

# MATHEMATICS (MATH)

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## **MATH 101 Algebra (3 semester hours)**

Polynomials, rational expressions, exponents, radicals, equations in one and two variables, the quadratic formula, functions and graphs.

## **MATH 102 Quantitative Skills for the Modern World (3 semester hours)**

Quantitative and analytic skills used to understand personal and social issues faced in everyday life. Topics include problem solving, logical arguments, computer spreadsheets, probability and statistics, and the mathematics of finance. Corequisite: MATH 103. University Core fulfilled: Foundations: Quantitative Reasoning.

## **MATH 103 Quantitative Skills for the Modern World Lab (0 semester hours)**

Concurrent laboratory for MATH 102. Corequisite: MATH 102.

## **MATH 104 Elementary Statistics (3 semester hours)**

Introduction to methods of inferential statistics, histograms, elementary probability, and random variables and distributions. University Core fulfilled: Foundations: Quantitative Reasoning.

## **MATH 106 Mathematics for Elementary Teachers I (3 semester hours)**

Foundations of arithmetic from an advanced standpoint: sets, numeration systems, the structure of number systems, and problem solving strategies. Prerequisite: MATH 101 with a minimum grade of C (2.0) or Mathematic Placement Examination. Liberal Studies majors only, or by permission of instructor. University Core fulfilled: Foundations: Quantitative Reasoning; Explorations: Nature of Science, Technology, and Mathematics.

## **MATH 112 Calculus for Business (3 semester hours)**

Introduction to the differential and integral calculus of elementary functions. Applications of the methods of calculus to business and economics problems. Students may not take both MATH 112 and MATH 122 for credit. Prerequisite: MATH 120 or Mathematics Placement Examination. A laboratory fee may be required.

## **MATH 120 Precalculus Mathematics (3 semester hours)**

Functions; polynomial, rational, trigonometric, exponential and logarithmic functions. Prerequisite: MATH 101 or Mathematics Placement Examination. University Core fulfilled: Foundations: Quantitative Reasoning.

## **MATH 122 Calculus for the Life Sciences I (3 semester hours)**

An introduction to calculus. Derivatives and integrals of the elementary functions, including computational techniques and applications. Prerequisite: MATH 120 or Mathematics Placement Examination. Students may not take both MATH 112 and MATH 122 for credit. University Core fulfilled: Foundations: Quantitative Reasoning; Explorations: Nature of Science, Technology, and Mathematics.

## **MATH 123 Calculus for the Life Sciences II (3 semester hours)**

Integration methods with applications, differential equations and modeling, introduction to multivariate calculus. Prerequisite: MATH 122 or equivalent. University Core fulfilled: Foundations: Quantitative Reasoning; Explorations: Nature of Science, Technology, and Mathematics.

## **MATH 131 Calculus I (4 semester hours)**

Limits, continuity, derivatives of algebraic and transcendental functions, applications of the derivative, antiderivatives, introduction to the definite integral, Fundamental Theorem of Calculus. Prerequisite: MATH 120 or Mathematics Placement Examination. University Core fulfilled: Foundations: Quantitative Reasoning; Explorations: Nature of Science, Technology, and Mathematics.

## **MATH 132 Calculus II (4 semester hours)**

Techniques of integration, numerical methods of integration with error analysis, applications of the integral, improper integral, infinite series, an introduction to parametric equations and polar coordinates. Prerequisite: MATH 131 or equivalent. University Core fulfilled: Foundations: Quantitative Reasoning; Explorations: Nature of Science, Technology, and Mathematics.

## **MATH 181 Introduction to Programming (2 semester hours)**

An introduction to the basics of procedural programming useful for solving problems in mathematics, science, and engineering. Root finding, integration, and other mathematical methods (e.g. numerical differentiation, interpolation, and line-fitting) will be covered. Suggested programming languages and software may include Python, R, MATLAB. Prerequisite: MATH 131 or equivalent. For Mathematics majors and minors only, or by consent of instructor.

## **MATH 190 Workshop in Mathematics I (2 semester hours)**

Study skills, analytical and problem solving skills, technical writing, recent fields of study and advances in mathematics, mathematical career opportunities. Math majors only, or by permission of instructor.

## **MATH 191 Workshop in Mathematics II (2 semester hours)**

A continuation of MATH 190.

## **MATH 198 Special Studies (1-4 semester hours)**

## **MATH 199 Independent Studies (1-4 semester hours)**

## **MATH 204 Applied Statistics (3 semester hours)**

This course provides an introduction to statistics emphasizing data analysis and applications to life sciences. Topics include: descriptive statistics, elementary probability, various discrete and continuous distributions, confidence intervals and hypothesis tests for means and proportions, correlation and linear regression, as well as analysis of variance. This course will also include the use of computer programs to analyze data sets. Prerequisite: MATH 122 or MATH 131.

## **MATH 205 Applied Statistics (4 semester hours)**

An introduction to basic methods of extracting information from data with a focus on statistical methods and interpretation of results. Exploratory and descriptive data analysis including graphical examination of data and measures of central tendency and spread. Classical and non-parametric tools of hypothesis testing (t tests, one-way, and two-way ANOVA, Mann-Whitney and Kruskal-Wallis for mean-comparison problems). Simple linear regression. Practical considerations of experimental design. Analysis of data using modern computational software (e.g. R). Prerequisite: MATH 122 or MATH 131.

## **MATH 207 Mathematics for Elementary Teachers II (3 semester hours)**

Geometry, metric system, and introduction to probability and statistics. Prerequisite: MATH 106. For Liberal Studies majors only, or by permission of instructor. University Core fulfilled: Foundations: Quantitative Reasoning; Explorations: Nature of Science, Technology, and Mathematics.

## **MATH 234 Calculus III (4 semester hours)**

Partial derivatives, multiple integrals, three-dimensional space, vectors in two- and three-dimensional space, line integrals, Green's theorem. Prerequisite: MATH 132 or equivalent.

## **MATH 245 Ordinary Differential Equations (3 semester hours)**

Differential equations as mathematical models, analytical, qualitative, and numerical approaches to differential equations and systems of differential equations, and Laplace transform techniques. Prerequisite: MATH 132 or equivalent. University Core fulfilled: Flag: Quantitative Literacy.

**MATH 246 Differential Equations and Linear Algebra (4 semester hours)**

Systems of linear algebraic equations, Gaussian elimination, matrices, and matrix algebra. Algebra of complex numbers. Linear dynamical systems and equilibrium. Analytical solutions of linear differential equations, including Laplace transform and linear time-domain analysis. Eigenvalues, eigenvectors and the matrix exponential. Differential equations as mathematical models. Analysis of nonlinear differential equations, including analytical and numerical solutions and qualitative analysis. Students will use software (e.g. C++, MATLAB, or Python) to compute and graph solutions using analytical and numerical methods. Prerequisites: MATH 132.

**MATH 249 Introduction to Methods of Proof (4 semester hours)**

Number theory, sets, functions, equivalence relations, cardinality, methods of proof, induction, contradiction, contraposition. Student portfolios will be collected. Prerequisite: MATH 132 or equivalent.

**MATH 250 Linear Algebra (3 semester hours)**

Systems of linear equations, Gauss and Gauss-Jordan elimination, matrices and matrix algebra, determinants. Linear transformations of Euclidean space. General vector spaces, linear independence, inner product spaces, orthogonality. Eigenvalues and eigenvectors, diagonalization. General linear transformations. Prerequisites: MATH 234 or MATH 248 or consent of instructor.

**MATH 251 Applied Linear Algebra (4 semester hours)**

An introduction to matrix methods with an emphasis on modern computational techniques. Topics include: Gaussian elimination, LU factorization, vector spaces and subspaces, orthogonality, QR factorization, determinant, eigenvalues and eigenvectors, diagonalization, least square optimization problem, Markov chains, and singular value decomposition. Students will use software (e.g. C++, MATLAB, or Python) to do computations with large matrices and investigate modern applications in various fields. Prerequisites: MATH 131 and (MATH 181 or CMSI 1010 or ENGR 160 or ENGR 1200 or consent of instructor).

**MATH 261 Mathematics: Contributions by Women (3 semester hours)**

A study of the biographies and mathematics of women mathematicians from the 1st through the 20th centuries. Topics include prime numbers, conic sections, cycloid curve, functions, sequences, series, polyhedra, and group theory. Prerequisite: MATH 101 or higher, or placement into MATH 106 or higher.

**MATH 264 Cryptography through the Ages (3 semester hours)**

A study of mathematical systems used for enciphering and deciphering information and the context in which these systems arose. Prerequisite: MATH 101 or higher, or placement into MATH 106 or higher.

**MATH 290 Workshop in Mathematics II (1 semester hour)**

Continuation of MATH 190. Activities will include attending departmental events (e.g. career talks, seminars, senior thesis presentations, math community events), improving study skills, analytical and problem solving skills, mathematical writing and presentation skills, and other activities at the discretion of the instructor. For Mathematics majors only, or by permission of instructor.

**MATH 293 Mathematics Teaching Field Experience (0 semester hours)**

Planned observation, instruction or tutoring experiences appropriate for future secondary or middle school mathematics teachers; related professional reading and reflections.

**MATH 298 Special Studies (1-4 semester hours)****MATH 299 Independent Studies (1-4 semester hours)****MATH 304 Multivariable Statistics (4 semester hours)**

Statistical analysis of large multivariate datasets. Multivariate densities and distributions. The general linear model and multivariate regression, analysis of variance. Multilevel linear models. Clustering and factor analysis. Time series models. Modern computational software. Prerequisites: MATH 205 and MATH 251 and (MATH 181 or CMSI 1010 or ENGR 160 or ENGR 1200 or consent of instructor).

**MATH 307 Teaching Math Practicum (2 semester hours)**

Students serve as Teaching Assistants for MATH 207. Students will integrate pedagogy with their mathematical content knowledge prepare for mathematics teaching careers. Junior standing and permission of instructor.

**MATH 323 Real Analysis I (4 semester hours)**

The real number system, least upper bound, sequences, Cauchy sequences, functions, limits of functions, continuity, derivatives, infinite series, sequences and series of functions, and Riemann integration. Prerequisite: MATH 249.

**MATH 332 Elements of the Theory of Rings and Fields (3 semester hours)**

Rings, integral domains, fields, ideals, factor rings, polynomial rings, and unique factorization domains. Prerequisite: MATH 331.

**MATH 333 Abstract Algebra I (4 semester hours)**

Groups, rings, integral domains, and fields, and the corresponding structure and isomorphism theorems, quotient and factor objects, and direct sums and products. Finite(ly generated) abelian groups, Cauchy's Theorem, complex roots and the Fundamental Theorem of Algebra, and an introduction to Sylow Theory. Prerequisite: MATH 249.

**MATH 356 Methods of Applied Mathematics (4 semester hours)**

Linear partial differential equations: Laplace, Poisson, heat and wave equations. Fourier analysis and its applications to signal processing and linear partial differential equations. Discrete Fourier Transform and the Fast Fourier Transform. Numerical approaches to partial differential equations: finite differences and spectral methods. Modeling of distributed parameter systems (i.e., systems whose state variable is infinite dimensional). Prerequisites: MATH 246.

**MATH 358 Complex Analysis (4 semester hours)**

Complex arithmetic, functions of complex variables, analytic functions, integration in the complex plane, Taylor and Laurent expansions and residues; conformal mappings, evaluation of real integrals by residues; integral transforms. Prerequisite: MATH 234.

**MATH 361 Probability and Mathematical Statistics (4 semester hours)**

Probability and statistics with an emphasis on mathematical techniques of analysis. Probability topics include: sample space, basic probability rules, conditional probability, independence, Bayes theorem, density and cumulative distribution functions, expectations, law of large numbers, Central Limit Theorem, functions of random variables, and stochastic modeling. Statistics topics include: sampling distributions, point and interval estimation, and mathematical methods of hypothesis testing. Additional topics may include stochastic simulation, bootstrapping, Bayesian inference, and regression. Prerequisites: MATH 132 and (MATH 181 or CMSI 1010 or ENGR 160 or ENGR 1200. University Core fulfilled: Explorations: Nature of Science, Technology, and Mathematics.

**MATH 367 Discrete Methods (4 semester hours)**

An introduction to graph theory; trees; coloring; Eulerian circuits. Combinatorics; permutations and combinations; recurrence relations; algorithmic approaches to combinatorics problems; implementation of algorithms in graph theory and combinatorics. Prerequisites: MATH 249 and (MATH 181 or CMSI 1010 or ENGR 160 or ENGR 1200).

**MATH 382 Applied Numerical Methods (4 semester hours)**

Algorithms for the numerical approximation of solutions to mathematical problems arising in applications. Integration, direct and iterative solutions of linear and nonlinear systems, optimization, and solution of differential equations. Discussion of convergence properties. Prerequisites: MATH 234 and MATH 246 and MATH 251.

**MATH 388 Survey of Biomathematics (3 semester hours)**

Introduction to the application of mathematical tools and techniques in biology. Application areas range from gene regulatory networks to physiological systems to ecology and environment biology. Mathematical methods include deterministic and probabilistic approaches to modeling dynamical systems, development, analysis, and simulation of model equations, and problems of fitting models to data. Prerequisites: BIOL 101 and MATH 123 or 132.

**MATH 390 Workshop in Mathematics III (1 semester hour)**

Continuation of MATH 290. Activities will include attending departmental events (e.g. career talks, seminars, senior thesis presentations, math community events), improving study skills, analytical and problem-solving skills, mathematical writing and presentation skills, and other activities at the discretion of the instructor. For Mathematics majors only, or by permission of instructor.

**MATH 393 Mathematics Internship (1-3 semester hours)**

Internship conducted in an industrial, business, government, or educational setting involving applied mathematical work or teaching. This will involve a research project (or paper) coordinated jointly with an on-site supervisor and a Department faculty member. Enrollment is subject to available opportunities and approval of the Department Chairperson.

**MATH 397 Putnam Competition Preparation (0-1 semester hours)**

A study of problem-solving techniques and skills to prepare students to participate in the William Lowell Putnam Mathematical Competition, a prestigious national exam. The course may not be used to satisfy any of the requirements of the mathematics major or minor. Permission of instructor required.

**MATH 398 Special Studies (1-4 semester hours)****MATH 399 Independent Studies (1-4 semester hours)****MATH 423 Real Analysis II (4 semester hours)**

Advanced topics in real analysis (e.g. measure theory, functional analysis, Fourier analysis, functions of several variables, etc.) chosen by the instructor. Written and oral presentations are required. Prerequisite: MATH 323.

**MATH 433 Abstract Algebra II (4 semester hours)**

Advanced topics in abstract algebra (e.g. Galois theory, representation theory, algebraic geometry, etc.) chosen by the instructor. Written and oral presentations are required. Prerequisite: MATH 333.

**MATH 450 Advanced Linear Algebra (4 semester hours)**

Abstract vector spaces (vector spaces over an arbitrary field), abstract linear transformations, dual spaces, diagonalizability (review of eigenspaces), Cayley-Hamilton Theorem, canonical forms (Jordan, etc.), inner product spaces, spectral theorem, additional topics as time permits. Prerequisites: MATH 249 and MATH 251.

**MATH 451 Fundamental Concepts of Geometry (4 semester hours)**

Euclidean and non-Euclidean planar geometries, axiomatic systems, synthetic and analytic representations, relationships with algebra, and selected topics and applications. Prerequisites: MATH 249 and MATH 251.

**MATH 460 Advanced Topics in Probability (4 semester hours)**

Advanced topics in probability (e.g. Stochastic processes, Markov chains, Monte Carlo methods, etc.) chosen by the instructor. Written and oral presentations are required. Prerequisite: MATH 361.

**MATH 470 Machine Learning (4 semester hours)**

Linear regression, logistic/softmax regression, support vector machine, k-nearest neighbors, tree-based methods, linear separability, overfitting/underfitting, regularizers, gradient descent method. Possible additional topics include: kernel methods, k-means clustering, principal component analysis, dimensionality reduction, semi-supervised learning, boosting, random forest, and sampling methods. Prerequisites: MATH 234 and MATH 251 and CMSI 1010 or permission of instructor.

**MATH 472 Topology (4 semester hours)**

An introduction to metric and topological spaces; continuity and homeomorphism; separation properties; connectivity and compactness; examples and applications. Written and oral presentations are required. Prerequisite: MATH 323.

**MATH 473 Differential Geometry (3 semester hours)**

Curves, parametrizations, and arc length; surfaces, differential functions, and the first fundamental form (area); the Gauss map; isometries, Gauss' Theorema Egregium, geodesics, and the Gauss-Bonnet theorem. Prerequisites: MATH 234 and 250.

**MATH 480 Big Data Visualization (4 semester hours)**

Introduction to the tools and techniques of modern data visualization including concepts of scraping, wrangling, cleaning, and processing data from the web and other large databases. The course focuses on visualizing multidimensional data and designing clear and appropriate data graphics through apps and interactive displays (e.g., maps). This course requires a willingness to write code. Prerequisite: MATH 304.

**MATH 482 Advanced Numerical Methods (4 semester hours)**

Advanced topics in numerical methods and scientific computation (e.g. iterative solutions of linear systems on advanced computer architectures, high-dimensional numerical integration, numerical solution of PDEs, optimal control, constrained optimization, matrix factorization, conjugate gradient, etc.) chosen by the instructor. Written and oral presentations are required. Prerequisite: MATH 382.

**MATH 490 History of Mathematics (3 semester hours)**

The development of mathematics from historical and cultural viewpoints including both European and non-European roots of mathematics as well as contributions by women. Prerequisite: MATH 248.

**MATH 491 Senior Mathematics Seminar (3 semester hours)**

Topics in mathematics chosen by the instructor. Written and oral presentations are required.

**MATH 492 Workshop in Mathematics IV (1 semester hour)**

Continuation of MATH 390. Activities will include attending departmental events (e.g. career talks, seminars, senior thesis presentations, math community events), improving study skills, analytical and problem-solving skills, mathematical writing and presentation skills, and other activities at the discretion of the instructor. For Mathematics majors only, or by permission of instructor.

**MATH 493 Senior Seminar for Future Mathematics Educators (3 semester hours)**

Topics in high school mathematics are examined from an advanced standpoint by developing and exploring extensions and generalizations of typical high school problems, by making explicit connections between these problems and upper division mathematics courses, and by providing historical context. Current issues in secondary mathematics education will be investigated. Written and oral presentations are required. Senior standing or permission of instructor required.

**MATH 494 Senior Seminar for Future Mathematics Educators (2 semester hours)**

Topics in high school mathematics are examined from an advanced standpoint by developing and exploring extensions and generalizations of typical high school problems, by making explicit connections between these problems and upper division mathematics courses, and by providing historical context. Current issues in secondary mathematics education will be investigated. Written and oral presentations are required. Senior standing and permission of instructor.

**MATH 495 Mathematical Modeling (3 semester hours)**

Introduction to various modeling techniques, design and implementation of algorithms, organization and presentation of results, introduction to problem solving using computer algebra systems. Written and oral presentations are required. Senior standing or permission of instructor required.

**MATH 496 Mathematical Modeling (4 semester hours)**

Introduction to various modeling techniques, design and implementation of algorithms, organization and presentation of results, introduction to problem solving using computer algebra systems. Written and oral presentations are required. Senior standing or permission of instructor required.

**MATH 497 Senior Thesis (3 semester hours)**

This course is intended to provide the student with an opportunity to complete a substantive research project under the guidance of a faculty member. The student will prepare a written report and an oral presentation on the project at the end of the semester. Senior standing and the consent of both the Chairperson and a faculty thesis advisor required.

**MATH 498 Special Studies (1-4 semester hours)****MATH 499 Independent Studies (1-3 semester hours)****MATH 504 Modern Computational Statistics (4 semester hours)**

Generalized linear models: logistic, multinomial, and Poisson regression; bootstrapping: resampling simulations, estimation, confidence sets, and hypothesis testing; Bayesian methods: computational techniques such as Markov Chain Monte Carlo and Metropolis-Hastings, estimation, credible sets, and hypothesis testing. Prerequisites: MATH 304 and MATH 361.

**MATH 540 Deep Learning (4 semester hours)**

Neural networks and related algorithms: stochastic gradient descent and backpropagation. Modern deep learning framework (e.g. TensorFlow, Pytorch) and GPU computing. Convolutional Neural Networks and applications to image recognition. Recurrent Neural Network, Transformer networks and applications to natural language processing (e.g. sentiment analysis, translation, natural language modeling). Prerequisites: MATH 234 and MATH 251 and CMSI 1010 or permission of instructor.

**MATH 550 Fundamental Concepts of Geometry (3 semester hours)**

Euclidean and non-Euclidean planar geometries, axiomatic systems, synthetic and analytic representations, relationships with algebra, and selected topics and applications. Prerequisites: MATH 248 and 250.

**MATH 560 Advanced Topics in Probability and/or Statistics (3 semester hours)**

Material to be covered will be determined by the instructor. Consult with the instructor for the specific topics in probability and statistics that will be covered in any given semester. Prerequisites: MATH 234 and 360.

**MATH 561 Computational Methods in Linear Algebra (3 semester hours)**

Numerical solutions of linear systems of equations, Gauss elimination and iterative methods, eigenvalues and eigenvectors. Prerequisites: ENGR 160 or MATH 282 or ENGR 1200, and MATH 250 or permission of instructor.

**MATH 562 Numerical Analysis (3 semester hours)**

Numerical solutions of non-linear equations, interpolation, numerical differentiation, integration, and solution of differential equations. Prerequisites: ENGR 160 or MATH 282 or ENGR 1200, and MATH 245 or permission of instructor.

**MATH 590 History of Mathematics for Secondary Teachers (3 semester hours)**

The development of mathematics from historical and cultural viewpoints, including both European and non-European roots of mathematics as well as contributions by women. Course content will be connected to the secondary classroom. Prerequisite: MATH 248.

**MATH 593 Seminar for Mathematics Educators (3 semester hours)**

Topics in high school mathematics are examined from an advanced standpoint by developing and exploring extensions and generalizations of typical high school problems, by making explicit connections between these problems and upper division mathematics courses, and by providing historical context. Current issues in secondary mathematics education will be investigated. Written and oral presentations are required. Permission of instructor required.

**MATH 598 Special Studies (1-3 semester hours)****MATH 599 Independent Studies (1-3 semester hours)****MATH 601 Methods of Proof for Teachers (3 semester hours)**

This course introduces number theory proofs, analysis proofs with limits and functions, cardinality, geometry, logic and language, and set theory proofs. The importance of proof writing and explanation in mathematics are emphasized. Students are exposed to mathematical problem solving that extends the concepts of secondary mathematics. Consent of instructor required.

**MATH 604 Statistics/Modeling for Teachers (3 semester hours)**

This course selects from topics in statistics and modeling, such as basic descriptive statistics, inference, regression analysis, and modeling relationships. The use of statistics in the media and in educational studies is also a focus. The class is aligned with state standards in 6-12 grade statistics and is aligned with national recommendation from the American Statistical Association on teacher preparation of statistics. Permission of instructor required.

**MATH 621 Real Analysis for Teachers (3 semester hours)**

This course surveys topics in calculus, measure theory, and analysis. Calculus concepts are explored from an advanced perspective so as to reveal connections between secondary-school level analysis, calculus, and more advanced collegiate mathematics. Permission of instructor required.



**MATH 631 Abstract Algebra for Teachers (3 semester hours)**

This course introduces topics in number theory and abstract algebra, including modular arithmetic, properties of number systems, group, ring and field theory, and applications of abstract algebra, such as cryptography. Students will apply this knowledge in the context of the Standards for Mathematical Practice. Permission of instructor required.

**MATH 650 Geometry for Teachers (3 semester hours)**

This course investigates geometry from 4 perspectives: Euclid's axioms and constructions, Cartesian coordinates and algebra, projective and perspective geometry, and rigid and similarity transformations. This approach reinforces essential skills required for teaching geometry courses in the secondary curriculum by making connections to proving geometric theorems, using precise definitions, showing the connections between geometry and algebra and complex numbers, perfecting how to visualize in 2 and 3 dimensions, and understanding congruence and similarity through transformations. Permission of instructor required.

**MATH 660 Discrete Math and Probability for Teachers (3 semester hours)**

This course covers topics including combinatorics, recursion, algorithms, graph theory and probability. Students will also explore how these are integrated in secondary math and explore how topics of discrete math can extend secondary math curriculum. Permission of instructor required.

**MATH 698 Special Studies (1-3 semester hours)****MATH 699 Independent Studies (1-3 semester hours)**