MATHEMATICS (MATH)

MATH Class Schedule (https://courses.illinois.edu/schedule/DEFAULT/DEFAULT/MATH)

Courses

MATH 002  Introductory Algebra  credit: 3 Hours.
Methods of elementary algebra, including simplification of algebraic expressions, solving linear and quadratic equations, equations of lines, systems of linear equations, and radicals. Approved for Letter and S/U grading. Enrollment is restricted. Credit may not be used toward graduation at the University of Illinois. Prerequisite: Score on appropriate placement test, or consent of Mathematics Department.

MATH 101  Thinking Mathematically  credit: 3 Hours.
Designed for students in majors that do not specifically require a mathematics course beyond the level of precalculus. Focus is on critical thinking and applications. All topics are covered from a contextual standpoint. Topics include proportional reasoning and modeling, functions, sets, consumer math, probability, and statistics. Other topics may be covered as time permits. Prerequisite: Three years of high school mathematics. Undergraduates only.

MATH 103  Theory of Arithmetic  credit: 4 Hours.
Analyses of the mathematical issues and methodology underlying elementary mathematics in grades K-5. Topics include sets, arithmetic algorithms, elementary number theory, rational and irrational numbers, measurement, and probability. There is an emphasis on problem solving. Priority registration will be given to students enrolled in teacher education programs leading to certification in elementary or childhood education. Prerequisite: MATH 112 (formerly MATH 012) or equivalent. This course satisfies the General Education Criteria for: Quantitative Reasoning I

MATH 112  Algebra  credit: 3 Hours.
Rapid review of basic techniques of factoring, rational expressions, equations and inequalities; functions and graphs; exponential and logarithm functions; systems of equations; matrices and determinants; polynomials; and the binomial theorem. Prerequisite: 1.5 units of high school algebra; 1 unit of high school geometry.

MATH 114  Trigonometry  credit: 2 Hours.
Studies degrees and radians, the trigonometric functions, identities and equations, inverse functions, oblique triangles and applications. Credit is not given for MATH 114 and either MATH 014 or MATH 115. Prerequisite: 1.5 units of high school algebra; 1 unit of high school geometry.

MATH 115  Preparation for Calculus  credit: 3 Hours.
Reviews trigonometric, rational, exponential, and logarithmic functions; provides a full treatment of limits, definition of derivative, and an introduction to finding area under a curve. Intended for students who need preparation for MATH 220, either because they lack the content background or because they are not prepared for the rigor of a university calculus course. Credit is not given for both MATH 115 and either MATH 014 or MATH 114. Credit is not given for MATH 115 if credit for either MATH 220 or MATH 221 has been earned. Prerequisite: An adequate ALEKS placement score as described at http://math.illinois.edu/ALEKS/, demonstrating knowledge of the topics of MATH 112. This course satisfies the General Education Criteria for: Quantitative Reasoning I

MATH 117  Elementary Mathematics  credit: 4 Hours.
Analyses of the mathematical issues and methodology underlying elementary mathematics in grades 6-8. Topics include the Real number system and field axioms, sequences and series, functions and math modeling with technology, Euclidean and non-Euclidean geometry, probability and statistics. Priority registration will be given to students enrolled in teacher education programs leading to certification in elementary education. Prerequisite: MATH 112 (formerly MATH 012) or equivalent. This course satisfies the General Education Criteria for: Quantitative Reasoning I

MATH 119  Ideas in Geometry  credit: 3 Hours.
General education course in mathematics, for students who do not have mathematics as a central part of their studies. The goal is to convey the spirit of mathematical thinking through topics chosen mainly from plane geometry. Prerequisite: Two units of high school algebra; one unit of high school geometry; or equivalent. This course satisfies the General Education Criteria for: Quantitative Reasoning I

MATH 124  Finite Mathematics  credit: 3 Hours.
Introduction to finite mathematics for students in the social sciences; introduces the student to the basic ideas of logic, set theory, probability, vectors and matrices, and Markov chains. Problems are selected from social sciences and business. Prerequisite: MATH 112 (formerly MATH 012) or an adequate ALEKS score. This course satisfies the General Education Criteria for: Quantitative Reasoning I

MATH 125  Elementary Linear Algebra  credit: 3 Hours.
Basic concepts and techniques of linear algebra; includes systems of linear equations, matrices, determinants, vectors in n-space, and eigenvectors, together with selected applications, such as Markov processes, linear programming, economic models, least squares, and population growth. Credit is not given for both MATH 125 and any of MATH 225, MATH 410, or MATH 415. Prerequisite: MATH 112 (formerly MATH 012) or an adequate ALEKS score.

MATH 181  A Mathematical World  credit: 3 Hours.
Introduction to selected areas of mathematical sciences through application to modeling and solution of problems involving networks, circuits, trees, linear programming, random samples, regression, probability, inference, voting systems, game theory, symmetry and tilings, geometric growth, comparison of algorithms, codes and data management. Prerequisite: Three years of high school mathematics, including two years of algebra and one year of geometry. This course satisfies the General Education Criteria for: Quantitative Reasoning I

MATH 198  Freshman Seminar  credit: 3 Hours.
Guides the student in the study of selected topics not considered in standard courses. Prerequisite: Enrollment in the mathematics honors program; consent of department.

MATH 199  Undergraduate Open Seminar  credit: 1 to 5 Hours.
Approved for both letter and S/U grading. May be repeated.

MATH 210  Theory of Interest  credit: 3 Hours.
Study of compound interest and annuities; applications to problems in finance. Prerequisite: MATH 231 or equivalent.
MATH 213  Basic Discrete Mathematics  credit: 3 Hours.
Beginning course on discrete mathematics, including sets and relations, functions, basic counting techniques, recurrence relations, graphs and trees, and matrix algebra; emphasis throughout is on algorithms and their efficacy. Credit is not given for both MATH 213 and CS 173. Prerequisite: MATH 220 or MATH 221, or equivalent.
This course satisfies the General Education Criteria for: Quantitative Reasoning II

MATH 220  Calculus  credit: 5 Hours.
First course in calculus and analytic geometry; basic techniques of differentiation and integration with applications including curve sketching; antidifferentiation, the Riemann integral, fundamental theorem, exponential and trigonometric functions. Credit is not given for both MATH 220 and either MATH 221 or MATH 234. Prerequisite: An adequate ALEKS placement score as described at http://math.illinois.edu/ALEKS/, demonstrating knowledge of topics of MATH 115. Students with previous calculus experience should consider MATH 221.
This course satisfies the General Education Criteria for: Quantitative Reasoning I

MATH 221  Calculus I  credit: 4 Hours.
First course in calculus and analytic geometry for students with some calculus background; basic techniques of differentiation and integration with applications including curve sketching; antidifferentiation, the Riemann integral, fundamental theorem, exponential and trigonometric functions. Credit is not given for both MATH 221 and either MATH 220 or MATH 234. Prerequisite: An adequate ALEKS placement score as described at http://math.illinois.edu/ALEKS/ and either one year of high school calculus or a minimum score of 2 on the AB Calculus AP exam.
This course satisfies the General Education Criteria for: Quantitative Reasoning I

MATH 225  Introductory Matrix Theory  credit: 2 Hours.
Systems of linear equations, matrices and inverses, determinants, and a glimpse at vector spaces, eigenvalues and eigenvectors. Credit is not given for both MATH 225 and any of MATH 125, MATH 410, or MATH 415. Prerequisite: MATH 220 or MATH 221; or equivalent.

MATH 231  Calculus II  credit: 3 Hours.
Second course in calculus and analytic geometry: techniques of integration, conic sections, polar coordinates, and infinite series. Prerequisite: MATH 220 or MATH 221.
This course satisfies the General Education Criteria for: Quantitative Reasoning I

MATH 234  Calculus for Business I  credit: 4 Hours.
Introduction to the concept of functions and the basic ideas of the calculus. Credit is not given for both MATH 234 and either MATH 220 or MATH 221. Prerequisite: An adequate ALEKS placement score as described at http://math.illinois.edu/ALEKS/, demonstrating knowledge of the topics of MATH 112.
This course satisfies the General Education Criteria for: Quantitative Reasoning I

MATH 241  Calculus III  credit: 4 Hours.
Third course in calculus and analytic geometry including vector analysis: Euclidean space, partial differentiation, multiple integrals, line integrals and surface integrals, the integral theorems of vector calculus. Credit is not given for both MATH 241 and MATH 292. Prerequisite: MATH 231.
This course satisfies the General Education Criteria for: Quantitative Reasoning II

MATH 249  Honors Supplement  credit: 1 Hour.
Supplemental credit hour for honors courses with additional material or special projects. Prerequisite: Concurrent registration in a specially designated honors section and consent of department.

MATH 284  Intro Differential Systems  credit: 4 Hours.
First order differential equations; mathematical models and numerical methods; linear systems and matrices; higher-order linear differential equations; eigenvalues and eigenvectors; linear systems of differential equations; Laplace transform methods. Credit is not given for both MATH 284 and either MATH 285 or MATH 286. Prerequisite: MATH 231 or equivalent.

MATH 285  Intro Differential Equations  credit: 3 Hours.
Techniques and applications of ordinary differential equations, including Fourier series and boundary value problems, and an introduction to partial differential equations. Intended for engineering majors and others who require a working knowledge of differential equations. Credit is not given for both MATH 285 and any of MATH 284, MATH 286, MATH 441. Prerequisite: MATH 241.
This course satisfies the General Education Criteria for: Quantitative Reasoning II

MATH 286  Intro to Differential Eq Plus  credit: 4 Hours.
Techniques and applications of ordinary differential equations, including Fourier series and boundary value problems, linear systems of differential equations, and an introduction to partial differential equations. Covers all the MATH 285 plus linear systems. Intended for engineering majors and other who require a working knowledge of differential equations. Credit is not given for both MATH 286 and any of MATH 284, MATH 285, MATH 441. Prerequisite: MATH 241.
This course satisfies the General Education Criteria for: Quantitative Reasoning II

MATH 290  Symbolic Computation Lab  credit: 1 Hour.
Laboratory component to courses using a symbolic programming package. Prerequisite: Consent of department; concurrent registration in a designated section of a mathematics course with symbolic computation component. May be taken only once for credit.

MATH 292  Vector Calculus Supplement  credit: 2 Hours.
Course in multivariable calculus. Topics include gradient, divergence, and curl; line and surface integrals; and the theorems of Green, Stokes, and Gauss. Intended for transfer students whose multivariable calculus course did not include the integral theorems of vector calculus. Credit is not given for both MATH 292 and MATH 241. Prerequisite: Consent of instructor.

MATH 299  Topics in Mathematics  credit: 1 to 4 Hours.
Topics course; see Class Schedule or department office for current topics. May be repeated in the same or subsequent semesters to a maximum of 8 hours. Prerequisite: MATH 220 or MATH 221; consent of instructor.

MATH 347  Fundamental Mathematics  credit: 3 Hours.
Fundamental ideas used in many areas of mathematics. Topics will include: techniques of proof, mathematical induction, binomial coefficients, rational and irrational numbers, the least upper bound axiom for real numbers, and a rigorous treatment of convergence of sequences and series. This will be supplemented by the instructor from topics available in the various texts. Students will regularly write proofs emphasizing precise reasoning and clear exposition. Credit is not given for both MATH 347 and MATH 348. Prerequisite: MATH 231.
This course satisfies the General Education Criteria for: Quantitative Reasoning II
MATH 348  Fundamental Mathematics-ACP credit: 4 Hours.
Course is identical to MATH 347 except for the additional writing component. Credit is not given for both MATH 348 and MATH 347.
Prerequisite: MATH 231 and completion of the campus Composition I general education requirement.
This course satisfies the General Education Criteria for:
Quantitative Reasoning II

MATH 357  Numerical Methods I credit: 3 Hours.
Same as CS 357. See CS 357.

MATH 362  Probability with Engrg Applic credit: 3 Hours.
Same as ECE 313. See ECE 313.

MATH 370  Actuarial Problem Solving credit: 1 Hour.
Methods and techniques of solving problems in actuarial mathematics for advanced students intending to enter the actuarial profession. Approved for S/U grading only. May be repeated in the same or separate terms to a maximum of 4 hours. Prerequisite: Consent of instructor.

MATH 390  Individual Study credit: 0 to 3 Hours.
Guided individual study of advanced topics not covered in other courses. May be repeated to a maximum of 8 hours. Approved for both letter and S/U grading. Prerequisite: Consent of instructor.

MATH 399  Math/Actuarial Internship credit: 0 Hours.
Full-time or part-time practice of math or actuarial science in an off-campus government, industrial, or research laboratory environment. Summary report required. Approved for S/U grading only. May be repeated in separate terms. Prerequisite: After obtaining an internship, Mathematics majors must request entry from the Mathematics Director of Undergraduate Studies; Actuarial Science majors must request entry from the Director of the Actuarial Science Program.

MATH 402  Non Euclidean Geometry credit: 3 or 4 Hours.
Historical development of geometry; includes tacit assumptions made by Euclid; the discovery of non-Euclidean geometries; geometry as a mathematical structure; and an axiomatic development of plane geometry. 3 or 4 undergraduate hours. 3 or 4 graduate hours. 4 hours of credit requires approval of the instructor and department with completion of additional work of substance. Prerequisite: MATH 241; MATH 347 or MATH 348, or equivalent; or consent of instructor.
This course satisfies the General Education Criteria for:
Quantitative Reasoning II

MATH 403  Euclidean Geometry credit: 3 or 4 Hours.
Selected topics from geometry, including the nine-point circle, theorems of Cera and Menelaus, regular figures, isometries in the plane, ordered and affine geometries, and the inversive plane. 3 or 4 undergraduate hours. 3 or 4 graduate hours. 4 hours of credit requires approval of the instructor and department with completion of additional work of substance. Prerequisite: MATH 241; MATH 347 or MATH 348, or equivalent; or consent of instructor.
This course satisfies the General Education Criteria for:
Quantitative Reasoning II

MATH 405  Teacher's Course credit: 3 or 4 Hours.
In-depth, advanced perspective look at selected topics covered in the secondary curriculum. Connects mathematics learned at the university level to content introduced at the secondary level. Intended for students who plan to seek a secondary certificate in mathematics teaching. 3 or 4 undergraduate hours. 3 or 4 graduate hours. 4 hours of credit requires approval of the instructor and department with completion of additional work of substance. Prerequisite: MATH 241; MATH 347 or MATH 348, or equivalent; or consent of instructor.
This course satisfies the General Education Criteria for:
Quantitative Reasoning II

MATH 406  History of Calculus credit: 3 or 4 Hours.
Examination of the historical origins and genesis of the concepts of the calculus; includes mathematical developments from the ancient Greeks to the eighteenth century. 3 or 4 undergraduate hours. 3 or 4 graduate hours. 4 hours of credit requires approval of the instructor and department with completion of additional work of substance. Prerequisite: MATH 241 or equivalent.

MATH 408  Actuarial Statistics I credit: 4 Hours.
Same as STAT 408. See STAT 408.

MATH 409  Actuarial Statistics II credit: 4 Hours.
Same as STAT 409. See STAT 409.

MATH 410  Lin Algebra & Financial Apps credit: 3 or 4 Hours.
Emphasizes techniques of linear algebra and introductory and advanced applications to actuarial science, finance and economics. Topics include linear equations, matrix theory, vector spaces, linear transformations, eigenvalues and eigenvectors and inner product spaces. In addition, current research topics such as modeling, data mining, and generalized linear models are explored. 3 or 4 undergraduate hours. 3 or 4 graduate hours. Credit is not given for both MATH 410 and any of MATH 125, MATH 225, MATH 415 or MATH 416. 4 hours of credit requires approval of the instructor and department with completion of additional work of substance. Prerequisite: MATH 241; MATH 210 or FIN 221; or consent of instructor.

MATH 412  Graph Theory credit: 3 or 4 Hours.
Examines basic concepts and applications of graph theory, where graph refers to a set of vertices and edges that join some pairs of vertices; topics include subgraphs, connectivity, trees, cycles, vertex and edge coloring, planar graphs and their colorings. Draws applications from computer science, operations research, chemistry, the social sciences, and other branches of mathematics, but emphasis is placed on theoretical aspects of graphs. 3 or 4 undergraduate hours. 3 or 4 graduate hours. 4 hours of credit requires approval of the instructor and department with completion of additional work of substance. Prerequisite: MATH 347 or MATH 348 or equivalent experience or CS 374. This course satisfies the General Education Criteria for:
Quantitative Reasoning II

MATH 413  Intro to Combinatorics credit: 3 or 4 Hours.
Permutations and combinations, generating functions, recurrence relations, inclusion and exclusion, Polya's theory of counting, and block designs. Same as CS 413. 3 undergraduate hours. 3 or 4 graduate hours. 4 hours of credit requires approval of the instructor and department with completion of additional work of substance. Prerequisite: MATH 347 or MATH 348 or equivalent experience.

MATH 414  Mathematical Logic credit: 3 or 4 Hours.
Introduction to the formalization of mathematics and the study of axiomatic systems; expressive power of logical formulas; detailed treatment of propositional logical and predicate logic; compactness theorem and Godel completeness theorem, with applications to specific mathematical theories; algorithmic aspects of logical formulas. Proofs are emphasized in this course, which can serve as an introduction to abstract mathematics and rigorous proof; some ability to do mathematical reasoning required. 3 or 4 undergraduate hours. 3 or 4 graduate hours. 4 hours of credit requires approval of the instructor and department with completion of additional work of substance. Prerequisite: MATH 347 or MATH 348 or equivalent experience. This course satisfies the General Education Criteria for:
Quantitative Reasoning II
MATH 415  Applied Linear Algebra  credit: 3 or 4 Hours.  
Introductory course emphasizing techniques of linear algebra with applications to engineering; topics include matrix operations, determinants, linear equations, vector spaces, linear transformations, eigenvalues, and eigenvectors, inner products and norms, orthogonality, equilibrium, and linear dynamical systems. 3 or 4 undergraduate hours. 3 or 4 graduate hours. Credit is not given for both MATH 415 and any of MATH 125, MATH 225, MATH 410, or MATH 416. 4 hours of credit requires approval of the instructor and department with completion of additional work of substance. Prerequisite: MATH 241 or consent of instructor.

MATH 416  Abstract Linear Algebra  credit: 3 or 4 Hours.  
Rigorous proof-oriented course in linear algebra. Topics include determinants, vector spaces over fields, linear transformations, inner product spaces, eigenvectors and eigenvalues, Hermitian matrices, Jordan Normal Form. 3 or 4 undergraduate hours. 3 or 4 graduate hours. Credit is not given for both MATH 416 and either MATH 410 or MATH 415. 4 hours of credit requires approval of the instructor and department with completion of additional work of substance. Prerequisite: MATH 241 or consent of instructor; MATH 347 is recommended.

MATH 417  Intro to Abstract Algebra  credit: 3 or 4 Hours.  
Fundamental theorem of arithmetic, congruences. Permutations. Groups and subgroups, homomorphisms. Group actions with applications. Polynomials. Rings, subrings, and ideals. Integral domains and fields. Roots of polynomials. Maximal ideals, construction of fields. 3 or 4 undergraduate hours. 3 or 4 graduate hours. 4 hours of credit requires approval of the instructor and department with completion of additional work of substance. Prerequisite: Either MATH 416 or one of MATH 410, MATH 415 together with one of MATH 347, MATH 348, CS 374; or consent of instructor.

MATH 418  Intro to Abstract Algebra II  credit: 3 or 4 Hours.  
Rings of quotients of an integral domain. Euclidean domains, principal ideal domains. Unique factorization in polynomial rings. Fields extensions, ruler and compass constructions. Finite fields with applications. Modules. Structure theorem for finitely generated modules over principal ideal domains. Application to finitely generated abelian groups and canonical forms of matrices. Introduction to error-correcting codes. 3 or 4 undergraduate hours. 3 or 4 graduate hours. 4 hours of credit requires approval of the instructor and department with completion of additional work of substance. Prerequisite: MATH 417 or consent of instructor.

MATH 423  Differential Geometry  credit: 3 or 4 Hours.  
Applications of the calculus to the study of the shape and curvature of curves and surfaces; introduction to vector fields, differential forms on Euclidean spaces, and the method of moving frames for low-dimensional differential geometry. 3 or 4 undergraduate hours. 3 or 4 graduate hours. 4 hours of credit requires approval of the instructor and department with completion of additional work of substance. Prerequisite: MATH 241 or equivalent.

MATH 424  Honors Real Analysis  credit: 3 Hours.  
A rigorous treatment of basic real analysis via metric spaces recommended for those who intend to pursue programs heavily dependent upon graduate level Mathematics. Metric space topics include continuity, compactness, completeness, connectedness and uniform convergence. Analysis topics include the theory of differentiation, Riemann-Darboux integration, sequences and series of functions, and interchange of limiting operations. As part of the honors sequence, this course will be rigorous and abstract. 3 undergraduate hours. No graduate credit. Credit is not given for both MATH 424 and either MATH 444 or MATH 447. Approved for honors grading. Prerequisite: An honors section of MATH 347 or an honors section of MATH 416, and consent of the department.

MATH 425  Honors Advanced Analysis  credit: 3 Hours.  
A theoretical treatment of differential and integral calculus in higher dimensions. Topics include inverse and implicit function theorems, submanifolds, the theorems of Green, Gauss and Stokes, differential forms, and applications. As part of the honors sequence, this course will be rigorous and abstract. 3 undergraduate hours. No graduate credit. Approved for honors grading. Prerequisite: MATH 424 and either MATH 415 or MATH 416, and consent of the department.

MATH 427  Honors Abstract Algebra  credit: 3 Hours.  
Group theory, counting formulae, factorization, modules with applications to Abelian groups and linear operators. As part of the honors sequence, this course will be rigorous and abstract. 3 undergraduate hours. No graduate credit. Approved for honors grading. Credit is not given for both MATH 427 and MATH 417. Prerequisite: Consent of the department is required. Prerequisite courses are either an honors section of MATH 416, or MATH 415 together with an honors section of MATH 347.

MATH 428  Honors Topics in Mathematics  credit: 3 Hours.  
A capstone course in the Mathematics Honors Sequences. Topics will vary. As part of the honors sequence, this course will be rigorous and abstract. 3 undergraduate hours. No graduate credit. May be repeated in the same or separate terms to a maximum of 12 hours. Prerequisite: Consent of the department.

MATH 432  Set Theory and Topology  credit: 3 or 4 Hours.  
A rigorous treatment of basic real analysis via metric spaces. Metric space topics include continuity, compactness, completeness, connectedness and uniform convergence. Analysis topics include the theory of differentiation, Riemann-Darboux integration, sequences and series of functions, and interchange of limiting operations. As part of the honors sequence, this course will be rigorous and abstract. 3 undergraduate hours. No graduate credit. Credit is not given for both MATH 432 and MATH 417. Prerequisite: Consent of the department is required. Prerequisite courses are either an honors section of MATH 416, or MATH 415 together with an honors section of MATH 347.

MATH 439  Philosophy of Mathematics  credit: 3 or 4 Hours.  
Same as PHIL 439. See PHIL 439.

MATH 441  Differential Equations  credit: 3 or 4 Hours.  
Basic course in ordinary differential equations; topics include existence and uniqueness of solutions and the general theory of linear differential equations; treatment is more rigorous than that given in MATH 285. 3 or 4 undergraduate hours. 3 or 4 graduate hours. Credit is not given for both MATH 441 and any of MATH 284, MATH 285, MATH 286. 4 hours of credit requires approval of the instructor and department with completion of additional work of substance. Prerequisite: MATH 241; MATH 347 or MATH 348 is recommended.
MATH 442  Intro Partial Diff Equations  credit: 3 or 4 Hours.
Introduces partial differential equations, emphasizing the wave, diffusion and
potential (Laplace) equations. Focuses on understanding the
physical meaning and mathematical properties of solutions of partial
fundamental equations. Includes fundamental solutions and transform
methods for problems on the line, as well as separation of variables
using orthogonal series for problems in regions with boundary. Covers
convergence of Fourier series in detail. 3 or 4 undergraduate hours. 3 or
4 graduate hours. 4 hours of credit requires approval of the instructor
and completion of additional work of substance. Prerequisite: One of
MATH 284, MATH 285, MATH 286, MATH 441.

MATH 444  Elementary Real Analysis  credit: 3 or 4 Hours.
Careful treatment of the theoretical aspects of the calculus of functions
of a real variable intended for those who do not plan to take graduate
courses in Mathematics. Topics include the real number system, limits,
continuity, derivatives, and the Riemann integral. 3 or 4 undergraduate
hours. 3 or 4 graduate hours. Credit is not given for both MATH 444
and either MATH 424 or MATH 447. 4 hours of credit requires approval
of the instructor and department with completion of additional work of
substance. Prerequisite: MATH 241; MATH 347 or MATH 348, or
equivalent.

MATH 446  Applied Complex Variables  credit: 3 or 4 Hours.
For students who desire a working knowledge of complex variables;
covers the standard topics and gives an introduction to integration by
residues, the argument principle, conformal maps, and potential fields.
Students desiring a systematic development of the foundations of the
subject should take MATH 448. 3 or 4 undergraduate hours. 3 or 4
graduate hours. Credit is not given for both MATH 446 and MATH 448. 4
hours of credit requires approval of the instructor and department with
completion of additional work of substance. Prerequisite: MATH 241.

MATH 447  Real Variables  credit: 3 or 4 Hours.
Careful development of elementary real analysis for those who intend
to take graduate courses in Mathematics. Topics include completeness
property of the real number system; basic topological properties of n-
dimensional space; convergence of numerical sequences and series
of functions; properties of continuous functions; and basic theorems
differentiation and Riemann integration. 3 undergraduate
hours. 3 or 4 graduate hours. Credit is not given for both MATH 447 and
either MATH 424 or MATH 444. 4 hours of credit requires approval of the
instructor and completion of additional work of substance. Prerequisite:
MATH 241 or equivalent; junior standing; MATH 347 or MATH 348, or
equivalent experience; or consent of instructor.

MATH 448  Complex Variables  credit: 3 or 4 Hours.
For students who desire a rigorous introduction to the theory of
functions of a complex variable; topics include Cauchy's theorem, the
residue theorem, the maximum modulus theorem, Laurent series, the
fundamental theorem of algebra, and the argument principle. 3 or 4
undergraduate hours. 3 or 4 graduate hours. Credit is not given for both
MATH 448 and MATH 446. 4 hours of credit requires approval of the
instructor and department with completion of additional work of
substance. Prerequisite: MATH 447.

MATH 450  Numerical Analysis  credit: 3 or 4 Hours.
Same as CS 450, CSE 401 and ECE 491. See CS 450.

MATH 453  Elementary Theory of Numbers  credit: 3 or 4 Hours.
Basic introduction to the theory of numbers. Core topics include
divisibility, primes and factorization, congruences, arithmetic functions,
quadratic residues and quadratic reciprocity, primitive roots and orders.
Additional topics covered at the discretion of the instructor include sums
of squares, Diophantine equations, continued fractions, Farey fractions,
recurrences, and applications to primality testing and cryptography. 3 or
4 undergraduate hours. 3 or 4 graduate hours. 4 hours of credit requires
approval of the instructor and department with completion of additional
work of substance. Prerequisite: MATH 241 or equivalent. This course satisfies the General Education Criteria for: Quantitative Reasoning II

MATH 461  Probability Theory  credit: 3 or 4 Hours.
Introduction to mathematical probability; includes the calculus of
probability, combinatorial analysis, random variables, expectation,
distribution functions, moment-generating functions, and central limit
theorem. 3 or 4 undergraduate hours. 3 or 4 graduate hours. Credit is not
given for both MATH 461 and either MATH 408 or ECE 313. 4 hours of
credit requires approval of the instructor and department with completion
of additional work of substance. Prerequisite: MATH 241 or equivalent.

MATH 463  Statistics and Probability I  credit: 4 Hours.
Same as STAT 400. See STAT 400.

MATH 464  Statistics and Probability II  credit: 3 or 4 Hours.
Same as STAT 410. See STAT 410.

MATH 469  Methods of Applied Statistics  credit: 3 or 4 Hours.
Same as STAT 420. See STAT 420.

MATH 471  Life Contingencies I  credit: 4 Hours.
Distribution of the time-to-death random variable for a single life, and
its implications for evaluations of insurance and annuity functions,
net premiums, and reserves. 4 undergraduate hours. 4 graduate hours.
Prerequisite: MATH 408 and MATH 210.

MATH 472  Life Contingencies II  credit: 3 Hours.
Continuation of MATH 471. Introduction to tabular or parametric survival
models with single or multiple-life states; life insurance and annuity
premium calculations; reserving and profit measures; introductions to
universal life insurances, participating insurances, pension plans and
retirement benefits. 3 undergraduate hours. No graduate credit. Credit is not
given for MATH 472 and MATH 565. Prerequisite: MATH 471.

MATH 473  Fundamental Algorithms  credit: 3 or 4 Hours.
Same as CS 473 and CSE 414. See CS 473.

MATH 475  Formal Models of Computation  credit: 3 or 4 Hours.
Same as CS 475. See CS 475.

MATH 476  Investments and Financial Markets  credit: 3 Hours.
Theoretical foundation in financial models and their applications to
insurance and other financial risks. Topics include derivative markets, no
arbitrage pricing of financial derivatives, interest rate models, dynamic
hedging and other risk management techniques. 3 undergraduate hours.
No graduate credit. Credit is not given for MATH 476 and MATH 567.
Prerequisite: Credit or concurrent registration in STAT 409 or STAT 410.

MATH 477  Actuarial Modeling  credit: 3 Hours.
Foundation in the actuarial modeling process; construction, selection
and validation of empirical models and parametric models. Also covers
survival, severity, frequency and aggregate loss models; statistical
methods to estimate model parameters. 3 undergraduate hours. No
graduate credit. Credit is not given for MATH 478 and MATH 568.
Prerequisite: MATH 408, MATH 461 or MATH 463; credit or concurrent
registration in MATH 409 or MATH 464.
MATH 479   Casualty Actuarial Mathematics  credit: 3 or 4 Hours.
An introduction to property/casualty actuarial science, exploring its
mathematical financial, and risk-theoretical foundations. Specific
topics include risk theory, loss reserving, ratemaking, risk classification,
credibility theory, reinsurance, financial pricing of insurance, and other
special issues and applications. 3 or 4 undergraduate hours. No graduate
credit. Credit is not given for MATH 479 and MATH 569. Prerequisite:
MATH 210; credit or concurrent registration in MATH 409; or consent of
instructor.

MATH 481   Vector and Tensor Analysis  credit: 3 or 4 Hours.
Introductory course in modern differential geometry focusing on
examples, broadly aimed at students in mathematics, the sciences, and
engineering. Emphasis on rigorously presented concepts, tools and
ideas rather than on proofs. The topics covered include differentiable
manifolds, tangent spaces and orientability; vector and tensor fields;
differential forms; integration on manifolds and Generalized Stokes
Theorem; Riemannian metrics, Riemannian connections and geodesics.
Applications to configuration and phase spaces, Maxwell equations
and relativity theory will be discussed. 3 or 4 undergraduate hours.
3 or 4 graduate hours. 4 hours of credit requires approval of the
instructor and department with completion of additional work of
substance. Prerequisite: MATH 241 and one of MATH 415 or MATH 416
or equivalent.

MATH 482   Linear Programming  credit: 3 or 4 Hours.
Introductory course to a wide range of topics in optimization,
including a thorough treatment of basic ideas of linear programming,
with additional topics drawn from numerical considerations, linear
complementarity, integer programming and networks, polyhedral
methods. 3 or 4 undergraduate hours. 3 or 4 graduate hours. 4 hours of
credit requires approval of the instructor and department with completion
of additional work of substance. Prerequisite: MATH 410, MATH 415, or
MATH 416.

MATH 484   Nonlinear Programming  credit: 3 or 4 Hours.
Iterative and analytical solutions of constrained and unconstrained
problems of optimization; gradient and conjugate gradient solution
methods; Newton's method, Lagrange multipliers, duality and the Kuhn-
Tucker theorem; and quadratic, convex, and geometric programming.
3 or 4 undergraduate hours. 3 or 4 graduate hours. 4 hours of credit requires
approval of the instructor and department with completion of additional
work of substance. Prerequisite: MATH 220 or equivalent.

MATH 487   Advanced Engineering Math  credit: 3 or 4 Hours.
Complex linear algebra, inner product spaces, Fourier transforms and
analysis of boundary value problems, Sturm-Liouville theory. Same as
ECE 493. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: One of
MATH 284, MATH 285, MATH 286, MATH 441.

MATH 488   Math Methods In Engineering  credit: 3 or 4 Hours.
Matrices, determinants, bounds and approximations to eigenvalues,
introduction to linear operator theory and inner product spaces,
orthogonal expansions, and Fourier transforms. 3 or 4 undergraduate
hours. 3 or 4 graduate hours. 4 hours of credit requires approval of
the instructor and department with completion of additional work of
substance. Prerequisite: MATH 241 or equivalent.

MATH 489   Dynamics & Differential Eqns  credit: 3 or 4 Hours.
Studies mathematical theory of dynamical systems, emphasizing
both discrete-time dynamics and nonlinear systems of differential
equations. Topics include: chaos, fractals, attractors, bifurcations, with
application to areas such as population biology, fluid dynamics and
classical physics. Basic knowledge of matrix theory will be assumed.
3 or 4 undergraduate hours. 3 or 4 graduate hours. 4 hours of credit
requires approval of the instructor and completion of additional work
of substance. Prerequisite: One of MATH 284, MATH 285, MATH 286,
MATH 441.

MATH 490   Advanced Topics in Mathematics  credit: 1 to 4 Hours.
Deals with selected topics and applications of mathematics; see Class
Schedule or department office for current topics. 1 to 4 undergraduate
hours. 1 to 4 graduate hours. May be repeated with approval.
Prerequisite: Consent of instructor.

MATH 492   Undergraduate Research in Math  credit: 1 to 3 Hours.
Work closely with department faculty on a well-defined research project.
Topics and nature of assistance vary. Capstone paper or computational
project required. 1 to 3 undergraduate hours. No graduate credit.
Approved for Letter and S/U grading. May be repeated in separate terms
up to 8 hours. Prerequisite: Evidence of adequate preparation for such
study; consent of faculty member supervising the work; and approval of
the department head.

MATH 495   Models in Mathematical Biology  credit: 3 or 4 Hours.
Research-motivated subject material from Mathematical Biology with
emphasis on modeling. 3 undergraduate hours. 4 graduate hours.
Prerequisite: MATH 220 or equivalent.

MATH 496   Honors Seminar  credit: 3 Hours.
Careful study of a selected area of mathematics, carried out either
deductively from axioms or inductively through problems; subject matter
varies with instructor. 3 undergraduate hours. No graduate credit. May be
repeated to a maximum of 6 hours. Prerequisite: Consent of Mathematics
Honors Committee.

MATH 499   Introduction Graduate Research  credit: 1 Hour.
Seminar is required of all first-year graduate students in Mathematics.
It provides a general introduction to the courses and research work in
all of the areas of mathematics that are represented at the University of
Illinois at Urbana-Champaign. 1 undergraduate hour. 1 graduate hour.
Approved for S/U grading only. May be repeated to a maximum of 2
hours. Prerequisite: Graduate standing or consent of instructor.

MATH 500   Abstract Algebra I  credit: 4 Hours.
Isomorphism theorems for groups. Group actions. Composition
series. Jordan-Holder theorem. Solvable and nilpotent groups. Field
extensions. Algebraic and transcendental extensions. Algebraic closures.
Fundamental theorem of Galois theory, and applications. Modules
over commutative rings. Structure of finitely generated modules over a
principal ideal domain. Applications to finite Abelian groups and matrix
canonical forms. Prerequisite: MATH 417 and MATH 418.

MATH 501   Abstract Algebra II  credit: 4 Hours.
Modules over non commutative rings. Direct sums and products. Direct
and inverse limits. Categories and functors. Projective and injective
modules. Noetherian and Artinian rings and modules. Semisimple
modules. Wedderburn's theorem on semisimple Artinian rings.
Application to representation theory of groups. Multilinear algebra, tensor
products and flat modules. Tensor, symmetric and exterior algebras.
Additional advanced topics. Prerequisite: MATH 500.
MATH 502  Commutative Algebra  credit: 4 Hours.
Commutative rings and modules, prime ideals, localization, noetherian rings, primary decomposition, integral extensions and Noether normalization, the Nullstellensatz, dimension, flatness, Hensel's lemma, graded rings, Hilbert polynomial, valuations, regular rings, singularities, unique factorization, homological dimension, depth, completion. Possible further topics: smooth and etale extensions, ramification, Cohen-Macaulay modules, complete intersections. Prerequisite: MATH 501 or consent of instructor.

MATH 503  Intro Geometric Group Theory  credit: 4 Hours.
Free groups, groups given by generators and relations, van Kampen diagrams. Free product with amalgamations and HNN-extensions, Bass-Serre theory. Solvable and nilpotent groups. Quasi-isometries and geometric properties of groups. Prerequisite: MATH 500 or equivalent.

MATH 505  Homological Algebra  credit: 4 Hours.
Topics include: 1. Snake lemma, homology, long exact sequence in homology; 2. Projective and injective modules and resolutions; 3. Categories, functors and derived functors. Tor and Ext, local cohomology; 4. Group cohomology, bar resolution; 5. Spectral sequences, techniques of computation, Serre spectral sequence. Grothendieck spectral sequence of composite functors; 6. Time permitting: Derived categories, Gysin sequence, Kunen formula, universal coefficient theorem, Eilenberg-Moore sequence. Prerequisite: MATH 501 or equivalent.

MATH 506  Group Representation Theory  credit: 4 Hours.
Representation of groups by linear transformations, group algebras, character theory, and modular representations. Prerequisite: MATH 501 or equivalent.

MATH 510  Riemann Surf & Algebraic Curv  credit: 4 Hours.
An introduction to Riemann Surfaces from both the algebraic and function-theoretic points of view. Topics include holomorphic and meromorphic differential forms, integration of differential forms, divisors and linear equivalence, the genus of a compact Riemann surface, projective algebraic curves, the Riemann-Roch theorem, and applications. Prerequisite: MATH 542.

MATH 511  Intro to Algebraic Geometry  credit: 4 Hours.
An introduction to the study of algebraic sets defined by polynomial equations; affine and projective space and their subvarieties; rational and regular functions and mappings; divisors, linear systems, and projective embeddings; birational geometry, blowing up; Grassmannians and other special varieties. Prerequisite: MATH 500.

MATH 512  Modern Algebraic Geometry  credit: 4 Hours.
An introduction to the tools and ideas of contemporary algebraic geometry, with particular focus on the language of schemes. 4 graduate hours. No professional credit. Prerequisite: MATH 500, and one of MATH 510, MATH 511, or consent of instructor.

MATH 514  Complex Algebraic Geometry  credit: 4 Hours.
Hodge theory of complex manifolds; examples, applications, and topological invariants. 4 graduate hours. No professional credit. Credit is not given for MATH 514 if credit for MATH 524 has been earned. Prerequisite: MATH 448 or consent of instructor.

MATH 518  Differentiable Manifolds I  credit: 4 Hours.
Definitions and properties of differentiable manifolds and maps, (co)tangent bundles, vector fields and flows, Frobenius theorem, differential forms, exterior derivatives, integration and Stokes' theorem, DeRham cohomology, inverse function theorem, Sard's theorem, transversality and intersection theory. Prerequisite: MATH 423 or MATH 481, or consent of instructor.

MATH 519  Differentiable Manifolds II  credit: 4 Hours.
Vector bundles, principal bundles, connections, parallel transport, curvature, Chern-Weyl theory, Hodge-DeRham theory. Other topics may include Riemannian geometry, symplectic geometry, spin geometry, and harmonic maps. Prerequisite: MATH 518 or consent of instructor.

MATH 522  Lie Groups and Lie Algebras I  credit: 4 Hours.
A general introduction to Lie groups and algebras and their representation theory. Theory of finite group representations, Lie groups as matrix groups, and as differentiable manifolds, Lie algebras as tangent spaces and as abstract objects, and their representations. Examples of the classical groups. May be repeated up to 8 hours. Prerequisite: Undergraduate linear algebra, abstract algebra, point set topology, differentiation on manifolds.

MATH 525  Algebraic Topology I  credit: 4 Hours.
Introduction to the study of topological spaces by means of algebraic invariants. Topics include the fundamental group, covering spaces and their classification, simplicial and singular homology, applications such as the Brouwer fixed point theorem and the Jordan curve theorem. Prerequisite: MATH 417 and MATH 448 or consent of instructor.

MATH 526  Algebraic Topology II  credit: 4 Hours.
CW-complexes, relative homeomorphism theorem, cellular homology, cohomology, Künneth theorem, Eilenberg-Zilber theorem, cup products, Poincaré duality, examples. Prerequisite: MATH 525, MATH 500; or consent of instructor. MATH 501 is recommended but not required.

MATH 527  Homotopy Theory  credit: 4 Hours.
Homotopy groups, fibrations and cofibrations, Hurewicz theorem, obstruction theory, Whitehead theorem and additional topics perhaps drawn from Postnikov towers, Freudenthal suspension theorem, Blakers-Massey theorem, spectra. Prerequisite: MATH 526. MATH 501 is recommended but not required.

MATH 530  Algebraic Number Theory  credit: 4 Hours.
Further development of the theory of fields covering topics from valuation theory, ideal theory, units in algebraic number fields, ramification, function fields, and local class field theory. Prerequisite: MATH 500 or equivalent.

MATH 531  Analytic Theory of Numbers I  credit: 4 Hours.
Problems in number theory treated by methods of analysis; arithmetic functions, Dirichlet series, Riemann zeta function, L-functions, Dirichlet's theorem on primes in progressions, the prime number theorem. Prerequisite: MATH 448 and either MATH 417 or MATH 453.

MATH 532  Analytic Theory of Numbers II  credit: 4 Hours.
Development of themes from MATH 531 and further topics chosen from additive number theory, asymptotic properties of multiplicative functions, circle method, diophantine approximation, lattice point problems, metric theory, modular forms, sieve theory. May be repeated. Prerequisite: MATH 531.

MATH 533  Fiber Spaces and Char Classes  credit: 4 Hours.
Study of fiber bundles and their associated characteristic classes; applications to geometric problems. Prerequisite: MATH 526.

MATH 535  General Topology  credit: 4 Hours.
Study of topological spaces and maps, including Cartesian products, identifications, connectedness, compactness, uniform spaces, and function spaces. Prerequisite: Consent of instructor.

MATH 540  Real Analysis  credit: 4 Hours.
Lebesgue measure on the real line; integration and differentiation of real valued functions of a real variable; and additional topics at discretion of instructor. Prerequisite: MATH 447 or equivalent.
MATH 541  Functional Analysis  credit: 4 Hours.
Fundamental results in functional analysis; spectral theory of compact operators; further topics chosen by the instructor. Prerequisite: MATH 540.

MATH 542  Complex Variables I  credit: 4 Hours.
Topics include the Cauchy theory, harmonic functions, entire and meromorphic functions, and the Riemann mapping theorem. Prerequisite: MATH 446 and MATH 447, or MATH 448.

MATH 543  Complex Variables II  credit: 4 Hours.
Continuation of MATH 542. Topics include Riemann Surfaces, Hyperbolic Metric, Potential Theory and Quasiconformal Mappings. Prerequisite: MATH 542.

MATH 545  Harmonic Analysis  credit: 4 Hours.
Harmonic analysis on the circle, the line, and the integers, i.e., Fourier series and transforms; locally compact Abelian groups; convergence and summability; conjugate functions; Hardy spaces; uniqueness; Tauberian theorems; almost-periodic functions; commutative Banach algebras. Prerequisite: MATH 448 and MATH 541; knowledge of Banach spaces.

MATH 546  Hilbert Spaces  credit: 4 Hours.
Geometrical properties of Hilbert spaces, spectral theorems for compact, bounded and unbounded operators, basic theory of operator algebras, and additional material depending on the instructor. Prerequisite: MATH 541.

MATH 547  Banach Spaces  credit: 4 Hours.
Basic properties and fundamental theorems of Banach spaces and bounded linear maps, trace duality, absolutely summing maps, local theory, type and cotype, probabilistic techniques in Banach spaces, and further topics depending on the instructor. 4 graduate hours. No professional credit. Prerequisite: MATH 541.

MATH 548  Theory of Probability I  credit: 4 Hours.
Mathematical foundations of probability and stochastic processes. Probability measures, random variables, distribution functions, convergence theory, the Central Limit Theorem, conditional expectation, and martingale theory. Same as STAT 551. Prerequisite: MATH 489 or consent of instructor.

MATH 551  Dynamical Systems I  credit: 4 Hours.
A second course in the study of dynamical systems. Students who intend to do research in nonlinear dynamics are encouraged to take this course. A specific selection will be chosen from the following list to illustrate the theory and use of techniques from global analysis and nonlinear dynamics: (1) discrete dynamical systems, (2) global theory of ordinary differential equations, (3) Hamiltonian systems, (4) KAM theory, (5) bifurcation and stability, (6) Hopf index theory of vector fields, (7) Morse theory of gradient vector fields, (8) Lyapunov theory, (9) infinite dimensional dynamical systems, (10) structural stability. Prerequisite: Consent of instructor.

MATH 553  Partial Differential Equations  credit: 4 Hours.
Basic introduction to the study of partial differential equations; topics include: the Cauchy problem, power-series methods, characteristics, classification, canonical forms, well-posed problems, Riemann’s method for hyperbolic equations, the Goursat problem, the wave equation, Sturm-Liouville problems and separation of variables, Fourier series, the heat equation, integral transforms, Laplace’s equation, harmonic functions, potential theory, the Dirichlet and Neumann problems, and Green’s functions. Prerequisite: Consent of instructor.

MATH 554  Linear Analysis and Partial Differential Equations  credit: 4 Hours.
Course will provide students with the basic background in linear analysis associated with partial differential equations. The specific topics chosen will be largely up to the instructor, but will cover such areas as linear partial differential operators, distribution theory and test functions, Fourier transforms, Sobolev spaces, pseudodifferential operators, microlocal analysis, and applications of the above topics. 4 graduate hours. No professional credit. Prerequisite: MATH 447, MATH 489 or consent of instructor.

MATH 555  Nonlinear Analysis and Partial Differential Equations  credit: 4 Hours.
Course will provide students with the basic background in nonlinear analysis associated with partial differential equations. The specific topics chosen will be largely up to the instructor, but will cover such areas as existence and uniqueness techniques, nonexistence and finite time blow-up results, hyperbolic conservation laws, weak solutions, stability theory, nonlinear elliptic theory, regularity theory. 4 graduate hours. No professional credit. May be repeated as topics vary. Prerequisite: Consent of instructor.

MATH 558  Methods of Applied Mathematics  credit: 4 Hours.
Introduction to modern methods of applied mathematics, including nondimensionalization and scaling analysis, regular and singular asymptotics, analysis of multiscale systems, and analysis of complex systems. Each technique is illustrated with applications from science and engineering. The mathematical frameworks will include ordinary, partial and stochastic differential equations, point processes, and Markov chains. Prerequisite: Undergraduate background in ODEs, PDEs, and probability theory (MATH 441, MATH 442, and MATH 461, or equivalents), or consent of instructor.

MATH 561  Theory of Probability II  credit: 4 Hours.
Continuation of MATH 561. Same as STAT 552. Prerequisite: MATH 561.

MATH 562  Theory of Probability II  credit: 4 Hours.
Continuation of MATH 561. Same as STAT 552. Prerequisite: MATH 561.

MATH 563  Risk Modeling and Analysis  credit: 4 Hours.
Quantitative tools for measuring risks and modeling dependencies. Topics include risk measures, stochastic orders, copulas, dependence measures, and their statistical inferences. Same as STAT 558. 4 graduate hours. No professional credit. Prerequisite: MATH 408 or MATH 461.

MATH 564  Applied Stochastic Processes  credit: 4 Hours.
Introduction to topics such as spectral analysis, filtering theory, and prediction theory of stationary processes; Markov chains and Markov processes. Same as STAT 555. Prerequisite: MATH 446 and MATH 447.
MATH 565 Actuarial Models for Life Contingencies credit: 4 Hours. Tabular and parametric survival models with single or multiple-life states; life insurance and annuity premium calculations; reserving, and profit measures; introduction to universal life insurances, participating insurances, pension plans and retirement benefits. 4 graduate hours. No professional credit. Credit is not given for MATH 472 and MATH 565. Prerequisite: MATH 471.

MATH 567 Actuarial Models for Financial Economics credit: 4 Hours. Theoretical basis of financial models and their applications to insurance and other financial risks. Topics include derivative markets, no-arbitrage pricing of financial derivatives, interest rate models, dynamic hedging and other risk management techniques. 4 graduate hours. No professional credit. Credit is not given for MATH 476 and MATH 567. Prerequisite: MATH 409 or MATH 464.

MATH 568 Actuarial Loss Models credit: 4 Hours. Introduction to the actuarial modeling process: construction, selection and validation of empirical and parametric models. Survival, severity, frequency and aggregate loss models; statistical methods to estimate model parameters. 4 graduate hours. No professional credit. Credit is not given for MATH 478 and MATH 568. Prerequisite: MATH 408, MATH 461 or MATH 463.

MATH 569 Casualty Actuarial Science credit: 4 Hours. Principles and fundamental techniques of ratemaking for casualty and property insurances; risk classification; coinsurance; estimation of claim liabilities; financial reporting; catastrophe modeling. 4 graduate hours. No professional credit. Credit is not given for MATH 479 and MATH 569. Prerequisite: MATH 408.

MATH 570 Mathematical Logic credit: 4 Hours. Development of first order predicate logic; completeness theorem; formalized number theory and the Godel incompleteness theorem. Prerequisite: MATH 417 or consent of instructor.

MATH 571 Model Theory credit: 4 Hours. Techniques for constructing models, including compactness and Lowenheim-Skolem theorems, unions of elementary chains, and omitting types construction; categorical theorems; ultraproducts; saturated models; quantifier elimination; applications to algebraically closed fields, real closed fields, and other fundamental structures of mathematics. Prerequisite: MATH 570 or consent of instructor.

MATH 573 Recursive Function Theory credit: 4 Hours. Various characterizations of the class of recursive (i.e., computable) functions; the Church-Turing thesis; unsolvability of the halting problem; the recursion theorem and the enumeration theorem; relative computability, the jump operation, and the arithmetical hierarchy; recursively enumerable sets; degrees of unsolvability; and the priority method. Prerequisite: MATH 570 or consent of instructor.

MATH 574 Set Theory credit: 4 Hours. Zermelo-Fraenkel axiomatic set theory; basic concepts in set theory such as ordinal, cardinal, rank, and definition by transfinite recursion; Godel's constructible universe; introduction to forcing. Boolean valued universes; large cardinals; consistency and independence of the continuum hypothesis and the axiom of choice. Prerequisite: MATH 570 or consent of instructor.

MATH 580 Combinatorial Mathematics credit: 4 Hours. Fundamental results on core topics of combinatorial mathematics: classical enumeration, basic graph theory, extremal problems on finite sets, probabilistic methods, design theory, discrete optimization. Same as CS 571. Prerequisite: Consent of instructor.

MATH 581 Extremal Graph Theory credit: 4 Hours. Extremal problems and parameters for graphs. Distance and connectivity, matching and factors, vertex and edge colorings, perfect and imperfect graphs, intersection classes and intersection parameters, Turan's theorem, graph Ramsey theory, graph decomposition and other extremal problems. Same as CS 572. Prerequisite: MATH 580 or consent of instructor.

MATH 582 Structure of Graphs credit: 4 Hours. Structure of graphs and properties of special classes of graphs. Degree sequences and reconstruction, structure of k-connected graphs, Hamiltonian cycles and circumference, planar graphs and their properties, graph minors, cycle coverings, matroidal and algebraic aspects of graphs. Prerequisite: MATH 580 or consent of instructor.

MATH 583 Partial Orders and Comb Optim credit: 4 Hours. Combinatorial aspects of partially ordered sets and their relation to optimization problems. Structure of posets and lattices, Dilworth's theorem and generalizations, linear extensions and sorting, dimension of posets, order ideals, extremal set theory, integer programming and minmax relations, matroids and their applications. Prerequisite: MATH 580 or consent of instructor.

MATH 585 Probabilistic Combinatorics credit: 4 Hours. Techniques and applications of probabilistic methods in combinatorics. Draws applications from a variety of areas, but emphasizes theoretical aspects of random graphs, including connectivity, trees & cycles, planarity, and coloring problems. Techniques include the second moment method, Lovasz Local Lemma, martingales, Talgrand's Inequality, the Rold Nibble, and Szemeredi's Regularity Lemma. Applications may come from discrete geometry, coding theory, algorithms & complexity, additive number theory, percolation, positional games, etc. Prerequisite: MATH 580 or consent of instructor.

MATH 588 Optimization in Networks credit: 4 Hours. Theory and methods for optimization over directed graphs; paths, cuts, flows, and potentials; matchings; PERT and CPM; max flow, min path, out-of-kilter, Hungarian, and other algorithms; nonlinear cost functionals; painting theory; and existence and duality. Prerequisite: MATH 412 or 413 or equivalent.

MATH 589 Conjugate Duality and Optim credit: 4 Hours. Convex analysis for constrained extremum problems; convex sets, cones, and functions; separation; Fenchel transform; duality correspondences; differential theory; nonlinear programming; sensitivity; and perturbational duality for primal, dual, and Lagrangian problems. Prerequisite: MATH 415 and MATH 447, or equivalent.

MATH 593 Mathematical Internship credit: 0 Hours. Full-time or part-time practice of graduate-level mathematics in an off-campus government, industrial, or research laboratory environment. Summary report required. 0 graduate credit. No professional credit. Approved for S/U grading only. May be repeated in separate terms.
MATH 595  Advanced Topics in Mathematics  credit: 1 to 4 Hours.
See Class Schedule for current topics. 1 to 4 graduate hours. No
professional credit. May be repeated in the same or separate semesters.
Prerequisite: Consent of instructor.

MATH 597  Reading Course  credit: 1 to 8 Hours.
Independent study in Mathematics. 1 to 8 graduate hours. No
professional credit. Approved for Letter and S/U grading. May be
repeated in the same or separate terms, with a maximum of 8 hours per
semester. Prerequisite: Consent of instructor.

MATH 598  Literature Seminar in Math  credit: 0 to 4 Hours.
Seminar on topics of current interest in mathematics. Students present
seminars and discussions on various topics. See Class Schedule for
current topics. Recommended for all Mathematics students. Approved
for both letter and S/U grading. May be repeated as topics vary.
Prerequisite: Consent of instructor.

MATH 599  Thesis Research  credit: 0 to 16 Hours.
Approved for S/U grading only. May be repeated. Prerequisite: Consent of
instructor.