Mathematics (MATH)

Courses

MATH 1A. Pre-Calculus. 4 Workload Units.
Basic equations and inequalities, linear and quadratic functions, and systems of simultaneous equations. Course may be offered online.

MATH 1B. Pre-Calculus. 4 Units.
Preparation for calculus and other mathematics courses. Exponentials, logarithms, trigonometry, polynomials, and rational functions. Satisfies no requirements other than contribution to the 180 units required for graduation. Course may be offered online.

Prerequisite: MATH 1A or placement into MATH 1B via the Calculus Placement exam, or a score of 450 or higher on the Mathematics section of the SAT Reasoning Test.

MATH 2A. Single-Variable Calculus. 4 Units.
Introduction to derivatives, calculation of derivatives of algebraic and trigonometric functions; applications including curve sketching, related rates, and optimization. Exponential and logarithm functions.

Prerequisite: MATH 1B or placement into MATH 2A via the Calculus Placement exam (fee required), or a score of 3 on the AP Calculus AB exam, or a score of 600 or higher on the Mathematics section of the SAT Reasoning Test. MATH 1B with a grade of C or better.

Restriction: School of Physical Sciences, School of Engineering, and School of Information and Computer Sciences majors have first consideration for enrollment.

(Vb)

MATH 2B. Single-Variable Calculus. 4 Units.
Definite integrals; the fundamental theorem of calculus. Applications of integration including finding areas and volumes. Techniques of integration. Infinite sequences and series. Parametric and polar equations.

Prerequisite: MATH 2A.

Restriction: School of Physical Sciences, School of Engineering, and School of Information and Computer Sciences majors have first consideration for enrollment.

(Vb)

MATH 2D. Multivariable Calculus. 4 Units.
Differential and integral calculus of real-valued functions of several real variables, including applications. Polar coordinates.

Prerequisite: MATH 2A and MATH 2B.

Overlaps with MATH H2D.

Restriction: School of Physical Sciences, School of Engineering, and School of Information and Computer Sciences majors have first consideration for enrollment.

(Vb)

MATH 2E. Multivariable Calculus. 4 Units.
The differential and integral calculus of vector-valued functions. Implicit and inverse function theorems. Line and surface integrals, divergence and curl, theorems of Greens, Gauss, and Stokes.

Prerequisite: MATH 2D.

Overlaps with MATH H2E.

Restriction: School of Physical Sciences and School of Engineering majors have first consideration for enrollment.
MATH 3A. Introduction to Linear Algebra. 4 Units.
Systems of linear equations, matrix operations, determinants, eigenvalues and eigenvectors, vector spaces, subspaces and dimension.
Prerequisite: MATH 2B.
Overlaps with MATH 6G, I&C SCI 6N.
Restriction: School of Physical Sciences and School of Engineering majors have first consideration for enrollment.

MATH 3D. Elementary Differential Equations. 4 Units.
Linear differential equations, variation of parameters, constant coefficient cookbook, systems of equations, Laplace transforms, series solutions.
Prerequisite: MATH 2D and MATH 3A.
Restriction: School of Physical Sciences and School of Engineering majors have first consideration for enrollment.

MATH 4. Mathematics for Economists. 4 Units.
Topics in linear algebra and multivariable differential calculus suitable for economic applications.
Prerequisite: MATH 2B.
Overlaps with MATH 2D, MATH 2J, MATH 3A.
Restriction: MATH 4 may not be taken for credit if taken after MATH 2D and either MATH 2J or MATH 3A.

MATH 6G. Linear Algebra. 4 Units.
Linear equations, vector spaces and subspaces, linear functions and matrices, linear codes, determinants, scalar products.
Prerequisite: High school mathematics through trigonometry.
Overlaps with MATH 3A, I&C SCI 6N.

MATH 8. Explorations in Functions and Modeling. 4 Units.
Explorations of applications and connections in topics in algebra, geometry, calculus, and statistics for future secondary math educators. Emphasis on nonstandard modeling problems.
Corequisite: MATH 2A.

MATH 13. Introduction to Abstract Mathematics. 4 Units.
Introduction to formal definition and rigorous proof writing in mathematics. Topics include basic logic, set theory, equivalence relations, and various proof techniques such as direct, induction, contradiction, contrapositive, and exhaustion.
Prerequisite: MATH 2A or I&C SCI 6D.
Restriction: Mathematics majors have first consideration for enrollment.

MATH 77A. Mathematics and Computation in the Digital Age: Introduction to Signal Processing. 4 Units.
Signals in Matlab; blurring, filtering; elements of linear algebra, statistics, optimization; blind matrix inversion; de-correlation method, stochastic gradient descent method, applications to sounds and images.
Prerequisite: MATH 2B and I&C SCI 31.
Same as I&C SCI 77A.
Restriction: Lower-division students only.
MATH 77B. Mathematics and Computation in the Digital Age: Introduction to Collaborative Filtering. 4 Units.
Basic concepts of collaborative filtering; clustering; matrix factorization and principal components analysis; regression; classification: naive Bayes classifier, decision trees, Perceptron (neural networks).
Prerequisite: MATH 2B and I&C SCI 31.
Same as I&C SCI 77B.
Restriction: Lower-division students only.

MATH 77C. Mathematics and Computation in the Digital Age: Introduction to Image Processing. 4 Units.
Image de-noising, de-blurring, low pass filtering; image segmentation and classification; Sparse representation; visualization.
Prerequisite: MATH 2B and I&C SCI 31.
Same as I&C SCI 77C.
Restriction: Lower-division students only.

MATH 77D. Mathematics and Computation in the Digital Age: Intro to Game Simulation and Analysis. 4 Units.
Combinatorial Game Theory--game classification, tree graphs, strategy analysis, Sprague Grundy functions, Bouton's Theorem; Zero-Sum and General-Sum Game Theory--pay off matrices, Minimax Theorem, Nash equilibrium; machine learning--search algorithms.
Prerequisite: MATH 2B and I&C SCI 31.
Same as I&C SCI 77D.
Restriction: Lower-division students only.

MATH 105A. Numerical Analysis. 4 Units.
Introduction to the theory and practice of numerical computation. Floating point arithmetic, roundoff; solving transcendental equations; quadrature; linear systems, eigenvalues, power method.
Corequisite: MATH 105LA.
Prerequisite: MATH 3A. Some acquaintance with computer programming.
Overlaps with ENGRMAE 185.

MATH 105B. Numerical Analysis. 4 Units.
Introduction to the theory and practice of numerical computation. Lagrange interpolation, finite differences, splines, Padé approximations; Gaussian quadrature; Fourier series and transforms.
Corequisite: MATH 105LB.
Prerequisite: MATH 105A.

MATH 105LA. Numerical Analysis Laboratory. 1 Unit.
Provides practical experience to complement the theory developed in Mathematics 105A.
Corequisite: MATH 105A.

MATH 105LB. Numerical Analysis Laboratory. 1 Unit.
Provides practical experience to complement the theory developed in Mathematics 105B.
Corequisite: MATH 105B.

MATH 107. Numerical Differential Equations. 4 Units.
Theory and applications of numerical methods to initial and boundary-value problems for ordinary and partial differential equations.
Corequisite: MATH 107L.
Prerequisite: MATH 3D and MATH 105A and MATH 105B.
MATH 107L. Numerical Differential Equations Laboratory. 1 Unit.
Provides practical experience to complement the theory developed in Mathematics 107.
Corequisite: MATH 107.

MATH 112A. Introduction to Partial Differential Equations and Applications. 4 Units.
Introduction to ordinary and partial differential equations and their applications in engineering and science. Basic methods for classical PDEs (potential, heat, and wave equations). Classification of PDEs, separation of variables and series expansions, special functions, eigenvalue problems.
Prerequisite: MATH 2D and MATH 3D.

MATH 112B. Introduction to Partial Differential Equations and Applications. 4 Units.
Introduction to partial differential equations and their applications in engineering and science. Basic methods for classical PDEs (potential, heat, and wave equations). Green functions and integral representations, method of characteristics.
Prerequisite: MATH 2E and MATH 112A.

MATH 112C. Introduction to Partial Differential Equations and Applications. 4 Units.
Nonhomogeneous problems and Green’s functions, Sturm-Liouville theory, general Fourier expansions, applications of partial differential equations in different areas of science.
Prerequisite: MATH 3D and MATH 2D and MATH 3A.

MATH 113A. Mathematical Modeling in Biology. 4 Units.
Discrete mathematical and statistical models; difference equations, population dynamics, Markov chains, and statistical models in biology.
Prerequisite: MATH 2B.

MATH 113B. Mathematical Modeling in Biology. 4 Units.
Linear algebra; differential equations models; dynamical systems; stability; hysteresis; phase plane analysis; applications to cell biology, viral dynamics, and infectious diseases.
Prerequisite: MATH 113A.

MATH 113C. Mathematical Modeling in Biology. 4 Units.
Partial differential equations models in biology such as one dimensional blood flow, morphogen gradients, and tumor growth; stochastic models in cancer and epidemiology.
Prerequisite: MATH 113B.

MATH 114A. Applied Complex Analysis. 4 Units.
Introduction to complex functions and their applications to engineering and science. Complex numbers, elementary functions; analytic functions; complex integration; power series; residue theory; conformal maps; applications.
Prerequisite: MATH 2D and MATH 3A.
Overlaps with MATH 147.

MATH 115. Mathematical Modeling. 4 Units.
Mathematical modeling and analysis of phenomena that arise in engineering physical sciences, biology, economics, or social sciences.
Prerequisite: Corequisite or prerequisite: MATH 112A or ENGRMAE 140. MATH 2D and (MATH 3A or MATH 6G) and MATH 3D.

MATH 117. Dynamical Systems. 4 Units.
Introduction to the modern theory of dynamical systems including contraction mapping principle, fractals and chaos, conservative systems, Kepler problem, billiard models, expanding maps, Smale’s horseshoe, topological entropy.
Prerequisite: MATH 3D and MATH 140A.

MATH 118. The Theory of Differential Equations. 4 Units.
Existence and uniqueness of solutions, continuous dependence of solutions on initial conditions and parameteres, Lyapunov and asymptotic stability, Floquet theory, nonlinear systems, and bifurcations.
Prerequisite: MATH 3D and MATH 140A.
MATH 119. Boundary Value Problems. 4 Units.
Introduction to boundary value problems including Green's function representations, maximum principle, variational formulations, Sturm-Liouville problems, eigenfunction expansions, existence and uniqueness for nonlinear problems, method of shooting, finite difference methods.

Prerequisite: MATH 3D and MATH 140A.

MATH 120A. Introduction to Abstract Algebra: Groups. 4 Units.
Axioms for group theory; permutation groups, matrix groups. Isomorphisms, homomorphisms, quotient groups. Advanced topics as time permits. Special emphasis on doing proofs.

Prerequisite: (MATH 3A OR MATH 6G) and MATH 13. MATH 13 with a grade of C- or better.

Restriction: Mathematics majors have first consideration for enrollment.

MATH 120B. Introduction to Abstract Algebra: Rings and Fields. 4 Units.
Basic properties of rings; ideals, quotient rings; polynomial and matrix rings. Elements of field theory.

Prerequisite: MATH 120A.

Restriction: Mathematics majors have first consideration for enrollment.

MATH 120C. Introduction to Abstract Algebra: Galois Theory. 4 Units.
Galois Theory: proof of the impossibility of certain ruler-and-compass constructions (squaring the circle, trisecting angles); nonexistence of analogues to the "quadratic formula" for polynomial equations of degree 5 or higher.

Prerequisite: MATH 120B.

Restriction: Mathematics majors have first consideration for enrollment.

MATH 121A. Linear Algebra. 4 Units.

Prerequisite: (MATH 3A OR MATH 6G) and MATH 13. MATH 13 with a grade of C- or better.

Restriction: Mathematics majors have first consideration for enrollment.

MATH 121B. Linear Algebra. 4 Units.
Introduction to modern abstract linear algebra. Special emphasis on students doing proofs. Canonical forms; inner products; similarity of matrices.

Prerequisite: MATH 121A.

Restriction: Mathematics majors have first consideration for enrollment.

MATH 130A. Probability and Stochastic Processes. 4 Units.
Basic concepts of random variables, distributions, independence, correlations, moments, limit theorems, conditional probability, Markov chains, gambler's ruin, branching process, birth and death processes, numerical simulations in Matlab.

Prerequisite: MATH 2A and MATH 2B and (MATH 3A or MATH 6G).

Overlaps with MATH 131A, MATH 132A, STATS 120A.

MATH 130B. Probability and Stochastic Processes. 4 Units.
Exponential distributions, Poisson processes, continuous time Markov chains, renewal theory, insurance ruin and claim problems, numerical simulations in Matlab.

Prerequisite: MATH 130A OR MATH 131A or STATS 120A.

MATH 130C. Probability and Stochastic Processes. 4 Units.
Martingales, Invariance Principle, Brownian motions and applications in option pricing, stationary processes and applications in Wiener filter, numerical simulations in Matlab.

Prerequisite: MATH 130B.
MATH 131A. Introduction to Probability and Statistics. 4 Units.
Introductory course covering basic principles of probability and statistical inference. Axiomatic definition of probability, random variables, probability distributions, expectation.
Prerequisite: MATH 2A and MATH 2B and (MATH 2D or MATH 4).
Overlaps with MATH 130A, MATH 132A.

MATH 131B. Introduction to Probability and Statistics. 4 Units.
Introductory course covering basic principles of probability and statistical inference. Point estimation, interval estimating, and testing hypotheses, Bayesian approaches to inference.
Prerequisite: (MATH 131A or STATS 120A) and (MATH 3A or MATH 6G or MATH 4).

MATH 133A. Statistical Methods with Applications to Finance. 4 Units.
Overview of probability, statistics and financial concepts: distribution, point estimation, confidence interval, linear regression, hypothesis testing, principal component analysis, financial applications.
Prerequisite: MATH 130A or STATS 120A or MATH 2D or MATH 4.

MATH 133B. Statistical Methods with Applications to Finance. 4 Units.
Overview of markets and options: asset modeling, Brownian motion, risk neutrality, option pricing, value at risk, MC simulations.
Prerequisite: MATH 133A.

MATH 140A. Elementary Analysis. 4 Units.
Introduction to real analysis, including: convergence of sequence, infinite series, differentiation and integration, and sequences of functions. Students are expected to do proofs.
Prerequisite: MATH 2D and MATH 3A and MATH 13. MATH 13 with a grade of C- or better.
Restriction: Math majors have first consideration for enrollment.

MATH 140B. Elementary Analysis. 4 Units.
Introduction to real analysis including convergence of sequences, infinite series, differentiation and integration, and sequences of functions. Students are expected to do proofs.
Prerequisite: MATH 140A. MATH 140A with a grade of C- or better.
Restriction: Mathematics majors have first consideration for enrollment.

MATH 140C. Analysis in Several Variables . 4 Units.
Rigorous treatment of multivariable differential calculus. Jacobians, Inverse and Implicit Function theorems.
Prerequisite: MATH 140B.

MATH 141. Introduction to Topology. 4 Units.
The elements of naive set theory and the basic properties of metric spaces. Introduction to topological properties.
Prerequisite: MATH 140A.

MATH 146. Fourier Analysis. 4 Units.
Rigorous introduction to the theory of Fourier series and orthogonal expansions. Fourier transform.
Prerequisite: MATH 3D and MATH 140A and MATH 140B. Recommended: MATH 112A.

MATH 147. Complex Analysis. 4 Units.
Rigorous treatment of basic complex analysis: analytic functions, Cauchy integral theory and its consequences, power series, residue calculus, harmonic functions, conformal mapping. Students are expected to do proofs.
Corequisite: MATH 140B.
Prerequisite: MATH 140A.
Overlaps with MATH 114A.
Restriction: MATH 114A may not be taken for credit after MATH 147.
MATH 150. Introduction to Mathematical Logic. 4 Units.
First order logic through the Completeness Theorem for predicate logic.
Prerequisite: MATH 13 or (I&C SCI 6B and I&C SCI 6D). MATH 13 with a grade of C- or better.
Overlaps with LPS 105B, PHILOS 105B.

MATH 151. Set Theory. 4 Units.
Axiomatic development; infinite sets; cardinal and ordinal numbers.
Prerequisite: MATH 150.
Overlaps with SOC SCI 105A, LPS 105A.

MATH 152. Computability. 4 Units.
Computable functions; undecidability; Gödel's Incompleteness Theorem.
Prerequisite: MATH 150.
Overlaps with PHILOS 105C, LPS 105C.

MATH 161. Modern Geometry. 4 Units.
Euclidean Geometry; Hilbert's Axioms; Absolute Geometry; Hyperbolic Geometry; the Poincare Models; and Geometric Transformations.
Prerequisite: MATH 13 or (I&C SCI 6B and I&C SCI 6D). MATH 13 with a C- or better.
Restriction: Math majors have first consideration for enrollment.

MATH 162A. Introduction to Differential Geometry. 4 Units.
Applications of advanced calculus and linear algebra to the geometry of curves and surfaces in space.
Prerequisite: MATH 2E and MATH 3A and MATH 3D.

MATH 162B. Introduction to Differential Geometry. 4 Units.
Applications of advanced calculus and linear algebra to the geometry of curves and surfaces in space.
Prerequisite: MATH 162A.

MATH 171A. Mathematical Methods in Operations Research Linear Programming. 4 Units.
Simplex algorithm, duality, optimization in networks.
Prerequisite: MATH 3A or MATH 6G.

MATH 171B. Mathematical Methods in Operations Research Nonlinear Programming. 4 Units.
Conditions for optimality, quadratic and convex programming, search methods, geometric programming.
Prerequisite: MATH 2D and (MATH 3A or MATH 6G).

MATH 173A. Introduction to Cryptology. 4 Units.
Introduction to some of the mathematics used in the making and breaking of codes, with applications to classical ciphers and public key systems. The mathematics which is covered includes topics from number theory, probability, and abstract algebra.
Prerequisite: MATH 2B and (MATH 3A or MATH 6G) and (MATH 13 or (I&C SCI 6B and I&C SCI 6D)). MATH 13 with a grade of C- or better.

MATH 173B. Introduction to Cryptology. 4 Units.
Introduction to some of the mathematics used in the making and breaking of codes, with applications to classical ciphers and public key systems. The mathematics which is covered includes topics from number theory, probability, and abstract algebra.
Prerequisite: MATH 173A.

MATH 174A. Modern Graph Theory. 4 Units.
An introductory course emphasizing the fundamental concepts of graph theory by developing abilities to produce examples, following and devising simple proofs, and current applications of graph theory. Topics include: Graph Types; Matching in Graphs; Menger's Theorem; Kuratowski's Theorem.
Prerequisite: MATH 2B and (MATH 3A or MATH 6G) and (MATH 13 or (I&C SCI 6B and I&C SCI 6D)). MATH 13 with a grade of C- or better.
MATH 175. Combinatorics. 4 Units.
Introduction to combinatorics including basic counting principles, permutations, combinations, binomial coefficients, inclusion-exclusion, derangements, ordinary and exponential generating functions, recurrence relations, Catalan numbers, Stirling numbers, and partition numbers. Course may be offered online.
Prerequisite: MATH 2B and MATH 13. MATH 13 with a grade of C- or better.

MATH 176. Mathematics of Finance. 4 Units.
After reviewing tools from probability, statistics, and elementary differential and partial differential equations, concepts such as hedging, arbitrage, Puts, Calls, the design of portfolios, the derivation and solution of the Blac-Scholes, and other equations are discussed.
Prerequisite: MATH 3A.
Same as ECON 135.
Restriction: Mathematics, Economics, Quantitative Economics, and Business Economics majors have first consideration for enrollment.

MATH 180A. Number Theory. 4 Units.
Prerequisite: MATH 3A and MATH 13. MATH 13 with a grade of C- or better.
Restriction: Math majors have first consideration for enrollment.

MATH 180B. Number Theory. 4 Units.
Introduction to number theory and applications. Analytic number theory, character sums, finite fields, discrete logarithm, computational complexity. Introduction to coding theory. Other topics as time permits.
Prerequisite: MATH 180A.
Restriction: Mathematics majors have first consideration for enrollment.

MATH 184. History of Mathematics. 4 Units.
Topics vary from year to year. Some possible topics: mathematics in ancient times; the development of modern analysis; the evolution of geometric ideas. Students will be assigned individual topics for term papers.
Prerequisite: MATH 120A and MATH 140A.
Restriction: Math majors have first consideration for enrollment.

MATH 184L. History of Mathematics Lesson Lab. 1 Unit.
Aspiring math teachers research, design, present, and peer review middle school or high school math lessons that draw from history of mathematics topics.
Corequisite: MATH 184.
Prerequisite: PHY SCI 5.

MATH 189. Special Topics in Mathematics. 4 Units.
Offered from time to time, but not on a regular basis. Content and prerequisites vary with the instructor.
Prerequisite: Prerequisites vary.
Repeatability: Unlimited as topics vary.

MATH 191. Mathematical Modeling Seminar. 2 Units.
Developing, testing, and presenting mathematical models for real world problems. Students will prepare for and participate in the Mathematical Contest in Modeling (MCM) in late February. Separate contest registration fee required.
Prerequisite: MATH 3D.
Repeatability: May be taken for credit 2 times.
MATH 192. Studies in the Learning and Teaching of Secondary Mathematics. 2 Units.
Focus is on historic and current mathematical concepts related to student learning and effective math pedagogy, with fieldwork in grades 6-14.
Prerequisite: MATH 2D and MATH 2J and MATH 3D and (MATH 13 or MATH 120A or MATH 140A).
Grading Option: Pass/no pass only.
Repeatability: May be taken for credit 2 times.
Restriction: Upper-division students only. Math majors with specialization in Mathematics for Education only.

MATH 193. SMPP Capstone. 2 Units.
Capstone course for the Mathematics Subject-Matter Preparation (SMP) program. Engages students in reviewing and conducting current research on significant issues related to the teaching and learning of mathematics in the secondary classroom.
Corequisite: Recommended: MATH 192.
Repeatability: May be taken for credit 2 times.

MATH 194. Problem Solving Seminar. 2 Units.
Develops ability in analytical thinking and problem solving, using problems of the type found in the Mathematics Olympiad and the Putnam Mathematical Competition. Students taking the course in fall will prepare for and take the Putnam examination in December.
Grading Option: Pass/no pass only.
Repeatability: May be taken for credit 2 times.

MATH H195A. Honors Seminar. 4 Units.
Topics vary from year to year. Provides an integrative experience, including problem-solving and oral and written presentations. Required for the Honors Program in Mathematics and open to others with consent of instructor.
Restriction: Mathematics Honors Program students only.

MATH H195B. Honors Seminar. 4 Units.
Topics vary from year to year. Provides an integrative experience, including problem-solving and oral and written presentations. Required for the Honors Program in Mathematics and open to others with consent of instructor.
Restriction: Mathematics Honors Program students only.

MATH 199A. Special Studies in Mathematics. 2-4 Units.
Supervised reading. For outstanding undergraduate Mathematics majors in supervised but independent reading or research of mathematical topics.
Repeatability: Unlimited as topics vary.

MATH 199B. Special Studies in Mathematics. 2-4 Units.
Supervised reading. For outstanding undergraduate Mathematics majors in supervised but independent reading or research of mathematical topics.
Repeatability: Unlimited as topics vary.

MATH 199C. Special Studies in Mathematics. 2-4 Units.
Supervised reading. For outstanding undergraduate Mathematics majors in supervised but independent reading or research of mathematical topics.
Repeatability: Unlimited as topics vary.

MATH 205A. Introduction to Graduate Analysis. 5 Units.
Construction of the real number system, topology of the real line, concepts of continuity, differential and integral calculus, sequences and series of functions, equiconvergence, metric spaces, multivariable differential and integral calculus, implicit functions, curves and surfaces.
Prerequisite: MATH 2E and MATH 3A and MATH 13.

MATH 205B. Introduction to Graduate Analysis. 5 Units.
Construction of the real number system, topology of the real line, concepts of continuity, differential and integral calculus, sequences and series of functions, equiconvergence, metric spaces, multivariable differential and integral calculus, implicit functions, curves and surfaces.
Prerequisite: MATH 205A.
MATH 205C. Introduction to Graduate Analysis. 5 Units.
Construction of the real number system, topology of the real line, concepts of continuity, differential and integral calculus, sequences and series of functions, equicontinuity, metric spaces, multivariable differential and integral calculus, implicit functions, curves and surfaces.
Prerequisite: MATH 205B.

MATH 206A. Introduction to Graduate Algebra. 5 Units.
Introduction to abstract linear algebra, including bases, linear transformation, eigenvectors, canonical forms, inner products, symmetric operators. Introduction to groups, rings, and fields including examples of groups, group actions, Sylow theorems, modules over principal ideal domains, polynomials and Galois groups.
Prerequisite: MATH 3A.

MATH 206B. Introduction to Graduate Algebra. 5 Units.
Introduction to abstract linear algebra, including bases, linear transformation, eigenvectors, canonical forms, inner products, symmetric operators. Introduction to groups, rings, and fields including examples of groups, group actions, Sylow theorems, modules over principal ideal domains, polynomials and Galois groups.
Prerequisite: MATH 206A.

MATH 206C. Introduction to Graduate Algebra. 5 Units.
Introduction to abstract linear algebra, including bases, linear transformation, eigenvectors, canonical forms, inner products, symmetric operators. Introduction to groups, rings, and fields including examples of groups, group actions, Sylow theorems, modules over principal ideal domains, polynomials and Galois groups.
Prerequisite: MATH 206B.

MATH 210A. Real Analysis. 4 Units.
Prerequisite: MATH 140C.

MATH 210B. Real Analysis. 4 Units.
Prerequisite: MATH 210A.

MATH 210C. Real Analysis. 4 Units.
Prerequisite: MATH 210B.

MATH 211A. Topics in Analysis. 4 Units.
Studies in selected areas of Real Analysis, a continuation of MATH 210A-MATH 210B-MATH 210C. Topics addressed vary each quarter.
Prerequisite: MATH 210C.

MATH 211B. Topics in Analysis. 4 Units.
Studies in selected areas of Real Analysis, a continuation of MATH 210A-MATH 210B-MATH 210C. Topics addressed vary each quarter.
Prerequisite: MATH 211A.

MATH 211C. Topics in Analysis. 4 Units.
Studies in selected areas of Real Analysis, a continuation of MATH 210A-MATH 210B-MATH 210C. Topics addressed vary each quarter.
Prerequisite: MATH 211B.

MATH 218A. Introduction to Manifolds and Geometry. 4 Units.
General topology and fundamental groups, covering space; Stokes theorem on manifolds, selected topics on abstract manifold theory.
Prerequisite: MATH 205C.
MATH 218B. Introduction to Manifolds and Geometry. 4 Units.
General topology and fundamental groups, covering space; Stokes theorem on manifolds, selected topics on abstract manifold theory.
Prerequisite: MATH 218A.

MATH 218C. Introduction to Manifolds and Geometry. 4 Units.
General topology and fundamental groups, covering space; Stokes theorem on manifolds, selected topics on abstract manifold theory.
Prerequisite: MATH 218B.

MATH 220A. Analytic Function Theory. 4 Units.
Prerequisite: MATH 140C.

MATH 220B. Analytic Function Theory. 4 Units.
Prerequisite: MATH 220A.

MATH 220C. Analytic Function Theory. 4 Units.
Prerequisite: MATH 220B.

MATH 222A. Several Complex Variables and Complex Geometry. 4 Units.
Several Complex variables, d-bar problems, mappings, Kaehler geometry, de Rham and Dolbeault Theorems, Chern Classes, Hodge Theorems, Calabi conjecture, Kahler-Einstein geometry, Monge-Ampere.
Prerequisite: MATH 218C and MATH 220C.

MATH 222B. Several Complex Variables and Complex Geometry. 4 Units.
Several Complex variables, d-bar problems, mappings, Kaehler geometry, Lé Rham and Dolbeault Theorems, Chern Classes, Hodge Theorems, Calabi conjecture, Kahler-Einstein geometry, Monge-Ampere.
Prerequisite: MATH 222A.

MATH 222C. Several Complex Variables and Complex Geometry. 4 Units.
Several Complex variables, d-bar problems, mappings, Kaehler geometry, Lé Rham and Dolbeault Theorems, Chern Classes, Hodge Theorems, Calabi conjecture, Kahler-Einstein geometry, Monge-Ampere.
Prerequisite: MATH 222B.

MATH 225A. Introduction to Numerical Analysis and Scientific Computing. 4 Units.
Introduction to fundamentals of numerical analysis from an advanced viewpoint. Error analysis, approximation of functions, nonlinear equations.
Prerequisite: MATH 3D and ((MATH 105A and MATH 105B) or (MATH 140A and MATH 140B)) and MATH 121A and (MATH 112A or ENGRMAE 140).
Restriction: Graduate students only.

MATH 225B. Introduction to Numerical Analysis and Scientific Computing. 4 Units.
Introduction to fundamentals of numerical analysis from an advanced viewpoint. Numerical linear algebra, numerical solutions of differential equations; stability.
Prerequisite: MATH 225A.
Restriction: Graduate students only.

MATH 225C. Introduction to Numerical Analysis and Scientific Computing. 4 Units.
Introduction to fundamentals of numerical analysis from an advanced viewpoint. Numerical linear algebra, numerical solutions of differential equations; stability.
Prerequisite: MATH 225B.
Restriction: Graduate students only.
MATH 226A. Computational Differential Equations. 4 Units.
Prerequisite: MATH 3D and (MATH 112A or ENGRMAE 140) and (MATH 140B or MATH 105B).

MATH 226B. Computational Differential Equations. 4 Units.
Prerequisite: MATH 226A.

MATH 226C. Computational Differential Equations. 4 Units.
Prerequisite: MATH 226B.

MATH 227A. Mathematical and Computational Biology. 4 Units.
Prerequisite: MATH 2A and MATH 2B and MATH 3A.

MATH 227B. Mathematical and Computational Biology. 4 Units.
Prerequisite: MATH 227A.

MATH 227C. Mathematical and Computational Biology. 4 Units.
Prerequisite: MATH 227A.

Same as COMPSCI 285.

MATH 230A. Algebra. 4 Units.
Elements of the theories of groups, rings, fields, modules. Galois theory. Modules over principal ideal domains. Artinian, Noetherian, and semisimple rings and modules.
Prerequisite: MATH 120A and MATH 121A and MATH 121B.

MATH 230B. Algebra. 4 Units.
Elements of the theories of groups, rings, fields, modules. Galois theory. Modules over principal ideal domains. Artinian, Noetherian, and semisimple rings and modules.
Prerequisite: MATH 230A.

MATH 230C. Algebra. 4 Units.
Elements of the theories of groups, rings, fields, modules. Galois theory. Modules over principal ideal domains. Artinian, Noetherian, and semisimple rings and modules.
Prerequisite: MATH 230B.

MATH 232A. Algebraic Number Theory. 4 Units.
Algebraic integers, prime ideals, class groups, Dirichlet unit theorem, localization, completion, Cebotarev density theorem, L-functions, Gauss sums, diophantine equations, zeta functions over finite fields. Introduction to class field theory.
Prerequisite: MATH 230C.

MATH 232B. Algebraic Number Theory. 4 Units.
Algebraic integers, prime ideals, class groups, Dirichlet unit theorem, localization, completion, Cebotarev density theorem, L-functions, Gauss sums, diophantine equations, zeta functions over finite fields. Introduction to class field theory.
Prerequisite: MATH 232A.
MATH 232C. Algebraic Number Theory. 4 Units.
Algebraic integers, prime ideals, class groups, Dirichlet unit theorem, localization, completion, Cebotarev density theorem, L-functions, Gauss sums, diophantine equations, zeta functions over finite fields. Introduction to class field theory.
Prerequisite: MATH 232B.

MATH 233A. Algebraic Geometry. 4 Units.
Prerequisite: MATH 230C.

MATH 233B. Algebraic Geometry. 4 Units.
Prerequisite: MATH 233A.

MATH 233C. Algebraic Geometry. 4 Units.
Prerequisite: MATH 233B.

MATH 234B. Topics in Algebra. 4 Units.
Group theory, homological algebra, and other selected topics.
Prerequisite: MATH 230C.
Repeatability: May be repeated for credit unlimited times.

MATH 234C. Topics in Algebra. 4 Units.
Group theory, homological algebra, and other selected topics.
Prerequisite: MATH 234B.
Repeatability: May be repeated for credit unlimited times.

MATH 235A. Mathematics of Cryptography. 4 Units.
Mathematics of public key cryptography: encryption and signature schemes; RSA; factoring; primality testing; discrete log based cryptosystems, elliptic and hyperelliptic curve cryptography and additional topics as determined by the instructor.
Prerequisite: MATH 230C.

MATH 235B. Mathematics of Cryptography. 4 Units.
Mathematics of public key cryptography: encryption and signature schemes; RSA; factoring; primality testing; discrete log based cryptosystems, elliptic and hyperelliptic curve cryptography and additional topics as determined by the instructor.
Prerequisite: MATH 235A.

MATH 235C. Mathematics of Cryptography. 4 Units.
Mathematics of public key cryptography: encryption and signature schemes; RSA; factoring; primality testing; discrete log based cryptosystems, elliptic and hyperelliptic curve cryptography and additional topics as determined by the instructor.
Prerequisite: MATH 235B.

MATH 239A. Analytic Methods in Arithmetic Geometry. 4 Units.
Riemann zeta function, Dirichlet L-functions, prime number theorem, zeta functions over finite fields, sieve methods, zeta functions of algebraic curves, algebraic coding theory, L-Functions over number fields, L-functions of modular forms, Eisenstein series.
Prerequisite: MATH 220C and MATH 230C.

MATH 239B. Analytic Methods in Arithmetic Geometry. 4 Units.
Riemann zeta function, Dirichlet L-functions, prime number theorem, zeta functions over finite fields, sieve methods, zeta functions of algebraic curves, algebraic coding theory, L-Functions over number fields, L-functions of modular forms, Eisenstein series.
Prerequisite: MATH 239A.
MATH 239C. Analytic Methods in Arithmetic Geometry. 4 Units.
Riemann zeta function, Dirichlet L-functions, prime number theorem, zeta functions over finite fields, sieve methods, zeta functions of algebraic curves, algebraic coding theory, L-functions over number fields, L-functions of modular forms, Eisenstein series.
Prerequisite: MATH 239B.

MATH 240A. Differential Geometry. 4 Units.
Riemannian manifolds, connections, curvature and torsion. Submanifolds, mean curvature, Gauss curvature equation. Geodesics, minimal submanifolds, first and second fundamental forms, variational formulas. Comparison theorems and their geometric applications. Hodge theory applications to geometry and topology.
Prerequisite: MATH 240A.

MATH 240B. Differential Geometry. 4 Units.
Riemannian manifolds, connections, curvature and torsion. Submanifolds, mean curvature, Gauss curvature equation. Geodesics, minimal submanifolds, first and second fundamental forms, variational formulas. Comparison theorems and their geometric applications. Hodge theory applications to geometry and topology.
Prerequisite: MATH 240B.

MATH 245A. Topics in Differential Geometry. 4 Units.
Studies in selected areas of differential geometry, a continuation of MATH 240A-MATH 240B-MATH 240C. Topics addressed vary each quarter.
Prerequisite: MATH 240C.
Repeatability: Unlimited as topics vary.

MATH 245B. Topics in Differential Geometry. 4 Units.
Studies in selected areas of differential geometry, a continuation of MATH 240A-MATH 240B-MATH 240C. Topics addressed vary each quarter.
Prerequisite: MATH 245A.
Repeatability: Unlimited as topics vary.

MATH 245C. Topics in Differential Geometry. 4 Units.
Studies in selected areas of differential geometry, a continuation of MATH 240A-MATH 240B-MATH 240C. Topics addressed vary each quarter.
Prerequisite: MATH 245B.
Repeatability: Unlimited as topics vary.

MATH 250A. Algebraic Topology. 4 Units.
Provides fundamental materials in algebraic topology: fundamental group and covering space, homology and cohomology theory, and homotopy group.
Prerequisite: MATH 230A.

MATH 250B. Algebraic Topology. 4 Units.
Provides fundamental materials in algebraic topology: fundamental group and covering space, homology and cohomology theory, and homotopy group.
Prerequisite: MATH 250A.

MATH 250C. Algebraic Topology. 4 Units.
Provides fundamental materials in algebraic topology: fundamental group and covering space, homology and cohomology theory, and homotopy group.
Prerequisite: MATH 250B.

MATH 260A. Functional Analysis. 4 Units.
Prerequisite: MATH 210C and MATH 220C.
MATH 260B. Functional Analysis. 4 Units.
Normed linear spaces, Hilbert spaces, Banach spaces, Stone-Weierstrass Theorem, locally convex spaces, bounded operators on Banach and Hilbert spaces, the Gelfand-Neumark Theorem for commutative C*-algebras, the spectral theorem for bounded self-adjoint operators, unbounded operators on Hilbert spaces.
Prerequisite: MATH 260A.

MATH 260C. Functional Analysis. 4 Units.
Normed linear spaces, Hilbert spaces, Banach spaces, Stone-Weierstrass Theorem, locally convex spaces, bounded operators on Banach and Hilbert spaces, the Gelfand-Neumark Theorem for commutative C*-algebras, the spectral theorem for bounded self-adjoint operators, unbounded operators on Hilbert spaces.
Prerequisite: MATH 260B.

MATH 270A. Probability. 4 Units.
Prerequisite: MATH 130C and MATH 210C.

MATH 270B. Probability. 4 Units.
Prerequisite: MATH 270A.

MATH 270C. Probability. 4 Units.
Prerequisite: MATH 270B.

MATH 271A. Stochastic Processes. 4 Units.
Processes with independent increments, Wiener and Gaussian processes, function space integrals, stationary processes, Markov processes.
Prerequisite: MATH 210C.
Overlaps with STATS 270.

MATH 271B. Stochastic Processes. 4 Units.
Processes with independent increments, Wiener and Gaussian processes, function space integrals, stationary processes, Markov processes.
Prerequisite: MATH 271A.
Overlaps with STATS 270.

MATH 271C. Stochastic Processes. 4 Units.
Processes with independent increments, Wiener and Gaussian processes, function space integrals, stationary processes, Markov processes.
Prerequisite: MATH 271B.
Overlaps with STATS 270.

MATH 272A. Probability Models. 4 Units.
Spin systems, Ising models, contact process, exclusion process, percolation, increasing events, critical probabilities, sub- and super-critical phases, scaling theory, oriented percolation, concentration of measure, Gaussian fields, Borell's inequality, chaining, entropy.
Prerequisite: MATH 271C.

MATH 272B. Probability Models. 4 Units.
Spin systems, Ising models, contact process, exclusion process, percolation, increasing events, critical probabilities, sub- and super-critical phases, scaling theory, oriented percolation, concentration of measure, Gaussian fields, Borell's inequality, chaining, entropy.
Prerequisite: MATH 272A.
MATH 272C. Probability Models. 4 Units.
Spin systems, Ising models, contact process, exclusion process, percolation, increasing events, critical probabilities, sub- and super-critical phases, scaling theory, oriented percolation, concentration of measure, Gaussian fields, Borell's inequality, chaining, entropy.
Prerequisite: MATH 272B.

MATH 274. Topics in Probability. 4 Units.
Selected topics, such as theory of stochastic processes, martingale theory, stochastic integrals, stochastic differential equations.
Prerequisite: MATH 270C.
Repeatability: Unlimited as topics vary.

MATH 277A. Topics in Mathematical Physics. 4 Units.
Studies in selected areas of mathematical physics. Topics addressed vary each quarter.
Repeatability: May be repeated for credit unlimited times.

MATH 277B. Topics in Mathematical Physics. 4 Units.
Studies in selected areas of mathematical physics. Topics addressed vary each quarter.
Prerequisite: MATH 277A.
Repeatability: May be repeated for credit unlimited times.

MATH 277C. Topics in Mathematical Physics. 4 Units.
Studies in selected areas of mathematical physics. Topics addressed vary each quarter.
Prerequisite: MATH 277B.
Repeatability: May be repeated for credit unlimited times.

MATH 280A. Mathematical Logic. 4 Units.
Basic set theory; models, compactness, and completeness; basic model theory; Incompleteness and Gödel's Theorems; basic recursion theory; constructible sets.

MATH 280B. Mathematical Logic. 4 Units.
Basic set theory; models, compactness, and completeness; basic model theory; Incompleteness and Gödel's Theorems; basic recursion theory; constructible sets.
Prerequisite: MATH 280A.

MATH 280C. Mathematical Logic. 4 Units.
Basic set theory; models, compactness, and completeness; basic model theory; Incompleteness and Gödel's Theorems; basic recursion theory; constructible sets.
Prerequisite: MATH 280B.

MATH 281A. Set Theory. 4 Units.
Ordinals, cardinals, cardinal arithmetic, combinatorial set theory, models of set theory, Gödel's constructible universe, forcing, large cardinals, iterate forcing, inner model theory, fine structure.
Prerequisite: MATH 280C.

MATH 281B. Set Theory. 4 Units.
Ordinals, cardinals, cardinal arithmetic, combinatorial set theory, models of set theory, Gödel's constructible universe, forcing, large cardinals, iterate forcing, inner model theory, fine structure.
Prerequisite: MATH 281A.

MATH 281C. Set Theory. 4 Units.
Ordinals, cardinals, cardinal arithmetic, combinatorial set theory, models of set theory, Gödel's constructible universe, forcing, large cardinals, iterate forcing, inner model theory, fine structure.
Prerequisite: MATH 281B.
MATH 282A. Model Theory. 4 Units.
Prerequisite: MATH 280C.

MATH 282B. Model Theory. 4 Units.
Prerequisite: MATH 282A.

MATH 282C. Model Theory. 4 Units.
Prerequisite: MATH 282B.

MATH 285A. Topics in Mathematical Logic. 4 Units.
Studies in selected areas of mathematical logic, a continuation of MATH 280A-MATH 280B-MATH 280C. Topics addressed vary each quarter.
Prerequisite: MATH 280C.
Repeatability: Unlimited as topics vary.

MATH 285B. Topics in Mathematical Logic. 4 Units.
Studies in selected areas of mathematical logic, a continuation of MATH 280A-MATH 280B-MATH 280C. Topics addressed vary each quarter.
Prerequisite: MATH 285A.
Repeatability: Unlimited as topics vary.

MATH 285C. Topics in Mathematical Logic. 4 Units.
Studies in selected areas of mathematical logic, a continuation of MATH 280A-MATH 280B-MATH 280C. Topics addressed vary each quarter.
Prerequisite: MATH 285B.
Repeatability: May be repeated for credit unlimited times.

MATH 290A. Methods in Applied Mathematics. 4 Units.
Prerequisite: MATH 290A.

MATH 290B. Methods in Applied Mathematics. 4 Units.
Prerequisite: MATH 290A.

MATH 290C. Methods in Applied Mathematics. 4 Units.
Prerequisite: MATH 290B.

MATH 291C. Topics in Applied and Computational Math. 4 Units.
Studies in selected areas of applied and computational mathematics. Topics addressed vary each quarter.
Repeatability: May be repeated for credit unlimited times.
MATH 295A. Partial Differential Equations. 4 Units.
Prerequisite: MATH 210C and MATH 112B and MATH 112C.

MATH 295B. Partial Differential Equations. 4 Units.
Prerequisite: MATH 295A.

MATH 295C. Partial Differential Equations. 4 Units.
Prerequisite: MATH 295B.

MATH 296. Topics in Partial Differential Equations. 4 Units.
Studies in selected areas of partial differential equations, a continuation of MATH 295A-MATH 295B-MATH 295C. Topics addressed vary each quarter.
Prerequisite: MATH 295C.
Repeatability: Unlimited as topics vary.
Restriction: Graduate students only.

MATH 297. Mathematics Colloquium. 1 Unit.
Weekly colloquia on topics of current interest in mathematics.
Grading Option: Satisfactory/unsatisfactory only.
Repeatability: May be repeated for credit unlimited times.

MATH 298A. Seminar. 1-3 Units.
Seminars organized for detailed discussion of research problems of current interest in the Department. The format, content, frequency, and course value are variable.
Grading Option: Satisfactory/unsatisfactory only.
Repeatability: Unlimited as topics vary.

MATH 298B. Seminar. 2 Units.
Seminars organized for detailed discussion of research problems of current interest in the Department. The format, content, frequency, and course value are variable.
Prerequisite: MATH 298A.
Grading Option: Satisfactory/unsatisfactory only.
Repeatability: Unlimited as topics vary.

MATH 298C. Seminar. 2 Units.
Seminars organized for detailed discussion of research problems of current interest in the Department. The format, content, frequency, and course value are variable.
Prerequisite: MATH 298B.
Grading Option: Satisfactory/unsatisfactory only.
Repeatability: Unlimited as topics vary.

MATH 299A. Supervised Reading and Research. 1-12 Units.
Supervised reading and research with Mathematics faculty.
Repeatability: May be repeated for credit unlimited times.
MATH 299B. Supervised Reading and Research. 1-12 Units.
Supervised reading and research with Mathematics faculty.

Prerequisite: MATH 299A.

Repeatability: May be repeated for credit unlimited times.

MATH 299C. Supervised Reading and Research. 1-12 Units.
Supervised reading and research with Mathematics faculty.

Prerequisite: MATH 299B.

Repeatability: May be repeated for credit unlimited times.

MATH 399. University Teaching. 1-4 Units.
Limited to Teaching Assistants.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.