MATH - MATHEMATICS

MATH401 Applications of Linear Algebra (3 Credits)
Various applications of linear algebra: theory of finite games, linear programming, matrix methods as applied to finite Markov chains, random walk, incidence matrices, graphs and directed graphs, networks and transportation problems.
Prerequisite: 1 course with a minimum grade of C- from (MATH461, MATH240, MATH341).

MATH402 Algebraic Structures (3 Credits)
For students having only limited experience with rigorous mathematical proofs. Parallels MATH403. Students planning graduate work in mathematics should take MATH403. Groups, rings, integral domains and fields, detailed study of several groups; properties of integers and polynomials. Emphasis is on the origin of the mathematical ideas studied and the logical structure of the subject.
Prerequisite: 1 course with a minimum grade of C- from (MATH240, MATH341, MATH461).
Restriction: Must not be in any of the following programs (Mathematics (Master's); Mathematics (Doctoral)).
Credit Only Granted for: MATH402 or MATH403.

MATH403 Introduction to Abstract Algebra (3 Credits)
Integers; groups, rings, integral domains, fields.
Prerequisite: 1 course with a minimum grade of C- from (MATH240, MATH461, MATH340); and 1 course with a minimum grade of C- from (MATH341, MATH241); and minimum grade of C- in MATH310. Or students who have taken courses with comparable content may contact the department.

MATH404 Field Theory (3 Credits)
Prerequisite: Minimum grade of C- in MATH403.

MATH405 Linear Algebra (3 Credits)
Algebraic and transcendental elements, Galois theory, constructions with straight-edge and compass, solutions of equations of low degrees, insolubility of the quintic equation, Sylow theorems, fundamental theorem of finite Abelian groups.
Prerequisite: Minimum grade of C- in MATH403.

MATH406 Introduction to Number Theory (3 Credits)
Integers, divisibility, prime numbers, unique factorization, congruences, quadratic reciprocity, Diophantine equations and arithmetic functions.
Prerequisite: 1 course with a minimum grade of C- from (MATH240, MATH461, MATH340); and minimum grade of C- in MATH310.

MATH410 Advanced Calculus I (3 Credits)
First semester of a year course. Subjects covered during the year are: sequences and series of numbers, continuity and differentiability of real valued functions of one variable, the Riemann integral, sequences of functions and power series. Functions of several variables including partial derivatives, multiple integrals, line and surface integrals. The implicit function theorem.
Prerequisite: 1 course with a minimum grade of C- from (MATH240, MATH461, MATH341); and 1 course with a minimum grade of C- from (MATH340, MATH241); and minimum grade of C- in MATH310. Or students who have taken courses with comparable content may contact the department.

MATH411 Advanced Calculus II (3 Credits)
Continuation of MATH410.
Prerequisite: Minimum grade of C- in MATH410; and permission of CMNS-Mathematics department.
Credit Only Granted for: MATH411 or MATH412.

MATH416 Applied Harmonic Analysis: An Introduction to Signal Processing (3 Credits)
Introduces students to the mathematical concepts arising in signal analysis from the applied harmonic analysis point of view. Topics include applied linear algebra, Fourier series, discrete Fourier transform, Fourier transforms, Shannon Sampling Theorem, wavelet bases, multiresolution analysis, and discrete wavelet transform.
Prerequisite: Minimum grade of C- in MATH141; and 1 course with a minimum grade of C- from (MATH240, MATH461, MATH341); and familiarity with MATLAB is required.

MATH420 Mathematical Modeling (3 Credits)
The course will develop skills in data-driven mathematical modeling through individual and group projects. Emphasis will be placed on both analytical and computational methods, and on effective oral and written presentation of results.
Prerequisite: 1 course with a minimum grade of C- from (MATH240, MATH461, MATH341); and 1 course with a minimum grade of C- from (MATH241, MATH340); and 1 course with a minimum grade of C- from (MATH246, MATH341); and minimum grade of C- in STAT400. And 1 course with a minimum grade of C- from (CMSC106, CMSC131); or students who have taken courses with comparable content may contact the department. Cross-listed with AMSC420.
Credit Only Granted for: AMSC420 or MATH420.

MATH424 Introduction to the Mathematics of Finance (3 Credits)
Introduction to the mathematical models used in finance and economics with emphasis on pricing derivative instruments. Designed for students in mathematics, computer science, engineering, finance and physics.
Financial markets and instruments; elements from basic probability theory; interest rates and present value analysis; normal distribution of stock returns; option pricing; arbitrage pricing theory; the multiperiod binomial model; the Black-Scholes option pricing formula; proof of the Black-Scholes option pricing formula and applications; trading and hedging of options; Delta hedging; utility functions and portfolio theory; elementary stochastic calculus; Itô's Lemma; the Black-Scholes equation and its conversion to the heat equation.
Prerequisite: Minimum grade of C- in MATH141; and 1 course with a minimum grade of C- from (STAT400, STAT410); and permission of CMNS-Mathematics department.
Recommended: MATH246, MATH240, MATH241, MATH340, or MATH341.
Credit Only Granted for: BMGT444, MATH424.

MATH430 Euclidean and Non-Euclidean Geometries (3 Credits)
Prerequisite: 1 course with a minimum grade of C- from (MATH240, MATH341, MATH461).

MATH431 Geometry for Computer Applications (3 Credits)
Topics from projective geometry and transformation geometry, emphasizing the two-dimensional representation of three-dimensional objects and objects moving about in the plane and space. The emphasis will be on formulas and algorithms of immediate use in computer graphics.
Prerequisite: 1 course with a minimum grade of C- from (MATH461, MATH240, MATH341).
MATH432 Introduction to Topology (3 Credits)
Metric spaces, topological spaces, connectedness, compactness (including Heine-Borel and Bolzano-Weierstrass theorems), Cantor sets, continuous maps and homeomorphisms, fundamental group (homotopy, covering spaces, the fundamental theorem of algebra, Brouwer fixed point theorem), surfaces (e.g., Euler characteristic, the index of a vector field, hairy sphere theorem), elements of combinatorial topology (graphs and trees, planarity, coloring problems).
Prerequisite: Minimum grade of C- in MATH410.

MATH436 Differential Geometry of Curves and Surfaces I (3 Credits)
Curves in the plane and Euclidean space, moving frames, surfaces in Euclidean space, orientability of surfaces; Gaussian and mean curvatures; surfaces of revolution, ruled surfaces, minimal surfaces, special curves on surfaces, "Theorema Egregium"; the intrinsic geometry of surfaces.
Prerequisite: 1 course with a minimum grade of C- from (MATH241, MATH340); and 1 course with a minimum grade of C- from (MATH461, MATH240, MATH341); and must have completed two 400-level MATH courses with a minimum grade of C- (not including MATH461, 478, and 480's).

MATH437 Differential Forms (3 Credits)
Introduction to differential forms and their applications, and unites the fundamental theorems of multivariable calculus in a general Stokes Theorem that is valid in great generality. It develops this theory and techniques to perform calculations in analysis and geometry. Topics include an introduction to topological spaces, the Gauss-Bonnet Theorem, Gauss's formula for the linking number, and the Cauchy Integral Theorem. Applications include Maxwell's equations of electromagnetism, connections and gauge theory, and symplectic geometry and Hamiltonian dynamics.
Prerequisite: 1 course with a minimum grade of C- from (MATH241, MATH340); and 1 course with a minimum grade of C- from (MATH461, MATH240, MATH341); and must have completed any MATH or STAT course with a prerequisite of MATH141.

MATH456 Cryptography (3 Credits)
The theory, application, and implementation of mathematical techniques used to secure modern communications. Topics include symmetric and public-key encryption, message integrity, hash functions, block-cipher design and analysis, number theory, and digital signatures.
Prerequisite: (CMSC106, CMSC131, or ENEE150; or equivalent programming experience), and (2 courses from (CMSC330, CMSC351, ENEE324, or ENEE380); or any one of these courses and a 400-level MATH course, or two 400-level MATH courses). Or permission of instructor. Also offered as: CMSC456, ENEE456.
Credit Only Granted for: MATH456, CMSC456 or ENEE456.

MATH461 Linear Algebra for Scientists and Engineers (3 Credits)
Basic concepts of linear algebra. This course is similar to MATH 240, but with more extensive coverage of the topics needed in applied linear algebra: change of basis, complex eigenvalues, diagonalization, the Jordan canonical form.
Prerequisite: Minimum grade of C- in MATH141; and must have completed any MATH or STAT course with a prerequisite of MATH141.
Credit Only Granted for: MATH240, MATH341, or MATH461.

MATH463 Complex Variables (3 Credits)
The algebra of complex numbers, analytic functions, mapping properties of the elementary functions. Cauchy integral formula. Theory of residues and application to evaluation of integrals. Conformal mapping.
Prerequisite: 1 course with a minimum grade of C- from (MATH241, MATH340); and 1 course with a minimum grade of C- from (MATH246, MATH341).

MATH466 Transform Methods for Scientists and Engineers (3 Credits)
Fourier transform, Fourier series, discrete fast Fourier transform (DFT and FFT), Laplace transform. Poisson summations, and sampling. Optional Topics: Distributions and operational calculus, PDEs, Wavelet transform, Radon transform and applications such as Imaging, Speech Processing, PDEs of Mathematical Physics, Communications, Inverse Problems.
Prerequisite: 1 course with a minimum grade of C- from (MATH241, MATH340).

MATH470 Mathematics for Secondary Education (3 Credits)
An advanced perspective on some of the core mathematics underlying high school mathematics courses. Topics include number systems, functions of one variable, equations, inequalities, trigonometric functions, curve fitting, and polynomials. The course includes an analysis of alternate approaches to mathematical ideas and problems, and makes connections between ideas that may have been studied separately in different high school and college courses.
Prerequisite: MATH141 and MATH140; and must have completed one 400-level MATH course (not to include MATH461, 478, and 480's).
MATH475 Combinatorics and Graph Theory (3 Credits)
General enumeration methods, difference equations, generating functions. Elements of graph theory, matrix representations of graphs, applications of graph theory to transport networks, matching theory and graphical algorithms.
**Prerequisite:** 1 course with a minimum grade of C- from (MATH240, MATH341, MATH461); and 1 course with a minimum grade of C- from (MATH241, MATH340); and permission of CMNS-Mathematics department. Cross-listed with CMSC475.
**Credit Only Granted for:** MATH475 or CMSC475.

MATH478 Selected Topics For Teachers of Mathematics (1-3 Credits)

MATH480 Algebra for Middle School Teachers (3 Credits)
Prepares teachers with elementary certification to teach Algebra 1 in middle school. Focuses on basic algebra concepts and related theoretical ideas.
**Prerequisite:** MATH214.
**Restriction:** Must be a middle school teacher; and permission of CMNS-Mathematics department.
**Credit Only Granted for:** MATH480 or MATH483.

MATH481 Statistics and Data Analysis for Middle School Teachers (3 Credits)
Prepares teachers with elementary certification to teach simple data analysis and probability in middle school. Focuses on understanding basic statistics, data analysis, and related theoretical ideas.
**Prerequisite:** MATH214.
**Restriction:** Must be a middle school teacher; and permission of CMNS-Mathematics department.
**Credit Only Granted for:** MATH481 or MATH485.

MATH482 Geometry for Middle School Teachers (3 Credits)
Focuses on concepts related to geometry, including several geometry axiom schemes, transformations, and similarity. Includes constructions with Geometer’s Sketchpad.
**Prerequisite:** MATH141; or students who have taken courses with comparable content may contact the department.
**Restriction:** Senior standing.
**Credit Only Granted for:** MATH482, MATH484, or MATH498E.
**Formerly:** MATH498E.

MATH483 Algebra for High School Teachers (3 Credits)
Focuses on concepts related to algebra and trigonometry, including functions, equations, inequalities, and data analysis. Assumes a good understanding of calculus.
**Prerequisite:** MATH141.
**Restriction:** Senior standing.
**Credit Only Granted for:** MATH483 or MATH480.

MATH484 Geometry for High School Teachers (3 Credits)
Focuses on concepts related to geometry, including several geometry axiom schemes, transformations, and similarity. Includes constructions with Geometer’s Sketchpad.
**Prerequisite:** MATH141; or students who have taken courses with comparable content may contact the department.
**Restriction:** Senior standing.
**Credit Only Granted for:** MATH482, MATH484, or MATH498E.
**Formerly:** MATH498E.

MATH485 Statistics for High School Teachers (3 Credits)
Focuses on concepts related to statistics and data analysis, including probability, sampling, distribution of data, and inference.
**Prerequisite:** MATH141; or students who have taken courses with comparable content may contact the department.
**Credit Only Granted for:** MATH481 or MATH485.

MATH486 Calculus for High School Teachers (3 Credits)
Focuses on concepts related to one-variable calculus including limits, continuity, derivative, integrals, series, and applications of these topics.
**Prerequisite:** MATH141; and cannot be used toward the upper level math requirements for MATH/STAT majors.

MATH487 Number for Middle Grades Teachers (3 Credits)
The rational number and proportional reasoning concepts developed in the middle grades and the larger mathematical context for these. Multiple representations of relationships, including verbal descriptions, diagrams, tables, graphs, and equations. Common misconceptions.
**Prerequisite:** Must have admission to M.A. or M.Ed. with concentration in Mathematics Education; or permission of CMNS-Mathematics department.
**Restriction:** This course may not be used towards the upper level math requirements for the MATH/STAT major.
**Credit Only Granted for:** MATH487 or MATH498K.
**Formerly:** MATH498K.

MATH488 Calculus for Middle Grades Teachers (3 Credits)
The rational number and proportional reasoning concepts developed in the middle grades and the larger mathematical context for these. Multiple representations of relationships, including verbal descriptions, diagrams, tables, graphs, and equations. Common misconceptions.
**Prerequisite:** Must have admission to M.A. or M.Ed. with concentration in Mathematics Education; or permission of CMNS-Mathematics department.
**Restriction:** This course may not be used towards the upper level math requirements for the MATH/STAT major.
**Credit Only Granted for:** MATH487 or MATH498K.

MATH498 Research Interactions in Mathematics (1-3 Credits)
Students participate in a vertically integrated (undergraduate, graduate and/or postdoctoral, faculty) mathematics research group. Format varies. Students and supervising faculty will agree to a contract which must be approved by the department. Up to three credits of MATH498 may be applied to the mathematics degree requirements. See the department’s MATH498 online syllabus for further information.
**Prerequisite:** Permission of CMNS-Mathematics department.
**Repeatable to:** 10 credits if content differs.

MATH498K Selected Topics in Mathematics (1-9 Credits)
Topics of special interest to advanced undergraduate students will be offered occasionally under the general guidance of the departmental committee on undergraduate studies.
**Repeatable to:** 9 credits if content differs.

MATH600 Abstract Algebra I (3 Credits)
Groups with operators, homomorphism and isomorphism theorems, normal series, Sylow theorems, free groups, Abelian groups, rings, integral domains, fields, modules. Topics may include HOM (A,B), Tensor products, exterior algebra.
**Prerequisite:** MATH405 and MATH403; or students who have taken courses with comparable content may contact the department.
MATH601 Abstract Algebra II (3 Credits)
Field theory, Galois theory, multilinear algebra. Further topics from: Dedekind domains, Noetherian domains, rings with minimum condition, homological algebra.
Prerequisite: MATH600.

MATH602 Homological Algebra (3 Credits)
Projective and injective modules, homological dimensions, derived functors, spectral sequence of a composite functor. Applications.
Prerequisite: MATH600.

MATH603 Commutative Algebra (3 Credits)
Ideal theory of Noetherian rings, valuations, localizations, complete local rings, Dedekind domains.
Prerequisite: MATH600.

MATH606 Algebraic Geometry I (3 Credits)
Prime and primary ideals in Noetherian rings, Hilbert Nullstellensatz, places and valuations, prevarieties (in the sense of Serre), dimension, morphisms, singularities, varieties, schemes, rationality.
Prerequisite: MATH600 and MATH601.

MATH607 Algebraic Geometry II (3 Credits)
Topics in contemporary algebraic geometry chosen from among: theory of algebraic curves and surfaces, elliptic curves, Abelian varieties, theory of schemes, theory of zeta functions, formal cohomology, algebraic groups, reduction theory.
Prerequisite: MATH606.

MATH620 Algebraic Number Theory I (3 Credits)
Algebraic numbers and algebraic integers, algebraic number fields of finite degree, ideals and units, fundamental theorem of algebraic number theory, theory of residue classes, Minkowski's theorem on linear forms, class numbers, Dirichlet's theorem on units, relative algebraic number fields, decomposition group, inertia group and ramification group of prime ideals with respect to a relatively Galois extension.
Prerequisite: MATH601.

MATH621 Algebraic Number Theory II (3 Credits)
Valuation of a field, algebraic function fields, completion of a valuation field, ramification exponent and residue class degree, ramification theory, elements, differents, discriminants, product formula and characterization of fields by the formula, Gauss sum, class number formula of cyclotomic fields.
Prerequisite: MATH600. And MATH620; or students who have taken courses with comparable content may contact the department.

MATH630 Real Analysis I (3 Credits)
Prerequisite: MATH411; or students who have taken courses with comparable content may contact the department.

MATH631 Real Analysis II (3 Credits)
Prerequisite: MATH630.

MATH632 Functional Analysis (3 Credits)
Introduction to functional analysis and operator theory: normed linear spaces, basic principles of functional analysis, bounded linear operators on Hilbert spaces, spectral theory of selfadjoint operators, applications to differential and integral equations, additional topics as time permits.
Prerequisite: MATH631.

MATH634 Harmonic Analysis (3 Credits)
Prerequisite: MATH630.

MATH636 Representation Theory (3 Credits)
Introduction to representation theory of Lie groups and Lie algebras; initiation into non-abelian harmonic analysis through a detailed study of the most basic examples, such as unitary and orthogonal groups, the Heisenberg group, Euclidean motion groups, the special linear group. Additional topics from the theory of nilpotent Lie groups, semisimple Lie groups, p-adic groups or C-algebras.
Prerequisite: MATH631.

MATH642 Dynamical Systems I (3 Credits)
Entropy theory, variational principle for the entropy, expansiveness, measures with maximal entropy. Smooth systems on manifolds, diffeomorphisms and flows, periodic points, stable and unstable manifolds, homoclinic points, transversality, the Krupka-Smale theorem, Morse-Smale systems. Hyperbolicity, Anosov systems, distributions and foliations, strange attractors, Bowen's measure.
Prerequisite: MATH642; or students who have taken courses with comparable content may contact the department.

MATH643 Dynamical Systems II (3 Credits)
Entropy theory, variational principle for the entropy, expansiveness, measures with maximal entropy. Smooth systems on manifolds, diffeomorphisms and flows, periodic points, stable and unstable manifolds, homoclinic points, transversality, the Krupka-Smale theorem, Morse-Smale systems. Hyperbolicity, Anosov systems, distributions and foliations, strange attractors, Bowen's measure.
Prerequisite: MATH410; or students who have taken courses with comparable content may contact the department.

MATH650 Complex Analysis I (3 Credits)
Linear transformations, analytic functions, conformal mappings, Cauchy's theorem and applications, power series, partial fractions and factorization, elementary Riemann surfaces, Riemann's mapping theorem.
Prerequisite: MATH410; or students who have taken courses with comparable content may contact the department.

MATH651 Complex Analysis II (3 Credits)
Topics in conformal mappings, normal families, Picard's theorem, classes of univalent functions, extremal properties, variational methods, elliptic functions, Riemann surfaces.
Prerequisite: MATH630 and MATH660.

MATH669 Selected Topics in Riemann Surfaces (1-3 Credits)
Construction of Riemann surfaces, hyperbolic geometry, Fuchsian and Kleinian groups, potential theory, uniformisation spaces of meromorphic functions, line bundles, Picard variety, Riemann-Roch, Teichmüller theory.
Restriction: Permission of instructor.
Repeatable to: 99 credits if content differs.
MATH670 Ordinary Differential Equations I (3 Credits)
Existence and uniqueness, linear systems usually with Floquet theory for periodic systems, linearization and stability, planar systems usually with Poincare-Bendixon theorem.
Prerequisite: MATH405. And MATH410; or students who have taken courses with comparable content may contact the department. Cross-listed with AMSC670.
Credit Only Granted for: AMSC670 or MATH670.

MATH671 Ordinary Differential Equations II (3 Credits)
The content of this course varies with the interests of the instructor and the class. Stability theory, control, time delay systems, Hamiltonian systems, bifurcation theory, and boundary value problems, and the like.
Prerequisite: MATH630. And MATH670 or AMSC670; or students who have taken courses with comparable content may contact the department. Also offered as: AMSC671.
Credit Only Granted for: AMSC671 or MATH671.

MATH673 Partial Differential Equations I (3 Credits)
Prerequisite: MATH411; or students who have taken courses with comparable content may contact the department. Cross-listed with AMSC673.
Credit Only Granted for: AMSC673 or MATH673.

MATH674 Partial Differential Equations II (3 Credits)
Prerequisite: MATH673 or AMSC673; or permission of instructor. Also offered as: AMSC674.
Credit Only Granted for: AMSC674 or MATH674.

MATH689 Research Interactions in Mathematics (1-3 Credits)
The students participate in a vertically integrated (undergraduate, graduate and/or postdoctoral, faculty) research group. Format varies, but includes regular meetings, readings and presentations of material. See graduate program's online syllabus or contact the graduate program director for more information.
Restriction: Permission of instructor.
Repeatable to: 6 credits if content differs.

MATH695 Teaching Seminar (1 Credit)
A course intended for first year teaching assistants. Topics include: everyday mechanics of teaching; teaching methods and styles; technology; course enrichment, diversity in the classroom; sexual harassment; teacher-student interactions; presentations by students.
Restriction: Must be in one of the following programs (Mathematics (Doctoral); Mathematics (Master's); Mathematical Statistics (Doctoral); Applied Mathematics and Scientific Computation (Master's); Mathematical Statistics (Master's); Applied Mathematics and Scientific Computation (Doctoral)).

MATH712 Mathematical Logic I (3 Credits)
Sentential logic, first-order languages, models and formal deductions. Basic model theory including completeness and compactness theorems, other methods of constructing models, and applications such as non-standard analysis.

MATH713 Mathematical Logic II (3 Credits)
Incompleteness and undecidability results of Godel, Church, Tarski and others. Recursive function. Basic proof theory and axiomatic set theory.
Prerequisite: MATH712.

MATH730 Fundamental Concepts of Topology (3 Credits)
Survey of basic point set topology, fundamental group, covering spaces, Van Kampen's theorem, simplicial complexes, simplicial homology, Euler characteristics and classification of surfaces.
Prerequisite: MATH403, MATH410, and MATH411; or students who have taken courses with comparable content may contact the department.

MATH734 Algebraic Topology (3 Credits)
Singular homology and cohomology, cup products, Poincare duality, Eilenberg-Steenrod axioms, Whitehead and Hurewicz theorems, universal coefficient theorem, cellular homology.
Prerequisite: MATH403; or students who have taken courses with comparable content may contact the department.
Recommended: MATH730.

MATH742 Geometric Analysis (3 Credits)
Calculus of Variations, Bochner technique, Morse theory, weak solutions and elliptic regularity, maximum principle for elliptic and parabolic equations, Green's function of the Laplacian, isoperimetric and Sobolev inequalities, continuity method, curvature and comparison results, harmonic maps, curvature prescription problems.
Prerequisite: MATH673 and MATH674; or MATH740.

MATH744 Lie Groups I (3 Credits)
An introduction to the fundamentals of Lie groups, including some material on groups of matrices and Lie algebras.
Prerequisite: MATH405, MATH403, MATH411, and MATH432; or students who have taken courses with comparable content may contact the department.

MATH799 Master's Thesis Research (1-6 Credits)

MATH808 Selected Topics in Algebra (1-3 Credits)
Advanced topics of current interest.
Restriction: Permission of instructor.
Repeatable to: 18 credits.

MATH818 Selected Topics in Logic (1-3 Credits)
Advanced topics of current interest.
Restriction: Permission of instructor.
Repeatable to: 18 credits.

MATH848 Selected Topics in Geometry and Topology (1-3 Credits)
Advanced topics of current interest.
Restriction: Permission of instructor.
Repeatable to: 18 credits.

MATH858 Selected Topics in Analysis (1-3 Credits)
Advanced topics of current interest.
Restriction: Permission of instructor.
Repeatable to: 18 credits.

MATH868 Selected Topics in Complex Analysis (1-3 Credits)
Advanced topics of current interest.
Restriction: Permission of instructor.
Repeatable to: 18 credits.
MATH898 Pre-Candidacy Research (1-8 Credits)
MATH899 Doctoral Dissertation Research (1-8 Credits)