MATHEMATICS

Department of Mathematics
College of Natural Science

100E Intermediate Algebra Workshop for the Mathematics Enrichment Program
Fall, Spring. 1(0-4) R: Approval of department. C: MTH 1825 concurrently. Enrichment topics in intermediate algebra for students in the Mathematics Enrichment Program.

101 Quantitative Literacy I
Fall, Spring. 3 credits. Quantitative literacy including applications to health and risk, science, and the environment.

102 Quantitative Literacy II
Fall, Spring. 3 credits. Quantitative literacy including applications to finance, economics, and politics.

103 College Algebra
Fall, Spring. 3(3-0) P: (MTH 1825) or designated score on Mathematics Placement test SA: LBS 117 Not open to students with credit in MTH 116. Number systems; functions and relations; exponents and logarithms; elementary theory of equations; inequalities; and systems of equations.

103A College Algebra I
Fall. 3(3-0) Not open to students with credit in MTH 103 or MTH 116. Functions, graphing, and modeling, with a focus on linear functions and models.

103B College Algebra II
Spring. 3(3-0) P: MTH 103A Not open to students with credit in MTH 103 or MTH 116. Continuation of MTH 103A. Topics focus on exponential, logarithmic, polynomial, and rational functions.

103E College Algebra Workshop for the Mathematics Enrichment Program
Fall, Spring. 1(0-4) R: Approval of department. C: MTH 103 concurrently. Enrichment topics in college algebra for students in the Mathematics Enrichment Program.

110 Finite Mathematics and Elements of College Algebra

112 Finite Mathematics: Applications of College Algebra
Fall, Spring. Summer. 3(3-0) P: (MTH 103) or designated score on Mathematics Placement test SA: MTH 106 Not open to students with credit in MTH 110. Combinatorics, probability and statistics, mathematics of finance, geometry, transition matrices, and linear programming. The course emphasizes applications and includes work using spreadsheets.

114 Trigonometry
Fall, Spring, Summer. 3(3-0) P: MTH 103 SA: MTH 104 Not open to students with credit in MTH 116. Radian and degree measure of angles. Definitions and graphs of trigonometric functions and their inverses. Solving trigonometric equations. Applications including identities, indirect measurement and trigonometric modeling.

116 College Algebra and Trigonometry
Fall, Spring, Summer. 5(5-0) P: (MTH 1825) or designated score on Mathematics Placement test SA: LBS 117 Not open to students with credit in MTH 103. Functions and graphs. Equations and inequalities. Exponential and logarithmic functions. Trigonometric functions. Systems of equations. Binomial theorem.

124 Survey of Calculus I
Fall, Spring, Summer. 3(3-0) P: (MTH 103 or MTH 116) or designated score on Mathematics Placement test Study of limits, continuous functions, derivatives, integrals and their applications.

126 Survey of Calculus II
Fall, Spring, Summer. 3(3-0) P: MTH 124 Not open to students with credit in MTH 133 or MTH 153H. Application of partial derivatives, integrals, optimization of functions of several variables and differential equations.

132 Calculus I
Fall, Spring, Summer. 3(3-0) P: (MTH 103 and MTH 114) or (MTH 116 or designated score on Mathematics Placement test) Limits, continuous functions, derivatives and their applications. Integrals and the fundamental theorem of calculus.

133 Calculus II
Fall, Spring, Summer. 4(4-0) P: MTH 132 or MTH 152H or LB 118 Not open to students with credit in LB 119 or MTH 153H. Applications of the integral and methods of integration. Improper integrals. Polar coordinates and parametric curves. Sequences and series. Power series.

152H Honors Calculus I
Fall. 3(3-0) R: Open to students in the Honors College or approval of department. Not open to students with credit in LB 118 or MTH 132. Limits, continuous functions, derivatives, integrals, fundamental theorem of calculus. Special emphasis on concepts and theory.

153H Honors Calculus II
Fall, Spring. 4(5-0) P: MTH 152H or MTH 132 or LB 118 R: Open to students in the Honors College or approval of department. Not open to students with credit in MTH 133 or LB 119. The integral. Improper integrals. Polar coordinates and parametric curves. Sequences and series. Power and Taylor series. Special emphasis on concepts and theory.

1825 Intermediate Algebra
Fall, Spring, Summer. 3(3-0) Properties of real numbers. Factoring. Roots and radicals. First and second degree equations. Linear inequalities. Polynomials. Systems of equations.

201 Elementary Mathematics for Teachers I
Fall, Spring, Summer. 3(3-0) P: (MTH 103 or MTH 110 or MTH 116 or MTH 124 or MTH 132 or MTH 152H or LB 118) or designated score on Mathematics Placement test R: Open to students in the Child Development major or in the Education Major or in the Special Education-Learning Disabilities Major or in the Teacher Certification Internship Year Studies Program. Mathematics needed for K-8 teaching. Place value and models for arithmetic, mental math, word problems, and algorithms. Factors, primes, proofs, and prealgebra. Fractions, ratios, rates, and percent-ages. Negative, rational, and real numbers. Special emphasis on the appropriate sequential order for teaching.

202 Elementary Mathematics for Teachers II
Fall, Spring, Summer. 3(3-0) P: MTH 201 R: Open to students in the Education Major or in the Special Education-Learning Disabilities Major or in the Child Development major or in the Teacher Certification Internship Year Studies Program. A continuation of MTH 201. Geometry, measurement, and elementary data analysis.

234 Multivariable Calculus
Fall, Spring. Summer. 4(4-0) P: MTH 133 or MTH 153H or LB 119. Vectors in space. Functions of several variables and partial differentiation. Multiple integrals. Line and surface integrals. Green's and Stoke's theorems.

235 Differential Equations
Fall, Spring, Summer. 3(4-0) P: MTH 234 or MTH 254H or LB 220 R: Not open to students in the Bachelor of Science in Mathematics or in the Bachelor of Arts in Mathematics or in the Lyman Briggs Mathematics Coordinate Major. Not open to students with credit in MTH 347H or MTH 340. Separable and exact equations. Linear equations and variation of parameters. Higher order linear equations. Laplace transforms. Systems of first-order linear equations. Introduction to partial differential equations and Fourier series.

254H Honors Multivariable Calculus
Fall, Spring. 4(5-0) P: MTH 153H or MTH 133 or LB 119 R: Open to students in the Honors College or approval of department. Not open to students with credit in MTH 234 or LB 220. Vectors in space. Functions of several variables and partial differentiation. Multiple integrals. Line and surface integrals. Green's and Stoke's Theorems.

290 Directed Study
Fall, Spring, Summer. 1 to 4 credits. A student may earn a maximum of 6 credits in all enrollments for this course. Faculty directed study of selected mathematical topics.

299 Transitions
Fall, Spring, Summer. 4 credits. P: MTH 132 or MTH 152H or LB 118 RB: (MTH 133 or concurrently) or (LB 119 or concurrently). Introduction to mathematical reasoning, basic logic, set theory, integers, natural numbers and induction, basic number theory, real numbers, limits, sequences, series.
MTH—Mathematics

301 Foundations of Higher Mathematics
Fall, Spring. 3(3-0) P: (MTH 133 or MTH 153H or LB 119) and MTH 202 R. Open to students in the Mathematics Elementary Teaching Major or in Mathematics-Elementary Disciplinary Teaching Minor or approval of department.
Elementary set theory including permutations, combinations, cardinality theorems, relations, functions and quotient sets. Basic principles of logic and proof techniques. Elementary number theory and abstract algebra.

304 Algebra for Elementary and Middle School Teachers
Fall. 3 credits. Interdepartmental with Teacher Education. Administered by Mathematics. P: (MTH 201 and MTH 202 and MTH 301) and completion of Tier I writing requirement R: Open to undergraduate students in the College of Education or in the Department of Teacher Education. Approval of department.
Algebra needed for understanding connections between topics of algebra and the mathematics taught in elementary and middle school.

305 Functions and Calculus for Elementary and Middle School Teachers (W)
Spring. 3(3-0) Interdepartmental with Teacher Education. Administered by Mathematics. P: (MTH 304) and completion of Tier I writing requirement.
Functions and calculus needed for understanding connections between topics of calculus and the mathematics taught in middle school.

309 Linear Algebra I
Fall, Spring. 3(3-0) P: ((MTH 133 or MTH 153H or LB 119) and completion of Tier I writing requirement) and (MTH 299 or approval of department) Not open to students with credit in MTH 317.
Matrices, systems of linear equations, vector spaces, linear transformations, inner products and orthogonal spaces, eigenvalues and eigenvectors, and applications to geometry. A writing course with emphasis on proofs.

310 Abstract Algebra I and Number Theory
Fall, Spring, Summer. 3(3-0) P: (MTH 299 or MTH 317H) or approval of department and completion of Tier I writing requirement Not open to students with credit in MTH 418H.
Structure of the integers, congruences, rings, ring homomorphisms, ideals, quotient rings. A writing course with an emphasis on proofs.

314 Matrix Algebra with Applications
Fall, Spring, Summer. 3(3-0) P: MTH 133 or MTH 153H or LB 119 R. Not open to students in the Actuarial Science Major or in the Bachelor of Arts in Computational Mathematics or in the Bachelor of Science in Computational Mathematics or in the Mathematics Minor or in the Bachelor of Science in Mathematics or in the Bachelor of Arts in Mathematics or in the Bachelor of Science in Mathematics. Advanced or in the Bachelor of Arts in Mathematics, Advanced or in the Mathematics-Elementary Disciplinary Teaching Minor or in Mathematics-Secondary Disciplinary Teaching Minor.
Problem-solving and applications in matrix algebra for scientists and engineers. Vectors, matrices, linear transformations, inner products, dimension, eigenvalues and eigenvectors. Applications to systems of equations and to geometry.

317H Honors Linear Algebra
Fall, Honors, Spring. 4(5-0) P: MTH 133 or MTH 153H or LB 119 R. Not open to students in the Honors College or approval of department. Not open to students with credit in MTH 309.

320 Analysis I
Fall, Spring, Summer. 3(3-0) P: (MTH 133 or MTH 153H or LB 119) and (MTH 299 or MTH 317H or approval of department) Not open to students with credit in MTH 327H.

327H Honors Introduction to Analysis
Fall, Spring, Summer. 3(3-0) P: MTH 317H R: Approval of department.
Emphasis on foundations and metric topology. Convergence of sequence and series, continuity of functions. Differentiation and integration in one dimension.

330 Higher Geometry
Fall, Spring, Summer. 3(3-0) P: MTH 301 or MTH 299 or MTH 317H
Topics in transformations: isometries, similarities, inversions. Advanced Euclidean geometry: theorems of Menelaus, Ceva, and Desargues. Cross ratio, harmonic points, analytic, metric, and vector methods, and convexity.

340 Ordinary Differential Equations I
Fall, Spring, Summer. 3(3-0) P: (MTH 309 or MTH 317H) and (MTH 133 or MTH 153H or LB 119) Not open to students with credit in MTH 347H.
Techniques for solving differential equations, existence and uniqueness theorems, qualitative theory, Fourier series and applications.

347H Honors Ordinary Differential Equations
Spring. 3(3-0) P: (MTH 309 or MTH 317H) and (MTH 133 or MTH 153H or LB 119) R: Approval of department.
Separable and exact equations, linear equations and variation of parameters, higher order linear equations, Laplace Transforms, first-order linear systems, classification of singularities, nonlinear systems, partial differential equations and Fourier Series, existence and uniqueness theorems. Emphasis on theory.

360 Theory of Mathematical Interest
Fall, Spring. 3(3-0) P: (MTH 133 or concurrently) or (MTH 153H or concurrently) or (LB 119 or concurrently) or approval of department.
Measurement of interest rates, basic problems in interest theory, basic annuities, continuous and varying annuities, yield rates, amortization, bonds and other securities, practical applications, and stochastic approaches to interest.

361 Financial Mathematics for Actuaries I
Fall, Spring. 3(3-0) P: MTH 360 C: STT 441 concurrently.
Introduction to the mathematics of financial derivatives. Options, forwards, futures, swaps, investment and hedging strategies.

396 Capstone in Mathematics for Secondary Education (W)
Spring. 3(3-0) P: (MTH 309 or MTH 317H or approval of department) and (MTH 310 or MTH 418H or approval of department) and (MTH 320 or MTH 327H or approval of department) and Completion of Tier I Writing Requirement R: Approval of department. Not open to students with credit in MTH 496.
A capstone course for secondary education math majors. High school mathematics from an advanced viewpoint.

411 Abstract Algebra II
Fall, Spring. 3(3-0) P: MTH 310 Not open to students with credit in MTH 419H.
Continuation of MTH 310. Permutation groups, groups of transformations, normal subgroups, homomorphism theorems, modules. Principal ideal rings, unique factorization domains, noncommutative rings, rings of fractions, ideals.

414 Linear Algebra II
Fall. 3(3-0) P: MTH 309 or MTH 317H Not open to students with credit in MTH 415.
Linear transformations on finite dimensional vector spaces. Invariant subspaces, rank, eigenvalues and eigenvectors. Canonical forms. Bilinear and multilinear forms.

415 Applied Linear Algebra
Fall, Spring, Summer. 3(3-0) P: (MTH 235 or MTH 340 or MTH 347H) and (MTH 309 or MTH 314 or MTH 317H) Not open to students with credit in MTH 414.

416 Introduction to Algebraic Coding
Fall. 3(3-0) P: MTH 309 or MTH 317H RB: MTH 310.
Concepts and techniques of abstract algebra applied to the design of communication systems for use in imperfect circumstances. Theory of codes designed by algebraic means.

417 Topics in Number Theory
Spring of even years. 3(3-0) P: (MTH 310 or MTH 418H) and (MTH 411 or concurrently) or (MTH 419H or concurrently)
Congruences of higher degree, primitive roots and quadratic reciprocity. Number-theoretic functions, algebraic numbers. Dirichlet Series, p-order expansion, continued fractions.
418H Honors Algebra I
Fall, 3(3-0) P: MTH 317H or MTH 299 RB: Approval of department.
Theory of groups, Sylow theory, the structure of finite Abelian groups, ring theory, ideals, homomorphisms, and polynomial rings.

419H Honors Algebra II
Spring, 3(3-0) P: MTH 418H R: Approval of department.
Algebraic field extensions, Galois theory. Classification of finite fields. Fundamental Theorem of Algebra.

421 Analysis II
Fall, Spring, 3(3-0) P: (MTH 320 or MTH 327H) and (MTH 234 or MTH 254H or LB 220) Not open to students with credit in MTH 429H.

425 Complex Analysis
Fall, Spring, 3(3-0) P: MTH 320 Not open to students with credit in MTH 428H. Analytic functions of a complex variable, Cauchy integral theorem, conformal maps, bilinear transformation, harmonic functions. Classification of singularities, residues, conformal mappings.

428H Honors Complex Analysis
Fall, 3(3-0) P: MTH 327H R: Approval of department. Analytic functions of a complex variable, line integrals and harmonic functions, Cauchy's theorem and integral formula, power series, Laurent series, isolated singularities, residue calculus, Rouché's theorem, automorphisms of the disk, the Riemann mapping theorem.

429H Honors Real Analysis
Spring, 3(3-0) P: MTH 327H and (MTH 234 or MTH 254H or LB 220) R: Approval of department.
Continuation of MTH 327H. Convergence of sequences and series of functions, differentiation and integration in higher dimensional settings. Inverse and implicit function theorems.

432 Axiomatic Geometry
Spring, 3(3-0) P: MTH 299 or MTH 317H
Axiomatic systems and finite geometries: axioms of Euclidean and hyperbolic geometry, the Poincare model, independence of the parallel postulate, classical constructions and the impossibility of angle trisection.

441 Ordinary Differential Equations II
Fall, 3(3-0) P: (MTH 235 or MTH 540 or MTH 347H) and (MTH 309 or MTH 317H or MTH 314 or MTH 415) Existence and uniqueness theorems; Linearity; Local and global stability; Saddle-node, Hopf and heteroclinic bifurcations; Hamiltonian and gradient systems; The Poincare map; The Poincare-Bendixson theorem and limit cycles; Selected applications.

442 Partial Differential Equations
Spring, 3(3-0) P: MTH 235 or MTH 340 or MTH 347H Classification of second order partial differential equations. Boundary and initial value problems for heat, Laplace, and wave equations in dimensions 1, 2, and 3. Variational methods and maximum principles. Separation of variables, Fourier series, Sturm-Liouville theory. Greens functions.

451 Numerical Analysis I
Fall, 3(3-0) P: (CSE 131 or CSE 231) and (CSE 131 or CSE 231) and (MTH 235 or MTH 340 or MTH 347H) SA: MTH 351 Numerical solution of linear and nonlinear algebraic equations and eigenvalue problems. Curve fitting. Interpolation theory. Numerical integration, differentiation, and solution of differential equations. Algorithms implemented with a programming language like Fortran, C/C++ or MATLAB.

452 Numerical Analysis II

455 Actuarial Models I
Fall, 3(3-0) Interdepartmental with Statistics and Probability. Administered by Statistics and Probability. P: STT 441 and MTH 360 Stochastic models used in insurance. Survival distributions, life insurance, life annuities, benefit premiums, benefit reserves, and analysis of benefit reserves.

456 Actuarial Models II

457 Introduction to Financial Mathematics
Spring, 3(3-0) P: (MTH 309) and (MTH 235 or MTH 340 or MTH 347H) and (STT 441 or STT 351) Mathematical overview of basic financial instruments. A unified partial differential equation approach to model derivative securities. Partial differential equations in financial mathematics, Black-Scholes equations. Numerical methods for valuing derivatives.

458 Financial Mathematics for Actuaries II

459 Construction and Evaluation of Actuarial Models

461 Metric and Topological Spaces
Fall, 3(3-0) P: MTH 320 or MTH 327H Set theory, metric spaces, topological spaces, maps, product and quotient topologies. Connected and compact spaces, separation axioms, pointwise and uniform convergence.

481 Discrete Mathematics I

482 Discrete Mathematics II
Spring, 3(3-0) P: MTH 481 RB: MTH 310 Recurrence and generating functions, Ramsey theory, Block designs, Latin squares, Eulerian and Hamiltonian paths. Minimum spanning trees, network flows.

490 Directed Studies
Fall, Spring, Summer. 1 to 4 credits. A student may earn a maximum of 9 credits in all enrollments for this course. R: Approval of department. Faculty directed study in a selected mathematical topic.

491A Actuarial Internship
Summer, 3(3-0) P: Completion of Tier I Writing Requirement RB: STT 441 and FI 311 and MTH 360 R: Approval of department. Survey of typical actuarial type projects at an actuarial firm such as data analysis, risk analysis, interest rate models, life insurance, benefit programming, analysis of benefit reserves.

491B Teamwork Experience
Fall, Spring, Summer. 1(1-0) R: Approval of department. A field type experience to develop communication skills working in a group setting on multi-faceted projects.

492H Undergraduate Thesis (W)
Fall, Spring, Summer. 3 credits. A student may earn a maximum of 12 credits in all enrollments for this course. P: Completion of Tier I Writing Requirement R: Approval of department; application required. Undergraduate thesis on an advanced-level topic in mathematics.

496 Capstone in Mathematics (W)
Fall, Spring, 3(3-0) P: (MTH 309 or MTH 317H or approval of department) and (MTH 310 or MTH 318H or approval of department) and (MTH 320 or MTH 327H or approval of department) and Completion of Tier I Writing Requirement R: Approval of department. A capstone course integrating several areas of mathematics.
MTH—Mathematics

810 Error-Correcting Codes
Spring. 3(3-0) RB: MTH 411 or MTH 414 or MTH 415
Block codes, maximum likelihood decoding, Shan-
non's theorem. Generalized Reed-Solomon codes, modi-
fication of codes, subfield codes, Alatert and Goppa codes, cyclic codes and BCH codes.

818 Algebra I
Fall. 3(3-0) RB: MTH 411
Group theory: Sylow theory, permutation groups, Jor-
don-Holder theory, Abelian groups, free groups,
Ring theory: algebra of ideals, unique factorization,
polynomial rings, finitely generated modules over PiDs.

819 Algebra II
Spring. 3(3-0) RB: MTH 818
Modules and vector spaces, projectives modules,
tensor algebra. Fields and Galois groups, algebraic and transcendental numbers, non-commutative
rings. The Jacobson radical, the structure of semisim-
ple rings with the descending chain condition.

828 Real Analysis I
Fall. 3(3-0) RB: MTH 421 and MTH 461
Lebesgue measure on real line, general measure the-
yory, Convergence theorems, Lusin's theorem, Ego-
rov's theorem, Lp-spaces, Fubin'i's theorem. Func-
tions of bounded variation, absolutely continuous functions, Lebesgue differentiation theorem.

829 Complex Analysis I
Spring. 3(3-0) RB: MTH 421 and MTH 425
Cauchy theorem, identity principle, Liouville's the-
orem, maximum modulus theorem. Cauchy formula,
residue theorem, Rouche's theorem. Casorati-Weier-
strass theorem, Arzela-Ascoli theorem. Conformal
mapping, Schwarz lemma, Riemann mapping theo-
rem.

841 Boundary Value Problems I
Fall. 3(3-0) RB: MTH 414 and MTH 421
Methods for solving boundary and initial value prob-
lems for ordinary and partial differential equations.

842 Boundary Value Problems II
Spring. 3(3-0) RB: MTH 841
Continuation of MTH 841.

843 Survey of Industrial Mathematics
Fall. 3(3-0) RB: (MTH 414 or MTH 415) or Some familiarity with mathematical software such as Mathematica, Matlab, etc.) and
(MTH 421 and MTH 442) R: Open only to master's students in the Industrial Mathemat-
ics major or approval of department. Fundamentals of mathematical modeling in govern-
ment and industry, including modes of industrial com-
munication.

844 Projects in Industrial Mathematics
Spring. 3(3-0) RB: (MTH 414 or MTH 415) or some familiarity with mathematical soft-
ware such as Mathematica or Matlab.) and
(MTH 421 and MTH 442 and MTH 843) R: Open only to master's students in the Indus-
trial Mathematics major or approval of de-
partment. Participation as a member of a 3-4 person team on a significant industrial problem, with participation of an industrial liaison, including project report generation and reporting.

847 Partial Differential Equations I
Fall. 3(3-0) RB: Equivalent of MTH 414 R:
Open to doctoral students in the College of
Natural Science.
Basic theory and techniques for general first-order
and partial and hyperbolic types.

848 Ordinary Differential Equations
Fall. 3(3-0) RB: MTH 414 and MTH 421
Existence and uniqueness theorems. Theory of linear
equations. Cotected and hyperbolic theorems.

849 Partial Differential Equations
Spring. 3(3-0) RB: MTH 414 and MTH 421
Cauchy-Kowalewski theorem. Characteristics. Initial-
boundary value problems for parabolic and hyper-
bolic equations. Energy methods, boundary value
problems for elliptic equations, potential theory.
Green's function, maximum principles, Schauder's
method.

850 Numerical Analysis I
Fall. 3(3-0) RB: MTH 414 and MTH 421
Convergence and error analysis of numerical meth-
ods in applied mathematics.

851 Numerical Analysis II
Fall. 3(3-0) RB: MTH 850 and MTH 852
Spectral methods for boundary value problems, ei-
genvalue problems, and time-dependent problems.
Trigonometric and Chebychev polynomials. Fast
Fourier transforms.

852 Numerical Methods for Ordinary
Differential Equations
Spring. 3(3-0) RB: MTH 850
Linear multistep methods and single step nonlinear
methods for initial value problems. Consistency, sta-
tility and convergence. Finite difference, finite ele-
ment, shooting methods for boundary value prob-
lems.

858 Geometry and Topology I
Fall. 3(3-0) RB: (MTH 411 and MTH 421) or
approval of department.
Fundamental group and covering spaces, van
Kampen's theorem. Homotopy theory, Differentiable
manifolds, vector bundles, transversality, calculus on
manifolds. Differential forms, tensor bundles, deR-
ham theorem, Frobenius theorem.

869 Geometry and Topology II
Spring. 3(3-0) RB: MTH 868
Continuation of MTH 868.

879 Teaching College Mathematics
Fall of even years. 3(3-0) A student may earn a
maximum of 24 credits in all enrollments for this course. R: Approval of department.
Individualized study for Master's level students.

880 Combinatorics I
Fall. 3(3-0) RB: MTH 411 or MTH 482
Enumerative combinatorics, recurrence relations,
generating functions, asymptotics, applications to
graphs, partially ordered sets, generalized Moebius
inversions, combinatorial algorithms.

881 Graph Theory
Fall of even years. 3(3-0) RB: MTH 880
Basic concepts in graph theory, connectivity, alge-
braic and topological methods. Networks, graph algo-
rithms, Hamiltonian and Eulerian graphs, extremal
graph theory, random graphs.

882 Combinatorics II
Spring. 3(3-0) P: MTH 880
Algebraic combinatorics including symmetric func-
tions, group actions, and cluster algebra, geometric
combinatorics including shellability, discrete Morse
functions, and polytopes. Extremal combinatorics in-
cluding Ramsey Theory and Sperner Theory.

890 Readings in Mathematics
Fall, Spring, Summer. 1 to 6 credits. A stu-
dent may earn a maximum of 24 credits in all enrollments for this course. R: Approval of department.

910 Commutative Algebra
Fall of odd years. 3(3-0) RB: MTH 819
Noetherian rings and modules, localization and ten-
sor products, primary decomposition, Krull dimen-
sions, graded rings and modules, Hilbert's Nullstel-
 lensatz, integral extensions, discrete valuation rings,
Dedekind domains.

912 Group Theory I
Fall of even years. 3(3-0) RB: MTH 819
Permutation groups, solvable and nilpotent groups,
simple groups, Represenation and character theory.
Extension theory and cohomology groups.

913 Group Theory II
Spring of odd years. 3(3-0) RB: MTH 912
Groups of Lie type, linear groups, locally finite groups,
free groups and free products, the subgroup theo-
rems.

914 Lie Groups and Algebras
Fall of odd years. 3(3-0) RB: MTH 819
Nilpotent and semisimple algebras, the ad joint rep-
resentation, root spaces, Weyl groups, Dynkin dia-
grams, classification of simple algebras.

916 Introduction to Algebraic Geometry
Fall of even years. 3(3-0) RB: MTH 818 and
MTH 819
Affine and projective algebraic varieties and their
properties. Morphisms and singularities, schemes
and coherent sheaves. Sheaf cohomology and other
related topics.

917 Introduction to Algebraic Geometry
Spring of odd years. 3(3-0) RB: MTH 916
Continuation of MTH 916.
919 Number Theory I  
Fall of even years. 3(3-0) P: MTH 819 or approval of department. 
Number fields and algebraic integers, prime ideals and factorization, cyclotomic fields, the class group, the Dirichlet unit theorem, different, discriminant, decomposition and inertia groups, local fields.

919 Number Theory II  
Spring of odd years. 3(3-0) P: MTH 918 or approval of department. 
Topics include: class field theory, zeta and L-functions, modular forms, theory of elliptic curves, diophantine approximation, diophantine geometry.

920 Functional Analysis  
Spring. 3(3-0) RB: MTH 828 R: Open to graduate students in the College of Natural Science or approval of department. 
Introduction to operator and spectral theory. Topics include Banach algebras, bounded and unbounded operators on Banach spaces, spectral theory for normal operators on a Hilbert space, C*-algebras, compact operators.

921 Operator Theory  
Fall of even years. 3(3-0) RB: MTH 829 and MTH 920 R: Open to doctoral students in the College of Natural Science or approval of department. 
Introduction to operator and spectral theory. Topics include Banach algebras, bounded and unbounded operators on Banach spaces, spectral theory for normal operators on a Hilbert space, C*-algebras, Schatten - von Neumann classes, the theory of Fredholm operators, semigroup theory.

922 Harmonic Analysis  
Fall of odd years. 3(3-0) RB: MTH 829 and MTH 920 R: Open to doctoral students in the College of Natural Science or approval of department. 
Introduction to measure-theoretic probability theory. Topics include infinite product spaces, Kolmogorov extension theorem, Borel Cantelli Lemma, law of large numbers, central limit theorem, conditioning, filtrations, martingales, Markov chains, Wiener processes.

925 Random Variables and Stochastic Processes  
Fall. 3(3-0) R: Open to doctoral students in the College of Natural Science or approval of department. 
Introduction to measure-theoretic probability theory. Topics include infinite product spaces, Kolmogorov extension theorem, Borel Cantelli Lemma, law of large numbers, central limit theorem, conditioning, filtrations, martingales, Markov chains, Wiener processes.

928 Real Analysis II  
Spring of odd years. 3(3-0) RB: MTH 828 R: Open to doctoral students in the College of Natural Science or approval of department. 
Continuation of MTH 828. Topics include Borel measures on locally compact spaces, complex measures, differentiable transformations and changes of variables in Rn.

929 Complex Analysis II  
Spring of even years. 3(3-0) RB: MTH 828 and MTH 829 R: Open to doctoral students in the College of Natural Science or approval of department. 

930 Riemannian Geometry I  
Fall of even years. 3(3-0) RB: MTH 869 R: Open to doctoral students in the College of Natural Science or approval of department. 
Riemannian metrics, connections, curvature, geodesics. First and second variation, Jacobi fields, conjugate points, Rauch comparison theorems, Hodge theorem, Bochner technique, spinors. Further topics on curvature and submanifold theory.

931 Riemannian Geometry II  
Spring of odd years. 3(3-0) RB: MTH 930 R: Open to doctoral students in the College of Natural Science or approval of department. 
Continuation of MTH 930.

935 Complex Manifolds I  
Fall of odd years. 3(3-0) RB: MTH 829 and MTH 869 R: Open to doctoral students in the College of Natural Science or approval of department. 
Introduction to complex manifolds and complex analytic geometry. Topics include Riemann surfaces, Serre duality, Riemann-Roch theorem, Weierstrass points, Abel's theorem, Plucker formulas. Hermitian metrics, connections, curvature, Hodge theorem. Kaehler metrics, Kodaira vanishing theorem, Chern classes.

936 Complex Manifolds II  
Spring of even years. 3(3-0) RB: MTH 935 R: Open to doctoral students in the College of Natural Science or approval of department. 
Continuation of MTH 935.

940 Topics in Partial Differential Equations for Applied Math  
Fall of even years. 3(3-0) RB: MTH 828 R: Open to doctoral students in the College of Natural Science or approval of department. 
Partial differential equation techniques for applied mathematicians, including, bifurcation theory, partial differential equations as dynamical systems, boundary layers, asymptotic analysis, matched asymptotic and singular perturbations, and homogenization.

941 Linear and Nonlinear Parabolic Equations  
Spring of even years. 3(3-0) RB: MTH 940 R: Open to doctoral students in the College of Natural Science or approval of department. 
Introduction to evolutionary partial differential equations. Topics include parabolic equations and Hamilton-Jacobi-Bellman equations, with an emphasis on existence and uniqueness of both classical and weak solutions. Linear and nonlinear cases, including quasi-linear parabolic equations related to geometric flows.

942 Regularity for Second Order Elliptic Equations  
Fall of even years. 3(3-0) RB: MTH 848 and MTH 849 R: Open to doctoral students in the College of Natural Science or approval of department. 
Review of classical regularity results, such as Schauder theory and Lp theory. Elliptic equations with coefficients of low regularity (bounded and measurable) and nonlinear elliptic equations. The Harnack inequality and Holder regularity in the context of both weak solutions of divergence form equations and viscosity solutions of equations in non-divergence form. Higher regularity and applications to minimization problems.
Representation Theory II
Spring of even years. 3(3-0) P: MTH 988 or approval of department
Basic objects and notions of representation theory: associative algebras, algebras defined by generators and relations, group algebras, quivers and path algebras, basic general results of representation theory, representations of finite dimensional algebras and semi simple algebras, extensions of representations, representations of quivers.

Reading in Mathematics
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 9 credits in all enrollments for this course. R: Approval of department.
Individualized study for doctoral level students.

Special Topics in Algebra
Fall, Spring. 3 to 6 credits. A student may earn a maximum of 18 credits in all enrollments for this course. R: Approval of department.
Advanced topics in algebra.

Special Topics in Analysis
Fall, Spring. 3 to 6 credits. A student may earn a maximum of 18 credits in all enrollments for this course. R: Approval of department.
Advanced topics in analysis.

Special Topics in Geometry
Fall, Spring. 3 to 6 credits. A student may earn a maximum of 18 credits in all enrollments for this course. R: Approval of department.
Advanced topics in geometry.

Special Topics in Applied Mathematics
Fall, Spring. 3 to 6 credits. A student may earn a maximum of 24 credits in all enrollments for this course. R: Approval of department.
Advanced topics in applied mathematics.

Special Topics in Numerical Analysis and Operations Research
Fall, Spring. 3 to 6 credits. A student may earn a maximum of 18 credits in all enrollments for this course. R: Approval of department.
Advanced topics in numerical analysis or operations research.

Special Topics in Topology
Fall, Spring. 3 to 6 credits. A student may earn a maximum of 18 credits in all enrollments for this course. R: Approval of department.
Advanced topics in topology.

Doctoral Dissertation Research
Fall, Spring, Summer. 1 to 24 credits. A student may earn a maximum of 36 credits in all enrollments for this course. R: Approval of department.
Doctoral dissertation research.