862 Dislocation Theory
Fall. 3(3-0) SA: MSM 862
Advanced theory of dislocations and other crystal defects in metals, ceramics, aggregates and ordered compounds. Elasticity theory of straight dislocations, dislocation strain energy, mobility, obstacle interactions, reactions, and core effects.

865 Advanced Theory of Solids
Spring. 3(3-0) SA: MSM 865
Quantum mechanics. Free electron theory. Energy bands, semiconductors. Dielectrics and ferroelectrics. Dia-, para-, ferro-, and antiferro-magnetism. Superconductivity. Thermal properties.

870 Electron Microscopy in Materials Science
Spring. 3(2-3) R: Open only to graduate students in the Materials Science and Engineering major or approval of department. SA: MSM 870
Theory of electron diffraction. Electromagnetic lenses. Image formation in transmission electron microscopy. Defect analysis and diffraction contrast.

871 Material Surfaces and Interfaces
Fall of odd years. 3(3-0) Interdepartmental with Chemical Engineering. RB: (CEM 392 or CEM 434 or MSE 351) R: Open only to graduate students in the Department of Chemical Engineering and Materials Science or Department of Chemistry or School of Packaging. SA: MSM 871
Physical and chemical nature of solid surfaces and their interaction with gases, liquids, and other solids. Characterization of surfaces and solid-solid interfaces. Relation of surface and interfacial structure to engineering phenomena.

875 Engineering Ceramics
Fall of odd years. 3(3-0) RB: (MSE 851) SA: MSM 875
Physical properties of engineering ceramics. Transport properties of ceramics, especially in ferrites and garnets. Optical ceramic materials.

876 Advanced Polymeric Materials
Fall of even years. 3(3-0) SA: MSM 876
Advanced topics in polymer structure and properties. Thermoplastics, thermosets, polyblends and elastomers. Processing techniques. Deformation and mechanical properties. Thermal, optical and chemical properties. Composites.

885 Seminar
Fall, Spring. 1(1-0) SA: MSM 885
Oral presentations of students' research or literature survey.

890 Independent Study
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 6 credits in all enrollments for this course. R: Approval of department. SA: MSM 890
Individualized reading and research of student's interest.

891 Selected Topics
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 6 credits in all enrollments for this course. R: Approval of department. SA: MSM 891
Special topics of current importance in materials science or engineering.

899 Master's Thesis Research
Fall, Spring, Summer. 1 to 8 credits. A student may earn a maximum of 24 credits in all enrollments for this course. SA: MSM 899
Master's thesis research.

964 Advanced Physical and Mechanical Properties of Materials I
Fall of even years. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course. SA: MSM 960, MSM 964
Topics vary each semester. Topics such as anisotropic crystalline properties and displacive phase transformations.

964A Anisotropic Crystalline Properties
Fall of even years. 3(3-0) RB: (MSE 851) SA: MSM 960B, MSM 964A
Crystallography. Tensor representation. Magnetic susceptibility. Electric polarization. Stress and strain. Thermal expansion. Piezoelectricity. Elasticity. Transport properties.

964B Displacive Phase Transformations
Fall of even years. 3(3-0) SA: MSM 964B
Crystallography and thermodynamics of displacive phase transformations. Twinning. Thermoelastic and non-thermoelastic martensites. WLR theory. Multiple-well potentials. Self-accommodation and interface mobility. Shape memory, superelasticity, transformation toughening and transformation-induced plasticity.

965 Advanced Analytical Techniques
Fall of odd years. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course. SA: MSM 970, MSM 965
Topics vary each semester. Topics such as environmental effects on materials and advanced techniques in electron microscopy.

965A Environmental Effects on Materials
Fall of odd years. 3(3-0) SA: MSM 965A
Influence of external and internal environments on degradation and fracture of metallic/nonmetallic materials. Environment-induced transport phenomena due to benign and aggressive environmental conditions and related fracture behavior of materials.

965B Advanced Techniques in Electron Microscopy
Fall of odd years. 3(3-0) RB: (MSE 870) SA: MSM 970A, MSM 965B
Experimental methods in transmission electron microscopy. Microanalytical, chemical, microbeam, diffraction and lattice imaging techniques.

974 Advanced Physical and Mechanical Properties of Materials II
Spring of even years. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course. SA: MSM 960, MSM 974
Topics vary each semester. Topics such as microcracking in brittle materials, or high temperature deformation and processing.

974A Microcracking in Brittle Materials
Spring of even years. 3(3-0) RB: (MSE 875) SA: MSM 960A, MSM 974A
Microcracking mechanisms and the effect of microcracks on mechanical, thermal and electrical properties. Microcracking theories. Experimental investigations of microcracks.

974B High Temperature Deformation and Processing
Spring of even years. 3(3-0) RB: (MSE 851 and MSE 862) SA: MSM 980B, MSM 974B
Theoretical and design principles applied to the control of creep, superplasticity, cavitation, recrystallization, and texture changes. Metallic, alloy, intermetallic, ceramic, and composite systems.

975 Advanced Processing Techniques
Spring of odd years. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course. SA: MSM 980, MSM 975
Topics vary each semester. Topics such as laser and plasma processing and ceramic processing.

975A Laser and Plasma Processing
Spring of odd years. 3(3-0) RB: (MSE 851) SA: MSM 980C, MSM 975
Application of laser and plasma technology in materials processing. Optical and surface properties. Thin films. Heat and mass flow. Heat-treating. Cutting, drilling, and joining.

975B Ceramic Processing
Spring of odd years. 3(3-0) RB: (MSE 851 and MSE 875) SA: MSM 980A, MSM 975B
Fundamental aspects of and recent developments in ceramic powder processing. The processing stream from making the powder to consolidation.

990 Independent Study
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 6 credits in all enrollments for this course. SA: MSM 990
Individualized reading and research.

991 Selected Topics
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 6 credits in all enrollments for this course. R: Approval of department. SA: MSM 991
Special advanced topics in materials science and engineering, and mechanics.

999 Doctoral Dissertation Research
Fall, Spring, Summer. 1 to 24 credits. A student may earn a maximum of 72 credits in all enrollments for this course. SA: MSM 999
Doctoral dissertation research.

MATHEMATICS MTH

Department of Mathematics
College of Natural Science

1005 Fundamentals of Algebra
Summer. 1(1-0)
Factoring. Rational and exponential expressions. Linear and quadratic relations. Fractions and distributive laws. Functions

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.

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

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
Fall, Spring, Summer. 5(5-0) P:M: (MTH 1825) or designated score on Mathematics placement test. Not open to students with credit in MTH 112.
Functions and graphs. Equations and inequalities. Systems of equations. Matrices. Linear programming. Simplex algorithm. Probability and statistics.

112 Finite Mathematics: Applications of College Algebra
Fall, Spring, Summer. 3(3-0) P:M: (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.

112E Finite Mathematics Workshop for Mathematics Enrichment Program
Spring. 1(0-4) R: Approval of department SA: MTH 106E C: MTH 112 concurrently.
Enrichment topics in Finite Mathematics for students in the Mathematics Enrichment Program.

114 Trigonometry
Fall, Spring, Summer. 3(3-0) P:M: (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:M: (MTH 1825)or designated score on Mathematics placement test. Not open to students with credit in LBS 117 or MTH 103.
Functions and graphs. Equations and inequalities. Exponential and logarithmic functions. Trigonometric functions. Systems of equations. Binomial theorem.

116E Precalculus Workshop for the Emerging Scholars Program
Fall. 1(0-4) R: Approval of department. C: MTH 116 concurrently.
Enrichment topics in precalculus for students in the Emerging Scholars Program.

124 Survey of Calculus I
Fall, Spring, Summer. 3(3-0) P:M: (MTH 103 or MTH 116 or LBS 117)or designated score on Mathematics placement test. Not open to students with credit in LBS 118 or MTH 132 or MTH 152H.
Study of limits, continuous functions, derivatives, integrals and their applications.

124E Survey of Calculus with Applications I Mathematics Enrichment Workshop
Fall. 1(0-4) R: Approval of mathematics department C: MTH 124 concurrently.
Enrichment topics in Survey of Calculus with Applications for students in the Mathematics Enrichment Program.

126 Survey of Calculus II
Fall, Spring, Summer. 3(3-0) P:M: (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:M: (MTH 103 and MTH 114) or (MTH 116 or LBS 117)or designated score on Mathematics placement test. Not open to students with credit in LBS 118 or MTH 152H.
Limits, continuous functions, derivatives and their applications. Integrals and the fundamental theorem of calculus.

132E Calculus I Workshop for the Emerging Scholars Program
Fall, Spring. 2(0-6) R: Approval of department. C: MTH 132 concurrently.
Enrichment topics in Calculus I for students in the Emerging Scholars Program.

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

133E Calculus II Workshop for the Emerging Scholars Program
Fall, Spring. 1(0-4) R: Approval of department. C: MTH 133 concurrently.
Enrichment topics in Calculus II for students in the Emerging Scholars Program.

152H Honors Calculus I
Fall. 3(3-0) R: Honors College student or approval of department. Not open to students with credit in LBS 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. 3(3-0) P:M: (MTH 152H) Not open to students with credit in LBS 119 or MTH 133.
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 Mathematical Investigations I
Fall, Spring, Summer. 3(3-0) P:M: (MTH 103 or MTH 110 or MTH 116 or LBS 117 or MTH 124 or MTH 132 or MTH 152H or LBS 118) or designated score on Mathematics placement test. R: Open only to students in the Education major or Special
Education major whose area of emphasis is deaf education or learning disabilities or Child Development major or Teacher Certification Internship-Year Studies program. Mathematics for prospective elementary teachers. Numbers, problem solving, geometry, functions, statistics and probability.

202 Mathematical Investigations II
Fall, Spring, Summer. 3(3-0) P:M: (MTH 201) R: Open only to students in the Education major or Special Education major whose area of emphasis is deaf education or learning disabilities or Child Development major or Teacher Certification Internship-Year Studies program.
A continuation of MTH 201.

234 Multivariable Calculus
Fall, Spring, Summer. 4(4-0) P:M: (MTH 133 or MTH 153H or LBS 119) Not open to students with credit in MTH 254H.
Vectors in space. Functions of several variables and partial differentiation. Multiple integrals. Line and surface integrals. Green's and Stokes's theorems.

235 Differential Equations
Fall, Spring, Summer. 3(3-0) P:M: (MTH 234 or MTH 254H) R: Not open to students in the Bachelor or Arts or Bachelor of Science degree in Mathematics or Lyman Briggs School Mathematics coordinate majors. Not open to students with credit in MTH 255H.
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. 3(3-0) P:M: (MTH 153H) Not open to students with credit in LBS 220 or MTH 234.
Vectors in space. Functions of several variables and partial differentiation. Multiple integrals. Line and surface integrals. Green's and Stokes's Theorems.

255H Honors Differential Equations
Fall, Spring. 3(3-0) P:M: (MTH 254H) R: Not open to students in the Bachelor of Arts or Bachelor of Science degree in Mathematics or Lyman Briggs School Mathematics coordinate majors. Not open to students with credit in MTH 235.
Topics chosen from separable and exact equations, linear equations and variation of parameters, series solutions, higher order linear equations, Laplace transforms, systems of first-order linear equations, nonlinear equations and stability, introduction to partial differential equations.

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.

309 Linear Algebra I
Fall, Spring, Summer. 3(3-0) P:M: (MTH 234 or MTH 254H or LBS 220) and completion of Tier I writing requirement.
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:M: (MTH 309) and completion of Tier I writing requirement.
Structure of the integers, congruences, polynomial rings, and ideals. A writing course with emphasis on proofs.

314 Matrix Algebra with Applications
Fall, Spring, Summer. 3(3-0) P:M: (MTH 234 or MTH 254H or LBS 220) R: Not open to students in the Department of Mathematics or to students in Lyman Briggs Mathematics or Lyman Briggs Computational Mathematics.
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.

320 Analysis I
Fall, Spring, Summer. 3(3-0) P:M: (MTH 234 or MTH 254H or LBS 220) and (MTH 309) Not open to students with credit in MTH 428H.
Convergence of sequences and series. Upper and lower limits, completeness, limits and continuity. Derivatives. Uniform convergence.

330 Higher Geometry
Fall. 3(3-0) P:M: (MTH 309)
Topics in transformations: isometries, similarities, inversion. Advanced Euclidean geometry: theorems of Menelaus, Ceva, and Desargue. Cross ratio, harmonic points, analytic, metric and vector methods, convexity.

340 Ordinary Differential Equations I
Fall, Spring, Summer. 3(3-0) P:M: (MTH 309)
Techniques for solving differential equations, existence and uniqueness theorems, qualitative theory, Fourier series and applications.

360 Theory of Mathematical Interest
Fall. 3(3-0) P:M: (MTH 234 or concurrently)
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.

411 Abstract Algebra II
Fall, Spring. 3(3-0) P:M: (MTH 310) Not open to students with credit in MTH 418H.
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:M: (MTH 309 or MTH 314) 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:M: (MTH 235 or MTH 255H or LBS 220) RB: (MTH 309 or MTH 314) R: Not open to students in the Mathematics major. Not open to students with credit in MTH 414.
Matrices and linear algebra. General linear systems of equations, least squares minimization techniques. Eigenvalues and eigenvectors, spectral decompositions, exponentials.

416 Introduction to Algebraic Coding
Fall. 3(3-0) P:M: (MTH 309)
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:M: (MTH 310)
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:M: Completion of Tier I writing requirement. RB: (MTH 309) R: Approval of department. Not open to students with credit in MTH 411.
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:M: (MTH 418H) R: Approval of department.
Algebraic field extensions, Galois theory. Classification of finite fields. Fundamental Theorem of Algebra.

421 Analysis II
Fall, Spring, Summer. 3(3-0) P:M: (MTH 320) Not open to students with credit in MTH 424 or MTH 429H.
Continuation of MTH 320. Euclidean spaces: differentiation and integration in higher dimensions. Convergence of sequences of functions.

424 Applied Advanced Calculus
Spring, Summer. 3(3-0) P:M: (MTH 235 or MTH 255H or LBS 220) R: Not open to students in the Department of Mathematics. Not open to students with credit in MTH 421 or MTH 429H.
Vector analysis for scientists and engineers. Inverse and implicit function theorems, divergence and curl, Stokes's theorem. Sequences and series, uniform convergence.

425 Complex Analysis
Fall, Spring. 3(3-0) P:M: (MTH 320)
Analytic functions of a complex variable, Cauchy integral theorem, conformal maps, bilinear transformation, harmonic functions. Classification of singularities, residues, conformal mappings.

428H Honors Analysis I
Fall. 3(3-0) R: Approval of department. Not open to students with credit in MTH 320.
Honors analysis with emphasis on metric topology, differentiation, and integration in higher dimensional settings. Convergence of sequences of functions.

429H Honors Analysis II
Spring. 3(3-0) P:M: (MTH 428H) R: Approval of department. Not open to students with credit in MTH 421 or MTH 424.
Continuation of MTH 428H. Convergence of sequences of functions, inverse and implicit function theorems, integration in higher dimensional settings.

432 Axiomatic Geometry
Spring. 3(3-0) P:M: (MTH 309)
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:M: (MTH 235 or MTH 255H or LBS 220 or MTH 340) and (MTH 309 or MTH 415 or MTH 314)
Existence and uniqueness theorems, linearization, stability theory, and phase space analysis.

442 Partial Differential Equations
Spring. 3(3-0) P:M: (MTH 235 or MTH 255H or LBS 220 or MTH 340)
Classification and canonical forms for second order partial differential equations. Well posed boundary and initial value problems for the wave equation, the heat equation and the Laplace equation.

443 Boundary Value Problems for Engineers
Fall. 3(3-0) P:M: (MTH 235 or MTH 255H or LBS 220) R: Not open to students in the Department of Mathematics.
Fourier series and orthogonal functions, method of separation of variables for partial differential equations, Sturm-Liouville problems.

451 Numerical Analysis I
Fall. 3(3-0) P:M: (CSE 131 or CSE 231) and (MTH 309 or MTH 314 or MTH 415) and (MTH 235 or MTH 255H or LBS 220 or MTH 340) 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 and computer programming.

452 Numerical Analysis II
Spring. 3(3-0) P:M: (MTH 451)
A continuation of MTH 451.

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

457 Introduction to Financial Mathematics
Spring. 3(3-0) P:M: (MTH 309) and (MTH 340 or MTH 235) 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 equation. Numerical methods for valuing derivatives.

461 Metric and Topological Spaces
Fall. 3(3-0) P:M: (MTH 320 or MTH 428H)
Set theory, metric spaces, topological spaces, maps, product and quotient topologies. Connected and compact spaces, separation axioms, pointwise and uniform convergence.

472 Mathematical Logic
Spring. 3(3-0) P:M: (MTH 234 or MTH 254H or LBS 220)
Logics and formal systems, syntax and semantics. Completeness and axiomatizability. Decidable and undecidable theories and Goedel's theorems. Peano arithmetic.

481 Discrete Mathematics I
Fall, Spring. 3(3-0) P:M: (MTH 309)
Binomial and multinomial theorems. Graphs and digraphs, graph coloring. Generating functions, asymptotic analysis, trees. Representing graphs in computers.

482 Discrete Mathematics II
Spring. 3(3-0) P:M: (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.

496 Capstone in Mathematics
Fall, Spring. 3(3-0) R: Completion of Tier I writing requirement. Approval of department.
A capstone course integrating several areas of mathematics.

801 Current Issues in Mathematics Education
Fall. 3(3-0) R: Approval of department.
Recent developments in K-16 mathematics curriculum, teaching, learning, and evaluation.

802A Critical Content of School Mathematics: Algebra and Analysis
Spring of odd years. 3(3-0) RB: (MTH 310 and MTH 320 and MTH 801)
Foundations and development, evolution and applications in the school curriculum. Connections among content areas. Learning and teaching mathematics.

802B Critical Content of School Mathematics: Geometry and Discrete Mathematics
Spring of even years. 3(3-0) RB: (MTH 330 and MTH 481 and MTH 801) R: Open only to graduate students.
Foundations and development, evolution and applications in the school curriculum. Connections among content areas. Learning and teaching mathematics.

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

818 Algebra I
Fall. 3(3-0) RB: (MTH 411)
Group theory: Sylow theory, permutation groups, Jordon-Hoelder 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 semisimple rings with the descending chain condition.

822 Calculus on Manifolds
Fall. 3(3-0) RB: (MTH 414 and MTH 421) SA: MTH 422
A modern treatment of differential and integral calculus on manifolds in Euclidean space. Differential forms, generalized Stokes' Theorem. Interaction among linear algebra, topology and analysis.

828 Real Analysis I
Fall. 3(3-0) RB: (MTH 421 and MTH 461)
Lebesgue measure on real line, general measure theory. Convergence theorems, Lusin's theorem, Egorov's theorem, Lp-spaces, Fubini's theorem. Functions 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 theorem, maximum modulus theorem. Cauchy formula, residue theorem, Rouche's theorem. Casorati-Weierstrass theorem, Arzela-Ascoli theorem. Conformal mapping, Schwarz lemma, Riemann mapping theorem.

840 Chaos and Dynamical Systems
Spring. 3(3-0) RB: (MTH 441 and MTH 320 and MTH 414) and some experience with mathematical software such as Mathematica or Matlab.
Chaotic or random motions in differential and difference equations.

841 Boundary Value Problems I
Fall. 3(3-0) RB: (MTH 414 and MTH 421)
Methods for solving boundary and initial value problems 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) and (MTH 421 and MTH 442)Some familiarity with mathematical software such as Mathematica, Matlab, etc. R: Open only to students in master's students in the Industrial Mathematics major or approval of department.
Fundamentals of mathematical modeling in government and industry, including modes of industrial communication.

844 Projects in Industrial Mathematics
Spring. 3(3-0) RB: (MTH 414 or MTH 415) and (MTH 421 and MTH 442 and MTH 843) and some familiarity with mathematical software such as Mathematica or Matlab. R: Open only to master's students in the Industrial Mathematics major or approval of department.
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.

848 Ordinary Differential Equations
Fall. 3(3-0) RB: (MTH 414 and MTH 421)
Existence and uniqueness theorems. Theory of linear differential equations. Floquet theory. Stability theory and Poincare-Bendixson theory. Green's functions and boundary value problems.

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 hyperbolic 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 methods in applied mathematics.

851 Numerical Analysis II
Spring. 3(3-0) RB: (MTH 850)
Interpolation theory and approximation of functions. Numerical solutions of nonlinear equations. Numerical integration methods.

852 Numerical Methods for Ordinary Differential Equations
Fall. 3(3-0) RB: (MTH 851)
Linear multi-step methods and single step nonlinear methods for initial value problems. Consistency, stability and convergence. Finite difference, finite element, shooting methods for boundary value problems.

864 Geometric Topology
Spring. 3(3-0) RB: (MTH 421) SA: MTH 464
Topology of surfaces and higher dimensional manifolds, studied from combinatorial, algebraic or differential viewpoints.

868 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. Homology theory, Differentiable manifolds, vector bundles, transversality, calculus on manifolds. Differential forms, tensor bundles, deRham theorem, Frobenius theorem.

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

870 Set Theory and Foundations of Mathematics
Spring. 3(3-0) RB: (MTH 411 or MTH 421)
Zermelo-Fraenkel axioms. Cardinals and ordinals and their arithmetics. Axiom of choice and maximal principles. Transfinite induction and recursion, consistency and independence.

880 Combinatorics
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
Spring. 3(3-0) RB: (MTH 880)
Graph theory, connectivity, algebraic and topological methods. Networks, graph algorithms, Hamiltonian and Eulerian graphs, extremal graph theory, random graphs.

890 Readings in Mathematics
Fall, Spring, Summer. 1 to 6 credits. 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.

903 Topics in Mathematics Education Research
Fall of odd years. 3(3-0) RB: (MTH 802A or MTH 802B)
Research in mathematics education and its effect on policy, curriculum, and the teaching and learning of mathematics.

910 Commutative Algebra I
Fall of odd years. 3(3-0) RB: (MTH 819)
Noetherian rings and modules, localization and tensor products, primary decomposition, Krull dimensions, graded rings and modules, Hilbert's Nullstellensatz, integral extensions, discrete valuation rings, Dedekind domains.

911 Commutative Algebra II
Spring of even years. 3(3-0) RB: (MTH 910)
Ext and Tor, regular sequences, Cohen-Macauley rings, regular rings, Gorenstein rings, completion, modules of differentials, Cohen's structure theorems.

912 Group Theory I
Fall of even years. 3(3-0) RB: (MTH 819)
Permutation groups, solvable and nilpotent groups, simple groups. Representation 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 theorems.

914 Lie Groups and Algebras I
Fall of odd years. 3(3-0) RB: (MTH 819)
Nilpotent and semisimple algebras, the adjoint representation, root spaces, Weyl groups, Dynkin diagrams, classification of simple algebras.

915 Lie Groups and Algebras II
Spring of even years. 3(3-0) RB: (MTH 914)
Weights, symmetric spaces, groups of Lie type, finite groups of Lie type, Lang's theorem.

916 Introduction to Algebraic Geometry I
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 II
Spring of odd years. 3(3-0) RB: (MTH 916)
Continuation of MTH 916.

920 Functional Analysis I
Spring. 3(3-0) RB: (MTH 828)
Hilbert spaces: Riesz representation theorem, Parseval's identity, Riesz-Fisher theorem, Fourier series operators. Banach spaces: Hahn-Banach theorem, open mapping and closed graph theorems, Banach-Steinhaus theorem.

921 Functional Analysis II
Fall of even years. 3(3-0) RB: (MTH 829 and MTH 920)
Topological vector spaces, convexity, Krein-Milman theorem, Banach algebras, operators on Banach spaces, spectral theorem, C*-algebras.

922 Harmonic Analysis
Fall of odd years. 3(3-0) RB: (MTH 829 and MTH 920)
Fourier series, mean and pointwise convergence, conjugate functions, Fourier transform, Plancherel theorem, Paley-Wiener theorem, interpolation of operators, Hausdorff-Young thoerem.

928 Real Analysis II
Fall. 3(3-0) RB: (MTH 828)
Positive Borel measure, complex measures. Riesz representation theorem, Radon-Nikodym theorem, Lebesgue decomposition theorem. Differentiable transformations and change of variables, differentiation of measures, maximal functions.

929 Complex Analysis II
Spring. 3(3-0) RB: (MTH 828 and MTH 829)
Phragmen-Lindelof method. Hadamard's theorem, Runge's thoerem, Weierstrass factorization theorem, Mittag-Leffler theorem, and Picard's theorem. Poisson integrals, Harnack's inequality, Dirichlet problem. Hp-spaces and Blaschke products.

930 Riemannian Geometry I
Fall. 3(3-0) RB: (MTH 869)
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 or submanifold theory.

931 Riemannian Geometry II
Spring. 3(3-0) RB: (MTH 930)
Continuation of MTH 930.

935 Complex Manifolds I
Fall of odd years. 3(3-0) RB: (MTH 829 and MTH 869)
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)
Continuation of MTH 935.

940 Applied Analysis I
Fall. 3(3-0) RB: (MTH 828)
Sobolev spaces, trace theorem, imbedding theorems, sectorial forms. Linear elliptic boundary and eigenvalue problems.

941 Applied Analysis II
Spring. 3(3-0) RB: (MTH 940)
Fixed point theorems. Variational methods. Applications to nonlinear integral and elliptic differential equations. Semigroup theory.

942 Foundations of Applied Mathematics I
Fall. 3(3-0) RB: (MTH 848 and MTH 849)
Modeling in classical applied mathematics. Newtonian and continuum mechanics. Special mathematical techniques.

943 Foundations of Applied Mathematics II
Spring. 3(3-0) RB: (MTH 942)
Continuation of MTH 942.

950 Numerical Methods for Partial Differential Equations I
Spring of odd years. 3(3-0) RB: (MTH 852)
Finite difference methods for ordinary and partial differential equations.

960 Algebraic Topology I
Fall. 3(3-0) RB: (MTH 869)
Cohomology, products, duality, basic homotopy theory, bundles, obstruction theory, spectral sequences, characteristic classes, and other related topics.

961 Algebraic Topology II
Spring. 3(3-0) RB: (MTH 960)
Continuation of MTH 960.

990 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.

991 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.

992 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.

993 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.

994 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.

995 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.

996 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.

997 Special Topics in Mathematics Education
Fall, Spring, Summer. 3 to 6 credits. A student may earn a maximum of 18 credits in all enrollments for this course. RB: (MTH 903 or TE 950 or CEP 913)
Advanced topics in mathematics education.

998 Special Topics in Combinatorics and Graph Theory
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 combinatorics and graph theory.

999 Doctoral Dissertation Research
Fall, Spring, Summer. 1 to 24 credits. A student may earn a maximum of 120 credits in all enrollments for this course. R: Approval of department.
Doctoral dissertation research.