Mathematics (MATH)

Courses

MATH 000 Preparation for Calculus 0,2 Credits
Intensive review of fundamental concepts in mathematics utilized in calculus, including functions and graphs, exponentials and logarithms, and trigonometry. This course is for students who need to take MATH 51, 81, or 21, but who require additional preparation in precalculus. The credits for this course do not count toward graduation, but do count toward GPA and current credit count. Consent of department.
Attribute/Distribution: MA

MATH 005 Introduction to Mathematical Thought 3 Credits
Meaning, content, and methods of mathematical thought illustrated by topics that may be chosen from number theory, abstract algebra, combinatorics, finite or nonEuclidean geometries, game theory, mathematical logic, set theory, topology.
Attribute/Distribution: MA

MATH 009 Introduction to Finite Mathematics 4 Credits
Systems of linear equations, matrices, introduction to linear programming. Sets, counting methods, probability, random variables, introduction to Markov chains.
Attribute/Distribution: MA

MATH 012 Basic Statistics 0,4 Credits
A first course in the basic concepts and methods of statistics with illustrations from the social, behavioral, and biological sciences. Descriptive statistics; frequency distributions, mean and standard deviation, two-way tables, correlation and regression; random sampling, rules of probability, probability distributions and parameters, parameter estimation, confidence intervals, hypothesis testing, statistical significance. Note: Mathematics and Statistics majors may not receive credit for both MATH 012 & ECO 045.
Attribute/Distribution: MA

MATH 014 (PHIL 014) Symbolic Logic 4 Credits
This course is an introduction to logical theory. Our primary goal is to study the notions of logical consequence and provability. The central question that we will try to answer is this: What exactly does it mean to say that some conclusion is a logical consequence of or is provable from a certain collection of premises? To answer this question as clearly and rigorously as possible, we will develop three symbolic logical systems: Term Logic, Sentence Logic, and Predicate Logic.
Attribute/Distribution: MA

MATH 021 Calculus I 0,4 Credits
Functions and graphs; limits and continuity; derivative, differential, and applications; indefinite and definite integrals; trigonometric, logarithmic, exponential, and hyperbolic functions.
Attribute/Distribution: MA

MATH 022 Calculus II 0,4 Credits
Applications of integration; techniques of integration; separable differential equations; infinite sequences and series; Taylor's Theorem and other approximations; curves and vectors in the plane.
Prerequisites: MATH 021 or MATH 076
Attribute/Distribution: MA

MATH 023 Calculus III 0,4 Credits
Vectors in space; partial derivatives; Lagrange multipliers; multiple integrals; vector analysis; line integrals; Green's Theorem, Gauss's Theorem.
Prerequisites: MATH 022
Attribute/Distribution: MA

MATH 031 Honors Calculus I 4 Credits
Same topics as in MATH 021, but taught from a more thorough and rigorous point of view.
Attribute/Distribution: MA

MATH 032 Honors Calculus II 4 Credits
Same topics as in MATH 022, but taught from a more thorough and rigorous point of view.
Prerequisites: MATH 031 or MATH 021
Attribute/Distribution: MA

MATH 033 Honors Calculus III 0-4 Credits
Same topics as in MATH 023, but taught from a more thorough and rigorous point of view.
Prerequisites: MATH 022 or MATH 032
Attribute/Distribution: MA

MATH 043 Survey of Linear Algebra 3 Credits
Matrices, vectors, vector spaces and mathematical systems, special kinds of matrices, elementary matrix transformations, systems of linear equations, convex sets, introduction to linear programming.
Attribute/Distribution: MA

MATH 051 Survey of Calculus I 0,4 Credits
Limits. The derivative and applications to extrema, approximation, and related rates. Exponential and logarithm functions, growth and decay. Integration. Trigonometric functions and related derivatives and integrals.
Attribute/Distribution: MA

MATH 052 Survey of Calculus II 3 Credits
Techniques of integration. Differential equations. Probability and calculus. Partial derivatives and extrema. Multiple integrals and applications.
Prerequisites: MATH 051 or MATH 021 or MATH 076 or MATH 081
Attribute/Distribution: MA

MATH 075 Calculus I, Part A 2 Credits
Covers the same material as the first half of MATH 021. Meets three hours per week, allowing more class time for each topic than does MATH 021.
Attribute/Distribution: MA

MATH 076 Calculus I, Part B 2 Credits
Continuation of MATH 075, covering the second half of MATH 021. Meets three hours per week.
Prerequisites: MATH 075
Attribute/Distribution: MA

MATH 081 Calculus with Business Applications I 0,4 Credits
Limits and continuity; exponential, logarithmic and trigonometric functions; derivatives; extrema; approximations; indefinite and definite integrals. Applications with emphasis on business and economics.
Attribute/Distribution: MA

MATH 082 Calculus with Business and Economics Applications II 0,4 Credits
Integration by parts, partial fractions, Riemann sums; differential equations; series; Taylor series. Vectors, inner products and projections; functions of several variables, partial derivatives. Multiple integrals; vector-valued functions. Applications with emphasis on finance and economics.
Prerequisites: MATH 081 or MATH 021 or MATH 076 or MATH 051
Attribute/Distribution: MA

MATH 114 (PHIL 114) Metalogic 4 Credits
This is a course on the metatheory of First-Order Predicate Logic. It offers expositions of some of the most important results of this metatheory, such as the Soundness and Completeness Theorems, Gödel's first and second Incompleteness Theorems, Tarski's Indefinability Theorem, and Church's Undecidability Theorem. It also offers introductory expositions of set theory, computability theory, and Second-Order Predicate Logic. The course is structured to serve the needs of a mixed audience, including students with no background in symbolic logic.
Attribute/Distribution: MA

MATH 130 (BIOS 130) Biostatistics 0,4 Credits
Elements of statistics and probability with emphasis on biological applications. Statistical analysis of experimental and observational data.
Prerequisites: MATH 052 or MATH 022

MATH 163 Introduction to Mathematical Reasoning 3 Credits
An introduction to the discipline of mathematics for students considering a major in mathematics. Provides an introduction to rigorous mathematical reasoning, including basic proof techniques (e.g., basic propositional calculus, induction, contradiction) and key concepts which recur throughout mathematics (e.g., universal and existential quantifiers, equivalence classes, basic set theory). Students majoring in mathematics should complete this course before MATH 242, MATH 243 or MATH 301 and are encouraged to complete this course in the first or second year of study.
Prerequisites: MATH 021

MATH 171 Readings 1-3 Credits
Study of a topic in mathematics under individual supervision. Intended for students with specific interests in areas not covered in the listed courses. Consent of department chair required.
Attribute/Distribution: MA

MATH 201 Problem Solving 1 Credit
Practice in solving challenging mathematics problems using a variety of techniques. Permission of instructor required.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA

MATH 202 Actuarial Exam I 1 Credit
Preparation for the first actuarial exam – probability. Problems in calculus and probability with insurance applications.
Prerequisites: (MATH 023 or MATH 052 or MATH 082) and (MATH 231 or MATH 263 or MATH 309)

MATH 203 Actuarial Exam II - Financial Mathematics 2 Credits
Preparation for the second actuarial exam - financial mathematics. Mathematics of interest and investments, interest rate measurement, present value, annuities, loan repayment schemes, bond valuation, introduction to derivative securities. Practice in solving problems from past exams.
Prerequisites: MATH 022 or MATH 052 or MATH 082
Attribute/Distribution: MA

MATH 205 Linear Methods 3 Credits
Linear differential equations and applications; matrices and systems of linear equations; vector spaces; eigenvalues and application to linear systems of differential equations.
Prerequisites: MATH 022 or MATH 082

MATH 208 Complex Variables 3 Credits
Functions of a complex variable; calculus of residues; contour integration; applications to conformal mapping and Laplace transforms.
Prerequisites: MATH 023

MATH 214 (PHIL 214) Topics in Philosophical Logic 4 Credits
Topics may include the many systems of non-classical logic, truth theory, the impact of incompleteness and undecidability results on philosophy, the foundational projects of various philosophers/mathematicians, or the work of an important figure in the history of philosophical logic. Student must have completed at least one Philosophy course at the 100-level.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA

MATH 229 Geometry 3-4 Credits
Discussion of geometry as an axiomatic system. Euclid's postulates. History of and equivalent versions of Euclid's fifth postulate. Finite projective geometries. NonEuclidean geometries based upon negation of the fifth postulate: Geometry on the sphere; Hyperbolic and elliptic geometries. Examination of the concepts of “straight”, angle, parallel, symmetry and duality in each of these geometries. Applications of the different geometries will be considered.
Attribute/Distribution: MA

MATH 230 Numerical Methods 3 Credits
Representation of numbers and rounding error; polynomial and spline interpolation; numerical differentiation and integration; numerical solution of nonlinear systems; numerical solution of initial and boundary value problems; Monte Carlo methods. Knowledge of MATLAB or PYTHON or C required.
Prerequisites: MATH 205 or MATH 241 or MATH 242

MATH 231 Probability and Statistics 3 Credits
Probability and distribution of random variables; populations and random sampling; chi-square and t distributions; estimation and tests of hypotheses; correlation and regression theory of two variables. Not available for credit to students who have completed both MATH 263 and MATH 264.
Prerequisites: MATH 022 or MATH 052 or MATH 082

MATH 234 Fractal Geometry 3 Credits
Metric spaces and iterated function systems; various types of fractal dimension; Julia and Mandelbrot sets. Other topics such as chaos may be included. Small amount of computer use.
Prerequisites: MATH 023

MATH 241 Applied Linear Algebra 3,4 Credits
The theoretical basis for applying linear algebra in other fields, including statistics. Topics will include systems of equations, vector spaces, matrices, and linear transformations. Additional topics will include matrix factorizations (including LU, QR, eigen-decomposition, and SVD) and how they can be used in computer analysis of data sets. Some students may optionally choose to take MATH 205 as preparation for this course. Not available for credit to students who have completed MATH 242 or STAT 342.
Prerequisites: MATH 022 or MATH 082

MATH 242 Linear Algebra 3-4 Credits
An introduction to the study of vector spaces and linear transformations, with emphasis on mathematical rigor. Not available for credit to students who have completed MATH 241 / STAT 342.
Prerequisites: MATH 022 and MATH 163

MATH 243 Algebra 3,4 Credits
Introduction to basic concepts of modern algebra: groups, rings, and fields.
Prerequisites: MATH 242

MATH 252 Introduction to Combinatorics and Graph Theory 3 Credits
Topics in combinatorics and graph theory chosen to introduce the subjects and some of their common proof techniques. Sequences and recursive formulas; counting formulas; bijections; inclusion/exclusion; the Pigeonhole Principle; generating functions; equivalence relations. Graph theory topics include trees, connectivity, traversability, matching and coloring. Not available for credit to students who have completed MATH 305.
Prerequisites: MATH 022

MATH 261 (CSE 261) Discrete Structures 3 Credits
Topics in discrete mathematical structures chosen for their applicability to computer science and engineering. Sets, propositions, induction, recursion; combinatorics; binary relations and functions; ordering, lattices and Boolean algebra; graphs and trees; groups and homomorphisms.
Prerequisites: MATH 021 or MATH 076

MATH 263 Introduction to the Theory of Probability 3 Credits
An introduction to the basics of Calculus-based theory of Probability. Includes combinatorial techniques, events, independence, and conditional probability; discrete and continuous probability distributions, expectation and variance; joint distributions and covariance; moment generating functions; basic form of the Laws of Large Numbers and the Central Limit Theorem. Prior knowledge of Probability not required. Not available for credit to students who have completed (MATH 231 and MATH 264) or MATH 309. Cannot be taken concurrently to MATH 309.
Prerequisites: MATH 023 or MATH 052 or MATH 082
Can be taken Concurrently: MATH 023

MATH 264 Introduction to Statistical Reasoning and Methods 0,4 Credits
Introduction to the basic concepts, logic and issues involved in statistical reasoning and statistical methods used to analyze data and evaluate studies. Topics include descriptive statistics and exploratory data analysis, and basic concepts of machine learning; elementary probability and statistical inference. Examples drawn from various areas of application. Use of computer software (e.g., Minitab, R) to facilitate understanding and to complete data analysis. Not available for credit to students who have completed both MATH 231 and MATH 263.
Prerequisites: MATH 021 or MATH 051 or MATH 081

MATH 271 Readings 1-3 Credits
Study of a topic in mathematics under individual supervision. Intended for students with specific interests in areas not covered in the listed courses. Consent of department chair required.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA

MATH 291 Undergraduate Research 1-4 Credits
Research in mathematics or statistics under the direction of a faculty member. Department permission required.
Repeat Status: Course may be repeated.
Attribute/Distribution: ND

MATH 300 Apprentice Teaching 1-4 Credits
Repeat Status: Course may be repeated.

MATH 301 Principles of Analysis I 3-4 Credits
Existence of limits, continuity and uniform continuity; HeineBorel Theorem; existence of extreme values; mean value theorem and applications; conditions for the existence of the Riemann integral; absolute and uniform convergence; emphasis on theoretical material from the calculus of one variable.
Prerequisites: MATH 023

MATH 305 Enumerative Combinatorics 3 Credits
An introduction to basic theoretical results and techniques of enumerative combinatorics such as combinatorial identities, generating functions, inclusion/exclusion, recurrence relations, bijective proofs and permutations. Additional topics will be covered as time permits.
Prerequisites: MATH 242

MATH 307 General Topology I 3-4 Credits
An introductory study of topological spaces, including metric spaces, separation and countability axioms, connectedness, compactness, product spaces, quotient spaces, function spaces.
Prerequisites: MATH 301
Attribute/Distribution: MA

MATH 309 Probability with Applications and Simulations 3 Credits
Foundations of Probability; Random Variables; Probability Models; Expectations and Moment Generating Functions; Joint and Conditional Distributions; Functions of Random Variables. Introduction to fundamental ideas and techniques of stochastic modeling, with an emphasis on the applications. The last part of the course is devoted to techniques and methods of Monte Carlo simulation. R or other software will be used in this course.
Prerequisites: MATH 023 or MATH 052 or MATH 082
Can be taken Concurrently: MATH 023

MATH 310 Random Processes and Applications 3-4 Credits
Theory and applications of stochastic processes. Limit theorems, introduction to random walks, Markov chains, Poisson processes, birth and death processes, and Brownian motion. Applications to financial mathematics, biology, business and engineering.
Prerequisites: MATH 263 or MATH 309 or (MATH 231 and (MATH 205 or MATH 241),)

MATH 311 Graph Theory 3 Credits
An introduction to basic theoretical results and techniques of graph theory such as trees, connectivity, matchings, coloring, planar graphs and Hamiltonicity. Additional topics will be covered as time permits.
Prerequisites: MATH 163 or MATH 252 or CSE 140

MATH 312 Statistical Computing and Applications 3,4 Credits
Use of statistical computing packages; exploratory data analysis; Monte Carlo methods; randomization and resampling, application and interpretation of a variety of statistical methods in real world problems.
Prerequisites: MATH 012 or MATH 231 or MATH 264 or ECO 045

MATH 316 Complex Analysis 3-4 Credits
Concept of analytic function from the points of view of the CauchyRiemann equations, power series, complex integration, and conformal mapping.
Prerequisites: MATH 301
Attribute/Distribution: MA

MATH 319 Introduction to Differential Equations 3 Credits
An introductory, yet rigorous treatment of topics in differential equations chosen to prepare students for advanced work in mathematics or applied mathematics. Homogeneous and non-homogeneous linear differential equations, existence and uniqueness theorems, Gronwall's inequality; systems of first order linear differential equations; autonomous first-order systems: critical points, stability, bifurcation; series and periodic solutions, Fourier series and their convergence; introduction to numerical simulation methods.
Prerequisites: MATH 242 or MATH 205 or MATH 241

MATH 320 Ordinary Differential Equations 3-4 Credits
The analytical and geometric theory of ordinary differential equations, including such topics as linear systems, systems in the complex plane, oscillation theory, stability theory, geometric theory of nonlinear systems, finite difference methods, general dynamical systems.
Prerequisites: MATH 023 and (MATH 205 or MATH 319)

MATH 321 Topics in Discrete Mathematics 3 Credits
Selected topics in areas of discrete mathematics. Consent of department chair required.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA

MATH 322 Methods of Applied Analysis I 3 Credits
Fourier series, eigenfunction expansions, SturmLiouville problems, Fourier integrals and their application to partial differential equations; special functions. Emphasis is on a wide variety of formal applications rather than logical development.
Prerequisites: MATH 205 or MATH 319

MATH 323 Methods of Applied Analysis II 3 Credits
Green's functions; integral equations; variational methods; asymptotic expansions, method of saddle points; calculus of vector fields, exterior differential calculus.
Prerequisites: MATH 322
Attribute/Distribution: MA

MATH 327 Groups and Rings 3-4 Credits
An intensive study of the concepts of group theory including the Sylow theorems, and of ring theory including unique factorization domains and polynomial rings.
Prerequisites: MATH 242 and MATH 243
Attribute/Distribution: MA

MATH 331 Differential Geometry of Curves and Surfaces 3 Credits
Local and global differential geometry of curves and surfaces in Euclidean 3space. Frenet formulas for curves, isoperimetric inequality, 4vertex theorem; regular surfaces, first fundamental form, Gauss map, second fundamental form; curvatures for curves and surfaces and their relations; The GaussBonnet theorem.
Prerequisites: MATH 023 and (MATH 205 or MATH 242)

MATH 334 Mathematical Statistics 3-4 Credits
Populations and random sampling; sampling distributions; theory of statistical estimation; criteria and methods of point and interval estimation; theory of testing statistical hypotheses.
Prerequisites: MATH 263 or MATH 309

MATH 338 Linear Models in Statistics with Applications 3,4 Credits
Least square principles in multiple regression and their interpretations; estimation, hypotheses testing, confidence and prediction intervals, modeling, regression diagnostic, multicollinearity, model selection, analysis of variance and covariance; logistic regression. Introduction to topics in time series analysis such as ARMA, ARCH, and GARCH models. Applications to natural sciences, finance and economics. Use of computer packages.
Prerequisites: (MATH 012 or MATH 231 or MATH 264) and (MATH 043 or MATH 205 or MATH 241 or MATH 242 or STAT 342)

MATH 339 Time Series and Forecasting 3,4 Credits
This course introduces the student to the statistical analysis of time series data and useful models: autocorrelation, stationarity, trend removal, and seasonal adjustment, basic time series models like AR, MA, ARMA; estimation, forecasting, and GARCH models; multivariate models, and factor models. The course emphasizes the main ideas and the most popular and widely used methods, and the use of a computer to practice the methods. Knowledge of scientific programming in a language such as R required.
Prerequisites: (MATH 264 or MATH 312) and (MATH 263 or MATH 309)

MATH 340 (CSE 340) Design and Analysis of Algorithms 3 Credits
Algorithms for searching, sorting, manipulating graphs and trees, finding shortest paths and minimum spanning trees, scheduling tasks, etc.: proofs of their correctness and analysis of their asymptotic runtime and memory demands. Designing algorithms: recursion, divide-and-conquer, greediness, dynamic programming. Limits on algorithm efficiency using elementary NP-completeness theory.
Prerequisites: (MATH 021 or MATH 031 or MATH 076) and CSE 140 and CSE 017

MATH 341 Mathematical Models and Their Formulation 3 Credits
Mathematical modeling of engineering and physical systems with examples drawn from diverse disciplines. Emphasis is on building models of real world problems and the analysis as well as numerical simulations of the models.
Prerequisites: MATH 205 or MATH 241 or MATH 242

MATH 342 Number Theory 3-4 Credits
Basic concepts and results in number theory, including such topics as primes, the Euclidean algorithm, Diophantine equations, congruences, quadratic residues, quadratic reciprocity, primitive roots, number-theoretic functions, distribution of primes, Pell's equation, Fermat's theorem, partitions. Consent of instructor required.
Attribute/Distribution: MA

MATH 343 Introduction To Cryptography 3,4 Credits
Classical elementary cryptography: Caesar cipher, other substitution ciphers, block ciphers, general linear ciphers. Fast random encryption (DES and AES: Advanced Encryption Standard). Public key systems (RSA and discrete logs). Congruences, modular arithmetic, fast exponentiation, polynomials, matrices. Distinction between polynomial time (primality), Subexponential time (factoring) and fully Exponential computation (elliptic curves). Introduction to sieving and distributed computation. Consent of instructor required.
Attribute/Distribution: MA

MATH 350 Special Topics 3 Credits
A course covering special topics not sufficiently covered in listed courses. Consent of department chair required.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA

MATH 365 Statistical Machine Learning 3,4 Credits
This course provides a broad introduction to concepts, methods, and practices of statistical machine learning: parametric and nonparametric regression, logistic regression, classification, and basic neural networks; kernel and nearest neighbor estimation, clustering, Bayesian and mixture models. In addition, we will explore selected topics like model selection, cross-validation; PCA, dimension reduction, regularized regression; trees, and ensemble learning. Knowledge of scientific programming in a language such as R required.
Prerequisites: (MATH 205 or MATH 241 or MATH 242) and (MATH 264 or MATH 312) and (MATH 263 or MATH 309)

MATH 371 Readings 1-3 Credits
The study of a topic in mathematics under appropriate supervision, designed for the individual student who has studied extensively and whose interests lie in areas not covered in the listed courses. Consent of department chair required.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA

MATH 374 Statistical Project 3 Credits
Supervised field project or independent reading in statistics or probability. Consent of department chair required.
Attribute/Distribution: MA

MATH 381 Undergraduate Research 1-4 Credits
Research in mathematics or statistics under the direction of a faculty member. Consent of department chair required.
Repeat Status: Course may be repeated.

MATH 391 Senior Honors Thesis 3 Credits
Independent research under faculty supervision, culminating in a thesis presented for departmental honor. Consent of department chair required.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA

MATH 401 Real Analysis I 3 Credits
Set theory, real numbers; introduction to measures, Lebesgue measure; integration, general convergence theorems; differentiation, functions of bounded variation, absolute continuity; Lp spaces.
Prerequisites: MATH 301

MATH 402 Real Analysis II 3 Credits
Metric spaces; introduction to Banach and Hilbert space theory; Fourier series and Fejer operators; general measure and integration theory, RadonNikodym and Riesz representation and theorems; LebesgueStieljtes integral.
Prerequisites: MATH 307 or MATH 401

MATH 405 Partial Differential Equations I 3 Credits
Classification of partial differential equations; methods of characteristics for first order equations; methods for representing solutions of the potential, heat, and wave equations, and properties of the solutions of these equations; maximum principles.
Prerequisites: MATH 319 or MATH 320

MATH 406 Partial Differential Equations II 3 Credits
Continuation of MATH 405. Emphasis on second order equations with variable coefficients and systems of first order partial differential equations.
Prerequisites: MATH 405

MATH 408 Algebraic Topology I 3 Credits
Polyhedra; fundamental groups; simplicial and singular homology.

MATH 409 Mathematics Seminar 1-6 Credits
An intensive study of some field of mathematics not offered in another course. Consent of department chair required.

MATH 410 Independent study 1-4 Credits
The study of a topic in mathematics under appropriate supervision, designed for the individual student who has studied extensively and whose interests lie in areas not covered in the listed courses. Consent of department chair required.
Repeat Status: Course may be repeated.

MATH 416 Complex Function Theory 3 Credits
Continuation of MATH 316.
Prerequisites: MATH 316

MATH 423 Differential Geometry I 3 Credits
Differential manifolds, tangent vectors and differentials, submanifolds and the implicit function theorem. Lie groups and Lie algebras, homogeneous spaces. Tensor and exterior algebras, tensor fields and differential forms, de Rham cohomology, Stokes' theorem, the Hodge theorem. Must have completed the required course prerequisites or receive permission of instructor.
Prerequisites: MATH 243 and MATH 301 and MATH 307

MATH 424 Differential Geometry II 3 Credits
Curves and surfaces in Euclidean space; mean and Gaussian curvatures, covariant differentiation, parallelism, geodesics, GaussBonnet formula. Riemannian metrics, connections, sectional curvature, generalized GaussBonnet theorem. Further topics.
Prerequisites: MATH 423

MATH 428 Fields And Modules 3 Credits
Field theory, including an introduction to Galois theory; the theory of modules, including tensor products and classical algebras.
Prerequisites: MATH 327

MATH 430 Numerical Analysis 3 Credits
Multistep methods for ordinary differential equations; finite difference methods for partial differential equations; numerical approximation of functions. Use of computer required.
Prerequisites: MATH 230

MATH 435 Functional Analysis I 3 Credits
Banach spaces and linear operators; separation and extension theorems; open mapping and uniform boundedness principles; weak topologies; local convexity and duality; Banach algebras; spectral theory of operators; and compact operators.
Prerequisites: MATH 307 and MATH 401

MATH 444 Algebraic Topology II 3 Credits
Continuation of MATH 408. Cohomology theory, products, duality.
Prerequisites: MATH 408

MATH 445 Topcs in Algebraic Topology 3 Credits
Selected topics reflecting the interests of the professor and the students.
Prerequisites: MATH 444

MATH 449 Topics In Algebra 3 Credits
Intensive study of topics in algebra with emphasis on recent developments. Consent of department chair required.
Repeat Status: Course may be repeated.

MATH 450 Special Topics 3 Credits
Intensive study of some field of the mathematical sciences not covered in listed courses. Consent of department chair required.
Repeat Status: Course may be repeated.

MATH 455 Topics In Number Theory 3 Credits
Selected topics in algebraic and/or analytic number theory. Consent of instructor required.
Repeat Status: Course may be repeated.

MATH 461 Topics In Mathematical Statistcs 3 Credits
An intensive study of one or more topics such as theory of statistical tests, statistical estimation, regression, analysis of variance, nonparametric methods, stochastic approximation, and decision theory.
Repeat Status: Course may be repeated.
Prerequisites: MATH 334 and MATH 401

MATH 462 Modern Nonparametric Methods in Statistics 3 Credits
Classical and modern methods of nonparametric statistics; order and rank statistics; tests based on runs, signs, ranks, and order statistics; distribution free statistical procedures for means, variances, correlations, and trends; relative efficiency; KolmogorovSmirnov statistics; statistical applications of Brownian process; modern techniques such as robust methods, nonparametric smoothing, and bootstrapping; additional topics such as nonparametric regression and dimension reduction.
Prerequisites: (MATH 334 or STAT 334) and (MATH 338 or STAT 338)

MATH 463 (STAT 463) Advanced Probability 3 Credits
Measure theoretic foundations; random variables, integration in a measure space, expectations; convergence of random variables and probability measures; conditional expectations; characteristic functions; sums of random variables, limit theorems.
Prerequisites: MATH 309 and MATH 401

MATH 464 Advanced Stochastic Process 3 Credits
Theory of stochastic processes; stopping times; martingales; Markov processes; Brownian motion; stochastic calculus; Brownian bridge, laws of suprema; Gaussian processes.
Prerequisites: MATH 309 and MATH 401

MATH 465 Topics in Probability 3 Credits
Selected topics in probability. Consent of department chair required.
Repeat Status: Course may be repeated.

MATH 467 Stochastic Calculus 3 Credits
Brownian Motion, Martingales. Introduction to the theory of Stochastic Calculus, Itô Formula, and Stochastic Differential Equations, Black-Scholes model. Development of the Martingale Representation Theorem and Girsanov's theorem for change of measure. Multidimensional Stochastic Calculus. Applications to different problems from finance, physics, biology, etc.
Prerequisites: MATH 231 or MATH 309

MATH 468 Financial Stochastic Analysis 3 Credits
Basic mathematical concepts behind pricing of derivative securities. Hedging and pricing by arbitrage in the setting of binary trees and Black-Scholes model. Application of Stochastic Calculus to the pricing of a variety of financial instruments: multiple stock models, American and exotic options, and foreign currency interest rate. Heath-Jarrow-Morton model for the term structure of interest rates and short rate models. Applications of the theory to a variety of interest rates contracts including swaps, caps, floors, swap options.
Prerequisites: MATH 467

MATH 470 Proseminar 1-3 Credits
Preparation for entering the mathematics profession. Topic of emphasis typically include methods of teaching mathematics, commonly available research tools and the publication process, the responsibilities of an academic position, and searching for a job. Consent of department chair required.
Repeat Status: Course may be repeated.

MATH 471 Homological Algebra 3 Credits
Modules, tensor products, categories and functors, homology functors, projective and injective modules.
Prerequisites: MATH 428

MATH 472 Group Representations 3 Credits
Linear representations and character theory with emphasis on the finite and compact cases.
Prerequisites: MATH 428

MATH 475 Topics in Geometry 3 Credits
Selected topics in geometry, such as geometric analysis, algebraic geometry, complex geometry, characteristic classes, geometric flows or geometric measure theory, with emphasis on recent developments. Consent of department chair required.
Repeat Status: Course may be repeated.

MATH 490 Thesis 1-6 Credits

MATH 491 Research 1-4 Credits
Research in mathematics or statistics under the direction of a faculty member. Consent of department chair required.
Repeat Status: Course may be repeated.

MATH 499 Dissertation 1-15 Credits
Repeat Status: Course may be repeated.