MATHEMATICS (MATH)

MATH .000. Review of Basic Algebra. 3 Credits.

MATH 50. First-Year Seminar: The Predictability of Chance and Its Applications in Applied Mathematics. 3 Credits.
This seminar will examine the ways in which some types of behavior of random systems cannot only be predicted, but also applied to practical problems.
Gen Ed: QI.
Grading status: Letter grade.

MATH 51. First-Year Seminar: 'Fish Gotta Swim, Birds Gotta Fly': The Mathematics and the Mechanics of Moving. 3 Credits.
This seminar allows students to have hands-on exposure to a class of physical and computer experiments designed to challenge intuition on how motion is achieved in nature.
Gen Ed: QI.
Grading status: Letter grade.

MATH 52. First-Year Seminar: Fractals: The Geometry of Nature. 3 Credits.
Many natural objects have complex, infinitely detailed shapes in which smaller versions of the whole shape are seen appearing throughout. Such a shape is a fractal, the topic of study.
Gen Ed: QI.
Grading status: Letter grade.

MATH 52H. First-Year Seminar: Fractals: The Geometry of Nature. 3 Credits.
Many natural objects have complex, infinitely detailed shapes in which smaller versions of the whole shape are seen appearing throughout. Such a shape is a fractal, the topic of study.
Gen Ed: QI.
Grading status: Letter grade.

MATH 53. First-Year Seminar: Symmetry and Tilings. 3 Credits.
Through projects using software programs, Web sites, and readings, students will discover the geometric structure of tilings, learn to design their own patterns, and explore the many interdisciplinary connections.
Gen Ed: QI.
Grading status: Letter grade.

MATH 54. First-Year Seminar: The Science of Conjecture: Its Math, Philosophy, and History. 3 Credits.
Seminar will cover the history and philosophy of probability, evidence, and conjecture, consider the development of the field of probability, and look at current and future uses of probability.
Gen Ed: QI.
Grading status: Letter grade.

MATH 54H. First-Year Seminar: The Science of Conjecture: Its Math, Philosophy, and History. 3 Credits.
Seminar will cover the history and philosophy of probability, evidence, and conjecture, consider the development of the field of probability, and look at current and future uses of probability.
Gen Ed: QI.
Grading status: Letter grade.

MATH 55. First-Year Seminar: Geometry and Symmetry in Nature. 3 Credits.
The nature of space imposes striking constraints on organic and inorganic objects. This seminar examines such constraints on both biological organisms and regular solids in geometry.
Gen Ed: QI.
Grading status: Letter grade.

MATH 56. First-Year Seminar: Information and Coding. 3 Credits.
With the growth of available information on almost anything, can it be reliably compressed, protected, and transmitted over a noisy channel? Students will take a mathematical view of cryptography throughout history and information handling in modern life.
Gen Ed: QI.
Grading status: Letter grade.

MATH 56H. First-Year Seminar: Information and Coding. 3 Credits.
With the growth of available information on almost anything, can it be reliably compressed, protected, and transmitted over a noisy channel? Students will take a mathematical view of cryptography throughout history and information handling in modern life.
Gen Ed: QI.
Grading status: Letter grade.

MATH 57. First-Year Seminar: The Fourth Dimension. 3 Credits.
The idea of a fourth dimension has a rich and varied history. This seminar explores the concept of fourth (and higher) dimensions both mathematically and more widely in human thought.
Gen Ed: QI.
Grading status: Letter grade.

MATH 58. First-Year Seminar: Math, Art, and the Human Experience. 3 Credits.
Students will explore the relevance of mathematical ideas to fields typically perceived as "nonmathematical" (e.g., art, music, film, literature) and how these "nonmathematical" fields influence mathematical thought.
Gen Ed: QI.
Grading status: Letter grade.

MATH 58H. First-Year Seminar: Math, Art, and the Human Experience. 3 Credits.
Students will explore the relevance of mathematical ideas to fields typically perceived as "nonmathematical" (e.g., art, music, film, literature) and how these "nonmathematical" fields influence mathematical thought.
Gen Ed: QI.
Grading status: Letter grade.

MATH 59. First-Year Seminar: The Mystery and Majesty of Ordinary Numbers. 3 Credits.
Problems arising from the arithmetic of ordinary counting numbers have for centuries fascinated both mathematicians and nonmathematicians. This seminar will consider some of these problems (both solved and unsolved).
Gen Ed: QI.
Grading status: Letter grade.

MATH 60. First-Year Seminar: Simulated Life. 3 Credits.
This seminar introduces students to the thought process that goes into developing computational models of biological systems. It will also expose students to techniques for simulating and analyzing these models.
Gen Ed: QI.
Grading status: Letter grade.

MATH 60H. First-Year Seminar: Simulated Life. 3 Credits.
This seminar introduces students to the thought process that goes into developing computational models of biological systems. It will also expose students to techniques for simulating and analyzing these models.
Gen Ed: QI.
Grading status: Letter grade.

MATH 61. First-Year Seminar: The Language of Mathematics: Making the Invisible Visible. 3 Credits.
This course will consider mathematics to be the science of patterns and will discuss some of the different kinds of patterns that give rise to different branches of mathematics.
Gen Ed: QI.
Grading status: Letter grade.

MATH 62. First-Year Seminar: Combinatorics. 3 Credits.
Students will discuss combinatorics' deep roots in history, its connections with the theory of numbers, and its fundamental role for natural science, as well as various applications, including cryptography and the stock market.
Gen Ed: QI.
Grading status: Letter grade.

MATH 62H. First-Year Seminar: Combinatorics. 3 Credits.
Students will discuss combinatorics' deep roots in history, its connections with the theory of numbers, and its fundamental role for natural science, as well as various applications, including cryptography and the stock market.
Gen Ed: QI.
Grading status: Letter grade.

MATH 63. First-Year Seminar: From "The Sound of Music" to "The Perfect Storm". 3 Credits.
Students will develop the conceptual framework necessary to understand waves of any kind, starting from laboratory observations.
Gen Ed: PL, QI.
Grading status: Letter grade
Same as: MASC 57.

MATH 63H. First-Year Seminar: From "The Sound of Music" to "The Perfect Storm". 3 Credits.
Students will develop the conceptual framework necessary to understand waves of any kind, starting from laboratory observations.
Gen Ed: PL, QI.
Grading status: Letter grade
Same as: MASC 57H.

MATH 64. First-Year Seminar: A View of the Sea: The Circulation of the Ocean and Its Impact on Coastal Water. 3 Credits.
Why is the Gulf Stream so strong, why does it flow clockwise, and why does it separate from the United States coast at Cape Hatteras? Students will study the circulation of the ocean and its influence on coastal environments by reading the book A View of the Sea by the eminent oceanographer Hank Stommel and by examining satellite and on-site observations.
Gen Ed: QI.
Grading status: Letter grade.

MATH 65. First-Year Seminar: Colliding Balls and Springs: The Microstructure of How Materials Behave. 3 Credits.
Students will follow the intellectual journey of the atomic hypothesis from Leucippus and Democritus to the modern era, combining the history, the applications to science, and the mathematics developed to study particles and their interactions.
Gen Ed: QI.
Grading status: Letter grade.

MATH 66. First-Year Seminar: Non-Euclidean Geometry in Nature and History. 3 Credits.
The seminar will investigate non-Euclidean geometry (hyperbolic and spherical) from historical, mathematical, and practical perspectives. The approach will be largely algebraic, in contrast to the traditional axiomatic method.
Gen Ed: QI.
Grading status: Letter grade.

MATH 67. The Mathematics of Climate Change: Can We Predict the Future of Our Planet?. 3 Credits.
Is the Earth warming? Predictions are based largely on mathematical models. We shall consider the limitations of models in relation to making predictions. Examples of chaotic behavior will be presented.
Gen Ed: CI, QI.
Grading status: Letter grade.

MATH 89. First-Year Seminar: Special Topics. 3 Credits.
Special topics course. Content will vary each semester.
Repeat rules: May be repeated for credit; may be repeated in the same term for different topics; 6 total credits. 2 total completions.
Grading status: Letter grade.

MATH 89H. First-Year Seminar: Special Topics. 3 Credits.
Special topics course. Content will vary each semester.
Repeat rules: May be repeated for credit. 6 total credits. 2 total completions.
Grading status: Letter grade.

MATH 110. Algebra. 3 Credits.
Provides a one-semester review of the basics of algebra. Basic algebraic expressions, functions, exponents, and logarithms are included, with an emphasis on problem solving. This course should not be taken by those with a suitable score on the achievement test.
Grading status: Letter grade.

MATH 116. Intuitive Calculus. 3 Credits.
Provides an introduction in as nontechnical a setting as possible to the basic concepts of calculus. The course is intended for the nonscience major. A student may not receive credit for this course after receiving credit for MATH 152 or 231.
Gen Ed: QR.
Grading status: Letter grade.

MATH 117. Aspects of Finite Mathematics. 3 Credits.
Introduction to basic concepts of finite mathematics, including topics such as counting methods, finite probability problems, and networks. The course is intended for the nonscience major.
Gen Ed: QR.
Grading status: Letter grade.

MATH 118. Aspects of Modern Mathematics. 3 Credits.
Introduction to mathematical topics of current interest in society and science, such as the mathematics of choice, growth, finance, and shape. The course is intended for the nonscience major.
Gen Ed: QR.
Grading status: Letter grade.

MATH 119. Introduction to Mathematical Modeling. 3 Credits.
Provides an introduction to the use of mathematics for modeling real-world phenomena in a nontechnical setting. Models use algebraic, graphical, and numerical properties of elementary functions to interpret data. This course is intended for the nonscience major.
Gen Ed: QR.
Grading status: Letter grade.

MATH 129P. Precalculus Mathematics. 0 Credits.
Awarded as placement credit based on test scores. Does not fulfill a graduation requirement.
Grading status: Letter grade.

MATH 130. Precalculus Mathematics. 3 Credits.
Covers the basic mathematical skills needed for learning calculus. Topics are calculating and working with functions and data, introduction to trigonometry, parametric equations, and the conic sections. A student may not receive credit for this course after receiving credit for MATH 231.
Requisites: Prerequisite, MATH 110.
Gen Ed: QR.
Grading status: Letter grade.

MATH 152. Calculus for Business and Social Sciences. 3 Credits.
An introductory survey of differential and integral calculus with emphasis on techniques and applications of interest for business and the social sciences. This is a terminal course and not adequate preparation for MATH 232. A student cannot receive credit for this course after receiving credit for MATH 231 or 241.
Requisites: Prerequisite, MATH 110.
Gen Ed: QR.
Grading status: Letter grade.

MATH 190. Special Topics in Mathematics. 3 Credits.
An undergraduate seminar course that is designed to be a participatory intellectual adventure on an advanced, emergent, and stimulating topic within a selected discipline in mathematics. This course does not count as credit towards the mathematics major.
Grading status: Letter grade.

MATH 231. Calculus of Functions of One Variable I. 4 Credits.
Limits, derivatives, and integrals of functions of one variable. Students may not receive credit for both MATH 231 and MATH 241.
Requisites: Prerequisites, MATH 110 and 130; Requires a grade of C- or better in MATH 130 or placement by the department.
Gen Ed: QR.
Grading status: Letter grade.

MATH 232. Calculus of Functions of One Variable II. 4 Credits.
Calculus of the elementary transcendental functions, techniques of integration, indeterminate forms, Taylor's formula, infinite series.
Requisites: Prerequisite, MATH 231 or 241; requires a grade of C- or better in MATH 231 or 241 or placement by the department.
Gen Ed: QI.
Grading status: Letter grade.

MATH 233. Calculus of Functions of Several Variables. 4 Credits.
Vector algebra, solid analytic geometry, partial derivatives, multiple integrals.
Requisites: Prerequisite, MATH 232 or 283.
Gen Ed: QI.
Grading status: Letter grade.

MATH 233H. Calculus of Functions of Several Variables. 4 Credits.
Vector algebra, solid analytic geometry, partial derivatives, multiple integrals.
Requisites: Prerequisite, MATH 232 or 283.
Gen Ed: QI.
Grading status: Letter grade.

MATH 241. BioCalculus I. 3 Credits.
Limits, derivatives, and integrals of functions of one variable, motivated by and applied to discrete-time dynamical systems used to model various biological processes. Students may not receive credit for both MATH 231 and MATH 241.
Requisites: Prerequisite, MATH 130; Requires a grade of C- or better in MATH 130 or placement by the department.
Gen Ed: QR.
Grading status: Letter grade.

MATH 283. BioCalculus II. 3 Credits.
Techniques of integration, indeterminate forms, Taylor's series; introduction to linear algebra, motivated by and applied to ordinary differential equations; systems of ordinary differential equations used to model various biological processes. A student cannot receive credit for this course after receiving credit for MATH 383.
Requisites: Prerequisite, MATH 231 or 241; requires a grade of C- or better in either MATH 231 or 241, or placement by the department.
Gen Ed: QI.
Grading status: Letter grade.

MATH 290. Special Topics in Mathematics. 1-3 Credits.
Permission of the instructor. Elective topics in mathematics. This course has variable content and may be taken multiple times for credit.
Repeat rules: May be repeated for credit; may be repeated in the same term for different topics; 6 total credits. 6 total completions.
Grading status: Letter grade.

MATH 294. Undergraduate Seminar in Mathematics. 1-3 Credits.
Permission of the instructor. A seminar on a chosen topic in mathematics in which the students participate more actively than in usual courses.
Repeat rules: May be repeated for credit. 6 total credits. 2 total completions.
Grading status: Letter grade.

MATH 296. Directed Exploration in Mathematics. 1-3 Credits.
By permission of the director of undergraduate studies. Experimentation or deeper investigation under the supervision of a faculty member of topics in mathematics that may be, but need not be, connected with an existing course. No one may receive more than seven semester hours of credit for this course. Formerly offered as MATH 290.
Gen Ed: EE-Mentored Research.
Repeat rules: May be repeated for credit; may be repeated in the same term for different topics; 7 total credits. 7 total completions.
Grading status: Letter grade.

MATH 307. Revisiting Real Numbers and Algebra. 3 Credits.
Central to teaching precollege mathematics is the need for an in-depth understanding of real numbers and algebra. This course explores this content, emphasizing problem solving and mathematical reasoning.
Gen Ed: QI.
Grading status: Letter grade.

MATH 381. Discrete Mathematics. 3 Credits.
This course serves as a transition from computational to more theoretical mathematics. Topics are from the foundations of mathematics: logic, set theory, relations and functions, induction, permutations and combinations, recurrence.
Requisites: Prerequisite, MATH 232 or 283.
Gen Ed: QI.
Grading status: Letter grade.

MATH 381H. Discrete Mathematics. 3 Credits.
This course serves as a transition from computational to more theoretical mathematics. Topics are from the foundations of mathematics: logic, set theory, relations and functions, induction, permutations and combinations, recurrence.
Requisites: Prerequisite, MATH 232 or 283.
Gen Ed: QI.
Grading status: Letter grade.

MATH 383. First Course in Differential Equations. 3 Credits.
Introductory ordinary differential equations, first- and second-order differential equations with applications, higher-order linear equations, systems of first-order linear equations (introducing linear algebra as needed).
Requisites: Prerequisite, MATH 233.
Gen Ed: QI.
Grading status: Letter grade.

MATH 383H. First Course in Differential Equations. 3 Credits.
Introductory ordinary differential equations, first- and second-order differential equations with applications, higher-order linear equations, systems of first-order linear equations (introducing linear algebra as needed).
Requisites: Prerequisite, MATH 233.
Gen Ed: QI.
Grading status: Letter grade.

MATH 383L. First Course in Differential Equations Laboratory. 1 Credit.
Course is computational laboratory component designed to help students visualize ODE solutions in Matlab. Emphasis is on differential equations motivated by applied sciences. Some applied linear algebra will appear as needed for computation and modeling purposes.
Requisites: Prerequisite, MATH 233; pre- or corequisite, MATH 383.
Grading status: Letter grade.

MATH 396. Undergraduate Reading and Research in Mathematics. 1-3 Credits.
Permission of the director of undergraduate studies. This course is intended mainly for students working on honors projects. No one may receive more than three semester hours credit for this course.
Gen Ed: EE-Mentored Research.
Repeat rules: May be repeated for credit; may be repeated in the same term for different topics; 6 total credits. 2 total completions.
Grading status: Letter grade.

MATH 406. Mathematical Methods in Biostatistics. 1 Credit.
Special mathematical techniques in the theory and methods of biostatistics as related to the life sciences and public health. Includes brief review of calculus, selected topics from intermediate calculus, and introductory matrix theory for applications in biostatistics.
Requisites: Prerequisite, MATH 232.
Gen Ed: QI.
Grading status: Letter grade.

MATH 410. Teaching and Learning Mathematics. 4 Credits.
Study of how people learn and understand mathematics, based on research in mathematics, mathematics education, psychology, and cognitive science. This course is designed to prepare undergraduate mathematics majors to become excellent high school mathematics teachers. It involves field work in both the high school and college environments.
Gen Ed: EE-Field Work.
Grading status: Letter grade.

MATH 411. Developing Mathematical Concepts. 3 Credits.
Permission of the instructor. An investigation of various ways elementary concepts in mathematics can be developed. Applications of the mathematics developed will be considered.
Gen Ed: QI.
Grading status: Letter grade.

MATH 418. Basic Concepts of Analysis for High School Teachers. 3 Credits.
An examination of high school mathematics from an advanced perspective, including number systems and the behavior of functions and equations. Designed primarily for prospective or practicing high school teachers.
Requisites: Prerequisites, MATH 233 and 381.
Gen Ed: QI.
Grading status: Letter grade.

MATH 515. History of Mathematics. 3 Credits.
A general survey of the history of mathematics with emphasis on elementary mathematics. Some special problems will be treated in depth.
Requisites: Prerequisite, MATH 381.
Gen Ed: QI.
Grading status: Letter grade.

MATH 521. Advanced Calculus I. 3 Credits.
A grade of A- or better in STOR 215 may substitute for MATH 381. The real numbers, continuity and differentiability of functions of one variable, infinite series, integration.
Requisites: Prerequisites, MATH 233 and 381.
Gen Ed: QI.
Grading status: Letter grade.

MATH 521H. Advanced Calculus I. 3 Credits.
A grade of A- or better in STOR 215 may substitute for MATH 381. The real numbers, continuity and differentiability of functions of one variable, infinite series, integration.
Requisites: Prerequisites, MATH 233 and 381.
Gen Ed: QI.
Grading status: Letter grade.

MATH 522. Advanced Calculus II. 3 Credits.
Functions of several variables, the derivative as a linear transformation, inverse and implicit function theorems, multiple integration.
Requisites: Prerequisites, MATH 383 and 521.
Gen Ed: QI.
Grading status: Letter grade.

MATH 522H. Advanced Calculus II. 3 Credits.
Functions of several variables, the derivative as a linear transformation, inverse and implicit function theorems, multiple integration.
Requisites: Prerequisites, MATH 383 and 521.
Gen Ed: QI.
Grading status: Letter grade.

MATH 523. Functions of a Complex Variable with Applications. 3 Credits.
The algebra of complex numbers, elementary functions and their mapping properties, complex limits, power series, analytic functions, contour integrals, Cauchy's theorem and formulae, Laurent series and residue calculus, elementary conformal mapping and boundary value problems, Poisson integral formula for the disk and the half plane.
Requisites: Prerequisite, MATH 383.
Gen Ed: QI.
Grading status: Letter grade.

MATH 524. Elementary Differential Equations. 3 Credits.
Linear differential equations, power series solutions, Laplace transforms, numerical methods.
Requisites: Prerequisite, MATH 383.
Gen Ed: QI.
Grading status: Letter grade.

MATH 528. Mathematical Methods for the Physical Sciences I. 3 Credits.
Theory and applications of Laplace transform, Fourier series and transform, Sturm-Liouville problems. Students will be expected to do some numerical calculations on either a programmable calculator or a computer. This course has an optional computer laboratory component: MATH 528L.
Requisites: Prerequisite, MATH 383.
Gen Ed: QI.
Grading status: Letter grade.

MATH 528L. Laboratory for Mathematical Methods for the Physical Sciences I. 1 Credit.
Training in the use of symbolic and numerical computing packages and their application to the MATH 528 lecture topics. Students will need a CCI-compatible computing device.
Requisites: Prerequisite, MATH 383; pre- or corequisite, MATH 528.
Grading status: Letter grade.

MATH 529. Mathematical Methods for the Physical Sciences II. 3 Credits.
Introduction to boundary value problems for the diffusion, Laplace and wave partial differential equations. Bessel functions and Legendre functions. Introduction to complex variables including the calculus of residues. This course has an optional computer laboratory component: MATH 529L.
Requisites: Prerequisite, MATH 521, 524, or 528.
Gen Ed: QI.
Grading status: Letter grade.

MATH 529L. Laboratory for Mathematical Methods for the Physical Sciences II. 1 Credit.
Training in the use of symbolic and numerical computing packages and their application to the MATH 529 lecture topics. Students will need a CCI-compatible computing device.
Requisites: Prerequisite, MATH 383; pre- or corequisite, MATH 529.
Grading status: Letter grade.

MATH 533. Elementary Theory of Numbers. 3 Credits.
A grade of A- or better in STOR 215 may substitute for MATH 381. Divisibility, Euclidean algorithm, congruences, residue classes, Euler's function, primitive roots, Chinese remainder theorem, quadratic residues, number-theoretic functions, Farey and continued fractions, Gaussian integers.
Requisites: Prerequisite, MATH 381.
Gen Ed: QI.
Grading status: Letter grade.

MATH 534. Elements of Modern Algebra. 3 Credits.
A grade of A- or better in STOR 215 may substitute for MATH 381. Binary operations, groups, subgroups, cosets, quotient groups, rings, polynomials.
Requisites: Prerequisite, MATH 381.
Gen Ed: QI.
Grading status: Letter grade.

MATH 535. Introduction to Probability. 3 Credits.
Introduction to mathematical theory of probability covering random variables; moments; binomial, Poisson, normal and related distributions; generating functions; sums and sequences of random variables; and statistical applications.
Requisites: Prerequisite, MATH 233.
Gen Ed: QI.
Grading status: Letter grade
Same as: STOR 435.

MATH 547. Linear Algebra for Applications. 3 Credits.
Algebra of matrices with applications: determinants, solution of linear systems by Gaussian elimination, Gram-Schmidt procedure, eigenvalues. MATH 416 may not be taken for credit after credit has been granted for MATH 547.
Requisites: Prerequisite, MATH 233 or 283.
Gen Ed: QI.
Grading status: Letter grade.

MATH 548. Combinatorial Mathematics. 3 Credits.
Counting selections, binomial identities, inclusion-exclusion, recurrences, Catalan numbers. Selected topics from algorithmic and structural combinatorics, or from applications to physics and cryptography.
Requisites: Prerequisite, MATH 381 or STOR 215.
Gen Ed: QI.
Grading status: Letter grade.

MATH 550. Topology. 3 Credits.
Introduction to topics in topology, particularly surface topology, including classification of compact surfaces, Euler characteristic, orientability, vector fields on surfaces, tessellations, and fundamental group.
Requisites: Prerequisites, MATH 233 and 381; co-requisite, MATH 383; A grade of A- or better in STOR 215 may substitute for MATH 381.
Gen Ed: QI.
Grading status: Letter grade.

MATH 551. Euclidean and Non-Euclidean Geometries. 3 Credits.
A grade of A- or better in STOR 215 may substitute for MATH 381. Critical study of basic notions and models of Euclidean and non-Euclidean geometries: order, congruence, and distance.
Requisites: Prerequisite, MATH 381.
Gen Ed: QI.
Grading status: Letter grade.

MATH 553. Mathematical and Computational Models in Biology. 3 Credits.
This course introduces analytical, computational, and statistical techniques, such as discrete models, numerical integration of ordinary differential equations, and likelihood functions, to explore various fields of biology.
Requisites: Prerequisites, BIOL 201 and 202, MATH 231, and either MATH 232 or STOR 155; Co-requisite, BIOL 553L/MATH 553L; permission of the instructor for students lacking the requisites.
Gen Ed: QI.
Grading status: Letter grade
Same as: BIOL 553.

MATH 553L. Mathematical and Computational Models in Biology Laboratory. 1 Credit.
This lab introduces analytical, computational, and statistical techniques, such as discrete models, numerical integration of ordinary differential equations, and likelihood functions, to explore various fields of biology.
Requisites: Prerequisites, BIOL 201 and 202, MATH 231, and either MATH 232 or STOR 155; Co-requisite, BIOL 553/MATH 553; Permission of the instructor for students lacking the prerequisites.
Grading status: Letter grade
Same as: BIOL 553L.

MATH 555. Introduction to Dynamics. 3 Credits.
Topics will vary and may include iteration of maps, orbits, periodic points, attractors, symbolic dynamics, bifurcations, fractal sets, chaotic systems, systems arising from differential equations, iterated function systems, and applications.
Requisites: Prerequisite, MATH 383.
Gen Ed: QI.
Grading status: Letter grade.

MATH 564. Mathematical Modeling in the Life Sciences. 3 Credits.
Requires some knowledge of computer programming. Model validation and numerical simulations using ordinary, partial, stochastic, and delay differential equations. Applications to the life sciences may include muscle physiology, biological fluid dynamics, neurobiology, molecular regulatory networks, and cell biology.
Requisites: Prerequisite, MATH 383.
Gen Ed: QI.
Grading status: Letter grade
Same as: BIOL 534.

MATH 565. Computer-Assisted Mathematical Problem Solving. 3 Credits.
Personal computer as tool in solving a variety of mathematical problems, e.g., finding roots of equations and approximate solutions to differential equations. Introduction to appropriate programming language; emphasis on graphics.
Requisites: Prerequisite, MATH 383.
Gen Ed: QI.
Grading status: Letter grade.

MATH 566. Introduction to Numerical Analysis. 3 Credits.
Requires some knowledge of computer programming. Iterative methods, interpolation, polynomial and spline approximations, numerical differentiation and integration, numerical solution of ordinary and partial differential equations.
Requisites: Prerequisite, MATH 383.
Gen Ed: QI.
Grading status: Letter grade.

MATH 577. Linear Algebra. 3 Credits.
Vector spaces, linear transformations, duality, diagonalization, primary and cyclic decomposition, Jordan canonical form, inner product spaces, orthogonal reduction of symmetric matrices, spectral theorem, bilinear forms, multilinear functions. A much more abstract course than MATH 416 or 547.
Requisites: Prerequisites, MATH 381 and 383; A grade of A- or better in STOR 215 may substitute for MATH 381.
Gen Ed: QI.
Grading status: Letter grade.

MATH 578. Algebraic Structures. 3 Credits.
Permutation groups, matrix groups, groups of linear transformations, symmetry groups; finite abelian groups. Residue class rings, algebra of matrices, linear maps, and polynomials. Real and complex numbers, rational functions, quadratic fields, finite fields.
Requisites: Prerequisite, MATH 547 or 577.
Gen Ed: QI.
Grading status: Letter grade.

MATH 590. Topics in Mathematics. 3 Credits.
Permission of the instructor. Topics may focus on matrix theory, analysis, algebra, geometry, or applied and computational mathematics.
Repeat rules: May be repeated for credit; may be repeated in the same term for different topics; 12 total credits. 4 total completions.
Grading status: Letter grade.

MATH 594. Nonlinear Dynamics. 3 Credits.
Interdisciplinary introduction to nonlinear dynamics and chaos. Fixed points, bifurcations, strange attractors, with applications to physics, biology, chemistry, finance.
Requisites: Prerequisite, MATH 383; permission of the instructor for students lacking the prerequisite.
Grading status: Letter grade
Same as: PHYS 594.

MATH 635. Probability. 3 Credits.
Foundations of probability. Basic classical theorems. Modes of probabilistic convergence. Central limit problem. Generating functions, characteristic functions. Conditional probability and expectation.
Requisites: Prerequisite, STOR 634; permission of the instructor for students lacking the prerequisite.
Grading status: Letter grade
Same as: STOR 635.

MATH 641. Enumerative Combinatorics. 3 Credits.
Basic counting; partitions; recursions and generating functions; signed enumeration; counting with respect to symmetry, plane partitions, and tableaux.
Requisites: Prerequisite, MATH 578.
Grading status: Letter grade.

MATH 643. Combinatorial Structures. 3 Credits.
Graph theory, matchings, Ramsey theory, extremal set theory, network flows, lattices, Moebius inversion, q-analogs, combinatorial and projective geometries, codes, and designs.
Requisites: Prerequisite, MATH 578.
Grading status: Letter grade.

MATH 653. Introductory Analysis. 3 Credits.
Requires knowledge of advanced calculus. Elementary metric space topology, continuous functions, differentiation of vector-valued functions, implicit and inverse function theorems. Topics from Weierstrass theorem, existence and uniqueness theorems for differential equations, series of functions.
Grading status: Letter grade.

MATH 656. Complex Analysis. 3 Credits.
A rigorous treatment of complex integration, including the Cauchy theory. Elementary special functions, power series, local behavior of analytic functions.
Requisites: Prerequisite, MATH 653.
Grading status: Letter grade.

MATH 657. Qualitative Theory of Differential Equations. 3 Credits.
Requires knowledge of linear algebra. Existence and uniqueness theorems, linear and nonlinear systems, differential equations in the plane and on surfaces, Poincare-Bendixson theory, Lyapunov stability and structural stability, critical point analysis.
Requisites: Prerequisite, MATH 653.
Grading status: Letter grade.

MATH 661. Scientific Computation I. 3 Credits.
Requires some programming experience and basic numerical analysis. Error in computation, solutions of nonlinear equations, interpolation, approximation of functions, Fourier methods, numerical integration and differentiation, introduction to numerical solution of ODEs, Gaussian elimination.
Grading status: Letter grade
Same as: ENVR 661.

MATH 662. Scientific Computation II. 3 Credits.
Theory and practical issues arising in linear algebra problems derived from physical applications, e.g., discretization of ODEs and PDEs. Linear systems, linear least squares, eigenvalue problems, singular value decomposition.
Requisites: Prerequisite, MATH 661.
Grading status: Letter grade
Same as: COMP 662, ENVR 662.

MATH 668. Methods of Applied Mathematics I. 3 Credits.
Requires an undergraduate course in differential equations. Contour integration, asymptotic expansions, steepest descent/stationary phase methods, special functions arising in physical applications, elliptic and theta functions, elementary bifurcation theory.
Grading status: Letter grade
Same as: ENVR 668.

MATH 669. Methods of Applied Mathematics II. 3 Credits.
Perturbation methods for ODEs and PDEs, WKBJ method, averaging and modulation theory for linear and nonlinear wave equations, long-time asymptotics of Fourier integral representations of PDEs, Green's functions, dynamical systems tools.
Requisites: Prerequisite, MATH 668.
Grading status: Letter grade
Same as: ENVR 669.

MATH 676. Modules, Linear Algebra, and Groups. 3 Credits.
Requires knowledge of linear algebra and algebraic structures. Modules over rings, canonical forms for linear operators and bilinear forms, multilinear algebra, groups and group actions.
Repeat rules: May be repeated for credit. 6 total credits. 2 total completions.
Grading status: Letter grade.

MATH 677. Groups, Representations, and Fields. 3 Credits.
Internal structure of groups, Sylow theorems, generators and relations, group representations, fields, Galois theory, category theory.
Requisites: Prerequisite, MATH 676.
Grading status: Letter grade.

MATH 680. Geometry of Curves and Surfaces. 3 Credits.
Topics include (curves) Frenet formulas, isoperimetric inequality, theorems of Crofton, Fenchel, Fary-Milnor; (surfaces) fundamental forms, Gaussian and mean curvature, special surfaces, geodesics, Gauss-Bonnet theorem.
Requisites: Prerequisite, advanced calculus.
Grading status: Letter grade.

MATH 681. Introductory Topology. 3 Credits.
Topological spaces, connectedness, separation axioms, product spaces, extension theorems. Classification of surfaces, fundamental group, covering spaces.
Requisites: Prerequisites, MATH 653 and 680.
Grading status: Letter grade.

MATH 690. Topics In Mathematics. 3 Credits.
Permission of the department. Directed study of an advanced topic in mathematics. Topics will vary.
Repeat rules: May be repeated for credit; may be repeated in the same term for different topics; 12 total credits. 4 total completions.
Grading status: Letter grade.

MATH 691H. Honors Research in Mathematics. 3 Credits.
Permission of the director of undergraduate studies. Readings in mathematics and the beginning of directed research on an honors thesis.
Gen Ed: EE-Mentored Research.
Grading status: Letter grade.

MATH 692H. Honors Thesis in Mathematics. 3 Credits.
Permission of the director of undergraduate studies. Completion of an honors thesis under the direction of a member of the faculty. Required of all candidates for graduation with honors in mathematics.
Gen Ed: EE-Mentored Research.
Grading status: Letter grade.

MATH 751. Introduction to Partial Differential Equations. 3 Credits.
Basic methods in partial differential equations. Topics may include: Cauchy-Kowalewski Theorem, Holmgren's Uniqueness Theorem, Laplace's equation, Maximum Principle, Dirichlet problem, harmonic functions, wave equation, heat equation.
Requisites: Prerequisite, MATH 653.

MATH 753. Measure and Integration. 3 Credits.
Lebesgue and abstract measure and integration, convergence theorems, differentiation, Radon-Nikodym theorem, product measures, Fubini theorem, Lebesgue spaces, invariance under transformations, Haar measure and convolution.
Requisites: Prerequisite, MATH 653; permission of the instructor for students lacking the prerequisite.

MATH 754. Introductory Functional Analysis. 3 Credits.
Hahn-Banach and separation theorems. Normed and locally convex spaces, duals of spaces and maps, weak topologies; closed graph and open mapping theorems, uniform boundedness theorem, linear operators. Spring.
Requisites: Prerequisite, MATH 753.

MATH 755. Advanced Complex Analysis. 3 Credits.
Laurent series; Mittag-Leffler and Weierstrass Theorems; Riemann mapping theorem; Runge's theorem; additional topics chosen from: harmonic, elliptic, univalent, entire, meromorphic functions; Dirichlet problem; Riemann surfaces.
Requisites: Prerequisite, MATH 656.

MATH 756. Several Complex Variables. 3 Credits.
Elementary theory, the Cousin problems, domains of holomorphy, Runge domains and polynomial approximation, local theory, complex analytic structures, coherent analytic sheaves and Stein manifolds, Cartan's theorems.
Requisites: Prerequisite, MATH 656.

MATH 761. Numerical ODE/PDE, I. 3 Credits.
Single, multistep methods for ODEs: stability regions, the root condition; stiff systems, backward difference formulas; two-point BVPs; stability theory; finite difference methods for linear advection diffusion equations.
Requisites: Prerequisites, MATH 661 and 662.
Same as: ENVR 761, MASC 781.

MATH 762. Numerical ODE/PDE, II. 3 Credits.
Elliptic equation methods (finite differences, elements, integral equations); hyperbolic conservation law methods (Lax-Fiedrich, characteristics, entropy condition, shock tracking/capturing); spectral, pseudo-spectral methods; particle methods, fast summation, fast multipole/vortex methods.
Requisites: Prerequisite, MATH 761.
Same as: ENVR 762, MASC 782.

MATH 768. Mathematical Modeling I. 3 Credits.
Nondimensionalization and identification of leading order physical effects with respect to relevant scales and phenomena; derivation of classical models of fluid mechanics (lubrication, slender filament, thin films, Stokes flow); derivation of weakly nonlinear envelope equations. Fall.
Requisites: Prerequisites, MATH 661, 662, 668, and 669.
Same as: ENVR 763, MASC 783.

MATH 769. Mathematical Modeling II. 3 Credits.
Current models in science and technology: topics ranging from material science applications (e.g., flow of polymers and LCPs); geophysical applications (e.g., ocean circulation, quasi-geostrophic models, atmospheric vortices).
Requisites: Prerequisites, MATH 661, 662, 668, and 669.
Same as: ENVR 764, MASC 784.

MATH 771. Commutative Algebra. 3 Credits.
Field extensions, integral ring extensions, Nullstellensatz and normalization theorem, derivations and separability, local rings, valuations, completions, filtrations and graded rings, dimension theory.
Requisites: Prerequisite, MATH 677.

MATH 773. Lie Groups. 3 Credits.
Lie groups, closed subgroups, Lie algebra of a Lie group, exponential map, compact groups, Haar measure, orthogonality relations, Peter-Weyl theorem, maximal torus, representations, Weyl character formula, homogeneous spaces.
Requisites: Prerequisites, MATH 676 and 781.

MATH 774. Lie Algebras. 3 Credits.
Nilpotent, solvable, and semisimple Lie algebras, structure theorems, root systems, Weyl groups, weights, classification of semisimple Lie algebras and their finite dimensional representations, character formulas.
Requisites: Prerequisite, MATH 676.

MATH 775. Algebraic Geometry. 3 Credits.
Topics may include: algebraic varieties, algebraic functions, abelian varieties, projective and complete varieties, algebraic groups, schemes and the Grothendieck theory, Riemann-Roch theorem.
Requisites: Prerequisite, MATH 771.

MATH 776. Algebraic Topology. 3 Credits.
Homotopy and homology; simplicial complexes and singular homology; other topics may include cohomology, universal coefficient theorems, higher homotopy groups, fibre spaces.
Requisites: Prerequisites, MATH 676 and 681.

MATH 781. Differentiable Manifolds. 3 Credits.
Calculus on manifolds, vector bundles, vector fields and differential equations, Lie Groups, connections, de Rham cohomology.
Requisites: Prerequisites, MATH 653, 676, and 681.

MATH 782. Differential Geometry. 3 Credits.
Riemannian geometry, first and second variation of area and applications, effect of curvature on homology and homotopy, Chern-Weil theory of characteristic classes, Chern-Gauss-Bonnet theorem.
Requisites: Prerequisite, MATH 781.

MATH 853. Harmonic Analysis. 3 Credits.
Permission of the instructor. Subjects may include topological groups, abstract harmonic analysis, Fourier analysis, noncommutative harmonic analysis and group representation, automorphic forms, and analytic number theory.

MATH 854. Advanced Functional Analysis. 3 Credits.
Permission of the instructor. Subjects may include operator theory on Hilbert space, operators on Banach spaces, locally convex spaces, vector measures, Banach algebras.

MATH 857. Theory of Dynamical Systems. 3 Credits.
Permission of the instructor. Topics may include: ergodic theory, topological dynamics, stability theory of differential equations, classical dynamical systems, differentiable dynamics.

MATH 891. Special Topics. 1-3 Credits.
Advance topics in current research in statistics and operations research.
Repeat rules: May be repeated for credit; may be repeated in the same term for different topics.
Same as: GNET 891, BCB 891.

MATH 892. Topics in Computational Mathematics. 3 Credits.
Topics may include: finite element method; numerical methods for hyperbolic conservation laws, infinite dimensional optimization problems, variational inequalities, inverse problems.
Requisites: Prerequisites, MATH 661 and 662.

MATH 893. Topics in Algebra. 3 Credits.
Topics from the theory of rings, theory of bialgebras, homological algebra, algebraic number theory, categories and functions.
Requisites: Prerequisite, MATH 677.

MATH 894. Topics in Combinatorial Mathematics. 3 Credits.
Topics may include: combinatorial geometries, coloring and the critical problem, the bracket algebra, reduced incidence algebras and generating functions, binomial enumeration, designs, valuation module of a lattice, lattice theory.
Requisites: Prerequisite, MATH 641; permission of the instructor for students lacking the prerequisite.

MATH 895. Special Topics in Geometry. 3 Credits.
Topics may include elliptic operators, complex manifolds, exterior differential systems, homogeneous spaces, integral geometry, submanifolds of Euclidean space, geometrical aspects of mathematical physics.
Requisites: Prerequisite, MATH 781.

MATH 896. Topics in Algebraic Topology. 3 Credits.
Topics primarily from algebraic or differential topology, such as cohomology operations, homotopy groups, fibre bundles, spectral sequences, K-theory, cobordism, Morse Theory, surgery, topology of singularities.
Requisites: Prerequisite, MATH 776; permission of the instructor for students lacking the prerequisite.

MATH 920. Seminar and Directed Readings. 1-3 Credits.

MATH 921. Seminar. 3 Credits.

MATH 925. Practical Training Course in Mathematics. 3-5 Credits.
Required preparation, passed Ph.D. written comprehensive exam. An opportunity for the practical training of a graduate student interested in mathematics is identified. Typically this opportunity is expected to take the form of a summer internship.
Repeat rules: May be repeated for credit.

MATH 992. Master's (Non-Thesis). 3 Credits.

MATH 993. Master's Research and Thesis. 3 Credits.
This should not be taken by students electing non-thesis master's projects.
Repeat rules: May be repeated for credit.

MATH 994. Doctoral Research and Dissertation. 3 Credits.