

# MATHEMATICS (MATH)

## Courses

### MATH 95 DEVELOPMENTAL MATHEMATICS (3)

A review of elementary and intermediate algebra including equations and inequalities, graphing linear equations, exponents and polynomials. Required for students whose required Math course sequence includes MATH 102 as a prerequisite, but whose placement test score is not adequate for placement in MATH 102. No credit toward graduation. Replacing DVMT 101. Graded S/U.

### MATH 100 FOUNDATIONS OF MATHEMATICAL REASONING (3)

Designed to provide students the necessary mathematical knowledge and skills associated with quantitative literacy and which are needed for success in various Core courses other than those in an algebra-intensive pathway. The topics for this course are both mathematical and contextual: Numeracy; Proportional Reasoning; Algebraic Competence, Reasoning, and Modeling; Probabilistic Reasoning to Assess Risk; Quantitative reasoning in personal Finance; and Quantitative reasoning in civic life. 4 contact hours; 3 units. Prerequisite: not open to students completing MATH 105 or higher.

### MATH 102 INTERMEDIATE ALGEBRA (3)

Intended primarily for students who will use algebraic skills in future mathematics courses. Topics include: factoring of polynomials, rational expressions and equations, graphs, relations and functions, radicals and exponents, and quadratic equations. Prerequisites: qualifying score on placement test or MATH 95 [DVMT 101] and consent of the department; not open to students completing MATH 115 or higher (except MATH 231 and MATH 237).

### MATH 102S SUPPORT FOR INTERMEDIATE ALGEBRA (1)

Explorations and focused skill preparation to support MATH 102. Helps students to review prior mathematical knowledge that is relevant to upcoming topics in Intermediate Algebra and apply emerging knowledge to demonstrate understanding. Students will develop their mathematical communication skills, study skills, and mathematical mindset through discussions and activities. Not open to those who successfully completed MATH 102 or higher. Graded S/U. Corequisite: MATH 102.

### MATH 105 MATHEMATICAL IDEAS (3)

Basic concepts and ideas in mathematics are selected to explore the aesthetics and utility of mathematics. Topics are chosen from sets, counting methods, mathematical systems, basic rules of probability, statistics, logic, finance, geometry, numeration systems and modeling. Not counted toward nor required for Early Childhood Education or Elementary Education majors. Not open to those who successfully completed MATH 103 or MATH 106. Prerequisite: Qualifying score on Math Placement exam or MATH 100. Core: Mathematics.

### MATH 111 FINITE MATHEMATICS (3)

Intended primarily for students in business, economics, psychology, and the social sciences. Applications of finite mathematics: linear equations, matrices, linear programming using graphical and simplex methods, sets and counting, elementary probability, and difference equations. Not open to students who have successfully completed MATH 115 or MATH 119 or MATH 109. Prerequisite: Qualifying score on Math Placement exam or MATH 100. Core: Mathematics.

### MATH 115 COLLEGE ALGEBRA (3)

Equations and the concept of function; linear, quadratic, higher-degree polynomial, exponential, logarithmic, and rational functions; complex numbers. Not open to those who have successfully completed MATH 119. Prerequisite: qualifying score on Math Placement exam or MATH 102. Core: Mathematics.

### MATH 117 TRIGONOMETRY AND ADVANCED COLLEGE ALGEBRA (3)

The second semester in a two-semester precalculus sequence, with a primary focus on trigonometry. Angle measures; trigonometric functions and their graphs; trigonometric identities; inverse trigonometric functions and their graphs; algebraic and graphical solutions of trigonometric equations and basic trigonometric inequalities; solving triangles; linear systems in two and three variables with applications to partial fractions; conic sections. Not open to students who have successfully completed MATH 119. Prerequisite: MATH 115.

### MATH 119 PRE-CALCULUS (4)

An overview of functions and their graphs as well as algebraic techniques and trigonometry in preparation for Calculus I (MATH 273). Functions emphasized are polynomial, rational, exponential, logarithmic, and trigonometric. Prerequisite: qualifying score on Math Placement exam. Core: Mathematics.

### MATH 119S CONNECTIONS TO PRE-CALCULUS (1)

Explorations to support MATH 119. Helps students to review prior mathematical knowledge relevant to upcoming topics in MATH 119. Students will develop their mathematical communication skills, study skills, and mathematical mindset through discussion and activities. Not designed for students who have successfully completed MATH 119. Graded S/U. Corequisite: MATH 119.

### MATH 204 MATHEMATICAL CONCEPTS AND STRUCTURES I (4)

Content knowledge for teaching elementary school mathematics. Problem solving, systems of numeration, development of numeration systems through rational numbers, arithmetic properties, operations, and algorithms, number theory, and the effective use of manipulative materials and educational technology. Prerequisite: qualifying score on Math Placement exam or MATH 100 or higher.

### MATH 205 MATHEMATICAL CONCEPTS AND STRUCTURES II (4)

Content knowledge for teaching elementary school mathematics. Proportional reasoning, algebra, and statistics and data analysis with probability concepts through statistical investigations. Appropriate technology is integrated throughout. Prerequisite: MATH 204. Core: Mathematics.

### MATH 211 CALCULUS FOR APPLICATIONS (3)

Intended primarily for students in biology, business, economics, psychology and the social sciences. Elements of differential and integral calculus from an intuitive standpoint with emphasis on the use of calculus in the above fields. Exponential and logarithmic functions, partial derivatives included. Not open to mathematics majors or minors. Prerequisite: qualifying score on the Math Placement Test or MATH 115 (recommended) or MATH 119. Core: Mathematics.

### **MATH 215 RATIONAL NUMBERS AND PROPORTIONAL REASONING FOR MIDDLE SCHOOL MATHEMATICS TEACHERS (4)**

Will provide students with a thorough and rigorous treatment of concepts in rational number, ratio, and proportional reasoning – topics that form the foundation of the middle school mathematics curriculum. These topics will be investigated through a variety of models, representations, and contexts, as well as through solving non-routine problems. Prerequisites: MATH 119 or MATH 273 (MATH 273 may be taken concurrently) and consent of department.

### **MATH 223 PEDAGOGICAL CONTENT KNOWLEDGE FOR MIDDLE SCHOOL MATHEMATICS (2)**

Best practices for teaching in the middle grades; integrating effective elements of planning, instruction, questioning, and assessment. Content areas of focus include proportional reasoning, expressions and equations, functions. Prerequisites: SEMS 130 or both SEMS 110 and SEMS 120.

### **MATH 225 ALGEBRA AND NUMBER CONCEPTS FOR MIDDLE SCHOOL TEACHERS (4)**

Will provide students with a thorough and rigorous treatment of the following topics in number theory and connections to algebra: factors and multiples; prime numbers and the Fundamental Theorem of Arithmetic; divisibility tests; integers; growing patterns; arithmetic and geometric sequences; functions (linear, quadratic, and exponential); expressions and equations; and additional connections between other branches of mathematics and algebra as time permits. These topics will be investigated through a variety of models, representations, and contexts, as well as through solving non-routine problems. Prerequisites: MATH 273 and department consent.

### **MATH 231 BASIC STATISTICS (3)**

A non-calculus based introduction to statistics with emphasis on applications. Topics include categorical and quantitative data collection through sampling and experimental design, data description and displays, confidence intervals and hypothesis tests for one- and two-samples, and matched-pairs design; normal and t-distributions; correlation and simple linear regression. Emphasis on interpretations of results throughout. Substantial use of a computer package as a learning and computational tool. Students who have successfully completed the honors version of this course (MATH 233) will not receive additional credit for this course. Prerequisite: qualifying score on Math Placement exam or MATH 100 (recommended) or MATH 102 or higher. Core: Mathematics.

### **MATH 233 HONORS BASIC STATISTICS (3)**

A non-calculus based introduction to statistics with emphasis on applications. Topics include categorical and quantitative data collection through sampling and experimental design, data description and displays, confidence intervals and hypothesis tests for one- and two-samples, and matched-pairs design; normal and t-distributions; correlation and simple linear regression. Emphasis on interpretations of results throughout. Substantial use of a computer package as a learning and computational tool. Students who have successfully completed the non-honors version of this course will not receive additional credit for this course. Prerequisites: qualifying score on Math Placement exam, admission to Honors College and MATH 100, or MATH 102 or higher. Core: Mathematics.

### **MATH 236 PROBABILITY AND STATISTICS FOR MIDDLE SCHOOL TEACHER PREPARATION (1)**

A supplement to Basic Statistics with content specific to the middle school mathematics curriculum. Topics include the display and analysis of data, conceptual meanings of measures of central tendency and variability, topics in probability, including theoretical approaches and experimental approaches via simulations. Graphing calculators and computer software are used extensively throughout the course. Prerequisite: MATH 231 (may be taken concurrently).

### **MATH 237 ELEMENTARY BIOSTATISTICS (4)**

Elementary statistical concepts and their application to the biological and health sciences. Descriptive statistics, estimation techniques, hypothesis testing, analysis of enumerative data, one-way analysis of variance, and simple linear regression and correlation analysis. A statistical package such as MINITAB is introduced as a computational tool. Not open to students who have successfully completed MATH 231 or MATH 330 or to mathematics majors. Prerequisite: qualifying score on Math Placement exam or MATH 100 (recommended) or MATH 102 or higher (except MATH 204). Core: Mathematics.

### **MATH 251 ELEMENTS OF GEOMETRY (4)**

Content knowledge for teaching elementary school mathematics. Geometric vocabulary, relationships, concepts and skills, including properties and classification of two- and three-dimensional shapes; transformations and symmetry; and measurement. Appropriate geometric tools and technology are integrated throughout. Prerequisites: major in ECED, ECSE, EESE, ELED, or SPED.

### **MATH 255 GEOMETRY FOR MIDDLE SCHOOL TEACHERS (4)**

Content includes angle relationships, parallel lines, triangle congruence and similarity, quadrilaterals, circles, and area and perimeter of such figures. Also included is the pedagogy of using the van Hiele Model of Geometric Thought. Prerequisites: MATH 273 and consent of department.

### **MATH 256 GEOMETRIC PROOF AND DEDUCTION FOR MIDDLE SCHOOL TEACHER (1)**

Provides additional information in both content and pedagogy to students who have successfully completed MATH 251 and wish to replace the required course of MATH 255. Focuses on the van Hiele Model for Geometric Thought, an introduction to logical reasoning through inductive and deductive methods, and geometric proofs. Not open to students who have successfully taken MATH 255. Prerequisite: MATH 251.

### **MATH 263 DISCRETE MATHEMATICS (3)**

Sets, logic, induction, functions, relations, sequences, recursion, combinatorics, graphs and trees, matrices with an emphasis on applications in computer science. Prerequisite: COSC 236.

### **MATH 265 ELEMENTARY LINEAR ALGEBRA (4)**

Matrix calculations and determinants, vector spaces over the real numbers, linear transformations, eigenvalues, eigenvectors, and inner products with emphasis on applications. Not open to students who successfully completed MATH 365 or MATH 463. Prerequisite: MATH 211 or MATH 273.

### **MATH 267 INTRODUCTION TO ABSTRACT MATHEMATICS (4)**

Sets, mappings, relations, logic, mathematical induction, properties of the integers, Fundamental Theorem of Arithmetic, polynomials, and elementary analytic concepts. Not open to those who successfully completed MATH 361 or MATH 467. Prerequisites: MATH 273 and MATH 265 or consent of the instructor.

### **MATH 273 CALCULUS I (4)**

Functions, limits, and continuity; differentiation of algebraic and trigonometric functions; mean value theorem; differentials; introduction to integration; applications. Four lecture hours and one laboratory hour per week. Students who have successfully completed the honors version of this course (MATH 283) will not receive additional credit for this course. Prerequisite: qualifying score on Math Placement exam or MATH 117 or MATH 119. Core: Mathematics.

### **MATH 273S CONNECTIONS TO CALCULUS I (1)**

Explorations to support MATH 273. Helps students to review prior mathematical knowledge that is relevant to upcoming topics in Calculus I. Students will develop their mathematical communication skills, study skills, and mathematical mindset through discussions and activities. Not designed for students who have successfully completed MATH 273. Graded S/U. Corequisite: MATH 273.

### **MATH 274 CALCULUS II (4)**

Differentiation and integration of exponential, logarithmic, and inverse trigonometric functions; techniques of integration and applications; indeterminate forms; improper integrals; sequences and series of numbers; power series. Prerequisite: MATH 273. Core: Mathematics.

### **MATH 275 CALCULUS III (4)**

Vectors in two and three dimensions, differential and integral calculus of functions of several variables. Four lecture hours and one laboratory hours per week. Prerequisite: MATH 274.

### **MATH 280 INDEPENDENT STUDY (1-4)**

Supervised original work in mathematics. May be repeated for up to eight units. Prerequisite: consent of instructor.

### **MATH 283 HONORS CALCULUS I (4)**

Functions, limits, and continuity; differentiation of algebraic and trigonometric functions; mean value theorem; differentials; introduction to integration; applications. Honors College course. Students who have successfully completed the non-honors version of this course will not receive additional credit for this course. Prerequisites: admission to Honors College and MATH 117 or MATH 119 or adequate score on placement test. Core: Mathematics.

### **MATH 293 HONORS SEMINAR IN MATHEMATICS (3)**

A problem solving seminar designed for students who have shown talent in mathematics but have not yet been exposed to advanced mathematics courses. Techniques of problem solving and the solution of challenging problems involving elementary mathematics, such as probability, number theory, graph theory, and counting. Honors College course. Qualified students will usually take this course during their freshman or sophomore year. Prerequisite: admission to Honors College and consent of department. Core: Mathematics.

### **MATH 310 FUNCTIONS AND MODELING FOR SECONDARY SCHOOL TEACHERS (3)**

Engagement in explorations of mathematics to broaden and deepen content knowledge, emphasizing concepts needed to teach secondary mathematics at various levels. Investigations into mathematical topics including regressions in modeling; functions, rates, and patterns; and functions in other systems, with an emphasis on written communication about mathematical ideas and models. Prerequisites: ENGL 102 or ENGL 190 or equivalent; MATH 273, MATH 274, and MATH 265; either SEMS 230 or SCED 305 (may be taken concurrently); MATH 267 is recommended. Core: Advanced Writing Seminar.

### **MATH 312 THEORY OF INTEREST (4)**

Covers the mathematical theory and applications of key financial management concepts and procedures including money growth, force of interest, annuities, perpetuities, amortization, stocks, bonds, yield approximation approaches, term structure of interest rates, swaps, determinants of interest, duration, convexity, and asset matching. Prerequisite: MATH 274.

### **MATH 314 INTRODUCTION TO CRYPTOGRAPHY (3)**

A broad introduction to cryptography and its mathematical foundations: Elementary number theory; classical and modern symmetric key cryptosystems; public key cryptography; primality tests, factoring algorithms; hash functions and digital signatures. Selected further topics may include security protocols, digital cash, elliptic curve cryptography, or quantum cryptography. Prerequisites: COSC 236; either MATH 263 or MATH 267; and either MATH 330 or MATH 331 (may be taken concurrently).

### **MATH 315 APPLIED COMBINATORICS (4)**

General counting methods, pigeonhole principle, inclusion-exclusion principle, generating functions, recurrence relations, summation techniques, partitions, permutations and pattern avoidance, Polya's enumeration, asymptotics, select topics from graph theory. Prerequisites: MATH 274; MATH 263 or MATH 267.

### **MATH 320 TEACHING ADVANCED PLACEMENT CALCULUS FOR PRESERVICE TEACHERS (3)**

Integration of mathematical knowledge and pedagogical techniques to successfully teach Advanced Placement Calculus at the secondary level. Prerequisites: MATH 273 and MATH 274.

### **MATH 321 TEACHING MATHEMATICS IN EARLY CHILDHOOD EDUCATION (3)**

Analysis of pedagogical methods and materials in early childhood mathematics instruction and assessment. Mathematics topics include, but are not limited to, those taught in grades PreK - 3. Prerequisites: MATH 204, MATH 205, and MATH 251, or their equivalents.

### **MATH 323 TEACHING MATHEMATICS IN ELEMENTARY SCHOOL (3)**

Analysis of pedagogical methods and materials in elementary school mathematics instruction and assessment. Mathematics topics include, but are not limited to, those taught in grades 1 - 6. Corequisite: MATH 324. Prerequisites: MATH 204, MATH 205, and MATH 251, or their equivalents.

**MATH 324 SUPERVISED OBSERVATION/PARTICIPATION IN ELEMENTARY SCHOOL MATHEMATICS (2)**

Application of pedagogy and methodology for developing and conducting classroom activities in mathematical concepts and skills during a weekly field experience at a local elementary school. Graded S/U. Corequisite: MATH 323.

**MATH 325 MATHEMATICAL PROBLEM SOLVING FOR MIDDLE SCHOOL TEACHERS (3)**

A problem solving seminar designed for students who have not yet been exposed to advanced mathematics courses. Problems solving strategies will be applied to a variety of challenging problems, related to topics from middle and high school mathematics curricula. An important focus of the course is oral and written justifications of solutions. No credit toward a Mathematics major or minor. Prerequisites: MATH 273 and one from MATH 215, MATH 225, MATH 235, or MATH 255; consent of department.

**MATH 330 INTRODUCTION TO STATISTICAL METHODS (4)**

An introductory course for students with mathematics and computing backgrounds emphasizing statistical ideas and techniques. Descriptive statistics, probability, estimation and sampling, hypothesis testing, regression and correlation, and analysis of variance. A statistical package such as MINITAB is introduced as a computational tool. Prerequisite: MATH 274.

**MATH 331 PROBABILITY (4)**

Probability in sample spaces, discrete and continuous random variables, distribution theory, Chebyshev's Theorem, Central Limit Theorem, expected values and moments. Prerequisite: MATH 275 (may be taken concurrently).

**MATH 332 MATHEMATICAL STATISTICS (3)**

Sample theory and distributions, point estimation, confidence intervals, tests of hypothesis, and theory of statistical inference. Prerequisite: Math 331 (MATH 531).

**MATH 337 APPLIED REGRESSION AND TIME SERIES PREDICTIVE MODELING (4)**

Simple and multiple regression, least squares estimates, hypothesis testing, confidence intervals and prediction intervals, model building methods and diagnostic checking. Non-seasonal time series models: autoregressive, moving-average and/or autoregressive integrated moving-average models, parameter estimation and forecasting. Minitab or a similar software is used for real data analysis. Prerequisites: MATH 265 or equivalent and MATH 332/ MATH 532 or equivalent.

**MATH 353 EUCLIDEAN AND NON-EUCLIDEAN GEOMETRIES (3)**

Review of synthetic Euclidean geometry, non Euclidean geometries, finite geometries and systems of axioms, classical theorems and elementary transformations. Prerequisites: MATH 265, MATH 273, and one of the following: MATH 251, MATH 263, or MATH 267.

**MATH 369 INTRODUCTION TO ABSTRACT ALGEBRA (4)**

Elementary number theory; congruences, groups up to and including the isomorphism theorems, commutative rings, polynomials, unique factorization, irreducibility, finite fields. Prerequisites: MATH 265, MATH 267, and MATH 274.

**MATH 371 INTRODUCTION TO MACHINE LEARNING (3)**

An introduction to the theory and implementation of machine learning. Linear methods in regression and classification; feature mapping; kernels; overfitting; model selection. Additional topics may include support vector machines or unsupervised learning. Course design integrates coding, algorithmic implementation, and mathematical theory. Prerequisites: MATH 265 and MATH 274; MATH 331 (may be taken concurrently).

**MATH 372 REAL ANALYSIS I (4)**

An introduction to the real numbers and the analytic properties of real-valued sequences and functions. The set of real numbers; sequences and series; continuous functions and uniform continuity; differentiation; Riemann integration. Prerequisites: MATH 267 and MATH 275.

**MATH 374 DIFFERENTIAL EQUATIONS (3)**

Theory and application of linear ordinary differential equations: homogeneous and nonhomogeneous linear equations, initial and boundary value problems, exact equations, variation of parameters, Euler equations; solutions of non-linear ordinary differential equations of the first order and second order; power series solutions; system of linear equations. Prerequisite: MATH 274.

**MATH 377 MATHEMATICAL MODELS (3)**

Developing appropriate mathematical models and techniques to solve mathematical problems in sociology, psychology, economics, management science, and ecology. Prerequisites: MATH 265, MATH 274, COSC 236 and at least junior standing.

**MATH 378 EXPERIMENTAL MATHEMATICS (3)**

A course-based introduction to undergraduate research and mathematical exploration through computational experimentation. Programming, computational methods, algorithms, and software environments used by research mathematicians. Students will apply these tools to explore patterns and make conjectures and explore the role of computation in formal mathematical proofs. Possible topics include: combinatorics, number theory, numerical analysis, modeling and visualization, fractals, computer-assisted proofs and graph theory. Prerequisites: COSC 236, MATH 265, MATH 274 and either MATH 263 or MATH 267 (or by permission of the instructor).

**MATH 379 FOURIER ANALYSIS WITH APPLICATIONS (3)**

Fourier series, orthogonal functions, partial differential equations, and boundary value problems. The Fourier integral and applications. Prerequisites: MATH 267 and MATH 275.

**MATH 420 APPLICATIONS OF TECHNOLOGY FOR SECONDARY SCHOOL TEACHERS (3)**

Utilization of instructional technology to teach mathematics for conceptual understanding, with topics from the areas of algebra, geometry, trigonometry, and calculus. Specific technologies for study will be chosen based on current use in school settings, and may include calculators, computers, mathematics software and apps, and digital fabrication tools or other makerspace technology. Prerequisites: MATH 330 and MATH 353.

**MATH 423 TEACHING MATHEMATICS IN THE SECONDARY SCHOOLS (4)**

Best practices for teaching mathematics at the secondary level; analysis and application (in integrated field experience) of methods for planning, conducting, and reflecting on mathematics instruction and assessment. Corequisite: SEMS 498. Prerequisite: MATH 353.



**MATH 424 SCHOOL-BASED METHODS FOR MIDDLE SCHOOL MATHEMATICS TEACHING (2)**

Application of methodology for developing and conducting classroom activities in mathematical concepts and skills relevant at the middle school level of instruction. No credit toward a Mathematics major or minor. Graded S/U. Corequisite: MATH 425.

**MATH 425 MATHEMATICS TEACHING IN THE MIDDLE SCHOOL (3)**

Best practices for delivery and assessment of mathematical concepts and skills relevant to the middle school level of instruction. No credit toward a Mathematics major or minor. Prerequisites: MATH 215, MATH 225, MATH 235, MATH 255, and MATH 325; department consent required.

**MATH 426 INTERNSHIP IN SECONDARY EDUCATION - MATHEMATICS (6-12)**

Field experience in public school classrooms under the guidance of master teachers and a university supervisor. May be repeated to a maximum of 12 units. Graded S/U. Prerequisites: MATH 423, SEMS 498, and permission of Mathematics Department and Towson UTeach. Internship/Practicum fee will be assessed.

**MATH 430 SEMINAR IN INTERNSHIP (1)**

Seminar for current student interns to discuss topics from the classroom experience and current issues. Prerequisites: MATH 423 or SEMS 370; and current with MATH 426.

**MATH 435 NUMERICAL ANALYSIS I (3)**

Error analysis, interpolation, numerical differentiation and integration, numerical solution of algebraic equations, direct and iterative techniques for solving linear systems of algebraic equations. Mathematical and comparable computer algebra systems will be used. Prerequisites: MATH 265, MATH 274, and COSC 236.

**MATH 437 OPERATIONS RESEARCH (3)**

Introduction to linear, integer and nonlinear programming, the simplex method and interior point methods, duality and sensitivity analysis; formulation of optimization models and applications to problems from industry. Prerequisites: MATH 265 and MATH 331.

**MATH 438 FUNDAMENTALS OF LONG-TERM ACTUARIAL MATHEMATICS (4)**

Mathematical foundations of life contingencies and their applications to the practice of long term insurance products, including life insurance, life annuities and pension plans. Topics include survival and longevity models, life tables, present value random variables, expected present values, higher moments for life insurance and life annuity payments, future loss random variables, the actuarial equivalence principle, percentile principles for premium calculation, reserves. Prerequisites: MATH 312 and MATH 331.

**MATH 439 COMPUTATIONAL PROBABILITY MODELS (3)**

Markov chains, exponential distribution, Poisson process, continuous time Markov chains, Brownian motion and stationary processes. Prerequisite: MATH 331.

**MATH 441 FUNDAMENTALS OF SHORT-TERM ACTUARIAL MATHEMATICS (3)**

Insurance and reinsurance coverages; severity, frequency, and aggregate models; parametric estimation; introduction to credibility; introduction to pricing and reserving for short-term insurance coverages. Prerequisite: MATH 331.

**MATH 442 ADVANCED SHORT-TERM ACTUARIAL MATHEMATICS (3)**

Advanced severity, frequency, and aggregate models; coverage modifications; construction and selection of parametric models; credibility; pricing and reserving for short-term insurance coverage. Prerequisite: MATH 441.

**MATH 447 STATISTICS FOR RISK MODELING (3)**

The theory and applications of key statistics for risk modeling concepts and procedures including supervised versus unsupervised learning, regression versus classification, the common methods of assessing model accuracy, data checking and validation, generalized linear models, principal component analysis, decision tree models, bagging, boosting, and random forests, cluster analysis, K-means clustering, and hierarchical clustering. R or a similar software package is used for data analysis. Prerequisite: MATH 337 (may be taken concurrently).

**MATH 448 ADVANCED LONG-TERM ACTUARIAL MATHEMATICS (3)**

Advanced actuarial models for long-term insurance coverage. Topics include survival models for multiple state contingent cash flows to single lives and joint lives; multiple state dependent insurance and annuity present value random variables and their expectation; premium and policy valuation for long-term state-contingent coverage; multiple state model estimation and the construction of multiple decrement models; pension plans and retirement health benefits; embedded options in life insurance and annuity products. Prerequisite: MATH 438.

**MATH 451 GRAPH THEORY (3)**

Hamiltonian and Eulerian graphs, coloring graphs, planar and non-planar graphs, connectivity problems; isomorphic graphs, and advanced topics. Prerequisite: MATH 263 or MATH 267.

**MATH 457 DIFFERENTIAL GEOMETRY (3)**

Curvatures of curves and surfaces in three dimensional Euclidean space, geodesics, invariants, mappings, and special surfaces. Prerequisite: MATH 275 and MATH 265.

**MATH 463 LINEAR ALGEBRA (3)**

Vector spaces over arbitrary fields, linear transformations, eigenvalues, eigenvectors, inner products, bilinear forms, direct sum decompositions and the Jordan form. Prerequisites: MATH 265 and MATH 267.

**MATH 465 NUMBER THEORY (3)**

An introduction to elementary number theory: prime numbers, prime factorization, modular arithmetic, arithmetic functions, primitive roots, and quadratic residues. Additional topics may include: elliptic curves, Diophantine equations, sums of squares, the distribution of primes, and applications. Prerequisites: MATH 263 or MATH 267; and MATH 274.

**MATH 467 ALGEBRAIC STRUCTURES (3)**

Topics include groups, solvability, and insolubility of polynomials, principal ideal, Euclidean, and unique factorization domains. Prerequisite: MATH 369.

**MATH 471 SEMINAR IN COMPUTATIONAL DATA SCIENCE (3)**

Integration of mathematical and computing knowledge in the field of computational data science and machine learning, with application. Prerequisite: MATH 371.

**MATH 472 REAL ANALYSIS II (3)**

A second course in real analysis. Sequences of functions and uniform convergence; Metric spaces, including completeness and compactness. Functions of several variables including derivatives and differentiability, multivariable integrals and Fubini's theorem, null sets and Riemann integrability. Prerequisite: MATH 372 or MATH 473.

**MATH 473 INTRODUCTORY REAL ANALYSIS (4)**

An introduction to mathematical analysis. Sequences, series, continuity, differentiation, integration and uniform convergence. Prerequisites: MATH 267 and MATH 275.

**MATH 475 COMPLEX ANALYSIS (3)**

Complex number system, analytic functions, Cauchy's integral theorem and integral formula, Taylor and Laurent series, isolated singularities, Cauchy's residue theorem and applications. Prerequisites: MATH 267 and MATH 275.

**MATH 477 TOPOLOGY (3)**

Basic concepts of point set topology, separation axioms, compact and connected spaces, product and quotient spaces, convergence, continuity and homeomorphisms. Prerequisites: MATH 267 and MATH 275.

**MATH 480 SELECTED TOPICS IN MATHEMATICS (1-4)**

Topics will be chosen from different areas in mathematics and statistics. Content will be determined so as to complement course offerings as well as the needs and desires of students. May be repeated for a maximum of 9 units, provided a different topic is covered.

**MATH 485 MATHEMATICAL FINANCE (3)**

Mathematical theory, computation and practical applications of financial derivatives in managing financial risk. Parity and option relationships, binomial option pricing, the Black-Scholes equation and formula, option Greeks, market-making and delta-hedging, exotic options, lognormal distribution, Brownian motion and Ito's lemma, interest rate models. Computer laboratory activities throughout. Prerequisite: MATH 331.

**MATH 486 RISK MANAGEMENT AND FINANCIAL ENGINEERING (3)**

Mean-variance portfolio theory, assets pricing models, market efficiency and behavioral finance, investment risk and project analysis, capital structures, Cash flow engineering, Monte Carlo methods, statistical analysis of simulated data, risk measures, framework for fixed income engineering, portfolio management, change of measures and Girsanov Theorem and tools for volatility engineering. Computer laboratory activities throughout. Prerequisite: MATH 485.

**MATH 490 SENIOR SEMINAR IN MATHEMATICS (3)**

Selected mathematical topics and their applications. Prerequisites: senior standing and a grade of C or better in MATH 331 and MATH 369; or permission of instructor.

**MATH 491 READINGS IN MATHEMATICS (1-3)**

Independent reading in selected areas of mathematics. May be repeated for a maximum of 6 units. Prerequisites: consent of instructor and senior status.

**MATH 492 RESEARCH IN MATHEMATICS (1-3)**

Supervised original work in pure or applied mathematics. Formal written report required. May be repeated for 6 units. Prerequisite: consent of instructor. Graded S/U.

**MATH 493 READINGS IN MATH EDUCATION (1-3)**

An introduction to the theory and methodology of mathematics education research, including quantitative and qualitative designs. Students will gain experience in reading and interpreting mathematics education research, with a specific focus on applying research findings to classroom practice. Prerequisites: consent of department and senior status.

**MATH 494 INDEPENDENT STUDY: RESEARCH IN MATHEMATICS EDUCATION (1-3)**

Supervised original work in mathematics education. May be repeated once for up to six units. Prerequisite: consent of instructor. Graded S/U.

**MATH 495 APPLIED MATHEMATICS LABORATORY I (3)**

Investigation by a team of students under faculty direction of a problem of mathematical and/or computational nature, chosen from proposals submitted by clients in the university or local industry. Team involvement may include literature searches, model definition, collection and analysis of data, and model verification. Restricted to invited students. Prerequisites: 9 units, of mathematics and/or computer science, at least junior standing, and consent of instructor.

**MATH 496 APPLIED MATHEMATICS LABORATORY II (3)**

Investigation by a team of students under faculty direction of a problem of mathematical and/or computational nature, chosen from proposals submitted by clients in the university or local industry. Team involvement may include literature searches, model definition, collection and analysis of data, and model verification. Restricted to invited students. Prerequisites: 9 units of mathematics and/or computer science, at least junior standing, and consent of instructor.

**MATH 498 SENIOR SEMINAR: ACTUARIAL SCIENCE AND RISK MANAGEMENT (3)**

Integration of mathematical and financial knowledge in the field of Actuarial Science and Risk Management. Prerequisites: MATH 438; must have attempted two Society of Actuaries exams and passed at least one Society of Actuaries exam.

**MATH 499 HONORS THESIS IN MATHEMATICS (1)**

Writing an honors thesis based on research in a two-course independent research sequence under the supervision of a thesis advisor and the presentation of an oral thesis defense open to the public. Graded S/U. Prerequisites: consent of department and senior standing.