

MATHEMATICS (MATH)

Courses primarily for undergraduates:

MATH 010: High School Algebra

(4-0) Cr. 0. F.S.

For students who do not have adequate facility with topics from high school algebra or do not meet the algebra admission requirement.

The course is divided into tracks of one- and two-semester lengths.

For most students a diagnostic exam will determine which track must be taken. Students will receive a grade in MATH 25 or MATH 30 respectively depending on the level of material covered. Satisfactory completion of MATH 30 is recommended for students planning to take MATH 140, MATH 143, MATH 145, MATH 150, or MATH 151, while MATH 25 is sufficient for MATH 104, MATH 105, MATH 195, STAT 101 or STAT 105. Students must complete MATH 30 to remove a deficiency in the algebra admission requirement. Topics include signed numbers, polynomials, rational and radical expressions, exponential and logarithmic expressions, and equations. Offered on a satisfactory-fail basis only.

MATH 025: High School Algebra

(4-0) Cr. 0. F.S.

Students should initially enroll in MATH 10. See description of MATH 10. Offered on a satisfactory-fail basis only.

MATH 030: High School Algebra

(4-0) Cr. 0. F.S.

Students should initially enroll in MATH 10. See description of MATH 10. Offered on a satisfactory-fail basis only.

MATH 101: Orientation in Mathematics

(1-0) Cr. 1. F.S.

For new majors. Campus resources and opportunities available to students. Careers and programs of study in mathematics. Mathematical reasoning, culture and resources. Description of main branches of mathematics. Offered on a satisfactory-fail basis only.

MATH 104: Introduction to Probability

(3-0) Cr. 3. F.S.SS.

Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of high school geometry

Permutations, combinations, probability, expected value, and applications. Either MATH 104 or MATH 150 may be counted toward graduation, but not both.

MATH 105: Introduction to Mathematical Ideas

(3-0) Cr. 3. F.S.SS.

Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of high school geometry.

Introduction to contemporary mathematics with an emphasis on use of mathematics to solve real world problems. Typical topics are the mathematics of voting, methods of fair division and apportionment, and elementary game theory.

MATH 106: Discovering Mathematics

(3-0) Cr. 3. F.S.

Inquiry-based approach to mathematics, emphasizing the art, history, and beauty of the subject. Typical topics are mathematics from art, music, puzzles, patterns, and reasoning.

MATH 140: College Algebra

(3-1) Cr. 3. F.S.SS.

Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of high school geometry; or MATH 30.

Coordinate geometry, quadratic and polynomial equations, functions, graphing, rational functions, exponential and logarithmic functions, inverse functions, quadratic inequalities, systems of linear equations. Prepares students for MATH 160. Students in the College of Liberal Arts and Sciences may not count MATH 140 toward the General Education Requirements.

MATH 143: Preparation for Calculus

(4-0) Cr. 4. F.S.

Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of high school geometry; or MATH 140.

Preparation for MATH 160, MATH 165, and MATH 181. Functions, graphing, basic trigonometry, logarithms, exponentials. Emphasis on co-variational reasoning. Students in the College of Liberal Arts and Sciences may not count MATH 143 toward General Education Requirements. Only one of MATH 143 and MATH 145 may count toward graduation.

MATH 145: Applied Trigonometry

(3-0) Cr. 3. F.S.

Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of high school geometry; or minimum of C- in MATH 140.

Mathematical ideas regarding the conception of space. General trigonometry, with an emphasis on the calculation of lengths, areas, and angles. The Law of Sines and the Law of Cosines. Polar, cylindrical, and spherical coordinate systems. Conic sections and quadric surfaces. Students in the College of Liberal Arts and Sciences may not count MATH 145 toward the General Education Requirements. Only one of MATH 143 and MATH 145 may count toward graduation.

MATH 150: Discrete Mathematics for Business and Social Sciences

(2-1) Cr. 3. F.S.SS.

Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of high school geometry

Linear equations and inequalities, matrix algebra, linear programming, discrete probability. Either MATH 104 or MATH 150 may be counted toward graduation, but not both.

MATH 151: Calculus for Business and Social Sciences

(2-1) Cr. 3. F.S.SS.

Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of high school geometry

Differential calculus, applications to max-min problems, integral calculus and applications. Will not serve as prerequisite for MATH 265 or MATH 266. Only one of MATH 151, MATH 160, the sequence MATH 165-MATH 166, or MATH 181 may be counted towards graduation.

MATH 160: Survey of Calculus

(4-0) Cr. 4. F.S.

Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of geometry; or minimum of C- in MATH 140; or minimum of C- in MATH 143

Analytic geometry, derivatives and integrals of elementary functions, simple differential equations, and applications. Will not serve as a prerequisite for MATH 265 or MATH 266. Only one of MATH 151, MATH 160, the sequence MATH 165-MATH 166, or MATH 181 may be counted towards graduation.

MATH 165: Calculus I

(4-0) Cr. 4. F.S.SS.

Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of geometry, 1 semester of trigonometry; or minimum of C- in MATH 143

Differential calculus, applications of the derivative, introduction to integral calculus. Only one of MATH 151 or MATH 160 or the sequence MATH 165-MATH 166, or MATH 181 may be counted towards graduation.

MATH 166: Calculus II

(4-0) Cr. 4. F.S.SS.

Prereq: Minimum of C- in MATH 165 or high math placement scores

Integral calculus, applications of the integral, infinite series, parametric curves and polar coordinates. Only one of MATH 151, MATH 160, the sequence MATH 165-MATH 166, or MATH 181 may be counted towards graduation.

MATH 166H: Calculus II, Honors

(4-0) Cr. 4. F.

Prereq: Permission of instructor and MATH 165 or high math placement scores

Integral calculus, applications of the integral, infinite series, parametric curves, and polar coordinates. Additional material of a theoretical, conceptual, computational, or modeling nature. Some of the work may require more ingenuity than is required for MATH 166. Preference will be given to students in the University Honors Program. Only one of MATH 151 or MATH 160, the sequence MATH 165-MATH 166, or MATH 181 may be counted towards graduation.

MATH 181: Calculus and Mathematical Modeling for the Life Sciences I

(4-0) Cr. 4. F.S.

Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of high school geometry, 1 semester of trigonometry; or minimum of C- in MATH 143

Exponential and logarithm functions, difference equations, derivatives, and applications of the derivative. Examples taken from biology. Only one of MATH 151, MATH 160, the sequence MATH 165-MATH 166, or MATH 181 may be counted towards graduation.

MATH 195: Mathematics for Elementary Education I

(2-2) Cr. 3. F.S.

Prereq: Satisfactory performance on placement assessment, 2 years high school algebra, 1 year of high school geometry, enrollment in elementary education or early childhood education

Whole number operations through analysis of properties, theoretical and hands-on models, mathematical analysis of elementary students' thinking; standard and non-standard algorithms; structure of the decimal system; linear measurement; two- and three-dimensional geometric shapes and spatial sense; number theory; algebra as it relates to elementary curricula/teaching profession. Students in the College of Liberal Arts and Sciences may not count MATH 195 toward General Education Requirements.

MATH 196: Mathematics for Elementary Education II

(2-2) Cr. 3. F.S.

Prereq: Minimum of C- in MATH 195 and enrollment in elementary education or early childhood education.

Integer, fraction and decimal operations through analysis of properties, theoretical and hands-on models, mathematical analysis of elementary students' thinking; standard and non-standard algorithms; two- and three-dimensional measurement; probability and statistics; proportional reasoning; algebra as it relates to elementary curricula/teaching profession.

MATH 201: Introduction to Proofs

(3-0) Cr. 3. F.S.

Prereq: MATH 166 or MATH 166H

Transition to advanced mathematics. Communicating mathematics. Logical arguments; techniques of proofs regarding sets, numbers (natural and real), functions, relations, and limits.

MATH 207: Matrices and Linear Algebra

(3-0) Cr. 3. F.S.SS.

Prereq: 2 semesters of calculus

Systems of linear equations, determinants, vector spaces, linear transformations, orthogonality, least-squares methods, eigenvalues and eigenvectors. Emphasis on applications and techniques. Only one of MATH 207 and MATH 317 may be counted toward graduation.

MATH 240: Mathematics of Investment and Credit

(3-0) Cr. 3. Alt. S., offered even-numbered years.

Prereq: MATH 166

Interest rates, time value of money, annuities. Loans, bonds, yield rates. Term structure of interest rates, asset and liability management. Duration, convexity, immunization.

MATH 265: Calculus III

(4-0) Cr. 4. F.S.SS.

Prereq: Minimum of C- in MATH 166 or MATH 166H

Analytic geometry and vectors, differential calculus of functions of several variables, multiple integrals, vector calculus.

MATH 265H: Calculus III, Honors

(4-0) Cr. 4. F.S.

Prereq: Permission of the instructor; and MATH 166 or MATH 166H

Analytic geometry and vectors, differential calculus of functions of several variables, multiple integrals, vector calculus. Additional material of a theoretical, conceptual, computational, or modeling nature. Some of the work may require more ingenuity than is required in MATH 265. Preference will be given to students in the University Honors Program.

MATH 266: Elementary Differential Equations

(3-0) Cr. 3. F.S.SS.

Prereq: Minimum of C- in MATH 166 or MATH 166H

Solution methods for ordinary differential equations. First order equations, linear equations, constant coefficient equations. Eigenvalue methods for systems of first order linear equations. Introduction to stability and phase plane analysis.

MATH 267: Elementary Differential Equations and Laplace Transforms

(4-0) Cr. 4. F.S.SS.

Prereq: Minimum of C- in MATH 166 or MATH 166H

Same as MATH 266 but also including Laplace transforms and power series solutions to ordinary differential equations.

MATH 268: Laplace Transforms

(1-0) Cr. 1. F.S.SS.

Prereq: MATH 266

Laplace transforms and power series solutions to ordinary differential equations. Together, MATH 266 and MATH 268 are the same as MATH 267.

MATH 269: Systems of Differential Equations

(1-0) Cr. 1. F.S.SS.

Prereq: Familiarity with ordinary differential equations of first and second order, permission of department.

Systems portion of MATH 266 and MATH 267: Eigenvalue methods for systems of first order linear equations. Introduction to stability and phase plane analysis. For students supplementing transfer courses in differential equations in order to earn credit in MATH 266 or 267. Students with credit in MATH 266 or MATH 267 may not earn credit in MATH 269.

MATH 290: Independent Study

Cr. 1-3. Repeatable.

Prereq: Permission of the instructor.

Independent study.

MATH 290H: Independent Study, Honors

Cr. 1-3. Repeatable.

Prereq: Permission of the instructor.

Independent study.

MATH 297: Intermediate Topics for School Mathematics

(2-2) Cr. 3. F.

Prereq: Enrollment in elementary education and minimum of C- in MATH 196

Mathematical reasoning and topics in Euclidean and non-Euclidean geometry, including transformations, congruence, and similarity; exploration of probability with simulations; linearity and connections to Calculus; fractals and fractal dimension.

MATH 301: Abstract Algebra I

(3-0) Cr. 3. F.S.

Prereq: MATH 166 or MATH 166H, MATH 317 or MATH 407, and grade of C- or better in MATH 201

Bijjective functions and equivalence relations. Basic divisibility properties of the integers. Theory of groups. Homomorphisms. Quotient groups. Introduction to rings. Emphasis on writing proofs.

MATH 302: Abstract Algebra II

(3-0) Cr. 3. S.

Prereq: MATH 301

Topics chosen from: Advanced group theory, theory of rings and fields, factorization theory in integral domains, Galois theory. Emphasis on writing proofs.

MATH 304: Combinatorics

(3-0) Cr. 3. F.

Prereq: MATH 166 or MATH 166H; MATH 201 or experience with proofs

Enumeration strategies involving permutations, combinations, partitions, binomial coefficients, inclusion-exclusion principle, recurrence relations, generating functions. Additional topics selected from probability, algebraic combinatorics, and applications.

MATH 314: Graph Theory

(3-0) Cr. 3. S.

Prereq: MATH 166 or MATH 166H; MATH 201 or experience with proofs

Structure and extremal properties of graphs. Topics are selected from: trees, networks, colorings, paths and cycles, connectivity, planarity, directed graphs, matchings, Ramsey theory, forbidden structures, enumeration, applications.

MATH 317: Theory of Linear Algebra

(4-0) Cr. 4. F.S.

Prereq: Credit or enrollment in MATH 201

Systems of linear equations, determinants, vector spaces, inner product spaces, linear transformations, eigenvalues and eigenvectors. Emphasis on writing proofs and results. Only one of MATH 207 and MATH 317 may be counted toward graduation.

MATH 331: Topology

(3-0) Cr. 3. Alt. F., offered even-numbered years.

Prereq: MATH 201; MATH 301, 317, 414, or 435.

Set theory, metric spaces, topological spaces, continuity, connectedness, homeomorphisms, compactness, and topological invariants. Examples from surfaces, knots, and various abstract objects. Emphasis on writing proofs.

MATH 341: Introduction to the Theory of Probability and Statistics I

(Cross-listed with STAT). (3-2) Cr. 4. F.S.

Prereq: MATH 265 (or MATH 265H)

Probability; distribution functions and their properties; classical discrete and continuous distribution functions; multivariate probability distributions and their properties; moment generating functions; transformations of random variables; simulation of random variables and use of the R statistical package. Credit for both STAT 341 and STAT 447 may not be applied toward graduation.

MATH 342: Introduction to the Theory of Probability and Statistics II

(Cross-listed with STAT). (3-2) Cr. 4. F.S.

Prereq: STAT 201 or equivalent; STAT 341; MATH 207 or MATH 317

Sampling distributions; confidence intervals and hypothesis testing; theory of estimation and hypothesis tests; linear model theory; resampling methods; introduction to Bayesian inference; use of the R statistical package for simulation and data analysis.

MATH 350: Number Theory

(Cross-listed with COM S). (3-0) Cr. 3. S.

Prereq: MATH 201 or COM S 230

Divisibility, integer representations, primes and divisors, linear diophantine equations, congruences, and multiplicative functions. Applications to cryptography.

MATH 365: Complex Variables with Applications

(3-0) Cr. 3. S.

Prereq: MATH 265

Functions of a complex variable, including differentiation, integration and series expansions, residues, evaluation of integrals, conformal mapping.

MATH 373: Introduction to Scientific Computing

(3-0) Cr. 3. F.

Prereq: MATH 265

Vector and matrix programming and graphing in MATLAB for scientific applications. Polynomial interpolation and approximation. Systems of linear equations and numerical linear algebra. Numerical differentiation and integration. Newton methods for solving nonlinear equations and optimization in one and several variables. Fast Fourier transform. Emphasis on effective use of mathematical software and understanding of its strengths and limitations.

MATH 385: Introduction to Partial Differential Equations

(3-0) Cr. 3. F.S.

Prereq: MATH 265 and one of MATH 266, MATH 267

Method of separation of variables for linear partial differential equations, including heat equation, Poisson equation, and wave equation. Topics from Fourier series, Sturm-Liouville theory, Bessel functions, spherical harmonics, and method of characteristics.

MATH 397: Teaching Secondary Mathematics Using University Mathematics

(2-2) Cr. 3. S.

Prereq: MATH 201, MATH 301

Coursework in university mathematics including calculus, abstract algebra, discrete mathematics, geometry, and other topics as it relates to teaching mathematics in grades 5-12.

MATH 398: Cooperative Education

Cr. R. Repeatable, maximum of 2 times. F.S.SS.

Prereq: Permission of the department cooperative education coordinator; junior classification

Required of all cooperative education students. Students must register for this course prior to commencing each work period.

MATH 407: Applied Linear Algebra

(Dual-listed with MATH 507). (3-0) Cr. 3. F.

Prereq: MATH 317; or MATH 207 and experience writing proofs

Advanced topics in applied linear algebra including eigenvalues, eigenvalue localization, singular value decomposition, symmetric and Hermitian matrices, nonnegative and stochastic matrices, matrix norms, canonical forms, matrix functions. Applications to mathematical and physical sciences, engineering, and other fields.

MATH 414: Analysis I

(3-0) Cr. 3. F.S.SS.

Prereq: Minimum of C- in MATH 201

A careful development of calculus of functions of one real variable: real number properties, sequences and series, limits, continuity, differentiation, and integration.

MATH 415: Analysis II

(3-0) Cr. 3. S.

Prereq: MATH 414; MATH 265; and MATH 317 or MATH 407

Sequences and series of functions of a real variable, uniform convergence, power series, metric spaces, calculus of functions of two or more real variables.

MATH 421: Logic for Mathematics and Computer Science

(Cross-listed with COM S). (3-0) Cr. 3.

Prereq: MATH 301 or MATH 207 or MATH 317 or COM S 230

Propositional and predicate logic. Topics selected from Horn logic, equational logic, resolution and unification, foundations of logic programming, reasoning about programs, program specification and verification, model checking and binary decision diagrams, temporal logic and modal logic.

MATH 424: Introduction to High Performance Computing

(Cross-listed with COM S, CPR E). (2-2) Cr. 3. F.

Prereq: MATH 265; MATH 207 or MATH 317

UNIX, serial programming for high performance, OpenMP for high performance, shared memory parallelization. Semester project required.

MATH 435: Geometry I

(3-0) Cr. 3. F.

Prereq: MATH 201; MATH 207 or MATH 317

Euclidean geometry of triangles, circles, and parallelograms, studied from several points of view, chosen from: synthetic, analytic, axiomatic, transformational, complex numbers, or vector methods. Possible and impossible constructions with compass and straightedge.

MATH 436: Geometry II

(3-0) Cr. 3. S.

Prereq: MATH 201; MATH 207 or MATH 317

Foundations of Euclidean geometry and the axiomatic method, including the use of models. The history, logical consistency, and basic theorems of non-Euclidean geometries, such as hyperbolic, elliptic, and projective geometry.

MATH 474: Mathematics of Finance

(3-0) Cr. 3. S.

Prereq: MATH 265; STAT 101 or 104 or 105 or 201 or 226.

Applications of mathematical methods to problems in finance. Lagrange Multiplier Method, applications to mean-variance portfolio selection and utility maximization, binomial asset pricing model. Binary Martingales, Optional Stopping Theorem, Central Limit Theorem, applications to financial derivative pricing.

MATH 481: Numerical Methods for Differential Equations

(Cross-listed with COM S). (3-0) Cr. 3. S.

Prereq: MATH 265 and either MATH 266 or MATH 267

First order Euler method, high order Runge-Kutta methods, and multistep methods for solving ordinary differential equations. Finite difference and finite element methods for solving partial differential equations. Local truncation error, stability, and convergence for finite difference method. Numerical solution space, polynomial approximation, and error estimate for finite element method. Computer programming required.

MATH 490: Independent Study

Cr. 1-3. Repeatable, maximum of 9 credits.

Prereq: Permission of instructor.

No more than 9 credits of Math 490 or Math 490H may be counted toward graduation.

MATH 490H: Independent Study: Honors

Cr. 1-3. Repeatable, maximum of 9 credits.

Prereq: Permission of the instructor.

No more than 9 credits of Math 490 or 490H may be counted toward graduation.

MATH 491: Undergraduate Thesis

Cr. 2-3.

Writing and presenting a formal mathematics paper. Upon approval by the department, the paper will satisfy the departmental advanced English requirement.

MATH 492: Undergraduate Seminar

(2-0) Cr. 2. F.S.

Prereq: MATH 317 or MATH 407

Introduction to independent mathematical thought, with emphasis on oral communication of an advanced topic. Seminar content varies.

MATH 495: Special Topics

Cr. arr. Repeatable, maximum of 9 credits.

Prereq: Permission of instructor

Topics of current interest.

MATH 497: Teaching Secondary School Mathematics

(Cross-listed with C I). (3-0) Cr. 3. F.

Prereq: 15 credits in college mathematics. If in a teacher licensure program, concurrent enrollment in C I 426 or C I 526.

Develop an understanding of instructional planning, lesson implementation, and assessment in grades 5-12 mathematics, with a focus on reform-based mathematics, equity, and conceptual understanding.

Courses primarily for graduate students, open to qualified undergraduates:

MATH 501: Introduction to Real Analysis

(3-0) Cr. 3. F.

Prereq: MATH 265 and (MATH 207 or MATH 317)

A development of the real numbers. Study of metric spaces, completeness, compactness, sequences, and continuity of functions. Differentiation and integration of real-valued functions, sequences of functions, limits and convergence, equicontinuity.

MATH 502: Topology

(3-0) Cr. 3. S.

Prereq: MATH 414 or MATH 501

Introduction to general topology. Topological spaces, continuous functions, connectedness, compactness. Topics selected from countability and separation axioms, metrization, and complete metric spaces. Topics in algebraic topology.

MATH 504: Abstract Algebra I

(3-0) Cr. 3. F.

Prereq: MATH 302

Algebraic systems and their morphisms, with emphasis on groups and rings.

MATH 505: Abstract Algebra II

(3-0) Cr. 3. S.

Prereq: MATH 504

Continuation of Math 504. Algebraic systems and their morphisms, with emphasis on modules and fields.

MATH 507: Applied Linear Algebra

(Dual-listed with MATH 407). (3-0) Cr. 3. F.

Prereq: MATH 317; or MATH 207 and experience writing proofs

Advanced topics in applied linear algebra including eigenvalues, eigenvalue localization, singular value decomposition, symmetric and Hermitian matrices, nonnegative and stochastic matrices, matrix norms, canonical forms, matrix functions. Applications to mathematical and physical sciences, engineering, and other fields.

MATH 510: Linear Algebra

(3-0) Cr. 3. S.

Prereq: MATH 317 or MATH 407 or (MATH 207 and one of MATH 301 or MATH 414)

Advanced topics in linear algebra including canonical forms; unitary, normal, Hermitian and positive-definite matrices; variational characterizations of eigenvalues.

MATH 511: Functions of a Single Complex Variable

(3-0) Cr. 3. S.

Prereq: MATH 414 or MATH 501

Theory of analytic functions, integration, topology of the extended complex plane, singularities and residue theory, maximum principle, conformal mapping, meromorphic functions, argument principle.

MATH 515: Real Analysis I

(3-0) Cr. 3. F.

Prereq: MATH 414 or MATH 501

Lebesgue measure and Lebesgue integral, one variable differentiation theory, Fubini and Tonelli theorems in \mathbb{R}^n , L_p spaces.

MATH 516: Real Analysis II

(3-0) Cr. 3. S.

Prereq: MATH 515

Metric spaces, topological spaces, compactness, abstract theory of measure and integral, differentiation of measures, Banach spaces.

MATH 517: Finite Difference Methods

(3-0) Cr. 3. S.

Prereq: MATH 481 or MATH 561

Finite difference methods for partial differential equations. Methods for elliptic equations; explicit and implicit methods for parabolic and hyperbolic equations; stability, accuracy, and convergence theory, including von Neumann analysis, modified equations, and the Courant-Friedrichs-Lewy condition.

MATH 519: Methods of Applied Mathematics I

(3-0) Cr. 3. F.

Prereq: MATH 414 or MATH 501

Techniques of classical and functional analysis with applications to differential equations and integral equations. Vector spaces, metric spaces, Hilbert and Banach spaces, Sobolev spaces and other function spaces, contraction mapping theorem, distributions, Fourier series and Fourier transform.

MATH 520: Methods of Applied Mathematics II

(3-0) Cr. 3. S.

Prereq: MATH 519

Continuation of Math 519. Linear operators, spectral theory of differential and integral operators, Green's functions and boundary value problems, weak solutions of partial differential equations and variational methods, calculus in Banach spaces and applications.

MATH 525: Numerical Analysis of High Performance Computing

(Cross-listed with COM S, CPR E). (3-0) Cr. 3. S.

Prereq: CPR E 308 or MATH 481; experience in scientific programming; knowledge of FORTRAN or C

Introduction to parallelization techniques and numerical methods for distributed memory high performance computers. A semester project in an area related to each student's research interests is required.

MATH 533: Cryptography

(Cross-listed with CPR E, INFAS). (3-0) Cr. 3. S.

Prereq: MATH 301 or CPR E 310 or COM S 330

Basic concepts of secure communication, DES and AES, public-key cryptosystems, elliptic curves, hash algorithms, digital signatures, applications. Relevant material on number theory and finite fields.

MATH 535: Steganography and Digital Image Forensics

(Cross-listed with CPR E, INFAS). (3-0) Cr. 3. S.

Prereq: EE 524 or MATH 317 or MATH 407 or COM S 330

Basic principles of covert communication, steganalysis, and forensic analysis for digital images. Steganographic security and capacity, matrix embedding, blind attacks, image forensic detection and device identification techniques. Related material on coding theory, statistics, image processing, pattern recognition.

MATH 540: Seminar in Mathematics Education

(1-0) Cr. 1. SS.

Prereq: Enrollment in the Master of School Mathematics program or professional studies in education

Research studies in mathematics learning and teaching, exemplary practices in mathematics education, and current state and national trends in the mathematics curriculum in grades K-12. Students in MSM take each of 540A, 540B, and 540C. Topics are offered on a 3-year cycle. A. Assessment, equity, and teaching of statistics. Offered SS 2017. B. Geometry and discrete mathematics, and problem solving. Offered SS 2018. C. Teaching of analysis, algebra, and the use of technology. Offered SS 2016.

MATH 540A: Seminar in Mathematics Education: Assessment, equity, and teaching of statistics.

(1-0) Cr. 1.

Prereq: Enrollment in the Master of School Mathematics program or professional studies in education

Research studies in mathematics learning and teaching, exemplary practices in mathematics education, and current state and national trends in the mathematics curriculum in grades K-12. Topics are offered on a 3-year cycle. Offered SS 2017.

MATH 540B: Seminar in Mathematics Education: Geometry and discrete mathematics, and problem solving.

(1-0) Cr. 1.

Prereq: Enrollment in the Master of School Mathematics program or professional studies in education

Research studies in mathematics learning and teaching, exemplary practices in mathematics education, and current state and national trends in the mathematics curriculum in grades K-12. Offered on a 3-year cycle. Offered SS 2018.

MATH 540C: Seminar in Mathematics Education: Teaching of analysis, algebra, and the use of technology.

(1-0) Cr. 1.

Prereq: Enrollment in the Master of School Mathematics program or professional studies in education

Research studies in mathematics learning and teaching, exemplary practices in mathematics education, and current state and national trends in the mathematics curriculum in grades K-12. Topics are offered on a 3-year cycle. Offered SS 2016.

MATH 545: Intermediate Calculus

(4-0) Cr. 4.

Prereq: 3 semesters of calculus and enrollment in the master of school mathematics program

Offered on a 3-year cycle, offered SS. 2016. The fundamental concepts of calculus which are critical to the effective understanding of the material in first year calculus. Emphasis is on a constructivist approach to learning, cooperative groups, problem solving, and use of technology.

MATH 546: Algorithms in Analysis and Their Computer Implementation

(2-2) Cr. 3.

Prereq: 3 semesters in calculus or concurrent enrollment in 545 and enrollment in the master of school mathematics program

Offered on a 3-year cycle, offered SS. 2016. The use of technology in secondary mathematics with an emphasis on the exploration, creation, and implementation of algorithms.

MATH 547: Discrete Mathematics and Applications

(4-0) Cr. 4.

Prereq: Enrollment in the master of school mathematics program

Offered on a 3-year cycle, offered SS. 2018. Applications of graph theory, game theory, voting theory, recursion, combinatorics, and algebraic structures. Issues in integrating discrete topics into the secondary curriculum. Use of the computer to explore discrete mathematics.

MATH 549: Intermediate Geometry

(3-0) Cr. 3.

Prereq: MATH 435 or equivalent and enrollment in the master of school mathematics program

Offered on a 3-year cycle, offered SS. 2018. A study of geometry with emphasis on metrics, the group of isometries, and the group of similarities. Specific spaces studied normally include the Euclidean plane, the 2-sphere, projective 2-space, and hyperbolic geometry. Emphasis on analytical methods. Incorporation of geometry software.

MATH 554: Introduction to Stochastic Processes

(Cross-listed with STAT). (3-0) Cr. 3. F.

Prereq: STAT 542

Markov chains on discrete spaces in discrete and continuous time (random walks, Poisson processes, birth and death processes) and their long-term behavior. Optional topics may include branching processes, renewal theory, introduction to Brownian motion.

MATH 557: Ordinary Differential Equations and Dynamical Systems

(3-0) Cr. 3. F.

Prereq: MATH 415 or MATH 501

The initial-value problem, existence and uniqueness theorems, continuous dependence on parameters, linear systems, stability and asymptotic behavior of solutions, linearization, dynamical systems, bifurcations, and chaotic behavior.

MATH 561: Numerical Analysis I

(3-0) Cr. 3. F.

Prereq: MATH 414 or MATH 501

Approximation theory, including polynomial interpolation, spline interpolation and best approximation; numerical differentiation and integration; numerical methods for ordinary differential equations.

MATH 562: Numerical Analysis II

(3-0) Cr. 3. S.

Prereq: MATH 317

Numerical linear algebra including LU factorization, QR factorization, linear least squares, singular value decomposition, eigenvalue problems, and iterative methods for large linear systems.

MATH 565: Continuous Optimization

(3-0) Cr. 3. S.

Prereq: MATH 265 and one of MATH 317, 507, 510

Theory and methods for constrained and unconstrained optimization. Steepest-descent, conjugate gradient, Newton and quasi-Newton, line search and trust-region, first and second order necessary and sufficient conditions, linear, quadratic and general nonlinear programming.

MATH 566: Discrete Optimization

(3-0) Cr. 3. F.

Prereq: MATH 317 or MATH 507 or MATH 510

Algorithms for linear programming, integer and combinatorial optimization. Linear programming, duality theory, simplex algorithm; the solution of the shortest-path, minimum spanning tree, max-flow/min-cut, minimum cost flow, maximum matching, and traveling salesman problems; integer linear programming, branch-and-bound, local and global search algorithms; matroids and greedy algorithms.

MATH 567: Graph Theory

(3-0) Cr. 3. F.

Prereq: MATH 317 or MATH 507 or MATH 510

Structural theory of graphs. Topics include basic structures (trees, paths, cycles and matchings), networks, colorings, connectivity, topological graph theory, Ramsey and Turan theory, spectral graph theory, introduction to probabilistic methods.

MATH 568: Enumerative Combinatorics and Ordered Sets

(3-0) Cr. 3. S.

Prereq: MATH 302 or MATH 504

Enumeration methods. Generating functions and sieve methods. Partially ordered sets, lattices, and Moebius inversion. Extremal set theory.

MATH 577: Linear Systems

(Cross-listed with AER E, E E, M E). (3-0) Cr. 3. F.

Prereq: E E 324 or AER E 331 or MATH 415; and MATH 207

Linear algebra review. Least square method and singular value decomposition. State space modeling of linear continuous-time systems. Solution of linear systems. Controllability and observability. Canonical description of linear equations. Stability of linear systems. State feedback and pole placements. Observer design for linear systems.

MATH 578: Nonlinear Systems

(Cross-listed with AER E, E E, M E). (3-0) Cr. 3. S.

Prereq: E E 577

Linear vs nonlinear systems. Phase plane analysis. Bifurcation and center manifold theory. Lyapunov stability. Absolute stability of feedback systems. Input-output stability. Passivity theory and feedback linearization. Nonlinear control design techniques.

MATH 590: Independent Study

Cr. arr. Repeatable.

MATH 591: Orientation for Mathematics Graduate Students I

(0.5-0) Cr. 0.5. F.

Fall semester orientation seminar. Required for graduate students in Mathematics and Applied Mathematics. Topics include teaching at the university level and communication of mathematics. Offered on a satisfactory-fail basis only.

MATH 592: Orientation for Mathematics Graduate Students II

(0.5-0) Cr. 0.5. S.

Spring semester orientation seminar. Required for graduate students in Mathematics and Applied Mathematics. Topics include teaching at the university level and communication of mathematics. Offered on a satisfactory-fail basis only.

MATH 595: Special Topics

Cr. arr. Repeatable.

MATH 599: Creative Component

Cr. arr.

Courses for graduate students:**MATH 601: Mathematical Logic**

(3-0) Cr. 3. Alt. F., offered odd-numbered years.

Prereq: MATH 504

Model theory of propositional and predicate logic, the Soundness Theorem, the Compactness Theorem, the Goedel-Henkin Completeness Theorem, the Incompleteness Theorem, computability theory. As time permits: modal and temporal logic, set theory (the continuum hypothesis). Emphasis on the relationship between 'provable' and 'true' and the relationship between 'computable' and 'definable'.

MATH 605: Design Theory and Association Schemes

(3-0) Cr. 3. Alt. S., offered odd-numbered years.

Prereq: MATH 504

Combinatorial designs and algebraic codes. Construction methods including finite fields. Error-correcting codes. Adjacency matrices and algebraic combinatorics.

MATH 608: Extremal Graph Theory

(3-0) Cr. 3. Alt. S., offered even-numbered years.

Prereq: MATH 567

Study of extremal graph problems and methods. Topics include probabilistic methods, generalizations of Turan's theorem, Szemerédi's regularity lemma, random graph theory.

MATH 610: Seminar

Cr. arr.

MATH 615: General Theory of Algebraic Structures I

(3-0) Cr. 3. Alt. F., offered even-numbered years.

Prereq: MATH 504

First semester of full-year course. Subalgebras, homomorphisms, congruence relations, and direct products. Lattices and closure operators. Varieties and quasivarieties of algebras, free algebras, Birkhoff's theorems, clones, Mal'cev conditions. Advanced topics.

MATH 616: General Theory of Algebraic Structures II

(3-0) Cr. 3. Alt. S., offered odd-numbered years.

Prereq: MATH 615

Continuation of MATH 615.

MATH 617: Category Theory

(3-0) Cr. 3. Alt. F., offered even-numbered years.

Prereq: MATH 504

Categories and functors and their applications.

MATH 618: Representation Theory

(3-0) Cr. 3. Alt. S., offered odd-numbered years.

Prereq: MATH 504

Representations of algebraic structures. Content varies by semester.

MATH 624: Manifolds, Tensors and Differential Geometry

(3-0) Cr. 3. Alt. S., offered odd-numbered years.

Prereq: MATH 501 or MATH 515

Topics selected from: Geometry of curves and surfaces. Manifolds, coordinate systems. Tangent and cotangent vectors, vector fields. Tensors, differential forms, Riemannian metrics. Connections, covariant differentiation, curvature tensors. Applications to physics and engineering.

MATH 631: Harmonic Analysis

Cr. 3. Alt. F., offered even-numbered years.

Prereq: MATH 515

Fourier Series on an interval, approximate identities and summation, Gibb's phenomenon, Fourier transform on the line, uncertainty principle. Additional topics may include distributions, Hardy-Littlewood maximal function, boundedness of singular integral operators, arithmetic combinatorics, wavelet theory.

MATH 633: Functional Analysis

(3-0) Cr. 3. Alt. F., offered odd-numbered years.

Prereq: MATH 515

Fundamental theory of normed linear spaces and algebras, such as topology and continuity, duality and spectral theory, emphasizing aspects that provide a framework for the study of the spectrum of an operator, analytic function theory, and modern operator theory.

MATH 641: Foundations of Probability Theory

(Cross-listed with STAT). (3-0) Cr. 3. F.

Prereq: MATH 414 or MATH 501 or equivalent course.

Sequences and set theory; Lebesgue measure, measurable functions. Absolute continuity of functions, integrability and the fundamental theorem of Lebesgue integration. General measure spaces, probability measure, extension theorem and construction of Lebesgue-Stieljes measures on Euclidean spaces. Measurable transformations and random variables, induced measures and probability distributions. General integration and expectation, L_p -spaces and integral inequalities. Uniform integrability and absolute continuity of measures. Probability densities and the Radon-Nikodym theorem. Product spaces and Fubini-Tonelli theorems.

MATH 642: Advanced Probability Theory

(Cross-listed with STAT). (3-0) Cr. 3. S.

Prereq: STAT 641, or STAT 543 and MATH 515.

Probability spaces and random variables. Kolmogorov's consistency theorem. Independence, Borel-Cantelli lemmas and Kolmogorov's 0-1 Law. Comparing types of convergence for random variables. Sums of independent random variables, empirical distributions, weak and strong laws of large numbers. Convergence in distribution and its characterizations, tightness, characteristic functions, central limit theorems and Lindeberg-Feller conditions. Conditional probability and expectation. Discrete parameter martingales and their properties and applications.

MATH 645: Advanced Stochastic Processes

(Cross-listed with STAT). (3-0) Cr. 3. S.

Weak convergence. Random walks and Brownian motion. Martingales. Stochastic integration and Ito's Formula. Stochastic differential equations and applications.

MATH 646: Mathematical Modeling of Complex Physical Systems

(Cross-listed with PHYS). (3-0) Cr. 3. S.

Modeling of the dynamics of complex systems on multiple scales: Classical and dissipative molecular dynamics, stochastic modeling and Monte-Carlo simulation; coarse grained nonlinear dynamics, interface propagation and spatial pattern formation.

MATH 655: Partial Differential Equations I

(3-0) Cr. 3. F.

Prereq: MATH 515 or MATH 519

Study of model problems of elliptic, parabolic and hyperbolic types, first order equations, conservation laws, transform methods, introduction to linear partial differential equations of arbitrary order, fundamental solutions.

MATH 656: Partial Differential Equations II

(3-0) Cr. 3. S.

Prereq: MATH 655

Sobolev spaces, general theory of second order linear elliptic, parabolic and hyperbolic partial differential equations, first order linear hyperbolic systems, variational methods, fixed point methods.

MATH 666: Finite Element Methods

(3-0) Cr. 3. Alt. F., offered even-numbered years.

Prereq: MATH 516 or MATH 520 or MATH 561 or MATH 656

Weak and variational formulations of elliptic problems; weak derivatives and Sobolev spaces; Lax-Milgram theorem, Bramble-Hilbert lemma; examples of finite element spaces; polynomial approximation theory; error estimates for finite element methods; implementation issues; mixed finite element methods for Stokes problems; applications.

MATH 667: Computational Methods for Hyperbolic Partial Differential Equations (PDE)

Cr. 3. Alt. F., offered odd-numbered years.

Prereq: MATH 561, MATH 562

Mathematical theory of weak/entropy solutions of nonlinear hyperbolic conservation laws; shock speed and Riemann problems; numerical methods for scalar equations and systems including Euler equations; conservative methods; approximate Riemann solvers; total variation stability; DG method.

MATH 680: Advanced Topics

Cr. 3. Repeatable.

MATH 680A: Advanced Topics: Algebra

Cr. 3. Repeatable.

MATH 680B: Advanced Topics: Analysis

Cr. 3. Repeatable.

MATH 680C: Advanced Topics: Applied Mathematics

Cr. 3. Repeatable.

MATH 680D: Advanced Topics: Combinatorics

Cr. 3. Repeatable.

MATH 680E: Advanced Topics: Differential Equations

Cr. 3. Repeatable.

MATH 680F: Advanced Topics: Linear Algebra

Cr. 3. Repeatable.

MATH 680G: Advanced Topics: Logic and Foundations

Cr. 3. Repeatable.

MATH 680H: Advanced Topics: Number Theory

Cr. 3. Repeatable.

MATH 680I: Advanced Topics: Numerical Analysis

Cr. 3. Repeatable.

MATH 680J: Advanced Topics: Optimization

Cr. 3. Repeatable.

MATH 680K: Advanced Topics: Probability

Cr. 3. Repeatable.

MATH 680L: Advanced Topics: Topology

Cr. 3. Repeatable.

MATH 699: Research

Cr. arr. Repeatable.