

# MATHEMATICS (MA-GY)

## MA-GY 848 Advanced Topics in Topology I (3 Credits)

Course content varies. | Prerequisite: MA-GY 7403

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

## MA-GY 942X Reading in Mathematics II (1-3 Credits)

*Typically offered occasionally*

In this course, reading is guided by faculty members and devoted mainly to scholarly papers. | Prerequisite: Department's permission.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** Yes

## MA-GY 997X MS THESIS IN MATH (3-9 Credits)

*Typically offered occasionally*

In this course, students present a thesis of independent investigation of a suitable problem in mathematics. Study must include adequate investigation of existing literature relating to the subject. Regular reports on progress of work and regular conferences with assigned faculty adviser are required. | Note: Re-registration fee, any part: 3-credit charge. Prerequisite: Degree status.

**Grading:** Satisfactory/Unsatisfactory

**Repeatable for additional credit:** Yes

## MA-GY 5024 ePoly: Fundamentals of Calculus 1 (4 Credits)

This course covers library of Functions: functions of one variable. Limits, derivatives of functions defined by graphs, tables and formulas, differentiation rules for power, polynomial, exponential and logarithmic functions, derivatives of trigonometric functions, the product and quotient rule, the chain rule, applications of the chain rule, maxima and minima, optimization. Note: this course does not apply as credit toward a student's graduate degree. Cannot be taken if student has completed MA-UY 1024. Students may be required to pay for ProctorU and WebAssign. | Prerequisite: Math Diagnostic Placement Exam or MA-UY 912 or MA-UY 914 or Departmental Permission.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**Prerequisites:** Math Diagnostic Placement Exam or MA-UY 912 or MA-UY 914 or Departmental Permission.

## MA-GY 5124 ePoly: Fundamentals of Calculus 2 (4 Credits)

This course covers definite integrals, theorems about integrals, anti-derivatives, second fundamental theorem of calculus, techniques of integration, introduction to ordinary differential equations, improper integrals, numerical methods of integration, applications of integration, sequences, series, power series, approximations of functions via Taylor polynomials, Taylor series. Note: this course does not apply as credit toward a student's graduate degree. Cannot be taken if student has completed MA-UY 1124. Students may be required to pay for ProctorU and WebAssign. | Prerequisite: MA-GY 5024 or MA-UY 1024.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**Prerequisites:** MA-GY 5024 or MA-UY 1024.

## MA-GY 5313 Applied Mathematics in Engineering and Science I (3 Credits)

This course covers: Use of matrix algebra techniques in applications. Vector spaces. Solutions of linear algebraic equations. Linear independence. Rank of matrix. Linear transformations. Orthogonality. Gram-Schmidt procedure. Orthogonal matrices. Eigenvalues and eigenvectors. Spectral decomposition. Similarity transformations. Pseudoinverses. Singular value decomposition. Jordan form. Condition numbers of matrices. Iterative methods for eigenvalues of symmetric matrices. | Prerequisite: MA-UY 2122 and MA-UY 2132 or equivalent Note: Not acceptable for graduate credit in the Department of Mathematics.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

## MA-GY 5323 Applied Mathematics in Engineering and Science II (3 Credits)

This course covers: Some common partial differential equations, boundary conditions, separation of variables. Wave equation, diffusion equation, Laplace equation. Axial symmetry and spherical symmetry. Adjoint operators and Sturm-Liouville problems. Expansions in orthogonal eigenfunctions. Method of Frobenius. Bessel functions. Integral representations. Asymptotic expansions. Legendre polynomials. Spherical harmonics. Spherical Bessel functions. | Prerequisite: MA-GY 5313. Co-Requisite: None. Note: Not acceptable for graduate credit in the Department of Mathematics.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

## MA-GY 5413 Stringology: Mathematics of String Comparisons in Computational Biology (3 Credits)

The course addresses basic combinatorial problems of string manipulation, string matching, string editing, string distance computations, arising from areas of text processing, computational biology and genomics. Classical, modern and entirely new approaches to these problems are presented with all necessary mathematical and computer science backgrounds (including coding theory and symbolic manipulation). Emphasis is on practical and effective algorithm implementations. | Prerequisite: None.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

## MA-GY 6003 Elements of Discrete Mathematics (3 Credits)

This course covers logic, sets and functions, algorithms, analysis of algorithms. Mathematical models, primitives of naïve set theory. Covered topics: Mathematical reasoning, methods of proof, mathematical induction, recursive definitions, recursive algorithms, Counting, the Pigeonhole principle, discrete probability, recurrence relations, generating functions, inclusion-exclusion. Introduction to graph theory, counting and algorithm analysis, relations, graphs, Boolean algebras, circuits. Turing Machines, algorithm complexity. Introduction to algebraic structures. | Prerequisite: Adviser's approval.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6013 Applied Matrix Theory I (3 Credits)**

This course covers the basics of linear algebra and matrix theory. Topics included: Vector Spaces, linear combinations, affine combinations, linear dependence, affine dependence, bases, dimension, isomorphism, subspaces, calculus of subspaces, dimension of subspaces, dual vector spaces and dual bases, direct sums of vector spaces, quotient spaces, bilinear forms, tensor products, permutations, cycles, parity, linear transformations, transformations as vectors, polynomials, inverses, matrices, matrices associated with linear transformations, invariance, reducibility, projections, adjoints, change of basis, similarity. | Prerequisite: MA-UY 2012 and MA-UY 2122 or equivalent. Co-Requisite:

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6023 APPLIED MATRIX THEORY II (3 Credits)**

This course is the sequel to MA-GY 6013, basics concepts of linear algebra and matrix theory. Topics covered: Linear mappings, their range and null spaces, tensor product of transformations, determinants, eigenvalues, multiplicities, triangular form, nilpotence, Jordan form, inner products, inner product spaces, orthogonality, completeness Schwarz's inequality, complete orthonormal sets, the projection theorem, linear functionals, self-adjoint transformations, polarization, positive transformations, isometries, change of orthonormal basis, characterization of spectra, the spectral theorem, normal transformations orthogonal transformations, functions of transformations, polar decomposition, commutativity. Applications for matrices and for Differential equations. | Prerequisite: MA-GY 6013.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6103 Graph Theory (3 Credits)**

This course covers: Graphs and digraphs, subgraphs, paths, cycles, trees and forests. Contraction and minors. Vertex-connectivity and edge-connectivity. Structure of  $k$ -connected graphs. Menger's theorem. Planar graphs, drawings and embeddings. Graph colorings: vertex-coloring, edge-coloring, list-coloring. Perfect graphs. Network flows, Ford-Fulkerson Theorem. Matching, Packing and Covering. Ramsey theory. Extremal graph theory, Szemerédi's regularity lemma. Hamilton cycles. Random graphs. The probabilistic method. Tree-decompositions, tree-width. The graph minor theorem. | Prerequisite: MA-GY 6003 or adviser's approval.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6123 Queuing Theory (3 Credits)**

This course covers: Steady-state solutions for single and multiple channels. Various arrival and service distributions and queuing disciplines. Transient solutions. Emphasis on theory, with solution techniques given for specific classes of queues. | Prerequisite: MA-GY 6003 or adviser's approval.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6133 Elements of Number Theory (3 Credits)**

This course covers: Prime numbers, the fundamental theorem of arithmetic, linear Diophantine equations. Fermat's Little Theorem, Wilson's Theorem, Euler's theorem. Linear congruences, Chinese Remainder Theorem, Euler phi function, Moebius inversion. Primitive roots and indices, quadratic congruences, Quadratic reciprocity law. Perfect numbers, sums of squares, Siegel's theorem. The prime number theorem. Computational number theory, primality testing, Cryptography. Elliptic curves. | Prerequisite: MA-GY 6003 or adviser's approval.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6143 Optimization: Linear and Nonlinear Programming (3 Credits)**

This course covers: Theory and application of linear programming techniques. Simplex and revised simplex algorithms. Duality theory, dual simplex method, post-optimality analysis. Degeneracy. Transportation and assignment problems. Quadratic programming, Kuhn-Tucker conditions. Wolfe's method. | Prerequisite: MA-GY 6003 or adviser's approval.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6213 Intro to Math Analysis I (3 Credits)**

*Typically offered occasionally*

This course and its sequel MA-GY 6223 rigorously treat the basic concepts and results in real analysis. Course topics include limits of sequences, topological concepts of sets for real numbers, properties of continuous functions and differentiable functions. Important concepts and theorems include supremum and infimum, Bolzano-Weierstrass theorem, Cauchy sequences, open sets, closed sets, compact sets, topological characterization of continuity, intermediate value theorem, uniform continuity, mean value theorems and inverse function theorem. | Prerequisite: MA-UY 2122 or permission of adviser.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6223 Intro to Math Analysis II (3 Credits)**

*Typically offered occasionally*

This course continues MA-GY 6213. The topics are integration, series of real numbers, sequences and series of functions and Fourier series. Important concepts and theorems include Riemann and Riemann-Stieltjes integral, fundamental theorem of calculus, the mean value theorem of integrals, Dirichlet test, absolute and conditional convergence, uniform convergence, Weierstrass test, power series, orthogonal functions and Fourier series. | Prerequisite: MA-GY 6213.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**Prerequisites:** MA-GY 6213 and graduate standing.

**MA-GY 6233 Theory of Ordinary Differential Equations I (3 Credits)**

This course covers: Ordinary differential equations. Existence and uniqueness theorems. Linear systems. Isolated singularities. Self-adjoint eigenvalue problems. Geometric theory of differential equations in the plane. | Prerequisite: MA-GY 6213 and MA-GY 6223

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6243 Theory of Ordinary Differential Equations II (3 Credits)**

This course covers: Ordinary differential equations. Existence and uniqueness theorems. Linear systems. Isolated singularities. Self-adjoint eigenvalue problems. Geometric theory of differential equations in the plane. | Prerequisite: MA-GY 6213 and MA-GY 6223, MA-GY 6233 for MA-GY 6243.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6253 Theory of Partial Differential Equations I (3 Credits)**

This course covers: Partial differential equations. Cauchy-Kowalewski theorem. First-order differential equations, systems of differential equations in two variables, characteristics and classification, hyperbolic, parabolic and elliptic systems. Well-posedness. | Prerequisites: MA-GY 6213 and MA-GY 6223

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6263 Theory of Partial Differential Equations II (3 Credits)**

This course covers: Partial differential equations. Cauchy-Kowalewski theorem. First-order differential equations, systems of differential equations in two variables, characteristics and classification, hyperbolic, parabolic and elliptic systems. Well-posedness. | Prerequisites: MA-GY 6253

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6283 Mathematical Modeling in Biology (3 Credits)**

This course covers: Linear and nonlinear difference equations for population growth and propagation. Stability. Competitive systems. Growth of microorganisms. Steady states in chemostats. Predator-prey models. Populations of infectious diseases. Michaelis-Menten kinetics. Cooperative reactions. Hodgkin-Huxley equations. Fitzhugh-Nagumo model of nerve impulses. Conservation equations. Convection and diffusion of species. Transport in axon. Slime molds. Aggregation. Morphogenesis. | Prerequisite: MA-UY 2122, MA-UY 2132.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6303 Elements of Complex Analysis (3 Credits)**

This course covers: Complex numbers, analytic functions, Cauchy's theorem and consequences, isolated singularities, analytic continuation, open mapping theorem, infinite series and products, harmonic and subharmonic functions, maximum principle, fractional linear transformations, geometric and local properties of analytic functions, Weierstrass Theorem, normal families, residues, conformal mapping, Riemann mapping theorem, branch points, second order linear O.D.E.'s. | Prerequisites: MA-UY 2122 and MA-UY 2132 or equivalent. Co-Requisite: Note: Not open to students who have taken MA-UY 3112 or MA-UY 4433.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6313 Applications of Complex Analysis (3 Credits)**

This course continues MA-GY 6303. Topics covered: Residues, complex integration, Laplace transforms, Harmonic functions and classical examples from thermodynamics, electricity and magnetism, fluid flow, The Schwarz-Christoffel transformation. | Prerequisites: MA-GY 6303.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6403 Elements of Geometry and Topology (3 Credits)**

This course covers: Differential geometry in the plane. Introduction to transformation groups. Space curves and ruled surfaces. Tensors and exterior forms. Manifolds and tensor fields. Theory of surfaces. Introduction to Riemannian geometry. | Prerequisite: MA-GY 2122 and MA-GY 2132 or equivalent.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6513 Applied Statistics I (Data Analysis) (3 Credits)**

This course covers: Treatment of statistical methods and application to analysis of data, fitting of functions to data. Estimation of population parameters, t-tests, chi square tests, rank tests. | Prerequisite: MA-UY 1124 or equivalent.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6523 Regression-Analysis of Variance-Time Series Analysis (3 Credits)**

This course discusses models and computational schemes associated with correlation, regression coefficients, analysis of variance and time series models. | Prerequisite: MA-UY 4113 or MA-GY 6513.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6583 Calculus of Variations (3 Credits)**

This course covers: Classical problems, such as geodesics, brachistochrones, isoperimetric problems. Euler equations. Geodesic coverings. Weierstrass condition. Hamilton-Jacobi equation. First and second variations. Transversality. Convex sets and functions. Duality. Existence theorems. Generalized curves. Control theory. Time-optimal problems. Optimal processes. Extension of elementary theory of maxima and minima. Euler equations, conditions of Weierstrass, Legendre and Jacobi; Mayer fields; Hamilton-Jacobi equations; transversality; conjugate and focal points. Applications to geodesics, minimal surfaces, isoperimetric problems, Hamilton's principle, Fermat's principle, brachistochrones. | Prerequisite: MA-UY 4623 or MA-GY 6223.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6653 Numerical Analysis (3 Credits)**

This course covers: Interpolation. Approximation of functions by polynomials. Fast Fourier transform. Numerical integration. Solution of nonlinear equations. Iterative improvement of solutions of linear equations. Eigenvalues of matrices. Numerical solution of ordinary differential equations. | Prerequisites: MA-UY 2122, MA-UY 2132 and some experience in computer programming.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6663 Numerical Solution of Partial Differential Equations (3 Credits)**

This course covers: Stability, consistency and convergence of finite-difference methods for initial-value problems. Explicit and implicit schemes. Alternating direction methods and fractional-step methods. Iterative solutions of finite-difference equations for elliptic boundary value problems. Finite elements. Integral equation methods. Nonlinear semigroups, conservation laws and level set methods. | Prerequisites: MA-GY 6013, MA-GY 6653 and some experience in computer programming.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6683 Partial Differential Equations of Mathematical Physics (3 Credits)**

This course covers: First and second order partial differential equations and systems of equations. Initial and boundary value problems. Fundamental solutions and Green's functions. Theory of characteristics. Eigenvalue problems. Rayleigh-Ritz and Ritz-Galerkin methods. Approximate and asymptotic methods. Nonlinear equations. Applications. | Prerequisite: MA-UY 4623 or equivalent.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6813 Elements of Probability (3 Credits)**

This course covers: Probability of events, distribution of random variables, joint distribution, transformations. | Prerequisite: MA-UY 2122 and MA-UY 3012 or equivalent.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6823 Stochastic Processes (3 Credits)**

This course covers: Normal and stationary processes, Wiener processes, Poisson and renewal processes, Markov processes. | Prerequisite: MA-GY 6813 or equivalent.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6833 Statistical Inference I (3 Credits)**

This course covers: Point and interval estimation of statistical parameters. Theory of statistical estimators. Fundamentals of statistical tests of hypotheses. Second semester: extended theory of hypothesis testing, including sequential tests. Nonparametric methods in statistics. | Prerequisite: MA-GY 6813 or equivalent.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6843 Statistical Inference II (3 Credits)**

This course covers: Point and interval estimation of statistical parameters. Theory of statistical estimators. Fundamentals of statistical tests of hypotheses. Second semester: extended theory of hypothesis testing, including sequential tests. Nonparametric methods in statistics. | Prerequisite: MA-GY 6833

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6853 Multivariate Analysis (3 Credits)**

This course covers: Multivariate normal distribution. Simple, partial and multiple correlation. Generalization of student's ratio. Tests of significance of sets of means. Tests of general linear hypothesis. Some generalizations of analysis of variance. | Prerequisite: MA-GY 6843.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6863 Regression and Analysis of Variance (3 Credits)**

This course covers: Linear regression of one or more independent variables. Least square estimates regression coefficients. Gauss-Markov theorem. Confidence regions for and tests of hypotheses about regression coefficients. Tests of general linear hypothesis. Multiple classification in analysis of variance. Power of F-test. Alternative models: I and II, mixed models, analysis of covariance and components of variance. | Prerequisite: MA-GY 6843.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6873 Nonparametric Methods in Statistics (3 Credits)**

This course covers: Statistical methods not bound by assumption of known parametric form of the distribution of observations. Applications to engineering and scientific research in which observations are not ordered on a numerical scale. Order statistics, tolerance regions, permutation tests, goodness of fit tests, limiting distributions and large-sample properties of tests. | Prerequisite: MA-GY 6813.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6913 Time Series Analysis I (3 Credits)**

In this course, students carefully study tractable models for statistical analysis of scalar time series. Models treated: (1) "error plus trend" models, (2) stationary stochastic process models with special emphasis on autoregressive models. Estimation, tests of hypotheses and multiple-decision procedures for these models. Spectral representation and filtering, estimation of spectral density. | Prerequisite: MA-GY 6813 and MA-GY 6843

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6923 Time Series Analysis II (3 Credits)**

In this course, students carefully study tractable models for statistical analysis of scalar time series. Models treated: (1) "error plus trend" models, (2) stationary stochastic process models with special emphasis on autoregressive models. Estimation, tests of hypotheses and multiple-decision procedures for these models. Spectral representation and filtering, estimation of spectral density. | Prerequisites: MA-GY 6913

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6963 Statistics (3 Credits)**

*Typically offered Spring*

Topics to be covered in this course include various statistical models (sampling model, randomization methods), estimation and margins of error (MLE, confidence intervals, asymptotic theory, efficiency and sufficiency, robustness), likelihood theory (score functions and ratio tests), Bayes theory, decision theory (hypothesis testing, goodness of fit, shrinkage), and finally, an introduction to some common computational methods (bootstrap, Markov Chain-Monte Carlo). | Prerequisites: Undergraduate level proficiency in Linear Algebra and Multivariable Calculus. Graduate level proficiency in Probability, at the level of MATH-GA 2901, MA-GY 6813 or ECE-GY 6303.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 6973 COMPUTATIONAL STATISTICS (3 Credits)**

*Typically offered Fall*

Computation plays a central role in modern statistics and machine learning. This course aims to cover topics needed to develop a broad working knowledge of modern computational statistics. We seek to develop a practical understanding of how and why existing methods work, enabling effective use of modern statistical methods. Achieving these goals requires familiarity with diverse topics in statistical computing, computational statistics, computer science, and numerical analysis. Specific topics include: intro to numerical linear algebra, regression and Gaussian processes, Newton's method and optimization, numerical integration, random variable generation, Markov chain Monte Carlo (MCMC) and variance reduction, the Bootstrap, density estimation, and an introduction to modern methods in machine learning (neural networks and deep learning). | Prerequisites: Undergraduate-level proficiency in Linear Algebra and Multivariable Calculus; Undergraduate-level proficiency in Probability and Statistics; Programming Experience required.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 7013 Abstract Algebra (3 Credits)**

This course covers: Basic algebraic structures, groups, rings, fields, integral domains and modules. Field extensions and Galois theory. | Prerequisite: MA-GY 6013 or equivalent.

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No

**MA-GY 7033 Linear Algebra I (3 Credits)**

*Typically offered occasionally*

This course covers: Basic ideas of linear algebra: Groups, Rings, Fields, vector spaces, basis, dependence, independence, dimension. Relation to solving systems of linear equations and matrices. Homomorphisms, duality, inner products, adjoints and similarity. | Prerequisites: MA-UY 2034 and MA-UY 2114 or Graduate Standing

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** No



**MA-GY 7043 Linear Algebra II (3 Credits)***Typically offered occasionally*

This course continues MA-GY 7033. Topics covered: Basic concepts of linear algebra continuing with: Range, nullity, determinants and eigenvalues of matrices and linear homomorphisms, the polar decomposition and spectral properties of linear maps, orthogonality, adjointness and its applications. | Prerequisite: MA-GY 7033.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** No**Prerequisites:** MA-GY 7033 and graduate standing.**MA-GY 7213 Real and Complex Analysis I (3 Credits)**

This course provides rigorously and comprehensively treats real analysis.

Topics covered: Outer measure, Lebesgue measure, Lebesgue integral, convergence theorems, functions of bounded variation, integration in measure spaces, the Radon- Nikodym Theorem and Fubini's theorem. | Prerequisites: MA-GY 6213 and MA-GY 6223 or equivalent.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** No**MA-GY 7223 Real and Complex Analysis II (3 Credits)**

This course continues MA-GY 7213 and provides a rigorous and comprehensive treatment of complex analysis. Topics covered: Analytic and meromorphic functions, differentiation and integration, Cauchy's theorem, Morera's theorem, Power and Laurent series, residue theory, Rouché's theorem, conformal mappings, the Riemann mapping theorem and Riemann surfaces. | Prerequisite: MA-GY 7213.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** No**MA-GY 7313 Functional Analysis I (3 Credits)**

This course, together with its sequel MA-GY 7323, introduces the language and methods of functional analysis. It covers normed spaces, Hilbert spaces, bounded linear functionals, Hahn-Banach theorem, the dual space, bounded operators, Fredholm theory of compact operators, self-adjoint operators and applications to classical analysis. | Prerequisite: MA-GY 6013 and MA-GY 7213

**Grading:** Grad Poly Graded**Repeatable for additional credit:** No**MA-GY 7323 FUNCTIONAL ANALYSIS II (3 Credits)**

This course, together with its sequel MA-GY 7323, introduces the language and methods of functional analysis. It covers normed spaces, Hilbert spaces, bounded linear functionals, Hahn-Banach theorem, the dual space, bounded operators, Fredholm theory of compact operators, self-adjoint operators and applications to classical analysis. | Prerequisite: MA-GY 7313

**Grading:** Grad Poly Graded**Repeatable for additional credit:** No**MA-GY 7333 Measure Theory I (3 Credits)**

This course presents a unified treatment of that part of measure theory that is most useful for its application in modern analysis. Topics covered: Sets and classes, measures and outer measures, measurable functions, integration, general set functions, product spaces, transformations, probability. The dominated convergence theorem, Riesz Representation Theorem, Vitali-Caratheodory theorem, etc. are covered in conjunction with many examples. | Prerequisite: Graduate status.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** No**MA-GY 7343 Measure Theory II (3 Credits)**

This course continues MA-GY 7333 and presents a unified treatment of that part of measure theory that is most useful for applications in modern analysis. Topics covered: Fubini's theorem, convolutions and distributions are applied to explicit examples. In this part, Baire's theorem, the Banach-Steinhaus theorem, the Open Mapping theorem, the Hahn-Banach Theorem are derived with the properties of the Radon-Nikodym derivatives to naturally generalize calculus both differential and integral. | Prerequisite: MA-GY 7333.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** No**MA-GY 7353 Fourier and Laplace Transforms (3 Credits)**

This course presents in a unified manner the fundamentals of both continuous and discrete versions of the Fourier and Laplace transforms. Topics covered: Application of transform methods to partial differential equations of mathematical physics. Includes introduction to the Wiener-Hopf technique. | Prerequisite: Graduate status or permission of adviser.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** No**MA-GY 7403 Topology (3 Credits)**

This course covers: Topological spaces. Compactness, connectedness, continua, extension theorems and metrization theorems. Simplexes, simplicial topology and applications. Fixed point theorems. Graphs and networks. Homology and cohomology theory. Introduction to Morse theory. | Prerequisite: MA-GY 6213 and MA-GY 6223 or equivalent. Co-Requirement:

**Grading:** Grad Poly Graded**Repeatable for additional credit:** No**MA-GY 7503 Manifolds and Lie Groups (3 Credits)**

This course covers: Elementary theory of manifolds. Tangent space, mappings, submanifolds, fields, fiber bundles, Lie groups, homogeneous spaces. Elements of the theory of connections, Riemannian geometry. Imbedded manifolds. Calculus of variations. Harmonic forms, complex manifolds and Morse theory. | Prerequisite: MA-GY 6213 and MA-GY 6223.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** No**MA-GY 7543 Topological Methods in Analysis (3 Credits)**

This course covers: Aspects of topological methods and applications to existence theorems in analysis. Use of fixed-point theorems and topological degree to study properties of solutions to ordinary and partial differential equations. No previous courses in topology are required. | Prerequisite: MA-UY 4623 or MA-GY 6223.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** No**MA-GY 7603 TOPICS IN ALGEBRA (3 Credits)**

Course content varies. In spring of the year before the course offering, a detailed description is posted and mailed to all graduate mathematics students. | Prerequisites: MA-GY 7603: MA-GY 7013 /MA-GY 7613: MA-GY 7603.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 7613 Topics in Algebra II (3 Credits)**

Course content varies. In spring of the year before the course offering, a detailed description is posted and mailed to all graduate mathematics students. | Prerequisite: MA-GY 7603

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes

**MA-GY 7623 Topics in Linear Algebra I (3 Credits)**

Course content varies. | Prerequisites: MA-GY 7033 and MA-GY 7043

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 7633 Topics in Linear Algebra II (3 Credits)**

Course content varies. | Prerequisites: MA-GY 7623

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 7643 Topics in Real Analysis I (3 Credits)**

Course content varies. | Prerequisites: MA-GY 6213 and MA-GY 6223

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 7653 TOPICS IN REAL ANALYSIS II (3 Credits)**

Course content varies. | Prerequisites: MA-GY 7643

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 7663 Topics in Complex Analysis I (3 Credits)**

Course content varies. | Prerequisites: MA-GY 6303 and MA-GY 6313

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 7673 Topics in Complex Analysis II (3 Credits)**

Course content varies. | Prerequisites: MA-GY 7663

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 7683 Topics in Geometry I (3 Credits)**

Course content varies. | Prerequisites: MA-GY 6403 and MA-GY 7693

**Grading:** Grad Poly Graded**Repeatable for additional credit:** No**MA-GY 7693 Topics in Geometry II (3 Credits)**

Course content varies. | Prerequisites: MA-GY 7683

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 7703 Topics in Topology I (3 Credits)**

Course content varies. | Prerequisites: MA-GY 6403 and MA-GY 7713

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 7713 Topics in Topology II (3 Credits)**

Course content varies. | Prerequisites: MA-GY 7703

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 7723 TOPICS IN APPLIED MATHEMATICS I (3 Credits)***Typically offered occasionally*

Course content varies. | Prerequisites: Graduate status or permission of advisor.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 7733 Topics in Applied Mathematics II (3 Credits)***Typically offered occasionally*

Course content varies. | Prerequisites: MA-GY 7723

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 7743 Topics in Probability I (3 Credits)**

Course content varies. | Prerequisites: MA-GY 6813

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 7753 Topics in Probability II (3 Credits)**

Course content varies. | Prerequisites: MA-GY 7743

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 7763 Topics in Statistics I (3 Credits)***Typically offered occasionally*

Course content varies. | Prerequisites: MA-GY 6833 and MA-GY 6843

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 7773 Topics in Statistics II (3 Credits)***Typically offered occasionally*

Course content varies. | Prerequisites: MA-GY 7763

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 7813 Probability (3 Credits)**

This course covers: Measure-theoretic foundations of probability. Expectations, distribution functions, characteristic functions. Modes of convergence of random variables and distribution functions. Laws of large numbers. The multidimensional central-limit theorems and related asymptotic expansions. Infinitely divisible distributions. | Prerequisite: MA-GY 7213.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** No**MA-GY 7833 Stochastic Processes I (3 Credits)**

This course covers: Foundations of stochastic processes. Kolmogorov's extension theorem. Properties of sample paths. Conditional expectation. Martingales. Classes of stochastic processes. Gaussian processes, Markov processes and others. Second order properties. Stationary processes. Applications. | Prerequisite: MA-GY 7813

**Grading:** Grad Poly Graded**Repeatable for additional credit:** No**MA-GY 7843 Stochastic Processes II (3 Credits)**

This course covers: Foundations of stochastic processes. Kolmogorov's extension theorem. Properties of sample paths. Conditional expectation. Martingales. Classes of stochastic processes. Gaussian processes, Markov processes and others. Second order properties. Stationary processes. Applications. | Prerequisite: MA-GY 7833

**Grading:** Grad Poly Graded**Repeatable for additional credit:** No**MA-GY 8003 Advanced Topics in Discrete Mathematics I (3 Credits)**

Course content varies. In spring of year before course offering, a detailed description is posted and mailed to all graduate mathematics students. | Prerequisite: MA-GY 6003

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8013 ADVANCED TOPICS IN DISCRETE MATHEMATICS II (3 Credits)**

Course content varies. In spring of year before course offering, a detailed description is posted and mailed to all graduate mathematics students. | Prerequisite: MA-GY 6003 / MA-GY 8013: MA-GY 8003.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8023 ADVANCED TOPICS IN ALGEBRA I (3 Credits)**

Course content varies. | Prerequisite: MA 7033-GY and MA-GY 7043 / MA-GY 8033: MA-GY 8023.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes

**MA-GY 8033 Advanced Topics in Algebra II (3 Credits)**

Course content varies. | Prerequisite: MA-GY 8023

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8043 Advanced Topics in Real Analysis I (3 Credits)**

Course content varies. | Prerequisite: MA-GY 6213 and MA-GY 6223 / MA-GY 8053: MA-GY 8043.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8053 Advanced Topics in Real Analysis II (3 Credits)**

Course content varies. | Prerequisite: MA-GY 6213 and MA-GY 6223 / MA-GY 8053: MA-GY 8043.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8063 ADVANCED TOPICS IN LINEAR ALGEBRA I (3 Credits)**

Course content varies. | Prerequisite: MA-GY 6303 and MA-GY 6313

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8073 ADVANCED TOPICS IN LINEAR ALGEBRA II (3 Credits)**

Course content varies. | Prerequisite: MA-GY 8073: MA-GY 8063.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8103 Advanced Topics in Complex Analysis I (3 Credits)**

Course content varies. | Prerequisite: MA-GY 7213 and MA-GY 7223

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8113 Advanced Topics in Complex Analysis II (3 Credits)**

Course content varies. | Prerequisite: MA-GY 7213 and MA-GY 7223

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8123 Advanced Topics in Geometry I (3 Credits)**

Course content varies. | Prerequisite: MA-GY 6403

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8133 Advanced Topics in Geometry II (3 Credits)**

Course content varies. | Prerequisite: MA-GY 6403

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8143 Advanced Topics in Topology I (3 Credits)**

Course content varies. | Prerequisite: MA-GY 7403

**Grading:** Grad Poly Graded**Repeatable for additional credit:** No**MA-GY 8153 Advanced Topics in Topology II (3 Credits)**

Course content varies. | Prerequisite: MA-GY 7403

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8163 Advanced Topics in Applied Mathematics I (3 Credits)**

Course content varies. | Prerequisite: MA-GY 6003

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8173 Advanced Topics in Applied Mathematics II (3 Credits)**

Course content varies. | Prerequisite: MA-GY 6003

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8183 Advanced Topics in Probability I (3 Credits)**

Course content varies. | Prerequisite: MA-GY 6813

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8193 Advanced Topics in Probability II (3 Credits)**

Course content varies. | Prerequisite: MA-GY 6813

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8203 Advanced Topics in Statistics I (3 Credits)**

Course content varies. | Prerequisite: MA-GY 6833 and MA-GY 6843

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8213 ADVANCED TOPICS IN STATISTICS II (3 Credits)**

Course content varies. | Prerequisite: MA-GY 6833 and MA-GY 6843.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8383 ADVANCED TOPICS IN DIFFERENTIAL EQUATIONS (3 Credits)**

Course content varies. | Prerequisite: MA-GY 6233 and MA-GY 6243.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 8583 Advanced Topics in Differential Geometry (3 Credits)**

Course content varies. | Prerequisite: MA-GY 6403.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 9413 Reading in Mathematics I (3 Credits)***Typically offered occasionally*

In this course, reading is guided by faculty members and devoted mainly to scholarly papers. | Prerequisite: Department's permission

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 9423 Reading in Mathematics II (1-3 Credits)**

In this course, reading is guided by faculty members and devoted mainly to scholarly papers. | Prerequisite: Department's permission.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 9433 Reading in Mathematics III (3 Credits)***Typically offered occasionally*

In this course, reading is guided by faculty members and devoted mainly to scholarly papers. | Prerequisite: Department's permission.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 9443 Reading in Mathematics VI (3 Credits)***Typically offered occasionally*

In this course, reading is guided by faculty members and devoted mainly to scholarly papers. | Prerequisite: Department's permission.

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes**MA-GY 9453 READINGS IN MATHEMATICS V (3 Credits)***Typically offered occasionally*

In this course, reading is guided by faculty members and devoted mainly to scholarly papers. | Prerequisite: Department's permission

**Grading:** Grad Poly Graded**Repeatable for additional credit:** Yes

**MA-GY 9463 READINGS IN MATH VI (3 Credits)**

In this course, reading is guided by faculty members and devoted mainly to scholarly papers. | Prerequisite: Department's permission

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** Yes

**MA-GY 9583 Selected Topics in Advanced Mathematics I (3 Credits)**

This course reviews current mathematics research. Specific topics vary, depending on instructor. | Prerequisite: Department's permission

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** Yes

**MA-GY 9593 Selected Topics in Advanced Mathematics II (3 Credits)**

This course reviews current mathematics research. Specific topics vary, depending on instructor. | Prerequisite: Department's permission

**Grading:** Grad Poly Graded

**Repeatable for additional credit:** Yes