MATHEMATICS (MATH)

Any experimental courses offered by MATH can be found at:
registrar.iastate.edu/faculty-staff/courses/explistings/ (http://www.registrar.iastate.edu/faculty-staff/courses/explistings/)

Courses primarily for undergraduates:

MATH 101: Orientation in Mathematics
(1-0) Cr. 1. F.
A required orientation for all first-year and transfer students in mathematics. Provides information about campus resources and opportunities available to students, assists with transition to the University, and academic planning. Offered on a satisfactory/fail basis only. 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
Permutations, combinations, probability, expected value, and applications. Satisfactory placement scores can be found at https://math.iastate.edu/academics/undergraduate/aleks/placement/. 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
Introduction to the use of basic mathematics to solve real-world problems in the areas of voting issues, measuring power in situations where people have different numbers of votes, apportionment, fair division, and elementary game theory. No prior background in politics or history is necessary for this course. Satisfactory placement scores can be found at https://math.iastate.edu/academics/undergraduate/aleks/placement/.

MATH 139: College Algebra Supplement
(1-0) Cr. 1. F.S.
Prereq: Satisfactory performance on placement assessment
Math concepts to provide supplemental assistance with course topics of MATH 140. Satisfactory placement scores can be found at https://math.iastate.edu/academics/undergraduate/aleks/placement/. Offered on a satisfactory-fail basis only.

MATH 140: College Algebra
(3-1) Cr. 3. F.S.SS.
Prereq: Satisfactory performance on placement assessment or concurrent enrollment in MATH 139
Coordinate geometry, quadratic and polynomial equations, functions, graphing, rational functions, exponential and logarithmic functions, inverse functions, quadratic inequalities, systems of linear equations. Satisfactory placement scores can be found at https://math.iastate.edu/academics/undergraduate/aleks/placement/.

MATH 143: Preparation for Calculus
(4-0) Cr. 4. F.S.
Prereq: Satisfactory performance on placement assessment or MATH 140
Preparation for MATH 160 or MATH 165. Functions, graphing, basic trigonometry, logarithms, exponentials. Emphasis on co-variational reasoning. Satisfactory placement scores can be found at https://math.iastate.edu/academics/undergraduate/aleks/placement/. 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 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. Satisfactory placement scores can be found at https://math.iastate.edu/academics/undergraduate/aleks/placement/. Only one of MATH 143 and MATH 145 may count toward graduation.

MATH 149: Discrete Mathematics for Business and Social Sciences Supplement
(1-0) Cr. 1. F.S.
Prereq: Satisfactory performance on placement assessment
Math concepts to provide supplemental assistance with course topics of MATH 150. Satisfactory placement scores can be found at https://math.iastate.edu/academics/undergraduate/aleks/placement/. Offered on a satisfactory-fail basis only.

MATH 150: Discrete Mathematics for Business and Social Sciences
(2-1) Cr. 3. F.S.SS.
Prereq: Satisfactory performance on placement assessment or concurrent enrollment in MATH 149
Linear equations and inequalities, matrix algebra, linear programming, discrete probability. Satisfactory placement scores can be found at https://math.iastate.edu/academics/undergraduate/aleks/placement/. 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
Differential calculus, applications to max-min problems, integral calculus and applications. Will not serve as prerequisite for MATH 265 or MATH 266. Satisfactory placement scores can be found at https://math.iastate.edu/academics/undergraduate/aleks/placement/. Only one of MATH 151, MATH 160, or the sequence MATH 165-MATH 166 may be counted towards graduation.

MATH 160: Survey of Calculus
(4-0) Cr. 4. F.S.
Prereq: Satisfactory performance on placement assessment or minimum of C- in (MATH 140 or 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. Satisfactory placement scores can be found at https://math.iastate.edu/academics/undergraduate/aleks/placement/. Only one of MATH 151, MATH 160, or the sequence MATH 165-MATH 166 may be counted towards graduation.

MATH 165: Calculus I
(4-0) Cr. 4. F.S.SS.
Prereq: Satisfactory performance on placement assessment or minimum of C- in MATH 143
Differential calculus, applications of the derivative, introduction to integral calculus. Satisfactory placement scores can be found at https://math.iastate.edu/academics/undergraduate/aleks/placement/. Only one of MATH 151 or MATH 160 or the sequence MATH 165-MATH 166 may be counted towards graduation.

MATH 166: Calculus II
(4-0) Cr. 4. F.S.SS.
Prereq: Minimum of C- in MATH 165 or satisfactory performance on placement assessments
Integral calculus, applications of the integral, parametric curves and polar coordinates, power series and Taylor series. Satisfactory placement scores can be found at https://math.iastate.edu/academics/undergraduate/aleks/placement/. Only one of MATH 151, MATH 160, or the sequence MATH 165-MATH 166 may be counted towards graduation.

MATH 166H: Calculus II, Honors
(4-0) Cr. 4. F.
Prereq: Minimum of C- in MATH 165 or satisfactory performance on placement assessments
Integral calculus, applications of the integral, parametric curves and polar coordinates, power series and Taylor series. 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. Satisfactory placement scores can be found at https://math.iastate.edu/academics/undergraduate/aleks/placement/. Only one of MATH 151 or MATH 160, or the sequence MATH 165-MATH 166 may be counted towards graduation.

MATH 195: Mathematics for Elementary Education I
(2-2) Cr. 3. F.S.
Prereq: Satisfactory performance on placement assessment; Early or Elementary Education major
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 measurement, shapes and spatial sense; number theory; algebra as it relates to elementary curricula/teaching profession. Satisfactory placement scores can be found at https://math.iastate.edu/academics/undergraduate/aleks/placement/. 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; Early or Elementary Education major
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; continuation of two- and three-dimensional measurement, shapes and spatial sense; 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 202: Career Development in Math and Statistics
(Cross-listed with STAT). Cr. 1. S.
Career development in the mathematics and statistics disciplines with an emphasis on contemporary social issues. Presentations by professionals in STEM fields about occupations, decision-making strategies, and career goal implementation; development of job searching, resume writing, negotiating, and interviewing techniques. Offered on a satisfactory-fail basis only.

MATH 207: Matrices and Linear Algebra
(3-0) Cr. 3. F.S.SS.
Prereq: MATH 166
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 230: Discrete Computational Structures
(Cross-listed with COM S). (3-1) Cr. 3. F.S.SS.
Prereq: Minimum of C- in (COM S 227; MATH 165); ENGL 150
Concepts in discrete mathematics as applied to computer science. Logic, set theory, functions, relations, cardinality of sets, combinatorics, graph theory and number theory. Proof techniques, induction and recursion.

MATH 240: Mathematics of Investment and Credit
(3-0) Cr. 3. F.S.
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
Geometry of space and vectors, multivariable differential calculus, multivariable integral calculus, vector calculus.

MATH 265H: Calculus III, Honors
(4-0) Cr. 4. F.S.
Prereq: Permission of Instructor; minimum of C- in MATH 166 or MATH 166H
Geometry of space and vectors, multivariable differential calculus, multivariable integral calculus, 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. Credit for either MATH 267 or the MATH 266, 268 pair of courses, but not both, may be applied toward graduation. Credit for only one of the following courses may be applied toward graduation: MATH 267, MATH 266, MATH 269.

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. Credit for either MATH 267 or the MATH 266, 268 pair of courses, but not both, may be applied toward graduation. Credit for only one of the following courses may be applied toward graduation: MATH 267, MATH 266, MATH 269.

MATH 268: Laplace Transforms
(1-0) Cr. 1. F.S.SS.
Prereq: MATH 266; Department Permission
Laplace transforms and power series solutions to ordinary differential equations. Credit for either MATH 267 or the MATH 266, 268 pair of courses, but not both, may be applied toward graduation.

MATH 269: Systems of Differential Equations
(1-0) Cr. 1. F.S.SS.
Prereq: Department Permission
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. Familiarity with ordinary differential equations of first and second order required. 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 Instructor
Independent study.

MATH 290H: Independent Study, Honors
Cr. 1-3. Repeatable.
Prereq: Permission of Instructor
Independent study.

MATH 297: Intermediate Topics for School Mathematics
(2-2) Cr. 3. F.
Prereq: Minimum of C- in MATH 196; Early or Elementary Education major
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; minimum of C- in MATH 201
Basic properties of integers, divisibility and unique factorization. Polynomial rings over a field. Congruence. Introduction to abstract rings, homomorphisms, ideals. Roots and irreducibility of polynomials. Introduction to groups. Emphasis on proofs.

MATH 304: Combinatorics
(3-0) Cr. 3. F.
Prereq: (MATH 166 or MATH 166H); (MATH 201 or COM S 230 or CPR E 310)
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 COM S 230 or CPR E 310)
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 concurrent enrollment
in MATH 201 or COM S 230 or CPR E 310
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 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 only one of the following courses may be applied toward graduation: STAT 341, STAT 347, STAT 447, or STAT 588.

MATH 342: Introduction to the Theory of Probability and Statistics II
(Cross-listed with STAT). (3-2) Cr. 4. F.S.
Prereq: (MATH 207 or MATH 317); (STAT 101 or STAT 104 or STAT 105 or STAT 201 or STAT 226 or STAT 231 or STAT 305 or STAT 322 or STAT 330); STAT 341
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: COM S 230 or CPR E 310 or MATH 201
Divisibility, integer representations, primes and divisors, linear diophantine equations, congruences, and multiplicative functions. Applications to cryptography. Additional topics, chosen at the discretion of the instructor.

MATH 365: Complex Variables with Applications
(3-0) Cr. 3. S.
Prereq: MATH 265
Functions of a complex variable, including differentiation, integration, series, residues, and conformal mappings.

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. Root-finding 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; (MATH 266 or 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: Junior classification; Permission of Department Cooperative Education Coordinator
Required of all cooperative education students. Students must register for this course prior to commencing each work period.

MATH 403: Intermediate Abstract Algebra
(Dual-listed with MATH 503). (3-0) Cr. 3. S.
Prereq: 403: Minimum of C in MATH 301, 503: Not taken MATH 504 or MATH 505
Properties of groups and rings, subgroups, ideals, and quotients, homomorphisms, structure theory for finite groups. PIDs, UFDs, and Euclidean Domains. Field extensions and finite fields. Selected applications.

MATH 407: Applied Linear Algebra
(Dual-listed with MATH 507). (3-0) Cr. 3. F.
Prereq: MATH 317 or (MATH 207; MATH 201)
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 COM S 230 or CPR E 310 or MATH 201
A rigorous development of calculus of functions of one real variable: real number properties and topology, limits, continuity, differentiation, integration, series.

MATH 415: Analysis II
(3-0) Cr. 3. S.
Prereq: MATH 265; (MATH 317 or MATH 407); MATH 414
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: COM S 230 or CPR E 310 or MATH 207 or MATH 301 or MATH 317
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 423: Mathematical Modeling in Biology
(Dual-listed with MATH 523). (3-0) Cr. 3. F.
Prereq: MATH 266 or MATH 267
Introduction to mathematical techniques for modeling and simulation, parameter identification, and analysis of biological systems. Applications drawn from many branches of biology and medicine. Apply differential equations, difference equations, and dynamical systems theory to a wide array of biological problems. MATH 265 or equivalent recommended.

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]) or Permission of Instructor
Unix, serial programming of scientific applications, OpenMP for shared-memory parallelization. No Unix, Fortran or C experience required.

MATH 435: Geometry I
(3-0) Cr. 3. F.
Prereq: (COM S 230 or CPR E 310 or 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: (COM S 230 or CPR E 310 or 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 441: Life Contingencies I
Cr. 3. F.
Prereq: MATH 240; credit or concurrent enrollment in MATH 265
Topics in life insurance for the Actuarial Sciences I: single life annuities, benefits premiums and reserves.

MATH 442: Life Contingencies II
Cr. 3. S.
Prereq: MATH 441
Topics in life insurance for the Actuarial Sciences II: multiple life functions, multiple decrement models, pension plan valuation, insurance models, applications.

MATH 469: Introduction to Discrete Mathematics
(Dual-listed with MATH 569). (3-0) Cr. 3. S.
Prereq: (MATH 207 or MATH 317); (MATH 304 or MATH 314)
Combinatorial counting, double-counting, generating functions, graph structure, planar graphs, probabilistic proofs, points in general positions, polytopes, Farkas lemma, linear programming and duality.

MATH 481: Numerical Methods for Differential Equations
(Dual-listed with MATH 581). (Cross-listed with COM S). (3-0) Cr. 3. S.
Prereq: MATH 265; (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 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 EDUC). (3-0) Cr. 3. F.
Prereq: 15 credits in college mathematics. Admitted to the Educator Preparation Program.
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 503: Intermediate Abstract Algebra
(Dual-listed with MATH 403). (3-0) Cr. 3. S.
Prereq: 403: Minimum of C in MATH 301, 503: Not taken MATH 504 or MATH 505
Properties of groups and rings, subgroups, ideals, and quotients, homomorphisms, structure theory for finite groups. PIDs, UFDs, and Euclidean Domains. Field extensions and finite fields. Selected applications.

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; MATH 201)
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 R^n, Lp 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 518: Mathematical Modeling and Differential Equations
(3-0) Cr. 3. S.
Prereq: MATH 414, MATH 415
Basic theory of ordinary differential equations, existence and uniqueness theorems, linear systems, linearization and stability, mathematical models in biology and physics, modeling with ordinary and partial differential equations, dynamical systems techniques.

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 523: Mathematical Modeling in Biology
(Dual-listed with MATH 423). (Cross-listed with BCB, BCBIO). (3-0) Cr. 3. F.
Prereq: MATH 266 or MATH 267
Introduction to mathematical techniques for modeling and simulation, parameter identification, and analysis of biological systems. Applications drawn from many branches of biology and medicine. Apply differential equations, difference equations, and dynamical systems theory to a wide array of biological problems. MATH 265 or equivalent recommended.

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, CYBSC). (3-0) Cr. 3. S.
Prereq: MATH 301 or CPR E 310 or COM S 230
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, CYBSC). (3-0) Cr. 3. S.
Prereq: E E 524 or MATH 317 or MATH 407 or COM S 230
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 554: Stochastic Process Models
(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. Alt. F., offered irregularly.
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 569: Introduction to Discrete Mathematics
(Dual-listed with MATH 469). (3-0) Cr. 3. S.
Prereq: (MATH 207 or MATH 317); (MATH 304 or MATH 314)
Combinatorial counting, double-counting, generating functions, graph structure, planar graphs, probabilistic proofs, points in general positions, polytopes, Farkas lemma, linear programming and duality.

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 581: Numerical Methods for Differential Equations
(Dual-listed with MATH 481). (3-0) Cr. 3. S.
Prereq: MATH 265; (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 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 603: Mathematical Logic II
(3-0) Cr. 3. Alt. S., offered even-numbered years.
Prereq: MATH 601
Topics in model theory, computability theory, and set theory such as infinitary logic, non-standard models of arithmetic, ultraproducts, and independence results.

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, Szemeredi's regularity lemma, random graph theory.

MATH 610: Seminar
Cr. arr.

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 619: Commutative Algebra
(3-0) Cr. 3. Alt. F., offered odd-numbered years.
Prereq: MATH 505.
Detailed study of commutative rings with applications to number theory and algebraic geometry, including prime ideals, Going Up and Going Down theorems, exact sequences, Ext and Tor, modules of fractions, primary decomposition, rings of integers, dimension theory.

MATH 620: Lie Algebras and Their Representations
(3-0) Cr. 3. Alt. F., offered even-numbered years.
Prereq: MATH 504; and MATH 507 or MATH 510
Nilpotent and solvable Lie algebras. Root systems and the classification of finite-dimensional complex semi-simple Lie algebras. The universal enveloping algebra. Representation theory including Weyl's theorem, Verma modules, highest weight theory.

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, Lp-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. Types and characterizations of convergence for random variables. Sums of independent random variables, empirical distributions, weak and strong laws of large numbers. Convergence in distribution and its formulations, tightness, characteristic functions, central limit theorems and Lindeberg-Feller conditions. Conditional probability and expectation, discrete parameter martingales.

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

(3-0) Cr. 3. Repeatable.

MATH 680A: Advanced Topics: Algebra

(3-0) Cr. 3. Repeatable.

MATH 680B: Advanced Topics: Analysis

(3-0) Cr. 3. Repeatable.

MATH 680C: Advanced Topics: Applied Mathematics

(3-0) Cr. 3. Repeatable.

MATH 680D: Advanced Topics: Combinatorics

(3-0) Cr. 3. Repeatable.

MATH 680E: Advanced Topics: Differential Equations

(3-0) Cr. 3. Repeatable.

MATH 680F: Advanced Topics: Linear Algebra

(3-0) Cr. 3. Repeatable.

MATH 680G: Advanced Topics: Logic and Foundations

Cr. 3. Repeatable.

MATH 680H: Advanced Topics: Number Theory

(3-0) Cr. 3. Repeatable.

MATH 680I: Advanced Topics: Numerical Analysis

(3-0) Cr. 3. Repeatable.

MATH 680J: Advanced Topics: Optimization

(3-0) Cr. 3. Repeatable.

MATH 680K: Advanced Topics: Probability

(3-0) Cr. 3. Repeatable.

MATH 680L: Advanced Topics: Topology

(3-0) Cr. 3. Repeatable.

MATH 699: Research

Cr. arr. Repeatable.