MATHEMATICS (MATH)

MATH 100 Critical Themes in Mathematics, Historical and Modern (4 Credits)
The courses will explore ideas central to the evolution of mathematics and its application. Students will actively participate in the development of ideas explored in the courses. Some courses will require good high-school mathematics background. Sample topics might include Limits and Infinity, Linearity, Coding and Cryptanalysis, Geometry and Physics of Archimedes.
College Curriculum: C100

MATH 103 Pre-Calculus Math (3 Credits)
A study of the real number system, sets, functions, graphs, equations, inequalities and systems of equations, followed by a study of the trigonometric functions and their properties. This course is designed only for students intending to take Math 108 or Math 111, and whose background is deficient in algebra and trigonometry. Juniors and seniors must obtain permission from the instructor to enroll. This course may not be applied toward either the minor or major in mathematics or the satisfaction of GER requirements. A student may not receive credit for this course after successfully completing a Mathematics course numbered higher than 107, with the exception of Math 150.

MATH 104 The Mathematics of Powered Flight (3 Credits)
Applications of elementary mathematics to airplane flight. Wind and its effect on airport design and aircraft operation. Maps and map projections. Magnetic variation and compass navigation. Static air pressure: buoyancy and the altimeter. Use of a flight simulator will illustrate the mathematical analysis of certain aircraft instruments. Not open to students who have credit for a Mathematics course numbered above 210.
College Curriculum: C200, MAPR
Domain: NQR

MATH 106 Elementary Probability and Statistics (3 Credits)
Introduction to basic concepts and procedures of probability and statistics including descriptive statistics, probability, classical distributions, estimation, hypothesis testing, correlation and regression, in the context of practical applications to data analysis from other disciplines. Not open to students who have successfully completed a mathematics course numbered above 210.
College Curriculum: MAPR

MATH 108 Brief Calculus with Applications (4 Credits)
An introduction to the calculus of polynomial, rational, exponential and logarithmic functions, including some multi-variable calculus, with applications in business, social and life sciences. Algebra proficiency required. Students may not receive credit for more than one of Math 108, 111, and 131, and may not receive credit for Math 108 after receiving credit for any Mathematics course numbered higher than 108, with the exception of Math 150. To use Math 108 as a prerequisite for Math 112 or 132, students need approval of the department chair.
College Curriculum: MAPR

MATH 109 Linear Algebra (3 Credits)
Linear equations, matrices, determinants, vector spaces, linear transformations, eigenvalues, orthogonality, least squares, singular value decomposition. Co-registration in the computational laboratory MATH 109L is required.
Corequisite(s): MATH 109L
College Curriculum: MAPR

MATH 109L Computational Linear Algebra Lab (1 Credit)
In this course, students will learn to use a programming language as a tool to implement linear algebra methods. They will also learn to apply these new skills to solve real-world problems. This course builds upon the linear algebra course MATH 109, which discusses the theory of linear algebra. No previous programming experience is required. Co-registration in MATH 109 is required unless a student has already received credit for MATH 109.
Prerequisite(s): MATH 109 (may be taken concurrently) or (MATH 211)

MATH 110 Topics in Math I (3 Credits)
An introduction to mathematical thought with topics not routinely covered in existing courses. Material may be chosen from calculus, probability, statistics and various other areas of pure and applied mathematics.

MATH 111 Calculus I (4 Credits)
Standard functions (linear, polynomial, trigonometric, exponential, logarithmic) and their graphs. Tangents, derivatives, the definite integral and the fundamental theorem. Formulas for differentiation. Applications to physics, chemistry, geometry and economics. Requires graphing calculator. Concurrent enrollment in Math 111 calculus lab required. Students may not receive credit for more than one of Math 108, 111, and 131.
College Curriculum: MAPR
Domain: NQR

MATH 112 Calculus II (4 Credits)
Methods of integration. Applications of the integral to geometry, chemistry, physics and economics. Slope fields and the qualitative behavior of solutions to differential equations. Approximations: sequences, series, and Taylor series. Students may not receive credit for more than one of Math 112 and 132.
Prerequisite(s): (MATH 111 or MATH 131)
College Curriculum: MAPR

MATH 131 Calculus I for Life Sciences (4 Credits)
Standard functions (linear, polynomial, trigonometric, exponential, logarithmic) and their graphs. Tangents, derivatives, the definite integral and the fundamental theorem. Formulas for differentiation. Mathematical topics are similar to those in Math 111, but applications in Math 131 focus on issues of importance in the life sciences, e.g., mathematical models of population dynamics, ecology, physiology, genetics, neurology. Students may not receive credit for more than one of Math 108, 111, and 131.
College Curriculum: MAPR

MATH 132 Calculus II for Life Sciences (4 Credits)
Methods of integration. Slope fields and the qualitative behavior of solutions to differential equations. Probability distributions and integration to calculate probability. Applications in this course focus on issues of importance in the life sciences, mathematical models of population dynamics, ecology, physiology, and epidemiology. Mathematical topics are similar to those in Math 112. Students may not receive credit for both Math 112 and Math 132.
Prerequisite(s): MATH 111 or MATH 131
College Curriculum: MAPR

MATH 150 First-Year Seminar (4 Credits)
An exploration of a specific topic in Mathematics. A grade of C- or better fulfills the COLL 150 requirement. Although topics vary, the courses emphasize academic writing skills, reading and analysis of texts, and discussion.
College Curriculum: C150

MATH 210 Linearity (4 Credits)
Linear equations, dimension, linear transformations and their eigenvalues. Quadratic forms and matrix factorization. An introduction to research problems will include work in MATLAB and the typesetting language LATEX. Students may not take both Math 210 and Math 211 for credit.
Prerequisite(s): MATH 112

MATH 212 Introduction to Multivariable Calculus (3 Credits)
Functions of several variables, surfaces in three-space, vectors, techniques of partial differentiation and multiple integration with applications. Students may not receive credit for both Math 212 and 213.
Prerequisite(s): (MATH 112 or MATH 113 or MATH 132)

MATH 213 Multivariable Calculus for Science and Mathematics (4 Credits)
Covers all Math 212 material plus other vector calculus topics (including Gauss' and Stokes' theorems). Students may not receive credit for both Math 212 and MATH 213. Math 213 may replace Math 212 as a prerequisite and is particularly recommended for science and mathematics students.
Prerequisite(s): (MATH 112 or MATH 132 or MATH 113)

MATH 214 Foundations of Math (3 Credits)
Fundamentals of advanced mathematics: Propositional logic, quantifiers and methods of proof; naive set theory including mathematical induction, relations, orders, functions, and countability. Students will be expected to complete assignments using the typesetting software LaTeX.
Prerequisite(s): (MATH 112 or MATH 132)

MATH 240 Programming for the Mathematical Sciences (4 Credits)
This course trains students in practical, reproducible, and modern scientific programming with an emphasis on building strong computational habits for the mathematical sciences. Students will gain proficiency in scientific programming and learn to manage scientific workflows, version control, and high-performance computation.
Prerequisite(s): CSCI 140 or CSCI 141

MATH 265 Financial Mathematics (3 Credits)
Simple and compound interest and discount, annuity-immediate, annuity-due, perpetuity, varying annuities, amortization schedule, loan balance, valuation of bonds, yield rate, rate of return, discounted cash flow technique, time- and dollar-weighted interest, spot and forward rate, yield curve, duration, convexity, immunizations, interest rate swap. Prepares students for the Society of Actuaries' Exam FM and Casualty Actuarial Society's Exam 2.
Prerequisite(s): MATH 112

MATH 300 Mathematical Sciences Writing (1 Credit)
Students will develop their mathematical writing skills in a term written project. Sources for topice include the history of mathematics, research conducted by the student, or topics from an upper division course that the student has taken or is currently taking. Fulfills the major writing requirement.
Prerequisite(s): MATH 214

MATH 302 Ordinary Differential Equations (3 Credits)
First-order separable, linear, and nonlinear differential equations. First-order systems and forced second-order linear equations. Systems of linear equations and linearization. Numerical methods, bifurcations, and qualitative analysis. Applications to biology, chemistry, economics, physics, and social sciences.
Prerequisite(s): (MATH 212 or MATH 213) and MATH 211 or MATH 109 or MATH 210

MATH 307 Abstract Algebra (3 Credits)
Groups, rings, fields, isomorphisms; polynomials. Additional topics chosen from group theory and ring theory, as time permits.
Prerequisite(s): (MATH 211 or MATH 210 or MATH 109) and (MATH 214)

MATH 307H Honors Abstract Algebra (3 Credits)
Groups, rings, fields, isomorphisms; polynomials. Additional topics chosen from group theory and ring theory, as time permits. Math 307H will move at a faster pace than Math 307, cover additional topics not typically included in Math 307 such as modules, and is recommended for students who intend to take further Algebra courses like Math 430 and advanced topics courses.
Prerequisite(s): (MATH 210 or MATH 211 or MATH 109) and (MATH 214)

MATH 309 Theory of Vector Spaces (3 Credits)
This course will cover the theory of vector spaces from an abstract perspective, i.e., this is a proof-based linear algebra course. Topics include complex numbers, vector spaces, linear maps, eigenvalues and eigenvectors, inner product spaces. Additional topics such as the Real and Complex Spectral Theorems, Singular Value Decomposition, Jordan Canonical Form, bilinear and quadratic forms may be included if time permits.
Prerequisite(s): (MATH 211 or MATH 210 or MATH 109) and (MATH 214)

MATH 311 Elementary Analysis (3 Credits)
An introduction to the theory of real variables, the topology of the real line, convergence and uniform convergence, limits and continuity, differentiation, Riemann integration and the Fundamental Theorem of Calculus.
Prerequisite(s): (MATH 212 or MATH 213) and (MATH 214)

MATH 311H Honors Elementary Analysis (3 Credits)
An introduction to the theory of real variables, the topology of the real line, convergence and uniform convergence, limits and continuity, differentiation, Riemann integration and the Fundamental Theorem of Calculus. Additional topics discussed in this course and not covered in Math 311 include: construction of the real numbers, topology of metric spaces, sequences and series of functions. Math 311H is recommended for students who intend to take further Analysis courses such as Math 403, Math 426, Math 428 and advanced topics courses.
Prerequisite(s): (MATH 212 or MATH 213) and MATH 214

MATH 316 Euclidean and Non-Euclidean Geometry (3 Credits)
This course will cover Euclidean and Non-Euclidean geometry from an axiomatic standpoint. Topics include incidence and projective geometry, Euclidean geometry and the Parallel Postulate, and hyperbolic geometry. The historical development, significance, and philosophical implications of the material will be discussed.
Prerequisite(s): MATH 214
College Curriculum: C200
Domain: NQR

MATH 317 Differential Geometry of Curves and Surfaces (3 Credits)
A proof-based introduction to Differential Geometry, focusing on curves and surfaces. Topics include: parametrizations of curves and surfaces, implicit functions, tangent lines and planes, arc length, geodesics, curvature and Gauss' Theorema Egregium.
Prerequisite(s): (MATH 210 or MATH 211 or MATH 109) and (MATH 212 or MATH 213) and (MATH 214)

MATH 323 Operations Research: Deterministic Models (3 Credits)
An introduction to operations research - how to use analytics to find the most efficient decision with available data. Focus is on quantitative modeling and formulation of optimization problems, which have been widely applied to management, engineering, and science. Model applications include machine learning, statistics, data science, sports analytics, supply chain, marketing, as well as other domains.
Prerequisite(s): MATH 211 or MATH 109 or MATH 210

MATH 332 Graph Theory and its Applications (3 Credits)
This is an introductory course about graph theory and its applications. It covers graph-theoretic concepts such as paths, Eulerian circuits, trees, distance, matchings, connectivity, network flows, colorings, planarity, and spanning cycles. It will also apply graph theory concepts in the analysis of social networks, and in the applications of natural and social sciences.
Prerequisite(s): MATH 211 or MATH 109 or MATH 210 or MATH 214
College Curriculum: C200, MAPR
Domain: NQR

MATH 345 Introduction to Mathematical Biology (3 Credits)
An introduction to developing, simulating, and analyzing models to answer biological questions. Mathematical topics may include matrix models, non-linear difference and differential equations, and stochastic models. Biological topics may include ecology, epidemiology, evolution, molecular biology, and physiology.
Prerequisite(s): MATH 211 or MATH 109

MATH 351 Probability and Statistics for Scientists (3 Credits)
Basic concepts in probability and statistical inference. Topics include: probability laws, counting techniques, discrete and continuous random variables, probability and cumulative distribution functions, sampling distributions, central limit theorem, point estimation, confidence intervals and one and two-sample tests of hypotheses. Mathematics majors are encouraged to take the more theoretical courses Math 451 and Math 452. Math 351 cannot not be taken concurrently with Math 451, nor after receiving credit for Math 451.
Prerequisite(s): MATH 112 or MATH 132

MATH 352 Statistical Data Analysis (3 Credits)
Concepts in statistical data analysis. Topics include: simple and multiple linear regression, nonlinear regression, experimental design, nonparametric statistics and the use of statistical software. Other selected topics for statistical data analysis in order to provide a more in-depth exposure to the practice of statistics.
Prerequisite(s): MATH 351 or MATH 451

MATH 353 Advanced Statistical Data Analysis (3 Credits)
This course will expose the student to advanced subjects in statistical data analysis. It will cover various advanced regression analysis and nonparametric approaches, experimental design, and generalized linear models. Theory, as well as fully worked-out numerical examples on data using statistical software, for each type of analysis will be presented. The emphasis will be on model development, accuracy, and the interpretation of results. Additional selected subjects in data analysis will be provided as time permits.
Prerequisite(s): MATH 352

MATH 356 Random Walks in Biology (3 Credits)
This course introduces random processes in biological systems. It focuses on how biological processes are inherently stochastic and driven by a combination of energetic and entropic factors. Topics include diffusion, cell motility, molecular motors, ion channels, and extinction in populations.
Prerequisite(s): MATH 111 or MATH 131 and (BIOL 203 (may be taken concurrently) or BIOL 225)

MATH 380 Mathematical Topics (1-3 Credits)
A study of 300-level mathematical topics not covered by existing courses. Topics may be pure or applied.
Prerequisite(s): (MATH 211 or MATH 210 or MATH 109) and (MATH 212) or (MATH 213)

MATH 400 Mathematical Connections (3 Credits)
This course gives a guide through the research process in mathematical sciences. Students will choose a topic on which to research throughout the semester. Students will give several presentations, give feedback on others' presentations, and will turn in a final paper. Math 400 is taken during the senior year and satisfies the College 400 requirement. Mathematical maturity is needed and is typically indicated by having completed at least 3 Math courses numbered higher than 300, at least one of which must be 307, 311, or at the 400-level. Otherwise, the course requires permission of the instructor to enroll. This course can satisfy the Writing Requirement (in place of Math 300) for the Mathematics major, but does not count as a 3-credit lecture courses toward the Mathematics major.
Prerequisite(s): MATH 307 or MATH 311
College Curriculum: C400

MATH 403 Integration and Measures (3 Credits)
Sequences and series of functions; analysis in metric spaces and normed linear spaces; general integration and differentiation theory.
Prerequisite(s): MATH 311 or MATH 311H

MATH 405 Complex Analysis (3 Credits)
The complex plane, analytic functions, Cauchy Integral Theorem and the calculus of residues. Taylor and Laurent series, analytic continuation.
Prerequisite(s): MATH 311

MATH 408 Matrix Analysis (3 Credits)
Matrix analysis concerns the study of matrices, their properties and applications to different areas. Specific topics include: matrix operations, determinants, eigenvalues, eigenvectors, Gershgorin's theorem, canonical forms, Cayley Hamilton theorem, inner products, Gram-Schmidt process, LU decomposition, singular value decomposition, polar decomposition, different classes of matrices, spectral theorem, norms of vectors and matrices, least square approximation, best approximation, functions of matrices, Perron Frobenius theory, applications to Markov chains, differential equations, mathematical biology, image processing, neural networks, data science, and quantum computing.
Prerequisite(s): (MATH 211 or MATH 109 or MATH 210) and (MATH 214)

MATH 410 Topics in Mathematics (1-3 Credits)
A treatment of topics of interest not routinely covered by existing courses. Material may be chosen from topology, algebra, differential equations and various other areas of pure and applied mathematics.

MATH 412 Intro Number Theory (3 Credits)
An introductory course to the theory of numbers, with applications to cryptography. Topics may include Fundamental Theorem of Arithmetic, Diophantine equations, congruences, RSA cryptosystem, prime number theory, and quadratic reciprocity.
Prerequisite(s): MATH 214

MATH 413 Introduction to Numerical Analysis I (3 Credits)
A discussion of the mathematical theory underlying selected numerical methods and the application of those methods to problems of practical importance. Computer programs are used to facilitate calculations and illustrate analytical results. The topics covered are: linear systems of equations, sensitivity analysis, least-squares problems, the singular value decomposition, and eigenvalue problems. Students planning to take 414 are encouraged to take 413 first.
Prerequisite(s): (MATH 212 or MATH 213) and (CSCI 141 or CSCI 140 or DATA 141 or DATA 140) and (MATH 214) and (MATH 211 or MATH 109 or MATH 210)

MATH 414 Introduction to Numerical Analysis II (3 Credits)
A discussion of the mathematical theory underlying selected numerical methods and the application of those methods to problems of practical importance. Computer programs are used to facilitate calculations and illustrate analytical results. The topics covered are: nonlinear equations, interpolation and approximation, numerical integration, and numerical methods for the solution of ordinary and partial differential equations. Students planning to take 414 are encouraged to take 413 first.
Prerequisite(s): (MATH 212 or MATH 213) and (CSCI 141 or CSCI 140) and (MATH 214) and (MATH 211 or MATH 109 or MATH 210)

MATH 416 Topics in Geometry (3 Credits)
A treatment of topics selected from Euclidean geometry, non-Euclidean geometry, projective geometry, finite geometry, differential geometry or algebraic geometry.
Prerequisite(s): (MATH 212 or MATH 213) and (MATH 214) and (MATH 211 or MATH 109 or MATH 210)

MATH 417 Vector Calculus for Scientists (3 Credits)
Directional derivatives, differential forms and the Poincare lemma. Vector bundles, contact forms and their application to ordinary and partial differential equations. Applications to Lagrangian and Hamiltonian mechanics.
Prerequisite(s): (MATH 211 or MATH 109 or MATH 210) and MATH 212 and MATH 302 or MATH 213

MATH 424 Operations Research: Stochastic Models (3 Credits)
A survey of probabilistic operations research models and applications. Topics include stochastic processes, Markov chains, queueing theory and applications, Markovian decision processes, inventory theory and decision analysis.
Prerequisite(s): MATH 351 or MATH 451

MATH 426 Topology (3 Credits)
A study of topological spaces, metric spaces, continuity, product spaces, compactness, connectedness and convergence. As time permits, additional topics may be chosen from homotopy theory, covering spaces, manifolds and surfaces, or other topics in algebraic or set theoretic topology.
Prerequisite(s): MATH 311

MATH 428 Functional Analysis (3 Credits)
Introduction to the geometry of Hilbert spaces, bounded linear operators, compact operators, spectral theory of compact self-adjoint operators, integral operators and other applications.
Prerequisite(s): MATH 311

MATH 430 Algebra II (3 Credits)
The theory of groups, rings, and fields. Topics may include the fundamental theorem of Abelian groups, Sylow's theorem, field extensions, and Galois theory.
Prerequisite(s): MATH 307

MATH 432 Combinatorics (3 Credits)
A study of combinatorial theory and applications to practical problems. Topics include: graph theory, graphical algorithms, enumeration principles, inclusion-exclusion principle, recurrence relations, and generating functions. Optional topics: Polya counting principle, combinatorial designs, coding, Boolean algebra, and switching functions.
Prerequisite(s): (MATH 211 or MATH 109 or MATH 210) and (MATH 214)

MATH 441 Nonlinear Dynamics (3 Credits)
Linear systems of ODEs. Nonlinear systems; dynamical systems, existence/uniqueness of solutions; phase plane analysis; bifurcation; Poincare-Bendixson theory. Applications in biology, circuit theory, and mechanics. Discrete dynamical systems.
Prerequisite(s): MATH 302

MATH 442 Partial Differential Equations (3 Credits)
An introduction to partial differential equations. Waves, diffusion, and boundary value problems; Fourier analysis; harmonic functions; Green's function and Green's identity. Introduction to numerical methods for approximating solutions.
Prerequisite(s): MATH 302

MATH 450 Statistical Learning with Survival Data (3 Credits)
Survival analysis, or time-to-event analysis, is a vital tool across disciplines including biostatistics, epidemiology, engineering, sociology, finance, and beyond. This course introduces students to the key statistical learning methods used to analyze survival data, where the outcome is the time until an event of interest occurs, such as death, disease onset, loan default, or recidivism. Students will build a solid foundation in survival analysis techniques, including Kaplan-Meier and Nelson-Aalen estimators, the Log-rank and Wilcoxon tests, regression models such as the Cox proportional hazards model, and modern machine learning approaches like Random Survival Forests and Survival Support Vector Machines. The course emphasizes both theoretical understanding and practical application, with hands-on data analysis in R.
Prerequisite(s): MATH 352

MATH 451 Probability (3 Credits)
Concepts in probability (formerly MATH 401). Topics include: probability laws, counting techniques, discrete and continuous random variables, probability and cumulative distribution functions, marginal and conditional probability distributions, moment generating functions, transformations of random variables, multivariate transformations, order statistics, sampling distributions and the central limit theorem. Math 451 cannot be taken concurrently with Math 351.
Prerequisite(s): (MATH 212 or MATH 213) and (MATH 214) and (MATH 211 or MATH 109 or MATH 210)

MATH 452 Mathematical Statistics (3 Credits)
Concepts in statistical inference. Topics include: point and interval estimation, consistency, convergence in distribution, sufficient statistics, minimum variance unbiased estimators, method of moments, maximum likelihood estimation, small and large-sample hypothesis tests, uniformly most powerful tests and likelihood ratio tests. Math 452 cannot be taken concurrently with Math 351.
Prerequisite(s): MATH 451

MATH 455 Statistical Learning (3 Credits)
Introduction to the theory of statistical learning techniques and application of these approaches to real data. Course broadly covers supervised and unsupervised learning, including topics in regression, classification, clustering, dimensionality reduction, model evaluation and selection.
Prerequisite(s): MATH 451

MATH 459 Topics in Statistics (1-3 Credits)
Statistical topics not covered in other courses. Possible topics include: linear models, nonparametrics, multivariable analysis, computationally intensive methods. This course may be repeated for credit as topics change.

MATH 465 Mathematics of Financial Economics (3 Credits)
Corporate finance and financial models applied to insurance and other financial risks. Mean-variance portfolio theory and its principal results, Capital Asset Pricing Model, measures of investment risk, Monte Carlo simulation, forwards and futures, call and put options, option strategies, put-call parity, binomial pricing models, lognormal distribution, Black--Scholes option pricing model, Option Greeks, and hedging. Prepares students for the Society of Actuaries' Exam IFM and Casualty Actuarial Society's Exam 3F.
Prerequisite(s): MATH 451

MATH 480 Independent Study in Mathematics (1-3 Credits)
A treatment of topics of interest not routinely covered by existing courses. Material may be chosen from topology, algebra, differential equations and various other areas of pure and applied mathematics. This course may be repeated for credit with permission of the instructor.

MATH 495 Honors (3 Credits)
Students admitted to Honors study in mathematics will be enrolled in this course during both semesters of their senior year. The course comprises: (a) supervised research in the student's special area of interest; (b) presentation by April 15 of an Honors thesis; and (c) satisfactory performance in a comprehensive oral examination in the field of the student's major interest.

MATH 496 Honors (3 Credits)
Students admitted to Honors study in mathematics will be enrolled in this course during both semesters of their senior year. The course comprises: (a) supervised research in the student's special area of interest; (b) presentation by April 15 of an Honors thesis; and (c) satisfactory performance in a comprehensive oral examination in the field of the student's major interest.
College Curriculum: C400

MATH 498 Internship (1,2 Credits)
This course is designed to allow students to apply mathematical knowledge through practical experience in real-world settings. Students wishing to receive academic credit for an internship program must request and obtain departmental approval prior to participation in the program. This course is designated as pass/fail only, and a final written report is required for the completion of the course.