## Mathematics (MATH)

<table>
<thead>
<tr>
<th>Courses</th>
<th>Mathematics (MATH) 1</th>
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<tbody>
<tr>
<td>MATH 000 Preparation for Calculus 2 Credits</td>
<td>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 or 21, but who require remediation in precalculus. In particular, students who fail the MATH 51 Readiness Exam must pass MATH 0 before being admitted to MATH 51. The credits for this course do not count toward graduation, but do count toward GPA and current credit count. Consent of department required.</td>
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<tr>
<td>Attribute/Distribution:</td>
<td>MA</td>
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<tr>
<td>MATH 009 Introduction to Mathematical Thought 3 Credits</td>
<td>Meaning, content, and methods of mathematical thought illustrated by topics that may be chosen from number theory, abstract algebra, combinatorics, finite or non-Euclidean geometries, game theory, mathematical logic, set theory, topology.</td>
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<td>Attribute/Distribution:</td>
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<tr>
<td>MATH 012 Basic Statistics 4 Credits</td>
<td>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 &amp; ECO 045.</td>
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<tr>
<td>Attribute/Distribution:</td>
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<tr>
<td>MATH 021 Calculus I 4 Credits</td>
<td>Functions and graphs; limits and continuity; derivative, differential, and applications; indefinite and definite integrals; trigonometric, logarithmic, exponential, and hyperbolic functions.</td>
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<tr>
<td>Attribute/Distribution:</td>
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<tr>
<td>MATH 022 Calculus II 4 Credits</td>
<td>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.</td>
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<tr>
<td>Prerequisites:</td>
<td>MATH 021 or MATH 076 or MATH 031 or MATH 097</td>
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<tr>
<td>Attribute/Distribution:</td>
<td>MA</td>
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<tr>
<td>MATH 023 Calculus III 4 Credits</td>
<td>Vectors in space; partial derivatives; Lagrange multipliers; multiple integrals; vector analysis; line integrals; Green's Theorem, Gauss's Theorem.</td>
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<tr>
<td>Prerequisites:</td>
<td>MATH 022 or MATH 096 or MATH 032</td>
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<td>Attribute/Distribution:</td>
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<tr>
<td>MATH 031 Honors Calculus I 4 Credits</td>
<td>Same topics as in MATH 021, but taught from a more thorough and rigorous point of view.</td>
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<td>Attribute/Distribution:</td>
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<tr>
<td>MATH 032 Honors Calculus II 4 Credits</td>
<td>Same topics as in MATH 022, but taught from a more thorough and rigorous point of view.</td>
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<tr>
<td>Prerequisites:</td>
<td>(MATH 031)</td>
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<tr>
<td>Attribute/Distribution:</td>
<td>MA</td>
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<tr>
<td>MATH 033 Honors Calculus III 4 Credits</td>
<td>Same topics as in MATH 023, but taught from a more thorough and rigorous point of view.</td>
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<tr>
<td>Attribute/Distribution:</td>
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<tr>
<td>MATH 043 Survey of Linear Algebra 3 Credits</td>
<td>Matrices, vectors, vector spaces and mathematical systems, special kinds of matrices, elementary matrix transformations, systems of linear equations, convex sets, introduction to linear programming.</td>
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<tr>
<td>MATH 051 Survey of Calculus I 4 Credits</td>
<td>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.</td>
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<tr>
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<tr>
<td>Prerequisites:</td>
<td>MATH 051 or MATH 021 or MATH 031 or MATH 076 or MATH 097 or MATH 081</td>
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<tr>
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<tr>
<td>MATH 075 Calculus I, Part A 2 Credits</td>
<td>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.</td>
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<tr>
<td>Attribute/Distribution:</td>
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<tr>
<td>MATH 076 Calculus I, Part B 2 Credits</td>
<td>Continuation of MATH 075, covering the second half of MATH 021. Meets three hours per week. Final exam for this course is similar to the MATH 021 final.</td>
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<tr>
<td>Prerequisites:</td>
<td>MATH 075</td>
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<tr>
<td>Attribute/Distribution:</td>
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<tr>
<td>MATH 081 Calculus with Business Applications 4 Credits</td>
<td>Limits and continuity; exponential, logarithmic and trigonometric functions; derivatives; extrema; approximations; indefinite and definite integrals. Applications with emphasis on business and economics.</td>
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<tr>
<td>MATH 114 (PHIL 114) Symbolic Logic 4 Credits</td>
<td>A first course in logical theory, introducing the notions of logical consequence and proof, as well as related concepts such as consistency and contingency. Formal systems taught may include: term, sentence logic, and predicate logic.</td>
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<td>Attribute/Distribution:</td>
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<tr>
<td>MATH 130 (BIOS 130) Biostatistics 4 Credits</td>
<td>Elements of statistics and probability with emphasis on biological applications. Statistical analysis of experimental and observational data.</td>
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<tr>
<td>Prerequisites:</td>
<td>MATH 052 or MATH 022</td>
</tr>
<tr>
<td>MATH 163 Introductory Seminar 3 Credits</td>
<td>An introduction to the discipline of mathematics designed for students considering a major in mathematics. The course will provide an introduction to rigorous mathematical reasoning and will survey some area of mathematics. Topics covered will vary.</td>
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<tr>
<td>MATH 171 Readings 1-3 Credits</td>
<td>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.</td>
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<td>Attribute/Distribution:</td>
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<tr>
<td>MATH 201 Problem Solving 1 Credit</td>
<td>Practice in solving problems from mathematical contests using a variety of techniques. Permission of instructor required.</td>
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<tr>
<td>Repeat Status:</td>
<td>Course may be repeated.</td>
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<tr>
<td>MATH 202 Actuarial Exam I 1 Credit</td>
<td>Preparation for the first actuarial exam – probability. Problems in calculus and probability with insurance applications.</td>
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<tr>
<td>Prerequisites:</td>
<td>(MATH 023 or MATH 033) and (MATH 231)</td>
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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
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 096 or MATH 032
Attribute/Distribution: MA

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 or MATH 033
Attribute/Distribution: MA

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 philosopher/mathematicians, or the work of an important figure in the history of philosophical logic. Consent of instructor required.
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. Non-Euclidean 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; Fast Fourier Transformation; numerical solution of initial and boundary value problems; Monte Carlo methods. Knowledge of MATLAB or PYTHON or C required.
Prerequisites: MATH 205
Attribute/Distribution: MA

MATH 231 Probability and Statistics 3 Credits
Probability and distribution of random variables; populations and random sampling; chi-square and 1 distributions; estimation and tests of hypotheses; correlation and regression theory of two variables.
Prerequisites: MATH 022 or MATH 096 or MATH 032 or MATH 052
Attribute/Distribution: MA

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 or MATH 033
Attribute/Distribution: MA

MATH 242 Linear Algebra 3-4 Credits
Solution of systems of linear equations, matrices, vector spaces, bases, linear transformations, eigenvalues, eigenvectors, additional topics as time permits.
Prerequisites: MATH 022 or MATH 096 or MATH 032
Attribute/Distribution: MA

MATH 243 Algebra 3,4 Credits
Introduction to basic concepts of modern algebra: groups, rings, and fields.
Prerequisites: (MATH 163 or MATH 261 or CSE 261) and (MATH 242 or MATH 205)
Attribute/Distribution: MA

MATH 245 Mathematical Models 3 Credits
An introduction to mathematical modeling and the theory of models. Mathematical techniques and applications in various disciplines. Computer software used.
Prerequisites: MATH 242 or MATH 205
Attribute/Distribution: MA

MATH 246 (PHIL 246) 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 philosopher/mathematicians, or the work of an important figure in the history of philosophical logic. Consent of instructor required.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA

MATH 250 Advanced Functions 4 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
Attribute/Distribution: MA

MATH 251 Linear Algebra 3-4 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 096 or MATH 032
Attribute/Distribution: MA

MATH 258 Complex Variables 3 Credits
Functions of a complex variable; calculus of residues; contour integration; applications to conformal mapping and Laplace transforms.
Prerequisites: MATH 023 or MATH 033
Attribute/Distribution: MA

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 031 or MATH 076)
Attribute/Distribution: MA

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 301 Principles of Analysis I 3-4 Credits
Existence of limits, continuity and uniform continuity; Heine-Borel 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 or MATH 033
Attribute/Distribution: MA

MATH 302 Principles of Analysis II 3-4 Credits
Continuation of MATH 301. Functions of several variables; the implicit function theorem, and further topics with applications to analysis and geometry.
Prerequisites: MATH 301
Attribute/Distribution: MA

MATH 303 (PHIL 303) Mathematical Logic 3-4 Credits
Detailed proofs are given for the basic mathematical results relating the syntax and semantics of first order logic (predicate logic): the Soundness and Completeness (and Compactness) Theorems, followed by a brief exposition of the celebrated limitative results of Gödel, Turing, and Church on incompleteness and undecidability. The material is conceptually rigorous and mathematically mature; the necessary background is a certain degree of mathematical sophistication or a basic knowledge of symbolic logic. Consent of instructor required.
Attribute/Distribution: MA

MATH 304 Axiomatic Set Theory 3-4 Credits
A development of set theory from axioms; relations and functions; ordinal and cardinal arithmetic; recursion theorem; axiom of choice; independence questions. Consent of instructor required.
Attribute/Distribution: MA

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 and (MATH 163 or MATH 261 or CSE 261)
Attribute/Distribution: MA

MATH 306 Introduction to Biomedical Engineering and Mathematical Biology 3 Credits
Prerequisites: MATH 205
Attribute/Distribution: MA
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 Theory of Probability 3 Credits
Probabilities of events on discrete and continuous sample spaces; random variables and probability distributions; expectations; transformations; simplest kind of law of large numbers and central limit theorem. The theory is applied to problems in physical and biological sciences.
Prerequisites: MATH 023 or MATH 033 or MATH 052
Attribute/Distribution: MA

MATH 310 Random Processes and Applications 3-4 Credits
Prerequisites: MATH 309 or MATH 231
Attribute/Distribution: MA

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 261
Attribute/Distribution: MA

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
Attribute/Distribution: MA

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

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 205 or (MATH 242 and (MATH 023 or MATH 033).)
Attribute/Distribution: MA

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, Sturm-Liouville 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
Attribute/Distribution: MA

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 329 Computability Theory 3-4 Credits
Core development of classical computability theory: enumeration, index and recursion theorems, various models of computation and Church's Thesis, uncomputability results, introduction to reducibilities and their degrees (in particular, Turing degrees, or degrees of uncomputability), computable operators and their fixed points.
Prerequisites: MATH 203 or MATH 231
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 Gauss-Bonnet theorem.
Prerequisites: MATH 023 or MATH 033
Attribute/Distribution: MA

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 309
Attribute/Distribution: MA

MATH 338 Linear Models in Statistics with Applications 3-4 Credits
Least square principles in multiple regression and their interpretations; estimation, hypothesis 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) and (MATH 043 or MATH 205 or MATH 242)
Attribute/Distribution: MA

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. Credit will not be given for both MATH 340 (CSE 340) and MATH 441 (CSE 441).
Prerequisites: (MATH 022 or MATH 096 or MATH 032) and (CSE 261 or MATH 261)

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 rather than learning mathematical techniques.
Prerequisites: MATH 205
Attribute/Distribution: MA

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.
Prerequisites: MATH 242
Attribute/Distribution: MA
MATH 408  Algebraic Topology I  3 Credits

MATH 405  Partial Differential Equations II  3 Credits
Continuation of MATH 405. Emphasis on second order equations; methods for representing solutions of the potential, heat, and wave equations, and properties of the solutions of these equations; maximum principles. Consent of instructor required.

MATH 404  Topics in Mathematical Logic  3 Credits
Field theory, including an introduction to Galois theory; the theory of modules, including tensor products and classical algebras.

MATH 403  Complex Function Theory  3 Credits
Continuation of MATH 402. Cohomology theory, products, duality. Consent of department chair required.

MATH 402  Complex Function Theory  3 Credits
Continuation of MATH 401 or the intensive study of a different field. Consent of department chair required.

MATH 401  Mathematics Seminar 1-6 Credits
Continuation of the field of study in MATH 400 or the intensive study of a different field. Consent of department chair required.

MATH 400  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.

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.

MATH 389  Topics in Mathematics  3 Credits
A course covering special topics not sufficiently covered in listed courses. Consent of department chair required.

MATH 388  Independent Study  1-3 Credits
A course covering special topics not sufficiently covered in listed courses. Consent of department chair required.

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.

MATH 370  Special Topics  3 Credits
A course covering special topics not sufficiently covered in listed courses. Consent of department chair required.

MATH 369  Independent Research  1-3 Credits
A course covering special topics not sufficiently covered in listed courses. Consent of department chair required.

MATH 350  Readings  1-3 Credits
Alexander groups, knot theory, homology, cohomology, duality and applications, hyperbolic geometry, Teichmüller space, the Nielsen realisation problem, surfaces as Riemann surfaces, finite volume metrics on 3-manifolds, Ricci flow, geometric flows, and related topics.

MATH 349  Topics In Algebra  3 Credits
Selected topics reflecting the interests of the professor and the students.

MATH 348  Topics In Mathematics  3 Credits
A course covering special topics not sufficiently covered in listed courses. Consent of department chair required.

MATH 347  Special Topics  3 Credits
A course covering special topics not sufficiently covered in listed courses. Consent of department chair required.

MATH 346  Advanced Algorithms  3 Credits
Multistep methods for ordinary differential equations; finite difference methods for partial differential equations; numerical approximation of functions. Use of computer required.

MATH 345  Functional Analysis I  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 theorems; Lp spaces; integral.

MATH 344  Algebraic Topology II  3 Credits
Continuation of MATH 404. Emphasis on second order equations with variable coefficients and systems of first order partial differential equations.

MATH 343  Introduction To Cryptography  3 Credits

MATH 342  Introduction To Wavelets  3 Credits
Continuous and discrete signals; review of Fourier analysis; discrete wavelets; time frequency spaces; Haar and Walsh systems; multiresolution analysis; Hilbert spaces; quadratic mirror filters; fast wavelet transforms; computer code; applications to filtering, compression, and imaging.

MATH 341  Advanced Algorithms  3 Credits
Algorithms for searching, sorting, manipulating graphs and trees, scheduling tasks, finding shortest path, matching patterns in strings, cryptography, matroid theory, linear programming, max-flow, etc., and their correctness proofs and analysis of their time and space complexity. Strategies for designing algorithms, e.g. recursion, divide-and-conquer, greediness, dynamic programming. Limits on algorithm efficiency are explored through NP completeness theory. Quantum computing is briefly introduced. Credit will not be given for both CSE 340 (MATH 340) and CSE 441 (MATH 441).

MATH 340  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.

MATH 339  Complex Analysis  3 Credits
Complex numbers; complex functions; Cauchy-Riemann conditions; Cauchy integral formula; residue theorem; entire functions. Consent of instructor required.

MATH 338  Topological Spaces  3 Credits
Topological spaces; continuous functions; separation axioms; compactness; connectedness. Consent of instructor required.

MATH 337  Differential Geometry I  3 Credits
Curves and surfaces in Euclidean space; mean and Gaussian curvatures, covariant differentiation, parallelism, geodesics, Gauss-Bonnet formula. Riemannian metrics, connections, sectional curvature, generalized Gauss-Bonnet theorem. Further topics.

MATH 336  Linear Algebra  3 Credits
Vector spaces; linear transformations; matrices; determinants; eigenvalues and eigenvectors; quadratic forms; inner product spaces. Consent of instructor required.

MATH 335  Elementary Number Theory  3 Credits
Divisibility, congruences, Diophantine equations, quadratic reciprocity, number-theoretic functions. Consent of instructor required.

MATH 334  Set Theory  3 Credits
Set theory, real numbers; introduction to measures, Lebesgue measure; integration, general convergence theorems; differentiation, functions of bounded variation, absolute continuity; Lp spaces.

MATH 333  Introduction To Analysis  3 Credits
Real numbers; limits and convergence of sequences; the continuum; infinite series; continuity; differentiation; the Riemann integral. Consent of instructor required.

MATH 332  Functional Analysis I  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 theorems; Lp spaces; integral.

MATH 331  Introduction To Topology  3 Credits
Topological spaces; continuous functions; separation axioms; compactness; connectedness. Consent of instructor required.

MATH 329  Algebraic Topology 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 MATH 301, or MATH 243 or MATH 205 with permission of instructor.

MATH 328  Fields And Modules  3 Credits
Field theory, including an introduction to Galois theory; the theory of modules, including tensor products and classical algebras.

MATH 327  Introduction To Cryptography  3 Credits
Introduction to modern cryptography, including: symmetric 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).
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 Statistics 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.

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; Kolmogorov-Smirnov 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 Financial Calculus I 3 Credits
Basic mathematical concepts behind derivative pricing and portfolio management of derivative securities. Development of hedging and pricing by arbitrage in the discrete time setting of binary trees and Black-Scholes model. Introduction to the theory of Stochastic Calculus, Martingale representation theorem, and change of measure. Applications of the developed theory to a variety of actual financial instruments.
Prerequisites: MATH 231 or MATH 309

MATH 468 Financial Calculus II 3 Credits
Models and mathematical concepts behind the interest rates markets. Heath-Jarrow-Morton model for random evolution of 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, swaptions. Development of multidimensional stochastic calculus and applications to multiple stock models, quantos, and foreign currency interest rate models.
Prerequisites: MATH 467

MATH 470 Proseminar 3 Credits
Preparation for entering the mathematics profession. Seminar will concentrate on methods of teaching mathematics, and will include other topics such as duties of a professor and searching for a job. Consent of department chair required.

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 485 Topics in Financial Mathematics 3 Credits
Selected topics in financial mathematics. Consent of department chair required.
Repeat Status: Course may be repeated.

MATH 490 Thesis 1-6 Credits
MATH 499 Dissertation 1-15 Credits
Repeat Status: Course may be repeated.