basic concepts relating to fractions, decimals, ratios, proportions, percent, selected geometry topics, topics of signed numbers, and 1-variable linear equations. The course is offered as a review and/or preparation for further studies in Mathematics. Common final.

## M 066 Pre-Algebra Lab and Study: 1 Credits (1 Other)

Students enrolled in M 065 co-enroll in this course for additional instruction and practice with M 065 curriculum and Math study skills. This course will help students understand Math concepts, practice course material, and prepare for Math tests. Course is offered pass/fail.

## M 090 Introductory Algebra: 4 Credits (4 Lec)

PREREQUISITE: M063 or ACT 17 or ACT 15/16 and HS GPA greater than 3. (F, Sp, Su) Offered by Gallatin College. Intended for students pursuing majors requiring the M 121Q track and/or chemistry. This course serves as an introduction to algebra, which includes the study of basic operations with algebraic fractions and polynomials, linear equations and inequalities in one and two variables, systems of linear equations, and linear applications in one and two variables including percent applications. Course does not earn college-level credit

## M 091 Special Topics: 1-4 Credits (1-4 Lec)

Repeatable up to 12 credits.

## M 105Q Contemporary Mathematics: 3 Credits (3 Lec)

PREREQUISITE: Math Level 290. (F, Sp, Su) Formerly M 145Q. Designed to give liberal arts students the skills required to understand and interpret quantitative information that they encounter in the news and in their studies, and to make numerically-based decision in their lives. Topics include working with large numbers and units, linear and exponential relations, financial mathematics, and essentials of probability and statistics. Common final

## M 108 Business Mathematics: 3 Credits (3 Lec)

(F, Sp) Students of this course will examine the mathematics of business ownership and will demonstrate an understanding of business decisions. Concepts to be covered include cash flow, simple and compound interest, inventory valuation, purchasing discounts, cost markup, business and consumer loans, and analysis of financial statements. Additional topics which may be covered include payroll, depreciation, and bonds and annuities.

## M 111 Technical Mathematics: 3 Credits (3 Lec)

(F) Offered by Gallatin College. This course presents basic mathematical topics as they are applied in a trades program. Topics covered include: use of measuring tools, measurement systems, dimensional arithmetic, percent, proportion, applied geometry, basic trigonometry. NOTE: This course is intended for specific programs and does NOT provide sufficient Pre-Algebra material to serve as a prerequisite for students wanting to take additional mathematics.

## M 121Q College Algebra: 3 Credits (3 Lec)

PREREQUISITE: Math Placement Level 300. (F, Sp, Su) Intended for students preparing for precalculus or calculus. Further development of algebraic skills through the study of linear, quadratic, polynomial, exponential, and logarithmic functions

## M 132 Numbers & Operations for K-8 Teachers: 3 Credits (3 Lec)

PREREQUISITE: M 121Q or Math Placement Level 300. (F, Sp) The study of number and operations for prospective elementary and middle school teachers, including whole numbers, decimals, fractions, percents, integers, operations, numeration systems, and problem solving

## M 133Q Geometry & Measure K-8 Teachers: 3 Credits (3 Lec)

PREREQUISITE: A grade of C or better in M 132. (F, Sp) The study of geometry and geometric measurement for prospective elementary and middle school teachers, including synthetic, transformational, and coordinate geometry, constructions, congruence and similarity, 2-dimensional and 3-dimensional measurement, and problem solving

## M 140 College Math for Healthcare: 3 Credits (3 Lec)

PREREQUISITE: Math Placement Level 290 or M 090 or M 105Q. (F, Sp) This course is designed to provide students with a solid mathematical foundation necessary to succeed in a health care profession. This course will review algebra, systems of measurement, ratio and proportions, basic probability and statistics concepts, and ionic solutions and pH calculations. This course will apply mathematical reasoning and problem solving as it applies to the health care field and is a suitable prerequisite for STAT 216Q

## M 151Q Precalculus: 4 Credits (4 Lec)

PREREQUISITE: M 121Q or Math Level 400. (F, Sp, Su) Functions, graphs, and the use of symbols for expressing mathematical thoughts. Polynomials, rational, exponential, logarithmic, and trigonometric functions

## M 161Q Survey of Calculus: 4 Credits (4 Lec)

PREREQUISITE: M 121Q or Math Placement Level 400. (F, Sp, Su) A survey of basic calculus including limits, differentiation, and integration with applications to business, biology, and social science problems. COMMON FINAL ONLY

## M 165Q Calculus for Technology I: 3 Credits (3 Lec)

PREREQUISITE: M 151Q or Math Level 500. (F, Sp) Calculus with emphasis on problems of interest to engineering technologists. Includes analytic geometry, differentiation, and introduction to integration

## M 166 Calculus for Technology II: 3 Credits (3 Lec)

PREREQUISITE: M 165Q or M 171Q. (F, Sp) Calculus with emphasis on problems of interest to engineering technologists. Includes integration, infinite series, and differential equations

**M 170 Supplemental Instruction in Trigonometry for Calculus: 1 Credits (1 Lec)**

PREREQUISITE: Math Placement Level 450

COREQUISITE: M 165Q or M 171Q. (F) For students concurrently enrolled in M 171Q or M 165Q. Provides supplemental instruction in concepts and procedures in trigonometry that are necessary for success in calculus. Students with credit for M 151Q are not eligible to also earn credit for M 170

**M 171Q Calculus I: 4 Credits (4 Lec)**

PREREQUISITE: M 151Q or Math Level 500. (F, Sp, Su) Functions, elementary transcendental functions, limits and continuity, differentiation, applications of the derivative, curve sketching, and integration theory. COMMON FINAL EXAM

**M 172 Calculus II: 4 Credits (4 Lec)**

PREREQUISITE: M 171Q. (F, Sp, Su) Methods of integration, applications of the integral, infinite sequences and series including Taylor series, parametric and polar equations. COMMON FINAL ONLY

**M 181Q Honors Calculus I: 4 Credits (4 Lec)**

PREREQUISITE: M 151Q with an "A" grade, 700 on the SAT Math exam, 31 on the ACT Math exam, 4 on an AP AB Calculus exam, or consent of the instructor. (F) Honors section of M 171Q. Topic coverage parallels M 171Q but with a greater emphasis on theory and more difficult problems

**M 182 Honors Calculus II: 4 Credits (4 Lec)**

PREREQUISITE: M 171Q with an "A" grade or M 181Q with a "B" grade or 5 on an AP AB exam or consent of instructor. (Sp) Honors section of M 172. Topic coverage parallels M 172 but with a greater emphasis on theory and more difficult problems

**M 194 Introduction to Mathematical Sciences: 1 Credits (1 Lec)**

(F) For first-year students. Integration into the department and campus community. Development of mathematical and statistical habits of mind and introduction to software relevant to the mathematical sciences.

**M 221 Introduction to Linear Algebra: 3 Credits (3 Lec)**

PREREQUISITE: M 166 or M 172. (F, Sp, Su) Matrix algebra, systems of linear equations, determinants, vector algebra and geometry in Euclidean 3-space, eigenvalues, eigenvectors

**M 234 Higher Math for K-8 Teachers: 3 Credits (3 Lec)**

PREREQUISITE: A grade of C or better in both M 132 and M 133Q. (F, Sp) The study of algebra, number theory, probability and statistics for prospective elementary and middle school teachers, including proportional reasoning, functions, elementary number theory, statistical modeling and inference, and elementary probability theory

**M 242 Methods of Proof: 3 Credits (3 Lec)**

PREREQUISITE: M 172. (F, Sp) Reasoning and communication in mathematics, including logic, generalization, existence, definition, proof, and the language of mathematics. Topics include functions, relations, set theory, recursion, algebra, number theory, and other areas of mathematics

**M 273 Multivariable Calculus: 4 Credits (4 Lec)**

PREREQUISITE: M 172. (F, Sp, Su) Topics in two and three dimensional geometry. Manipulation and application of vectors. Functions of several variables, contour maps, graphs, partial derivatives, gradients, double and triple integration, vector fields, line integrals, surface integrals, Green's Theorem, Stokes' Theorem, the Divergence Theorem. COMMON FINAL ONLY

**M 274 Introduction to Differential Equation: 4 Credits (4 Lec)**

PREREQUISITE: M 172. (F, Sp, Su) An introduction to qualitative, quantitative, and numerical methods for ordinary differential equations. Topics include modeling via differential equations, linear and nonlinear first order differential equations and systems, elementary phase plane analysis, forced oscillations, and Laplace transform techniques. COMMON FINAL ONLY

**M 283 Honors Multivariable Calculus: 4 Credits (4 Lec)**

PREREQUISITE: M 182 with a 'B' grade, M 172 with an 'A' grade, AP Calculus BC exam with a 5, or consent of the instructor. (F) Honors section of M 273. Topic coverage parallels M 273 but with a greater emphasis on theory and more difficult problem solving

**M 284 Honors Introduction to Differential Equations: 4 Credits (4 Lec)**

PREREQUISITE: M 182 with a grade of B or higher, M 172 with a grade of A, AP Calculus BC exam with a 5, or consent of the instructor. (Sp) Honors section of M 274. Topic coverage parallels M 274 but with a greater emphasis on theory and more difficult problem solving

**M 290R Undergraduate Research: 1-8 Credits (1 Other)**

PREREQUISITE: Consent of the department head. (F, Sp, Su) Directed undergraduate research. Course will address responsible conduct of research Repeatable up to 8 credits.

**M 291 Special Topics: 1-4 Credits (1-4 Lec)**

Offered on demand. Courses not required in any curriculum for which there is a particular one-time need, or given on a trial basis to determine acceptability and demand before requesting a regular course number. Repeatable up to 12 credits.

**M 328 Higher Math for Sec Teachers: 3 Credits (3 Lec)**

PREREQUISITE: M 242. (F) Offered every other fall; offered in even-numbered years. Concepts, processes, and proof relevant to school mathematics, including number theory, abstract algebra, combinatorics and probability; a focus on standards-based content for teachers in secondary schools

**M 329 Modern Geometry: 3 Credits (3 Lec)**

PREREQUISITE: M 242. (Sp) A study of Euclidean and non-Euclidean geometries, chosen from; hyperbolic, spherical, projective, finite, transformational, and fractal geometries; computer tools for geometry; a focus on standards-based content for teachers in secondary schools

**M 330 History of Mathematics: 3 Credits (3 Lec)**

PREREQUISITE: M 273 and M 274 or consent of instructor. () Offered on demand. Topics will be selected from the entire span of history from Egyptian, Babylonian, and Greek times through the 20th century. The course may focus on milestones that lead to the development of modern mathematics as well as the contributions of great mathematicians from ancient times until today. Some ideas will require mathematical sophistication at the upper division level

**M 333 Linear Algebra: 3 Credits (3 Lec)**

PREREQUISITE: M 221 and M 242. (F) Vector spaces, subspaces, bases, and dimension. Linear transformations, representation by matrices, nullity, rank, isomorphism. Eigenvalues, eigenvectors, and diagonalizability of linear transformations. Inner products, and vector, matrix, and operator norms. Singular value decomposition. The Perron-Frobenius theorem

**M 348 Techniques of Applied Math I: 3 Credits (3 Lec)**

PREREQUISITE: M 273 and M 274. (F) An introduction to advanced analytical techniques frequently used by scientists and engineers to study ordinary differential equations and two-point boundary value problems. Topics include series solution techniques, method of Frobenius, Laplace transforms, Fourier series, and boundary value problems

**M 349 Techniques of Applied Mathematics II: 3 Credits (3 Lec)**

PREREQUISITE: M 348. (Sp) Science and engineering majors often encounter partial differential equations in the study of heat flow, vibrations, electric circuits, and similar areas. Topics include Sturm-Liouville theory, partial differential equations boundary value problems, and Laplace Transform methods

**M 362 Linear Optimization: 3 Credits (3 Lec)**

PREREQUISITE: M 221. Introduction to linear programming and modeling techniques with applications. Topics may include basic convex geometry, geometry of linear programs, simplex method, duality, sensitivity analysis, game theory, transportation, assignment, and network models

**M 383 Introduction to Analysis I: 3 Credits (3 Lec)**

PREREQUISITE: M 273 and M 242, or consent of instructor. (F) A rigorous development of calculus with formal proofs. Functions, sequences, limits, continuity, differentiation, and integration

**M 384 Introduction to Analysis II: 3 Credits (3 Lec)**

PREREQUISITE: M 383. (Sp) A rigorous development of multivariate calculus. Differentiable functions, inversion theorem, multiple integrals, line and surface integrals, infinite series

**M 386R Software Applications in Mathematics: 3 Credits (3 Lec)**

PREREQUISITE: M 221, M 273, and M 274. (Sp) An introduction to modern mathematical and scientific computing. Software such as MAPLE and MATLAB will be used to explore, solve, and visualize solutions of standard mathematical problems as well as simple models of various physical and/or biological systems

**M 419 Ratio and Proportion in School Mathematics: 3 Credits (3 Lec)**

PREREQUISITE: A grade of C or better in M 242 and junior standing; or, admission to the MAT program. (Sp) Develop knowledge of ratio and proportion necessary to teach standards-based school mathematics. Connect ratio, rate, and proportion to elementary, middle, and high school topics. Explore use of manipulative materials and technologies, and discuss related pedagogical issues and national standards. Note: This course is not appropriate for students in the undergraduate Elementary Education program

**M 420 Geometry, Measurement, and Data in the Middle Grades: 3 Credits (3 Lec)**

PREREQUISITE: A grade of C or better in M 234, or M 242, and junior standing. () Offered Fall, odd years. Develop content knowledge necessary to teach standards based middle school mathematics. Investigate the underlying conceptual structure of topics in geometry, measurement and data analysis appropriate to middle school. Explore the use of manipulative materials and technologies, and discuss related pedagogical issues and national standards

**M 424 Algebraic Thinking and Number Sense in the Middle Grades: 3 Credits (3 Lec)**

PREREQUISITE: A grade of C or better in either M 234 or M 172. (Sp) Offered spring, even years. Develop algebraic knowledge necessary to teach standards-based middle school mathematics. Investigate the underlying conceptual structure of topics in algebra and number appropriate to middle school. Explore the use of manipulative materials and technologies, and discuss related pedagogical issues and national standards

**M 428 Mathematical Modeling for Teachers: 3 Credits (3 Lec)**

PREREQUISITE: M 242 and STAT 216Q. (F) Offered every other fall; offered odd-numbered years. Senior capstone course. Applications of the modeling process in key areas of mathematics and statistics. Simulation and other activities, use of relevant technology, modeling in the secondary curricula, and the classroom assessment of modeling activities. Emphasis on technology and authentic applications using pre-college mathematics

**M 430 Mathematical Biology: 3 Credits (3 Lec)**

PREREQUISITE: M 273 and M 274 or consent of the instructor. (Sp) Mathematical modeling of basic biological processes in ecology, physiology, neuroscience, epidemiology and molecular biology using difference equations, differential equations, and partial differential equations

**M 431 Abstract Algebra I: 3 Credits (3 Lec)**

PREREQUISITE: M 333. (Sp) Senior capstone course. The integers, integers modulo  $n$ , the Euclidean algorithm. Groups, subgroups, normal subgroups, quotient groups, homomorphism and isomorphism theorems, and abelian groups. Rings, ideals, homomorphism and isomorphism theorems. Integral domains, fields, and fields of quotients

**M 441 Numerical Linear Algebra & Optimization: 3 Credits (3 Lec)**

PREREQUISITE: M 221 and M 273. (F) Numerical solution of nonlinear equations. Numerical solutions of linear systems and eigenvalue problems. Least squares, data smoothing, and optimization techniques

**M 442 Numerical Solution of Differential Equations: 3 Credits (3 Lec)**

PREREQUISITE: M 221 and M 274. (Sp) Senior capstone course. Numerical integration, numerical solutions of initial and boundary value problems in ordinary differential equations. Numerical solutions of partial differential equations

**M 450 Applied Mathematics I: 3 Credits (3 Lec)**

PREREQUISITE: M 273 and M 274. (F) An introduction to modern methods in applied mathematics. Topics include introductions to dimensional analysis and scaling, perturbation and WKB methods, boundary layers, calculus of variations, stability, and bifurcation analysis

**M 451 Applied Mathematics II: 3 Credits (3 Lec)**

PREREQUISITE: M 450. () Offered Spring, even years. This is the second semester of a course that introduces modern methods in applied mathematics. Topics involve methods for linear and nonlinear partial differential equations, including introductions to Green's functions, Fourier analysis, shock waves, conservation laws, maximum and minimum principles, and integral equations

**M 454 Introduction of Dynamical Systems I: 3 Credits (3 Lec)**

PREREQUISITE: M 273 and M 274. (F) Existence and uniqueness of solutions to ordinary differential equations, linearization, phase portraits, stability theory, and the analysis of specific examples

**M 455 Introduction to Dynamical Systems II: 3 Credits (3 Lec)**

PREREQUISITE: M 454. () Offered Spring, odd years. Gradient systems, Poincare'-Bendixson theory, Poincare' maps, structural stability and chaotic systems

**M 472 Introduction to Complex Analysis: 3 Credits (3 Lec)**

PREREQUISITE: M 273 and M 242. (Sp) An introduction to the techniques of complex analysis that are frequently used by scientists and engineers. Topics include complex numbers, analytic functions, Taylor and Laurent expansions, Cauchy's theorem, and evaluation of integrals by residues

**M 476 Introduction to Topology: 3 Credits (3 Lec)**

PREREQUISITE: M 221 and M 242 or consent of instructor. () Offered Fall, odd years. Provides an intuitive and rigorous introduction to this important and broad-ranging discipline of modern mathematics. Students will learn to recognize those properties which are topological, i.e., stable under small perturbation. Course participants will compute and see the utility of various topological invariants which arise in a variety of fields from data science, to particle physics, to advanced mathematics

**M 490R Undergraduate Research: 1-6 Credits (1-6 Other)**

PREREQUISITE: Junior standing in mathematics and consent of department head. (F, Sp, Su) Directed undergraduate research which may culminate in a research paper, journal article, or undergraduate thesis. Course will address responsible conduct of research. May be repeated Repeatable up to 12 credits.

**M 491 Special Topics: 1-4 Credits (1-4 Lec)**

PREREQUISITE: Course prerequisites as determined for each offering. Offered on demand. Courses not required in any curriculum for which there is a particular one-time need, or given on a trial basis to determine acceptability and demand before requesting a regular course number. Repeatable up to 12 credits.

**M 492 Independent Study: 1-3 Credits (1-3 Other)**

PREREQUISITE: Junior standing, consent of instructor, and approval of department head. (F, Sp, Su) Directed research and study on an individual basis.

Repeatable up to 6 credits.

**M 494 Seminar: 1 Credits (1 Other)**

PREREQUISITE: Junior standing and as determined for each offering. () Offered on demand. Topics offered at the upper division level which are not covered in regular courses. Students participate in preparing & presenting material.

Repeatable up to 4 credits.

**M 497 Educational Methods: Teaching Fellowship: 1-3 Credits (1-3 Other)**

PREREQUISITE: Junior standing, consent of instructor, and approval of department head. (F, Sp) As co-teachers of a Mathematics course, students will learn and have the opportunity to practice classroom teaching strategies as well as mentoring skills. Does not satisfy upper division elective for Math-Teaching option.

Repeatable up to 4 credits.

**M 498 Internship: 2-12 Credits (2-12 Other)**

PREREQUISITE: Junior standing, consent of instructor, and approval of department head. (F, Sp, Su) An individualized assignment arranged with an agency, business, or other organization to provide guided experience in the field.

Repeatable up to 12 credits.

**M 501 Intermediate Probability & Statistics: 3 Credits (3 Lec)**

PREREQUISITE: STAT 422 or M 384. (F) Families of probability distributions, distributions of functions of random variables, limiting distributions, order statistics. Cross-listed with STAT 501.

**M 502 Intermediate Mathematical Statistics: 3 Credits (3 Lec)**

PREREQUISITE: STAT 501 or M 501. (Sp) Estimation, likelihood inference, statistical hypothesis tests, sufficient statistics, exponential families, Bayesian statistics. Cross-listed with STAT 502.

**M 503 Advanced Linear Algebra: 3 Credits (3 Lec)**

PREREQUISITE: M 333 or consent of instructor. (Sp) Topics include abstract vector spaces, diagonalization, Schur's Lemma, Jordan canonical form and spectral theory for finite dimensional operators.

**M 504 Abstract Algebra: 3 Credits (3 Lec)**

PREREQUISITE: M 431 or consent of instructor. (Sp) The theory of groups, rings and fields with particular emphasis on finite groups, polynomial rings and fields of characteristic zero.

**M 505 Principles of Mathematical Analysis: 3 Credits (3 Lec)**

PREREQUISITE: M 384 or consent of instructor. (F) Principles of analysis in Euclidean spaces and metric spaces.

**M 507 Mathematical Optimization: 3 Credits (3 Lec)**

PREREQUISITE: M 273, M 441. () Offered Fall, odd years. Introduction to mathematical optimization at the graduate level. Overview of computational methods for solving linear and nonlinear optimization problems. Fundamental concepts in optimization, simplex method, duality theory, methods for unconstrained optimization, optimality conditions for constrained problems, and penalty and augmented Lagrangian methods for solving nonlinear constrained problems.

**M 508 Mathematics of Machine Learning: 3 Credits (3 Lec)**

PREREQUISITE: M 273 and M 441. () Offered Spring, even years. Mathematical models for pattern recognition and machine learning. Fundamental concepts of parametric and non-parametric probability distributions and dimensionality reduction. Data classification and clustering, regression, kernel methods, artificial neural networks, and Markov-based models. Practical examples drawn from practical data science problems.

**M 509 Stochastic Processes: 3 Credits (3 Lec)**

PREREQUISITE: STAT 421. () Offered Spring, on demand. Conditional probability theory, discrete and continuous time markov chains including birth and death processes and long run behavior; Poisson processes; queuing systems; system reliability. Cross-listed with STAT 509.

**M 511 General Topology: 3 Credits (3 Lec)**

PREREQUISITE: M 384 or consent of instructor. (F) Definition of a topology, relative topology, metric topology, quotient topology, and the product topology. Connectedness, local connectedness, components and path components. Compactness and local compactness, countability and separation axioms, the Urysohn Lemma, metrization and compactification.

**M 512 Geometry & Algebraic Topology: 3 Credits (3 Lec)**

PREREQUISITE: M 511 or consent of instructor. (Sp) Topics in continuous theory, topics in dimension theory, covering spaces and the fundamental group, simplicial complexes, topics in homology and cohomology theory.

**M 516 Language of Mathematics for Teaching: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing in mathematics education, teaching endorsement in mathematics, or consent of instructor. (Su) Offered Summer, on demand. Features of the language of mathematics, including syntax, vocabulary, and structure. Logic, proof and mathematical communication for high school classrooms.

**M 517 Advanced Mathematical Modeling for Teaching: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing in mathematics education, teaching endorsement in mathematics, or consent of instructor. (Su) Offered Summer, even years. Focus on the use of modeling to solve real-world problems. Topics include the modeling process, an overview of relevant technology, strategies to engage students in modeling in the secondary classroom, and classroom assessment of modeling activities. Extensive use of mathematics to explore application areas, leading to the construction of original models.

**M 518 Statistics for Teaching: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing in mathematics or science education, teaching endorsement in mathematics or science, or consent of instructor. (Su) Stochastic concepts including probabilistic underpinnings of statistics, measures of central tendency, variability, correlation, distributions, sampling, and simulation. Exploratory data analysis including experiments, surveys, measures of association and inferential statistics. Discussion of methods for teaching statistics in secondary mathematics and science.

**M 519 Ratio and Proportion in School Mathematics: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing in mathematics education, teaching endorsement in mathematics, or consent of instructor. (Su) Offered Summer, on demand. Develop knowledge of ratio and proportion necessary to teach standards-based school mathematics. Connect ratio, rate, and proportion to elementary, middle, and high school topics. Explore use of manipulative materials and technologies, and discuss related pedagogical issues and national standards.



**M 520 Access and Equity in Mathematics Teaching: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing in mathematics education, teaching endorsement in mathematics, or consent of instructor. (Su) Study of the social context of schooling in the U.S. through the lens of access and equity in mathematics education. Key content themes and connections in algebra, geometry, probability/data analysis, number, and measurement with a focus on mathematical practices. Exploring, extending, designing, and teaching equity-oriented classroom activities for middle/high school students and reflecting on issues of access, equity, and student outcomes

**M 521 Mathematics Learning Theory for Teaching: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing, teaching endorsement in mathematics, or consent of instructor. (F) Offered Fall, even years. Examine theories of learning as they apply to the mathematics classroom. The course focuses on theories and research about learning and human development. These are used (a) to understand mathematics learning among students of all cultural, linguistic and socioeconomic backgrounds, and (b) to formulate effective, equitable teaching and learning strategies

**M 522 Assessment of Mathematics for Teaching: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing in mathematics education, teaching endorsement in mathematics, or consent of instructor. () Offered on demand. Connects assessment theory and models to teachers' practice through classroom observations and hand-on activities. Focus on assessment practices consistent with standards-based mathematics and classroom assessment of student learning

**M 523 Number Structure for Teaching: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing in mathematics education, teaching endorsement in mathematics, or consent of instructor. () Offered for two consecutive years; alternates with M 526. Develop the relationship and distinction between the mathematics that underlies the structure of number and the learning and teaching of number structure in schools. Explore representation, abstraction, and basic proof in the context of number and operations. Develop foundations of the real number system and examine relevant research about students' understanding of number

**M 524 Linear Algebra for Teaching: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing in mathematics education, teaching endorsement in mathematics, or consent of instructor. (Sp) Algebraic systems, special matrices, determinants, vector spaces, and linear programming. Includes applications relevant to industry and business and connections to topics in secondary mathematics

**M 525 Analysis for Teaching: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing in mathematics education, teaching endorsement in mathematics, or consent of instructor. (F) A study of calculus concepts and processes from graphical, numerical and algebraic perspectives. Technology is incorporated throughout the course. Includes connections to topics in secondary mathematics

**M 526 Discrete Mathematics for Teaching: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing in mathematics education, teaching endorsement in mathematics, or consent of instructor. (Su) Su for two consecutive years; alternates with M 523. A study of classical topics in discrete mathematics, chosen from combinatorics, probability, graph theory, & other areas relevant to secondary mathematics. Emphasis on problem solving and justification

**M 527 Geometry for Teaching: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing in mathematics education, teaching endorsement in mathematics, or consent of instructor. (Su) Offered Summer, odd years. Explorations of special topics in geometry, such as geometry of transformations including Euclidean motions and similarity, projective geometry, geometric topology and geometry of inversion. Technology is incorporated throughout the course

**M 528 Curriculum Design: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing in mathematics education, teaching endorsement in mathematics, or consent of instructor. () Offered Spring, even years. Focuses on the design, implementation, and evaluation of curricula in mathematics. Includes historical changes and trends in mathematics curriculum and an examination of current research

**M 529 Assessment Models and Issues: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing in mathematics education, teaching endorsement in mathematics, or consent of instructor. () Offered Fall, odd years. Examines critical K-12 issues including: alignment and interaction of assessment with standards, curriculum, and instruction; role of assessment systems at local, state, and national levels; evaluation of assessment tools and programs; equity considerations in assessment

**M 533 History of Mathematics for Teaching: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing in mathematics education, teaching endorsement in mathematics, or consent of instructor. () Offered on demand. Focus on the history of mathematics as a context for classroom instruction. Includes the changing nature of mathematics, classical problems, proofs and mathematical processes, and the development of teaching units that incorporate the history of mathematics

**M 534 Research in Mathematics Education: 3 Credits (3 Lec)**

PREREQUISITE: Consent of instructor. () Offered on demand. Examination of quantitative and qualitative research findings and methodology in mathematics education. Review of current trends and literature. Writing for publication and proposals

**M 535 Technology and Mathematics for Teaching: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing in mathematics education, teaching endorsement in mathematics, or consent of instructor. () Offered Summer, on demand. Calculator, computer and Web-based technologies for K-12 mathematics education. Analysis of the influence of technology on the K-12 mathematics curriculum, instruction, and assessment

**M 540 Introduction to Calculus on Manifolds: 3 Credits (3 Lec)**

PREREQUISITE: M 503 and M 505 or consent of instructor. (F) Offered Fall of odd years. An introduction to: manifolds and their atlases, fiber bundles, vector fields, tensor fields and differential forms, the exterior and Lie derivatives, Stokes Theorem, & de Rham cohomology

**M 544 Partial Differential Equations I: 3 Credits (3 Lec)**

PREREQUISITE: M 384 and M 451, or consent of instructor. () Offered Fall, odd years. An extended survey of the origins of a large number of scientific and mathematical partial differential equations and an overview of the theoretical techniques which are available to solve them

**M 545 Partial Differential Equations II: 3 Credits (3 Lec)**

PREREQUISITE: M 544 and M 547. () Offered Spring, even years. Linear partial differential equations and the function spaces and functional analysis which one uses to study them. Topics include: Holder and Sobolev functions, Sobolev and Poincare inequalities, embedding density, semigroup theory for evolution equations

**M 547 Measure Theory: 3 Credits (3 Lec)**

PREREQUISITE: M 384 or M 505. (F) Lebesgue measure, and the Lebesgue integral of functions of a real variable. General measure and integration theory. Lebesgue-Stieltjes integral and product measures

**M 551 Complex Analysis: 3 Credits (3 Lec)**

PREREQUISITE: M 505. (Sp) Analytic functions and conformal maps, contour integrals, Cauchy's theorem, Cauchy's integral formula, the maximum modulus theorem, harmonic functions, Taylor's theorem and Laurent series. Classification of singularities, the residue theorem and evaluation of definite integrals, Rouché's theorem and the argument principle

**M 554 Abstract Algebra II: 3 Credits (3 Lec)**

PREREQUISITE: M 504. (F) A second graduate-level course in Abstract Algebra, building on M 504 Abstract Algebra, covering further topics in groups, rings, and modules. Particular topics include: multilinear algebra, homological algebra, commutative algebra, and representation theory

**M 560 Methods of Applied Mathematics I: 3 Credits (3 Lec)**

PREREQUISITE: M 451. () Offered Fall, even years. Finite dimensional vector spaces, spectral theory, Fredholm theorem of matrices, pseudo-inverses. Integral equations, Fredholm alternative and resolvent kernels, singular integral equations. Differential equations and Green's functions, eigenvalue expansions for differential operators

**M 561 Methods of Applied Mathematics II: 3 Credits (3 Lec)**

PREREQUISITE: M 560. () Offered Spring, odd years. Calculus of variations, Hamilton's principle, asymptotic and perturbation methods, transform techniques and scattering theory. Partial differential equations, Green's functions, separation of variables and transform methods

**M 570 Individual Problems: 1-3 Credits (1-3 Other)**

PREREQUISITE: Graduate standing, consent of instructor, approval of department head and Dean of Graduate Studies. (F, Sp, Su) Directed research and study on an individual basis  
Repeatable up to 6 credits.

**M 575 Professional Paper and Project: 1-4 Credits (1 Other)**

PREREQUISITE: Graduate standing. (F, Sp, Su) A research or professional paper or project dealing with a topic in the field. The topic must have been mutually agreed upon by the student and his or her major advisor and graduate committee  
Repeatable up to 6 credits.

**M 576 Internship: 1-12 Credits (1-12 Other)**

PREREQUISITE: Graduate standing, consent of instructor and approval of department head. (F, Sp, Su) An individualized assignment arranged with an agency, business or other organization to provide guided experience in the field  
Repeatable up to 99 credits.

**M 577 Conducting Action Research in Mathematics Education: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing in mathematics education, teaching endorsement in mathematics and consent of instructor. (Sp) Offered Spring, odd years. With guidance from faculty, students conduct action research addressing a problem in the context of their classroom, school or district that influences student success in mathematics. Students work with a faculty advisor to implement an intervention, collect and analyze data resulting, and summarize results. Findings are presented orally to peers and faculty

**M 580 Special Topics: 4 Credits (4 Lec, 4 Other)**

PREREQUISITE: Upper division courses and others as determined for each offering. () Offered on demand. Courses not required in any curriculum for which there is a particular one time need, or given on a trial basis to determine acceptability & demand before requesting a regular course number  
Repeatable up to 12 credits.

**M 581 Numerical Solution of Partial Differential Equations I: 3 Credits (3 Lec)**

PREREQUISITE: M 442. (F) Finite difference and finite element solution techniques for elliptic, parabolic, and hyperbolic partial differential equations, numerical linear algebra

**M 582 Numerical Solution of Partial Differential Equations II: 3 Credits (3 Lec)**

PREREQUISITE: M 581. (Sp) A continuation of topics from M 581

**M 584 Functional Analysis I: 3 Credits (3 Lec)**

PREREQUISITE: M 547. (F) Offered Fall, even years. Banach spaces, fixed point theorems, Hilbert spaces, the Dirichlet principle, generalized Fourier series, & spectral theory

**M 585 Functional Analysis II: 3 Credits (3 Lec)**

PREREQUISITE: M 584. (Sp) Offered Spring, odd years. The Hahn Banach theorem, variational principles, weak convergence, uniform boundedness theorem, the open mapping theorem & the implicit function theorem

**M 586 Probability Theory: 3 Credits (3 Lec)**

PREREQUISITE: M 547. (Sp) Offered Spring, on demand. Combinatorial probability and measure theoretic foundations of probability; axioms for probability spaces. Borel-Cantelli Lemmas, weak & strong laws of large numbers, and the central limit problem

**M 587 Lie Groups: 3 Credits (3 Lec)**

PREREQUISITE: M 504, M 511. (F) Offered fall, even years. Lie groups, Lie algebras, representation theory

**M 588 Professional Development: 1-3 Credits (1-3 Lec)**

PREREQUISITE: Graduate standing, teaching experience or current employment in a school organization, consent of instructor and Dean of Graduate Studies. () Offered on demand. Courses offered on a one time basis to fulfill professional development needs of in-service educators. A specific focus is given to each course which is appropriately subtitled. May be repeated  
Repeatable up to 3 credits.

**M 589 Graduate Consultation: 3 Credits (3 Other)**

PREREQUISITE: Master's standing. (F, Sp, Su) This course may be used only by students who have completed all of their course work (and thesis, if on a thesis plan) but who need additional faculty or staff time

**M 590 Master's Thesis: 1-10 Credits (1 Other)**

PREREQUISITE: Master's standing  
Repeatable up to 99 credits.

**M 591 Topics in Applied Math I: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing and consent of instructor. On demand. Topics may include numerical solution of linear and nonlinear problems, eigenvalue problems, continuation methods, numerical optimization, computational mechanics, spectral methods, bifurcation theory, invariant manifold theory, index theory, nonlinear analysis, reaction-diffusion equations, nonlinear oscillations, asymptotic methods and perturbation methods

**M 592 Topics in Applied Math II: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing and consent of instructor. () On demand. Topics may include numerical solution of linear and nonlinear problems, eigenvalue problems, continuation methods, numerical optimization, computational mechanics, spectral methods, bifurcation theory, invariant manifold theory, index theory, nonlinear analysis, reaction-diffusion equations, nonlinear oscillations, asymptotic methods & perturbation methods

**M 594 Seminar: 1 Credits (1 Other)**

PREREQUISITE: Graduate standing or seniors by petition. () On demand. Course prerequisites as determined for each offering. Topics offered at the graduate level which are not covered in regular courses. Students participate in preparing & presenting discussion material  
Repeatable up to 6 credits.

**M 595 Dynamical Systems I: 3 Credits (3 Lec)**

PREREQUISITE: M 503. (F) Offered Fall, odd years. Topics in differential equations including existence and uniqueness, continuous dependence on parameters, extendibility, the existence and stability of equilibria and limit cycles & the Poincare-Bendixon theorem

**M 596 Dynamical Systems II: 3 Credits (3 Lec)**

PREREQUISITE: M 595. (Sp) Offered Spring, even years. Topics include Hartman's theorem, invariant manifold theory, Smale-Birkhoff theorem, horseshoe chaos, & the Melnikov method. Topics in discrete dynamical systems may also be covered

**M 597 Topics in Math I: Character Varieties and 3-manifolds: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing or consent of instructor. () Offered on demand. Topics include the theory of representations of finitely generated groups into matrix groups and applications of this theory to the study of low-dimensional topology. Our primary tools will be  $SL(2, \mathbb{C})$  and  $PSL(2, \mathbb{C})$  character varieties. Culler-Shalen theory and its applications will be discussed in depth. We will also cover some of the basics of low-dimensional topology along with classical affine and projective algebraic geometry. Computational techniques in algebraic geometry and commutative algebra will be highlighted to encourage experimentation and exploration

**M 598 Topics in Math II: 3 Credits (3 Lec)**

PREREQUISITE: Graduate standing, consent of instructor. () Offered on demand. Topics selected from: continuum theory, symbolic dynamics, ergodic theory and low dimensional topology

**M 689 Doctoral Reading & Research: 3-5 Credits (3 Other)**

PREREQUISITE: Doctoral standing. (F, Sp, Su) This course may be used by doctoral students who are reading research publications in the field in preparation for doctoral thesis research  
Repeatable up to 15 credits.

**M 690 Doctoral Thesis: 1-10 Credits (1 Other)**

PREREQUISITE: Doctoral standing  
Repeatable up to 99 credits.