MATHEMATICS (MATH)

MATH17 Introductory Calculus
This course is designed to introduce basic ideas and techniques of differential calculus. Students should enter with sound precalculus skills but with very limited or no prior study of calculus. Topics to be considered include differential calculus of algebraic, exponential, and logarithmic functions. (Integral calculus will be introduced in MATH118.)
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: None

MATH18 Introductory Calculus II: Integration and Its Applications
This course continues MATH17. It is designed to introduce basic ideas and techniques of calculus. Students should enter MATH118 with sound precalculus skills and with very limited or no prior study of integral calculus. Topics to be considered include differential and integral calculus of algebraic, exponential, and logarithmic functions.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: None

MATH19 Elements of Calculus, Part I
This course is the first half of a two-semester calculus sequence (and ampersand (&) course). This sequence is designed for students who have not previously studied calculus. The course, together with MATH120, will cover limits, derivatives, and integrals. Exponential, logarithmic, and trigonometric functions will be introduced and their calculus will be studied. Applications of calculus to biology, economics, physics, and/or other fields will be emphasized. Completion of both semesters (MATH119 and MATH120) is required to receive credit for MATH 119.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: None

MATH20 Elements of Calculus, Part II
This course is the second half of a two-semester calculus sequence (an ampersand (&) course). This sequence is designed for students who have not previously studied calculus. The course, together with MATH119, will cover limits, derivatives, and integrals. Exponential, logarithmic, and trigonometric functions will be introduced and their calculus will be studied. Applications of calculus to biology, economics, physics, and/or other fields will be emphasized. Completion of both semesters (MATH119 and MATH120) is required to receive credit for MATH119.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: MATH119

MATH21 Calculus I, Part I
MATH21 is designed for students who have completed a high school calculus course and who might pursue study in an area for which calculus is an essential tool but who are not prepared to place out of calculus. This course is a deeper and broader study of calculus than MATH17; theoretical aspects are not the main focus but will not be avoided. The course will, together with MATH22, treat limits, derivatives, and integrals; the calculus of exponential, logarithmic, trigonometric, and inverse trigonometric functions; techniques of integration; plane analytic geometry; various applications of calculus; sequences and series, including power series and intervals of convergence.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: None

MATH22 Calculus I, Part II
The continuation of MATH21. Topics covered include techniques and applications of integration and an introduction to sequences and series.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: None

MATH132 Elementary Statistics
Topics included in this course are organizing data, central measures, measures of variation, distributions, sampling, estimation, conditional probability (Bayes’ theorem), hypothesis testing, simple regression and correlation, and analysis of variation.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: None

MATH163 An Invitation to Mathematics
This course aims to introduce students to some of the great ideas of mathematics. We will investigate a variety of topics in number theory, set theory, probability, game theory, topology, and geometry. One major goal is to give students a chance to “think like a mathematician.” Thus, students will be encouraged to explore and to discover mathematical patterns and ideas for themselves. We will also gain an understanding of what constitutes a mathematical proof and why mathematicians are so insistent about them.
Offering: Host
Grading: Host
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: None

MATH211 Problem Solving for the Putnam
This course will explore the problems and problem-solving techniques of the annual William Lowell Putnam mathematical competition. Particular emphasis will be placed on learning to write clear and complete solutions to problems. The competition is open to all undergraduate students.
Offering: Host
Grading: Cr/U
Credits: 0.25
Gen Ed Area: NSM-MATH
Prereq: None

MATH221 Vectors and Matrices
This is a course in the algebra of matrices and Euclidean spaces that emphasize the concrete and geometric. Topics to be developed include solving systems of linear equations; matrix addition, scalar multiplication, and multiplication; properties of invertible matrices; determinants; elements of the theory of abstract finite dimensional real vector spaces; dimension of vector spaces; and the rank of a matrix. These ideas are used to develop basic ideas of Euclidean geometry and to illustrate the
behavior of linear systems. We conclude with a discussion of eigenvalues and the diagonalization of matrices.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: None

**MATH222 Multivariable Calculus**
This course treats the basic aspects of differential and integral calculus of functions of several real variables, with emphasis on the development of calculational skills. The areas covered include scalar- and vector-valued functions of several variables, their derivatives, and their integrals; the nature of extremal values of such functions and methods for calculating these values; and the theorems of Green and Stokes.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: None

**MATH223 Linear Algebra**
An alternative to MATH221, this course will cover vector spaces, inner-product spaces, dimension theory, linear transformations and matrices, determinants, eigenvalues and eigenvectors, Hermitian and unitary transformations, and elementary spectral theory. It will present applications to analytic geometry, quadratic forms, and differential equations as time permits. The approach here is more abstract than that in MATH221, though many topics appear in both.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: None

**MATH225 Fundamentals of Analysis: An Introduction to Real Analysis**
In this rigorous treatment of calculus, topics will include, but are not limited to, real numbers, limits, sequences and series, continuity and uniform continuity, differentiation, the Riemann integral, sequences and series of functions, pointwise and uniform convergence of functions, and interchange of limiting processes. MATH228 or comparable experience in writing mathematical proofs is strongly recommended for success in this course.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: (MATH222 AND MATH221) OR (MATH222 AND MATH223)

**MATH226 Complex Analysis**
We will present the basic properties of complex analytic functions. We begin with the complex numbers themselves and elementary functions and their mapping properties, then discuss Cauchy's integral theorem and Cauchy's integral formula and applications. Then we discuss Taylor and Laurent series, zeros and poles and residue theorems, the argument principle, and Rouche's theorem. In addition to a rigorous introduction to complex analysis, students will gain experience in communicating mathematical ideas and proofs effectively.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: (MATH222 AND MATH221) OR (MATH222 AND MATH223)

**MATH228 Discrete Mathematics**
This course is a survey of discrete mathematical processes. Students will be introduced to the process of writing formal mathematical proofs, including mathematical induction. Topics may include set theory, logic, number theory, finite fields, permutations, elementary combinatorics or graph theory.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: None

**MATH229 Differential Equations**
This course is an introduction to the theory of ordinary differential equations. Many aspects of mathematics and computer science are important in this discipline, and a broad view will be presented, in agreement with modern theory and practice. The only prerequisite for the course is multivariable calculus; all other necessary tools will be developed as the course proceeds.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: MATH222

**MATH231 An Introduction to Probability**
In this course you will learn the basic theory of probability. Although the notions are simple and the mathematics involved only requires a basic knowledge of the ideas of differential and integral calculus, a certain degree of mathematical maturity is necessary. The fundamental concepts to be studied are probability spaces and random variables, the most important ideas being conditional probability and independence. The main theorems we shall study are the law of large numbers and the central limit theorem.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: MATH222

**MATH232 Mathematical Statistics**
This course covers the basic notions of estimation, hypothesis testing, regression, analysis of variance, experimental design, and other topics in statistics from a rigorous mathematical perspective. This material will be supplemented by various case studies.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: MATH222

**MATH241 Set Theory**
Ordinal and cardinal numbers, cardinal arithmetic, theorems of Cantor and Schroeder-Bernstein, introduction to Zermelo-Fraenkel set theory, Axiom of Choice, and some infinitary combinatorics.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: None

**MATH243 Mathematical Logic**
An introduction to mathematical logic, including first-order logic and model theory, axiomatic set theory, and Goedel's incompleteness theorem as time permits.
Mathematics (MATH) 3

Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: MATH241 OR MATH261 OR MATH228

MATH244 Topology: Point Set
This is an introduction to general topology, the study of topological spaces. We will begin with the most natural examples, metric spaces, and then move on to more general spaces. This subject, fundamental to mathematics, enables us to discuss notions of continuity and approximation in their broadest sense. We will illustrate topology's power by seeing important applications to other areas of mathematics.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: None

MATH245 Algebraic Topology
This course will use linear algebra to learn about interesting general properties of shapes. The major goal will be the classification of closed, bounded surfaces such as the sphere, the torus, the Klein bottle, and the projective plane. We will introduce the point-set topology and the new linear algebra that we need, but MATH221 or 223 is essential for this course.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: (MATH221 AND MATH222) OR (MATH223 AND MATH222)

MATH252 Differential Forms
This class will be an introduction to differential forms, a central tool in modern topology, geometry, and physics. The course begins where MATH222 ends, with Green's theorem, the divergence theorem, and Stokes' theorem. All of these theorems are special cases of one theorem, known as the general Stokes' theorem, about integration of differential forms. The objective of the first part of the course will be to understand and prove this theorem. We will then discuss manifolds and what can be learned about them using differential forms, concentrating on de Rham cohomology.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: (MATH221 AND MATH222) OR (MATH223 AND MATH222)

MATH255 Fundamentals of Analysis II
Topics to be addressed will be the topology of metric spaces (continuity, connectedness, and compactness), convergence of sequences and series of functions, spaces of functions and their topologies, the Lebesgue integral (on the line) and its basic convergence theorems, and Fourier series.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: MATH225

MATH261 Abstract Algebra: Groups, Rings, and Fields
An introduction to abstract algebra, a core area of mathematics. The study of the basic properties of structures, with emphasis on fundamental results about groups and rings. MATH228, or comparable experience in writing proofs and in abstract reasoning, is strongly recommended.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: (MATH221 AND MATH228) OR (MATH223 AND MATH228)

MATH262 Abstract Algebra
This continuation of MATH261 will discuss fields and Galois theory. Additional topics will be covered as time permits.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: MATH261

MATH272 Elementary Number Theory
This is a course in the elements of the theory of numbers. Topics covered include divisibility, congruences, quadratic reciprocity, Diophantine equations, and a brief introduction to algebraic numbers.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: MATH228

MATH273 Combinatorics
This course will present a broad, comprehensive survey of combinatorics. Topics may include partitions, the topic of inclusion-exclusion, generating functions, recurrence relations, partially ordered sets, trees, graphs, and min-max theorems.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: MATH228

MATH274 Graph Theory
A graph is a set V of elements called vertices and a set E of pairs of elements of V called edges. From this simple definition, many elegant models have been developed. This course will be a survey course of topics in graph theory with an emphasis on the role of planar graphs. Graph connectivity, vertex and edge coloring, graph embedding, and descriptions of snarks (2-edge-connected 3-regular graphs that are not 3 colorable) will be covered.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: MATH221 OR MATH223

MATH275 Probabilistic Graphical Models
Graphical models are used to represent complex, uncertain relationships among several, possibly very many, variables. They are fundamental in many domains of application, including medical diagnosis and prognosis, vision and image processing, robotics, and computational biology. This course will familiarize students with the graph theory and probability theory needed to discuss graphical models. After that, students will investigate exact and approximate statistical inference for graphical models, learning/inference of parameters, and possibly learning of graph structure.
Offering: Host
Grading: A-F
Credits: 1.00
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Gen Ed Area: NSM-MATH
Prereq: MATH222

MATH283 Differential Geometry
This course is an introduction to the classical differential geometry of curves and surfaces in Euclidean 3-space. Topics from global differential geometry and extensions to higher dimensions will be considered as time and the background of the students permit.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: NSM-MATH
Prereq: (MATH222 AND MATH221) OR (MATH222 AND MATH223)

MATH401 Individual Tutorial, Undergraduate
Topic to be arranged in consultation with the tutor.
Offering: Host
Grading: OPT

MATH402 Individual Tutorial, Undergraduate
Topic to be arranged in consultation with the tutor.
Offering: Host
Grading: OPT

MATH407 Senior Tutorial (downgraded thesis)
Downgraded Senior Thesis Tutorial - Project to be arranged in consultation with the tutor. Only enrolled in through the Honors Coordinator.
Offering: Host
Grading: A-F

MATH408 Senior Tutorial (downgraded thesis)
Downgraded Senior Thesis Tutorial - Project to be arranged in consultation with the tutor. Only enrolled in through the Honors Coordinator.
Offering: Host
Grading: A-F

MATH409 Senior Thesis Tutorial
Topics to be arranged in consultation with the tutor.
Offering: Host
Grading: OPT

MATH410 Senior Thesis Tutorial
Topic to be arranged in consultation with the tutor.
Offering: Host
Grading: OPT

MATH411 Group Tutorial, Undergraduate
Topic to be arranged in consultation with the tutor.
Offering: Host
Grading: OPT

MATH412 Group Tutorial, Undergraduate
Topic to be arranged in consultation with the tutor.
Offering: Host
Grading: OPT

MATH419 Student Forum
Student-run group tutorial, sponsored by a faculty member and approved by the chair of a department or program.
Offering: Host
Grading: Cr/U

MATH421 Undergraduate Research, Science
Individual research projects for undergraduate students supervised by faculty members.
Offering: Host
Grading: OPT

MATH422 Undergraduate Research, Science
Individual research projects for undergraduate students supervised by faculty members.
Offering: Host
Grading: OPT

MATH423 Advanced Research Seminar, Undergraduate
Advanced research tutorial; project to be arranged in consultation with the tutor.
Offering: Host
Grading: OPT

MATH424 Advanced Research Seminar, Undergraduate
Advanced research tutorial; project to be arranged in consultation with the tutor.
Offering: Host
Grading: OPT

MATH465 Education in the Field, Undergraduate
Students must consult with the department and class dean in advance of undertaking education in the field for approval of the nature of the responsibilities and method of evaluation.
Offering: Host
Grading: OPT

MATH466 Education in the Field, Undergraduate
Students must consult with the department and class dean in advance of undertaking education in the field for approval of the nature of the responsibilities and method of evaluation.
Offering: Host
Grading: OPT

MATH469 Education in the Field, Undergraduate
Students must consult with the department and class dean in advance of undertaking education in the field for approval of the nature of the responsibilities and method of evaluation.
Offering: Host
Grading: OPT

MATH470 Independent Study, Undergraduate
Credit may be earned for an independent study during a summer or authorized leave of absence provided that (1) plans have been approved in advance, and (2) all specified requirements have been satisfied.
Offering: Host
Grading: OPT
Credits: 0.50
Gen Ed Area: None
Prereq: None

MATH491 Teaching Apprentice Tutorial
The teaching apprentice program offers undergraduate students the opportunity to assist in teaching a faculty member's course for academic credit.
Offering: Host
Grading: OPT

MATH492 Teaching Apprentice Tutorial
The teaching apprentice program offers undergraduate students the opportunity to assist in teaching a faculty member's course for academic credit.
Offering: Host
Grading: OPT
This course will emphasize model theoretic algebra. We will consider the model theory of fields, including algebraically closed, real-closed, and p-adically closed fields; algebraically closed valued fields; and also general questions of definability in fields. As time permits, we will consider more recent applications of model theory in number theory and arithmetic geometry. Ideally, the student should understand what it means to be first-order definable and should have the equivalent of a year's study of abstract algebra. To study various applications, it will be necessary to assume certain results from the areas of application, i.e., without proving them ab initio.
MATH516 Analysis II
This is a topics course in analysis and varies from year to year. It may be repeated for credit.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: None
Prereq: MATH513

MATH523 Topology I
Introduction to topological spaces and the fundamental group; topological spaces, continuous maps, metric spaces; product and quotient spaces; compactness, connectedness, and separation axioms; and introduction to homotopy and the fundamental group.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: None
Prereq: None

MATH524 Topology I
A continuation of MATH523, this course will be an introduction to algebraic topology, concentrating on the fundamental group and homology.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: None
Prereq: None

MATH525 Topology II: Topics in Topology
This is a topics course in topology that varies from year to year. This course may be repeated for credit. Recent topics have included knot theory, homotopy theory, Lie groups, and topological graph theory.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: None
Prereq: None

MATH526 Topology II
This is a topics course in topology that varies from year to year. It may be repeated for credit.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: None
Prereq: None

MATH543 Algebra I
Group theory including Sylow theorems, basic ring and module theory, including structure of finitely generated modules over principal-ideal domains.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: None
Prereq: None

MATH544 Algebra I
This course studies Galois theory, finitely generated modules over principal-ideal domains, and other topics as time permits.
Offering: Host
Grading: A-F
Credits: 1.00
Gen Ed Area: None
Prereq: None