MATHEMATICS (MATH)

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.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections 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. Honors version available.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections 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. Honors version available.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections 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.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making 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. Honors version available.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections 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.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections 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. Honors version available.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections 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.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections 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. Honors version available.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections 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).

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections 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. Honors version available.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections 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.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections 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. Honors version available.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections 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. Honors version available.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR, FC-NATSCI or FC-QUANT.
Making Connections Gen Ed: PL, QI.
Grading Status: Letter grade.
Same as: MASC 57.

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.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections 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.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections 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.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections 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.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections Gen Ed: CI, QI.
Grading Status: Letter grade.

MATH 68. First-Year Seminar: The Mathematics of Voting. 3 Credits.
What properties should a fair election have and are these properties achievable in theory and in practice? How can mathematics and statistics be used to expose election fraud and gerrymandering? Students will address these questions as they compare different election systems, evaluate their strengths, weaknesses, and abuses, and design improvements to current structures. Topics will include gerrymandering, ranked voting, approval voting, and Arrow's Impossibility Theorem.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections Gen Ed: QI.
Grading Status: Letter grade.

MATH 69. First-Year Seminar: Unfolding Infinity: Mathematical Origami and Fractal Symmetry. 3 Credits.
This seminar engages students in an exploration of the interplay between mathematics, origami, and fractal symmetry. Learning objectives will include mastering basic origami folding techniques, identifying and applying fundamental symmetry operations, recognizing and analyzing fractal symmetry, and creating geometric tessellations. Students will use image editing software (Illustrator and Photoshop), mathematical imaging software (Ultra Fractal), and the laser cutter in UNC's BeAM space, to design and create modular origami and fractal tessellation artwork.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections Gen Ed: QI.
Grading Status: Letter grade.

MATH 70. First-Year Seminar: Topology and Symmetry. 3 Credits.
In this seminar, students will explore ideas from topology and geometry and their application to symmetry patterns. Students will learn to identify and classify two-dimensional symmetry patterns and create their own designs. Students will relate symmetry patterns to their folded-up counterparts, called orbifolds, and use tools from topology and geometry to determine which patterns are possible and which patterns can never be achieved.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
Making Connections Gen Ed: QI.
Grading Status: Letter grade.

MATH 89. First-Year Seminar: Special Topics. 3 Credits.
Special topics course. Content will vary each semester. Honors version available.

Rules & Requirements

IDEAs in Action Gen Ed: FY-SEMINAR.
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 does not satisfy any general education requirements. It is intended for students who need it as a prerequisite for other classes. A student cannot receive credit for this course after receiving credit for MATH 231 or higher.

Rules & Requirements
Grading Status: Letter grade.

MATH 110L. Algebra Corequisite. 1 Credits.
This course provides just-in-time instruction and practice on basic algebra to support students in Algebra. It also provides additional practice on some of the more difficult topics from MATH 110. This course is intended for students currently enrolled in MATH 110 who need additional review of algebra.

Rules & Requirements
Requisites: Corequisite, MATH 110.
Grading Status: Pass/Fail.

MATH 115. Reasoning with Data: Navigating a Quantitative World. 3 Credits.
Students will use mathematical and statistical methods to address societal problems, make personal decisions, and reason critically about the world. Authentic contexts may include voting, health and risk, digital humanities, finance, and human behavior. This course does not count as credit towards the psychology or neuroscience majors.

Rules & Requirements

IDEAs in Action Gen Ed: FC-QUANT.
Making Connections Gen Ed: QR.
Grading Status: Letter grade.
Same as: BIOL 115, PSYC 115, STOR 115.

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.

Rules & Requirements

IDEAs in Action Gen Ed: FC-QUANT.
Making Connections 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. A student cannot receive credit for this course after receiving credit for MATH 231 or higher.

Rules & Requirements

IDEAs in Action Gen Ed: FC-QUANT.
Making Connections 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. A student cannot receive credit for this course after receiving credit for MATH 231 or higher .

Rules & Requirements

IDEAs in Action Gen Ed: FC-QUANT.
Making Connections 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.

Rules & Requirements

IDEAs in Action Gen Ed: FC-QUANT.
Making Connections 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.

Rules & Requirements
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.

Rules & Requirements
IDEAs in Action Gen Ed: FY-LAUNCH (only designated sections), FC-QUANT.
Making Connections Gen Ed: QR.
Requisites: Prerequisite, MATH 110; a grade of C- or better is required.
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.

Rules & Requirements
IDEAs in Action Gen Ed: FY-LAUNCH (only designated sections), FC-QUANT.
Making Connections Gen Ed: QR.
Requisites: Prerequisite, MATH 110.
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.

Rules & Requirements
Grading Status: Letter grade.

MATH 210. Mathematical Tools for Data Science. 3 Credits.
This course introduces students to the tools of linear algebra and optimization, including solving linear systems, matrices as linear transformations, eigenvalues and eigenvectors, approximations, root finding, derivatives, and optimization in multiple dimensions. This course emphasizes multidimensional thinking and applications to data science. A student cannot receive credit for this course after receiving credit for MATH 347.

Rules & Requirements
IDEAs in Action Gen Ed: FC-QUANT.
Making Connections Gen Ed: QR.
Requisites: Prerequisite, MATH 110 or 110P.
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. Honors version available.

Rules & Requirements
IDEAs in Action Gen Ed: FY-LAUNCH (only designated sections), FC-QUANT.
Making Connections Gen Ed: QR.
Requisites: Prerequisites, MATH 110 and 130; Requires a grade of C- or better in MATH 130 or placement by the department.
Grading Status: Letter grade.

MATH 231L. Calculus I Corequisite. 1 Credits.
This course provides just-in-time instruction and review on algebra and trigonometry to support students in MATH 231. It also provides additional practice on some of the more difficult topics from Calculus 1. This course is intended to be taken by students currently enrolled in MATH 231 who need review of algebra and trigonometry.

Rules & Requirements
Requisites: Prerequisites, MATH 110 and 130; requires a grade of C- or better in MATH 130 or placement by the department; Corequisite, MATH 231.
Grading Status: Pass/Fail.

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. Honors version available.

Rules & Requirements
IDEAs in Action Gen Ed: FY-LAUNCH (only designated sections), FC-QUANT.
Making Connections Gen Ed: QI.
Requisites: Prerequisite, A grade of C- or better in MATH 231 or placement by the department.
Grading Status: Letter grade.

MATH 233. Calculus of Functions of Several Variables. 4 Credits.
Vector algebra, solid analytic geometry, partial derivatives, multiple integrals. Honors version available.

Rules & Requirements
IDEAs in Action Gen Ed: FY-LAUNCH (only designated sections), FC-QUANT.
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 232.
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.

Rules & Requirements
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.

Rules & Requirements
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.

Rules & Requirements
IDEAs in Action Gen Ed: RESEARCH.
Making Connections 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.

Rules & Requirements
Making Connections Gen Ed: QI.
Grading Status: Letter grade.

MATH 347. Linear Algebra for Applications. 3 Credits.
Algebra of matrices with applications: determinants, solution of linear systems by Gaussian elimination, Gram-Schmidt procedure, and eigenvalues. Previously offered as MATH 547.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 232.
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. Honors version available.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 232.
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). Honors version available.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 233.
Grading Status: Letter grade.

MATH 383L. First Course in Differential Equations Laboratory. 1 Credits.
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.

Rules & Requirements
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.

Rules & Requirements
IDEAs in Action Gen Ed: RESEARCH.
Making Connections 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. 6 total completions.
Grading Status: Letter grade.

MATH 406. Mathematical Methods in Biostatistics. 1 Credits.
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.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 232.
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.

Rules & Requirements
IDEAs in Action Gen Ed: COMMBEYOND.
Making Connections 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.

Rules & Requirements
Making Connections 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.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisites, MATH 233 and 381.
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.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 381.
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. Honors version available.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisites, MATH 233 and 381.
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. Honors version available.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisites, MATH 383 and 521.
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.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 383.
Grading Status: Letter grade.

MATH 524. Elementary Differential Equations. 3 Credits.
Linear differential equations, power series solutions, Laplace transforms, numerical methods.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 383.
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.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 383.
Grading Status: Letter grade.

MATH 528L. Laboratory for Mathematical Methods for the Physical Sciences I. 1 Credits.
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.

Rules & Requirements
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.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 521, 524, or 528.
Grading Status: Letter grade.

MATH 529L. Laboratory for Mathematical Methods for the Physical Sciences II. 1 Credits.
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.

Rules & Requirements
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.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 381.
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.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 381.
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. Students may not receive credit for both
STOR 435 and STOR 535.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 233.
Grading Status: Letter grade.
Same as: STOR 435.

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.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 381.
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.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisites, MATH 233 and 381.
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.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 381.
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.

Rules & Requirements
Making Connections Gen Ed: QI.
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.
Grading Status: Letter grade.
Same as: BIOL 553.

**MATH 553L. Mathematical and Computational Models in Biology
Laboratory. 1 Credits.**
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.

Rules & Requirements
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.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 383.
Grading Status: Letter grade.

**MATH 560. Optimization with Applications in Machine Learning. 3
Credits.**
This course will provide an introduction to convex optimization, including
convex sets and functions, modeling, conic problems, optimality
conditions and algorithms. The second part of the course will address
non-convex problems, focusing on contemporary optimization challenges
in large-scale optimization and practical approaches for machine learning
and deep learning.

Rules & Requirements
Requisites: Prerequisites, MATH 233, MATH 347, and COMP 110 or
COMP 116.
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.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisites, MATH 383, and 347.
Grading Status: Letter grade.
Same as: BIOL 534.

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.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 383, or 347.
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 347.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisites, MATH 381 and 383; A grade of A- or better in STOR 215 may substitute for MATH 381.
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.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, MATH 347, or 577.
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.

Rules & Requirements
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.

Rules & Requirements
Requisites: Prerequisite, MATH 383; permission of the instructor for students lacking the prerequisite.
Grading Status: Letter grade.
Same as: PHYS 594.

MATH 635. Probability II. 3 Credits.
Foundations of probability. Basic classical theorems. Modes of probabilistic convergence. Central limit problem. Generating functions, characteristic functions. Conditional probability and expectation.

Rules & Requirements
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.

Rules & Requirements
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.

Rules & Requirements
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.

Rules & Requirements
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.

Rules & Requirements
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.

Rules & Requirements
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.

Rules & Requirements
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.

Rules & Requirements
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.

Rules & Requirements
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.

Rules & Requirements
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.

Rules & Requirements
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.

Rules & Requirements
Requisites: Prerequisite, MATH 676.
Grading Status: Letter grade.

MATH 680. Differentiable Manifolds. 3 Credits.
Calculus on manifolds, vector bundles, vector fields and differential equations, de Rham cohomology.

Rules & Requirements
Requisites: Prerequisite, MATH 681.
Grading Status: Letter grade.

MATH 681. Introductory Topology. 3 Credits.
Topological spaces, product spaces, connectedness, compactness. Classification of surfaces, fundamental group, covering spaces. Simplicial homology.

Rules & Requirements
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.

Rules & Requirements
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.

Rules & Requirements
IDEAs in Action Gen Ed: RESEARCH.
Making Connections 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.

Rules & Requirements
IDEAs in Action Gen Ed: RESEARCH.
Making Connections 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.

Rules & Requirements
Requisites: Prerequisite, MATH 653.
Grading Status: Letter grade.

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.

Rules & Requirements
Requisites: Prerequisite, MATH 653; permission of the instructor for students lacking the prerequisite.
Grading Status: Letter grade.

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.

Rules & Requirements
Requisites: Prerequisite, MATH 753.
Grading Status: Letter grade.

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.

Rules & Requirements
Requisites: Prerequisite, MATH 656.
Grading Status: Letter grade.

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.

Rules & Requirements
Requisites: Prerequisite, MATH 656.
Grading Status: Letter grade.

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.

Rules & Requirements
Requisites: Prerequisites, MATH 661 and 662.
Grading Status: Letter grade.
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.

Rules & Requirements
Requisites: Prerequisite, MATH 761.
Grading Status: Letter grade.
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.

Rules & Requirements
Requisites: Prerequisites, MATH 661, 662, 668, and 669.
Grading Status: Letter grade.
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).

Rules & Requirements
Requisites: Prerequisites, MATH 661, 662, 668, and 669.
Grading Status: Letter grade.
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.

Rules & Requirements
Requisites: Prerequisite, MATH 677.
Grading Status: Letter grade.

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.

Rules & Requirements
Requisites: Prerequisites, MATH 676 and 781.
Grading Status: Letter grade.

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.

Rules & Requirements
Requisites: Prerequisite, MATH 676.
Grading Status: Letter grade.

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.

Rules & Requirements
Requisites: Prerequisite, MATH 771.
Grading Status: Letter grade.

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.

Rules & Requirements
Requisites: Prerequisites, MATH 676 and 681.
Grading Status: Letter grade.

MATH 781. Differentiable Manifolds. 3 Credits.
Calculus on manifolds, vector bundles, vector fields and differential equations, Lie Groups, connections, de Rham cohomology.

Rules & Requirements
Requisites: Prerequisites, MATH 653, 676, and 681.
Grading Status: Letter grade.

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.

Rules & Requirements
Requisites: Prerequisite, MATH 781.
Grading Status: Letter grade.

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.

Rules & Requirements
Grading Status: Letter grade.

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.

Rules & Requirements
Grading Status: Letter grade.

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.

Rules & Requirements
Grading Status: Letter grade.

MATH 891. Special Topics. 1-3 Credits.
Advance topics in current research in statistics and operations research.

Rules & Requirements
Repeat Rules: May be repeated for credit; may be repeated in the same term for different topics.
Grading Status: Letter grade.
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.

Rules & Requirements
Requisites: Prerequisites, MATH 661 and 662.
Grading Status: Letter grade.

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

Rules & Requirements
Requisites: Prerequisite, MATH 677.
Grading Status: Letter grade.

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.

Rules & Requirements
Requisites: Prerequisite, MATH 641; permission of the instructor for students lacking the prerequisite.
Grading Status: Letter grade.

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.

Rules & Requirements
Requisites: Prerequisite, MATH 781.
Grading Status: Letter grade.

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.

Rules & Requirements
Requisites: Prerequisite, MATH 776; permission of the instructor for students lacking the prerequisite.
Grading Status: Letter grade.

MATH 920. Seminar and Directed Readings. 1-3 Credits.
Rules & Requirements
Repeat Rules: May be repeated for credit; may be repeated in the same term for different topics.
Grading Status: Letter grade.

MATH 921. Seminar. 3 Credits.
Rules & Requirements
Grading Status: Letter grade.

MATH 925. Practical Training Course in Mathematics. 1-3 Credits.
Required preparation, passed Ph.D. or M.S. 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.

Rules & Requirements
Requisites: Prerequisite, Successful completion of the written comprehensive examination degree requirement.
Repeat Rules: May be repeated for credit.
Grading Status: Letter grade.

MATH 992. Master's (Non-Thesis). 3 Credits.
Rules & Requirements
Repeat Rules: May be repeated for credit.

MATH 993. Master's Research and Thesis. 3 Credits.
This should not be taken by students electing non-thesis master's projects.

Rules & Requirements
Repeat Rules: May be repeated for credit.

MATH 994. Doctoral Research and Dissertation. 3 Credits.
Rules & Requirements
Repeat Rules: May be repeated for credit.