

## MARKETING AND TRANSPORTATION ADMINISTRATION

- 881\*.** **Professional Development Seminar**  
Fall. 1(1-0)  
R: Masters Business Approval of Department  
Development of strategic direction to students' professional careers. Professional managerial skills enhancement via participating in a dialogue and learning activities with expert consultants in the field and with industry executives.
- 890\*.** **Special Problems**  
Fall, Spring, Summer. 1 to 3 credits.  
May reenroll for a maximum of 6 credits.  
P: MTA 805 R: Graduate Business Approval of department  
An individually designed course to meet the needs of graduate students in marketing and transportation.  
QP: MTA 805 QA: MTA 890
- 905\*.** **Theory Development & Research Design in Marketing**  
Fall. 3(3-0)  
R: Doctoral  
Research concepts and scientific methods for the study of marketing. Design & research, formulation of hypotheses, concepts of measurements, and use of quantitative methods.  
QA: MTA 905
- 906\*.** **Quantitative Methods in Marketing**  
Spring. 3(3-0)  
P: MTA 905 or approval of department  
R: Doctoral  
Advanced concepts and quantitative methods in the scientific investigation of marketing phenomena. Focuses on the use of multivariate analytic tools.  
QP: MTA 905 QA: MTA 906
- 907\*.** **Causal Modelling in Marketing**  
Fall. 3(3-0)  
P: MTA 906 R: Doctoral  
Lecture and discussion of advanced quantitative statistical methods in marketing. Substantial emphasis on causal modelling.  
QP: MTA 906 QA: MTA 907
- 908\*.** **Marketing Decision Models**  
Fall. 3(3-0)  
P: MTA 906 R: Doctoral  
Marketing models for decision-making purposes. Focuses on applications in new product development, pricing, distribution, advertising, and sales promotion.  
QP: MTA 906 QA: MTA 908
- 920\*.** **History of Marketing Thought**  
Fall. 3(3-0)  
P: MTA 805 or equivalent R: Ph.D. Business  
Traces the evolution of marketing institutions, techniques, theories and criticisms. The influence of changing environmental and technological factors in marketing practice and thought.  
QP: MTA 805 QA: MTA 920
- 921\*.** **Theories of Competition in Marketing**  
Spring. 3(3-0)  
P: MTA 920 R: Doctoral Business  
Examine the relationships among competition, marketing, and corporate and economic growth. Competition phenomena are studied through a variety of disciplines, including marketing, economics, political science, and sociology and social psychology.  
QP: MTA 920 QA: MTA 921
- 922\*.** **Seminar in Social Sciences in Marketing**  
Spring. 3(3-0)  
P: MTA 906 or concurrent R: Ph.D. Business  
Application of social science topics in marketing.  
QP: MTA 906 QA: MTA 922
- 923\*.** **Seminar in Spatial/Temporal Marketing**  
Spring. 3(3-0)  
P: MTA 920 R: Ph.D. Business  
Examines the current state of theory concerning the planning and implementation of marketing strategies and programs in logistics, channels, and pricing to identify future research requirements.  
QP: MTA 920 QA: MTA 923
- 924\*.** **Special Topics Seminar**  
Fall, Spring. 3 to 3 credits in increments of 3 credits. May reenroll for a maximum of 6 credits.  
R: Ph.D. Business  
To allow doctoral students to pursue directed reading and research on an issue of interest in Marketing.  
QP: MTA 921 QA: MTA 924
- 930\*.** **Theory of Transportation-Distribution Systems**  
Fall of odd-numbered years. 3(3-0)  
P: MTA 805 or equivalent R: Ph.D. Business  
The micro-level course in transportation-distribution research which examines system integration. Develops the relevant elements of networks, systems and economic theory with empirical design. Applications to the design, evaluation, and control of log  
QP: MTA 809 QA: MTA 930
- 931\*.** **Transportation/Distribution Research Methods**  
Spring of odd-numbered years. 3(3-0)  
P: MTA 930 R: Ph.D. Business  
Research methodology in the design and administration of transportation and distribution systems. Emphasis on techniques and methodology for conducting system design, customer service and policy studies.  
QP: MTA 930 QA: MTA 931
- 932\*.** **Transportation & Distribution Development Policy**  
Fall of even-numbered years. 3(3-0)  
P: MTA 805 or equivalent R: Ph.D. Business  
The macro-level research and theory course in Transportation Distribution. The interaction of government, carrier, and user logistics and distribution strategies, particularly at the macro-corporate and national policy levels.  
QP: MTA 931 QA: MTA 932
- 940\*.** **International Business Theory**  
Fall of even-numbered years. 3(3-0)  
P: MTA 860 or MTA 862 R: Ph.D. candidate  
Comprehensive review and evaluation of theories explaining International Business phenomena. Varying perspectives on International Business activities, concepts, and frameworks.  
QP: MTA 860 OR MTA 862
- 941\*.** **International Business Research Issues**  
Spring of odd-numbered years. 3(3-0)  
P: MTA 940 R: Ph.D.  
Perspectives on application of scientific method of international business research. Research design, measurement, data analysis and interpretation. Evolution of research in International Business  
QP: MTA 862 QA: MTA 863
- 945\*.** **Directed Research Paper**  
Fall, Spring, Summer. 1(1-0)  
P: MTA 921 R: Doctoral Business MTA  
In this course a MTA Doctoral Student will write a publishable research paper under the direction of a senior faculty member.  
QP: MTA 921
- 999\*.** **Doctoral Dissertation Research**  
. 1 to 24 credits. May reenroll for a maximum of 99 credits.  
R: Ph.D. Approval of Department  
QA: MTA 999

## MATHEMATICS

## MTH

- 0823.** **Intermediate Algebra**  
Fall, Spring, Summer. 0(4-0)  
R: Designated score on mathematics placement test.  
Properties of real numbers. Factoring. Roots and radicals. First and second degree equations. Linear inequalities. Polynomials. Systems of equations.  
QA: MTH 082 / 1043
- 110.** **College Algebra and Finite Mathematics**  
Fall, Spring, Summer. 5(5-0)  
P: MTH 0823 or designated score on mathematics placement test. R: Not open to students with credit in MTH 116 or MTH 120.  
Functions and graphs. Equations and inequalities. Systems of equations. Matrices. Linear programming. Simplex algorithm. Probability.  
QP: MTH 108 QA: MTH 110
- 116.** **College Algebra and Trigonometry**  
Fall, Spring, Summer. 5(5-0)  
P: MTH 0823 or designated score on mathematics placement test. R: Not open to students with credit in MTH 110 or MTH 120.  
Functions and graphs. Equations and inequalities. Exponential and logarithmic functions. Trigonometric functions. Systems of equations. Binomial theorem.  
QP: MTH 108 QA: MTH 111 MTH 109 MTH 108
- 120.** **Algebra and a Survey of Calculus**  
Fall, Spring, Summer. 5(5-0)  
P: MTH 0823 or designated score on mathematics placement test. R: Not open to students with credit in MTH 110 or MTH 116 or MTH 120.  
Functions and graphs. Equations and inequalities. Systems of equations. Limits. Continuous functions. Derivatives. Applications of derivatives. Integrals. Fundamental theorem of calculus.
- 124.** **Survey of Calculus with Applications I**  
Fall, Spring, Summer. 3(3-0)  
P: Designated score on mathematics placement test. R: Not open to students with credit in MTH 120 or MTH 132 or MTH 152H.  
Study of limits, continuous functions, derivatives, integrals and their applications.  
QP: MTH 108 ORMTH 111
- 126.** **Survey of Calculus with Applications II**  
Fall, Spring, Summer. 3(3-0)  
P: MTH 120 or MTH 124. R: Not open to students with credit in MTH 133 or MTH 153H.  
Application of partial derivatives, integrals, optimization of functions of several variables and infinite series
- 132.** **Calculus I**  
Fall, Spring, Summer. 3(3-0)  
P: MTH 116 or designated score on mathematics placement test. R: Not open to students with credit in MTH 120 or MTH 124 or MTH 152H.  
Limits, continuous functions, derivatives and their applications. Integrals and the fundamental theorem of calculus.  
QP: MTH 109 ORMTH 111 QA: MTH 112 MTH 122

MATHEMATICS

- 133\*.** **Calculus II**  
 Fall, Spring, Summer. 4(4-0)  
 P: MTH 132 or MTH 152H. R: Not open to students with credit in MTH 126 or MTH 153H. Applications of the integral and methods of integration. Improper integrals. Polar coordinates and parametric curves.  
 QA: MTH 113 MTH 123
- 152H.** **Honors Calculus I**  
 Fall. 3(3-0)  
 P: Honors College student. R: Honors College student. Not open to students with credit in MTH 120 or MTH 124 or MTH 132. Limits, continuous functions, derivatives, integrals, fundamental theorem of calculus. Special emphasis on concepts and theory.  
 QA: MTH 112
- 153H.** **Honors Calculus II**  
 Spring. 3(3-0)  
 P: MTH 152H. R: Honors College student. Not open to students with credit in MTH 126 OR MTH 133. The integral. Improper integrals. Polar coordinates and parametric curves. Special emphasis on concepts and theory.  
 QA: MTH 113
- 234.** **Multivariable Calculus I**  
 Fall, Spring, Summer. 4(4-0)  
 P: MTH 133. R: Not open to students with credit in MTH 254H. Infinite Series. Vectors in space. Functions of several variables and partial derivatives.  
 QA: MTH 214
- 235.** **Multivariable Calculus II and Differential Equations**  
 Fall, Spring, Summer. 3(3-0)  
 P: MTH 234. R: Not open to students with credit in MTH 255H. Multiple integrals. Vector analysis. Green's Theorem. Systems of ordinary differential equations.  
 QA: MTH 215 MTH 310
- 254H.** **Honors Multivariable Calculus I**  
 Fall. 3(3-0)  
 P: MTH 153H. R: Honors College student. Not open to students with credit in MTH 234. Infinite series, vectors in space, partial derivatives.  
 QA: MTH 214
- 255H.** **Honors Multivariable Calculus II and Differential Equations**  
 Spring. 3(3-0)  
 P: MTH 254H. R: Honors College student. Not open to students with credit in MTH 235. Multiple integrals. Vector analysis. Green's Theorem. Ordinary differential equations.  
 QA: MTH 215 MTH 310
- 310\*.** **Abstract Algebra I and Number Theory**  
 Fall, Spring, Summer. 3(03-0)  
 P: MTH 133 or MTH 153H. A writing course with an emphasis on proofs. Structure of the integers, congruences, polynomial rings, ideals and fields.  
 QP: MTH 214 QA: MTH 337
- 314\*.** **Linear Algebra I**  
 Fall, Spring, Summer. 3(03-0)  
 P: MTH 234 or MTH 254H. Vectors, matrices, and linear transformations. Operations on matrices, inner products, dimension, eigenvalues and eigenvectors. Applications to systems of equations and to geometry.  
 QP: MTH 214 QA: MTH 334
- 320\*.** **Analysis I**  
 Fall, Spring, Summer. 3(03-0)  
 P: MTH 234 or MTH 254H; MTH 310. R: Not open to students with credit in MTH 424. Convergence of sequences and series. Upper and lower limits, completeness, limits and continuity. Derivatives, integrals. Fundamental Theorem of Calculus.  
 QP: MTH 324 QA: MTH 424 MTH 427

- 330\*.** **Higher Geometry**  
 Fall. 3(03-0)  
 P: MTH 310. 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.  
 QP: MTH 215 QA: MTH 316
- 351\*.** **Elements of Numerical Analysis**  
 Fall. 3(03-0)  
 P: MTH 235 or 255 R: Not for Mathematics majors. Techniques and elementary theory of numerical analysis for engineering and science students.  
 QP: MTH 310 QA: MTH 351
- 411\*.** **Abstract Algebra II**  
 Fall, Spring. 3(03-0)  
 P: MTH 310. R: 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.  
 QP: MTH 215 QA: MTH 432 MTH 433
- 412\*.** **Topics in Algebra**  
 Spring. 3(03-0)  
 P: MTH 411. R: Not open to students with credit in MTH 419H. A capstone course. Sylow theory, solvable groups, permutation groups. Extension fields, Galois groups, the classification of finite fields, constructibility. Applications to classical geometry and polynomial equations.  
 QP: MTH 432
- 414\*.** **Linear Algebra II**  
 Fall, Spring. 3(03-0)  
 P: MTH 310, MTH 314. R: 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.  
 QP: MTH 334 QA: MTH 335
- 415\*.** **Applied Linear Algebra**  
 Fall, Spring. 3(3-0)  
 P: MTH 314. R: 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.  
 QP: MTH 334 QA: MTH 335
- 416\*.** **Introduction to Algebraic Coding**  
 Spring. 3(03-0)  
 P: MTH 314. 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.  
 QP: MTH 334 QA: MTH 430
- 417\*.** **Topics in Number Theory**  
 Spring of odd-numbered years. 3(03-0)  
 P: MTH 310. Congruences of higher degree, primitive roots and quadratic reciprocity. Number-theoretic functions, algebraic numbers. Dirichlet Series, p-order expansion, continued fractions.  
 QP: MTH 331 QA: MTH 437
- 418H\*.** **Honors Algebra I**  
 Fall. 3(3-0)  
 P: MTH 310. R: 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.  
 QP: MTH 215 QA: MTH 432 MTH 433

- 419H\*.** **Honors Algebra II**  
 Spring. 3(3-0)  
 P: MTH 418H. R: Not open to students with credit in MTH 412. Algebraic field extensions, Galois theory. Classification of finite fields. Fundamental Theorem of Algebra.  
 QA: MTH 433 MTH 434
- 421\*.** **Analysis II**  
 Fall, Spring, Summer. 3(03-0)  
 P: MTH 320. R: Not open to students with credit in MTH 424 or MTH 428. Continuation of MTH 320. Euclidean spaces: differentiation and integration in higher dimensions. Convergence of sequences of functions.  
 QP: MTH 424 QA: MTH 425
- 422\*.** **Analysis on Manifolds**  
 Spring. 3(3-0)  
 P: MTH 314, MTH 421. A capstone course. A modern treatment of differential and integral calculus on manifolds in Euclidean space. Differential forms, generalized Stokes's Theorem. Interaction among linear algebra, topology, and analysis.  
 QP: MTH 334 ANDMTH 429ORMTH 426
- 424\*.** **Applied Advanced Calculus**  
 Spring, Summer. 3(3-0)  
 P: MTH 314; MTH 235 or 255H. R: Not open to students with credit in MTH 421 or MTH 428. Vector analysis for scientists and engineers. Inverse and implicit function theorems, divergence and curl, Stokes's theorem. Sequences and series, uniform convergence.  
 QP: MTH 334 QA: MTH 421
- 425\*.** **Complex Analysis**  
 Fall, Spring. 3(3-0)  
 P: MTH 320. Analytic functions of a complex variable: Cauchy integral theorem, conformal maps, bilinear transformation, harmonic functions. Classification of singularities, residues, conformal mappings.  
 QP: MTH 424 QA: MTH 423
- 428H\*.** **Honors Analysis I**  
 Fall, Spring. 3(3-0)  
 R: Honors College students or approval of department. Not open to students with credit in MTH 421. Honors analysis with emphasis on metric topology, differentiation, and integration in higher dimensional settings. Convergence of sequences of functions.  
 QA: MTH 427 MTH 428
- 429H\*.** **Honors Analysis II**  
 Spring. 3(03-0)  
 P: MTH 428H. R: Not open to students with credit in MTH 422. Continuation of MTH 428H. Convergence of sequences of functions, inverse and implicit function theorems, integration in higher dimensional settings.  
 QP: MTH 428 QA: MTH 428 MTH 429
- 432\*.** **Axiomatic Geometry**  
 Spring. 3(3-0)  
 P: MTH 310. 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.  
 QP: MTH 214 QA: MTH 315
- 434\*.** **Differential Geometry**  
 Fall. 3(3-0)  
 P: MTH 310; MTH 314; MTH 235 or MTH 255H. Curves and surfaces in Euclidean space. Curvature of curves on a surface. First and second fundamental forms. Geodesics, parallel transport, Gaussian and mean curvatures, special surfaces. Gauss-Bonnet theorem, other global results.  
 QP: MTH 215 MTH 334 QA: MTH 414

## MATHEMATICS

- 441\*.** **Ordinary Differential Equations**  
Fall. 3(03-0)  
P: MTH 314, MTH 320.  
Existence and uniqueness theorems, linearization, stability theory, and phase space analysis.  
QP: MTH 334 MTH 424 QA: MTH 420
- 442\*.** **Partial Differential Equations**  
Fall. 3(3-0)  
P: MTH 320.  
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.  
QP: MTH 424
- 443\*.** **Boundary Value Problems for Engineers**  
Fall. 3(03-0)  
P: MTH 235 or MTH 255H.  
Fourier series and orthogonal functions, method of separation of variables for partial differential equations, Sturm-Liouville problems.  
QP: MTH 310 QA: MTH 422
- 451\*.** **Numerical Analysis I**  
Fall. 3(3-0)  
P: CPS 130 or CPS 131 or CPS 230; MTH 314; MTH 320 or MTH 424.  
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.  
QP: MTH 424 QA: MTH 451
- 452\*.** **Numerical Analysis II**  
Spring. 3(3-0)  
P: MTH 451.  
A continuation of MTH 451.  
QP: MTH 451 QA: MTH 452
- 461\*.** **Metric and Topological Spaces**  
Fall. 3(3-0)  
P: MTH 421.  
Set theory, metric spaces, topological spaces, maps, product and quotient topologies. Connected and compact spaces, separation axioms, pointwise and uniform convergence.  
QP: MTH 426 QA: MTH 461
- 464\*.** **Geometric Topology**  
Spring. 3(03-0)  
P: MTH 421.  
A capstone course. Topology of surfaces and higher dimensional manifolds, studied from combinatorial, algebraic or differential viewpoints.  
QP: MTH 426 MTH 461
- 471\*.** **Computational Complexity**  
Fall. 3(3-0)  
P: MTH 310.  
Partially computable and computable functions. Primitive recursive functions and the loop complexity classification. Godel numbering and unsolvable problems. The P and NP classification of solvable problems.  
QP: MTH 334 QA: MTH 470
- 472\*.** **Mathematical Logic**  
Spring. 3(03-0)  
P: MTH 310.  
Logics and formal systems, syntax and semantics. Completeness and axiomatizability. Decidable and undecidable theories and Goedel's theorems. Peano arithmetic.  
QP: MTH 215 QA: MTH 471
- 481\*.** **Discrete Mathematics I**  
Fall, Spring. 3(03-0)  
P: MTH 310.  
Binomial and multinomial theorems. Graphs and digraphs, graph coloring. Generating functions, asymptotic analysis, trees. Representing graphs in computers.  
QP: MTH 215 QA: MTH 382 MTH 383
- 482\*.** **Discrete Mathematics II**  
Spring. 3(03-0)  
P: MTH 481.  
Recurrence and generating functions, Ramsey theory. Block designs, Latin squares, Eulerian and Hamiltonian paths. Minimum spanning trees, network flows.  
QA: MTH 383 MTH 484
- 490\*.** **Directed Studies**  
Fall, Spring, Summer. 1 to 4 credits.  
May reenroll for a maximum of 9 credits.  
R: Approval of department.  
Faculty directed study in a selected mathematical topic.  
QA: MTH 490
- 496\*.** **Capstone in Mathematics**  
Fall, Spring. 3(03-0)  
R: Approval of department.  
A capstone course integrating several areas of mathematics.
- 801\*.** **Current Issues in Mathematics Education**  
Fall. 3(03-0)  
P: Approval of Department.  
Recent developments in K-16 mathematics curriculum, teaching, learning, and evaluation.  
QA: MTH 801 MTH 802
- 802A\*.** **Critical Content of School Mathematics: Algebra and Analysis**  
Spring of odd-numbered years. 3(03-0)  
P: MTH 801, 310, and 320  
Examination of school algebra and analysis. Foundations and development, evolution and applications in the school curriculum, connections among content areas, and the learning and teaching of mathematics.  
QA: MTH 802 MTH 803
- 802B\*.** **Critical Content of School Mathematics: Geometry and Discrete Mathematics**  
Spring of even-numbered years. 3(03-0)  
P: MTH 801, MTH 330, and MTH 481  
R: Graduate  
Examination of school geometry and discrete mathematics. Foundations and development, evolution and applications in the school curriculum, connections among content areas, and the learning and teaching of mathematics.  
QA: MTH 802 MTH 803
- 803\*.** **Recent Research in Mathematics Education**  
Spring of odd-numbered years. 3(03-0)  
P: MTH 802A or MTH 802B R: Graduate  
Research in mathematics education and its effect on policy, curriculum, and the teaching and learning of mathematics.  
QP: MTH 803
- 810\*.** **Error-Correcting Codes**  
Spring. 3(03-0)  
P: 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, alternant and Goppa codes, cyclic codes and BCH codes.  
QP: MTH 335 MTH 434 QA: MTH 830
- 818\*.** **Algebra I**  
Fall. 3(03-0)  
P: MTH 411  
Group theory: Sylow theory, permutation groups, Jordan-Hoelder theory, Abelian groups, free groups. Ring theory: algebra of ideals, unique factorization, polynomial rings, finitely generated modules over PIDs.  
QP: MTH 434 QA: MTH 834 MTH 835
- 819\*.** **Algebra II**  
Spring. 3(03-0)  
P: MTH 418  
Modules and vector spaces, projective modules, tensor algebra, fields and Galois groups, algebraic and transcendental numbers, non-commutative rings, the Jacobson radical, the structure of semisimple rings with the dec.  
QP: MTH 834 QA: MTH 835 MTH 836
- 828\*.** **Real Analysis I**  
Fall. 3(03-00)  
P: MTH 421, 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.  
QP: MTH 426 QA: MTH 824 MTH 825
- 829\*.** **Complex Analysis I**  
Spring. 3(03-0)  
P: MTH 421, MTH 425  
Cauchy theorem, identity principle, Liouville's theorem, maximum modulus theorem, Cauchy formula, residue theorem, Rouché's theorem, Casorati-Weierstrass theorem, Arzela-Ascoli theorem. Conformal mapping, Schwarz lemma, Riemann mapping theorem.  
QP: MTH 426 QA: MTH 826
- 841\*.** **Boundary Value Problems I**  
Fall. 3(03-0)  
P: MTH 414, MTH 421  
Methods for solving boundary and initial value problems for ordinary and partial differential equations.  
QP: MTH 335 MTH 426 QA: MTH 841, MTH 842
- 842\*.** **Boundary Value Problems II**  
Spring. 3(03-0)  
P: MTH 841.  
Continuation of MTH 841.  
QP: MTH 841 QA: MTH 842 MTH 843
- 848\*.** **Ordinary Differential Equations**  
Fall. 3(03-0)  
P: MTH 414, 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.  
QP: MTH 426 QA: MTH 848 MTH 849
- 849\*.** **Partial Differential Equations**  
Spring. 3(03-0)  
P: MTH 414, 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.  
QP: MTH 426 QA: MTH 886 MTH 887
- 850\*.** **Numerical Analysis I**  
Fall. 3(03-0)  
P: MTH 414, MTH 421  
Convergence and error analysis of numerical methods in applied mathematics.  
QP: MTH 335 MTH 426 QA: MTH 851 MTH 852
- 851\*.** **Numerical Analysis II**  
Spring. 3(03-0)  
P: MTH 850  
Numerical methods for differential equations based on their discretizations. Introduction to stability and convergence.  
QP: MTH 851 QA: MTH 850 MTH 857

MATHEMATICS

- 868\*.** **Geometry and Topology I**  
Fall. 3(03-0)  
P: MTH 422  
Fundamental group and covering spaces, van Kampen's theorem, differentiable manifolds, vector bundles, transversality, calculus on manifolds, differential forms, tensor bundles, deRham theorem, Frobenius theorem.  
QP: MTH 426
- 869\*.** **Geometry and Topology II**  
Spring. 3(03-0)  
P: MTH 868  
Continuation of 868.
- 870\*.** **Set Theory and Foundations of Mathematics**  
Spring. 3(03-0)  
P: 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.  
QP: MTH 335 MTH 426 QA: MTH 800
- 880\*.** **Combinatorics**  
Fall. 3(03-0)  
P: MTH 411 or MTH 482  
Enumerative combinatorics, recurrence relations, generating functions, asymptotics, applications to graphs, partially ordered sets, generalized Moebius inversions, combinatorial algorithms.  
QP: MTH 434 QA: MTH 817
- 881\*.** **Graph Theory**  
Spring. 3(03-00)  
P: MTH 880  
Fundamental concepts of graph theory, connectivity, algebraic and topological methods, networks, graph algorithms, Hamiltonian and Eulerian graphs, extremal graph theory, random graphs.  
QP: MTH 817 QA: MTH 818
- 890\*.** **Readings in Mathematics**  
Fall, Spring, Summer. 1 to 3 credits.  
May reenroll for a maximum of 12 credits.  
P: Approval of Department  
Individualized study for Master's level students.  
QA: MTH 890
- 910\*.** **Commutative Algebra I**  
Fall of odd-numbered years. 3(03-00)  
P: 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.  
QP: MTH 836
- 911\*.** **Commutative Algebra II**  
Spring of even-numbered years.  
3(03-0)  
P: MTH 910  
Ext and Tor, regular sequences, Cohen-Macaulay rings, regular rings, Gorenstein rings, completion, modules of differentials, Cohen's structure theorems.
- 912\*.** **Group Theory I**  
Fall of even-numbered years. 3(03-0)  
P: MTH 819  
Permutation groups, solvable and nilpotent groups, simple groups. Representation and character theory. Extension theory and cohomology groups.  
QP: MTH836 QA: MTH934 MTH935
- 913\*.** **Group Theory II**  
Spring of odd-numbered years.  
3(03-00)  
P: MTH 912  
Groups of Lie type, linear groups, locally finite groups, free groups and free products, the subgroup theorems.  
QP: MTH 934 QA: MTH 935 MTH 936
- 914\*.** **Lie Groups and Algebras I**  
Fall of odd-numbered years. 3(03-00)  
P: MTH 819  
Nilpotent and semisimple algebras, the adjoint representation, root spaces, Weyl groups, Dynkin diagrams, classification of simple algebras.  
QP: MTH 836
- 915\*.** **Lie Groups and Algebras II**  
Spring of even-numbered years.  
3(03-00)  
P: MTH 914  
Weights, symmetric spaces, groups of Lie type, finite groups of Lie type, Lang's theorem.
- 920\*.** **Functional Analysis I**  
Fall. 3(03-0)  
P: 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.  
QP: MTH 825 QA: MTH 924 MTH 925
- 921\*.** **Functional Analysis II**  
Spring. 3(03-0)  
P: MTH 829, MTH 920  
Topological vector spaces, convexity, Krein-Milman theorem, Banach algebras, operators on Banach spaces, spectral theorem,  $C^*$ -algebras  
QP: MTH 924 QA: MTH 925 MTH 926
- 922\*.** **Harmonic Analysis**  
Spring. 3(03-0)  
P: MTH 829, MTH 920  
Fourier series, mean and pointwise convergence, conjugate functions, Fourier transform, Plancherel theorem, Paley-Wiener theorem, interpolation of operators, Hausdorff-Young theorem.  
QP: MTH 924 QA: MTH 920 MTH 928
- 928\*.** **Real Analysis II**  
Fall. 3(03-0)  
P: MTH 828 C: MTH 920  
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.  
QP: MTH 924
- 929\*.** **Complex Analysis II**  
Spring. 3(03-0)  
P: MTH 828, 829  
Phragmen-Lindelof method. Hadamard's theorem, Runge's theorem, Weierstrass factorization theorem, Mittag-Leffler theorem, and Picard's theorem. Poisson integrals, Harnack's inequality, Dirichlet problem. Hp-spaces and Blaschke products.  
QP: MTH 826
- 930\*.** **Riemannian Geometry I**  
Fall. 3(03-0)  
P: 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.  
QP: MTH 861 QA: MTH 814A MTH 814B
- 931\*.** **Riemannian Geometry II**  
Spring. 3(03-0)  
P: MTH 930  
Continuation of MTH 930.  
QA: MTH 814B MTH 814C
- 935\*.** **Complex Manifolds I**  
Fall of odd-numbered years. 3(03-0)  
P: MTH 869, MTH 829  
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.  
QP: MTH 826 MTH 861
- 936\*.** **Complex Manifolds II**  
Spring of even-numbered years.  
3(03-0)  
P: MTH 935  
Continuation of MTH 935.
- 940\*.** **Applied Analysis I**  
Fall. 3(03-0)  
P: MTH 848, MTH 849 C: MTH 920  
Sobolev spaces, trace theorem, imbedding theorems, sectorial forms. Linear elliptic boundary and eigenvalue problems.  
QA: MTH 844 MTH 845
- 941\*.** **Applied Analysis II**  
Spring. 3(03-0)  
P: MTH 940  
Fixed point theorems. Variational methods. Applications to nonlinear integral and elliptic differential equations. Semigroup theory.  
QP: MTH 844 QA: MTH 845 MTH 846
- 942\*.** **Foundations of Applied Mathematics I**  
Fall. 3(03-0)  
P: MTH 848, MTH 849  
Modeling in classical applied mathematics. Newtonian and continuum mechanics. Special mathematical techniques.  
QP: MTH 847 MTH 886 QA: MTH 881 MTH 882
- 943\*.** **Foundations of Applied Mathematics II**  
Spring. 3(03-0)  
P: MTH 942  
Continuation of MTH 942.  
QP: MTH 881 QA: MTH 882 MTH 883
- 950\*.** **Advanced Numerical Analysis I**  
Fall. 3(03-0)  
P: MTH 851, MTH 849  
Finite difference methods for ordinary and partial differential equations.  
QP: MTH 853 QA: MTH 850 MTH 858
- 951\*.** **Advanced Numerical Analysis II**  
Spring. 3(03-0)  
P: MTH 950  
Finite element methods for ordinary and partial differential equations.  
QP: MTH 858 QA: MTH 859
- 960\*.** **Algebraic Topology I**  
Fall. 3(03-0)  
P: MTH 869  
Homology, cohomology, products, orientation, and duality. Thom isomorphism homology. Hurewicz isomorphism theorem.  
QP: MTH 863 QA: MTH 964 MTH 965
- 961\*.** **Algebraic Topology II**  
Spring. 3(03-0)  
P: MTH 960  
Continuation of MTH 960.  
QA: MTH 965 MTH 966
- 990\*.** **Reading in Mathematics**  
Fall, Spring, Summer. 1 to 3 credits.  
May reenroll for a maximum of 8 credits.  
P: Approval of department  
Individualized study for Doctoral level students.

**MATHEMATICS**

- 991\*.** *Special Topics in Algebra*  
Fall, Spring. 3 to 6 credits in increments of 3 credits. May reenroll for a maximum of 18 credits.  
P: Approval of department  
Advanced topics in algebra.  
QA: MTH 993
- 992\*.** *Special Topics in Analysis*  
Fall, Spring. 3 to 6 credits in increments of 3 credits. May reenroll for a maximum of 18 credits.  
P: Approval of department  
Advanced topics in analysis.  
QA: MTH 992
- 993\*.** *Special Topics in Geometry*  
Fall, Spring. 3 to 6 credits in increments of 3 credits. May reenroll for a maximum of 18 credits.  
P: Approval of department  
Advanced topics in Geometry.  
QA: MTH 991
- 994\*.** *Special Topics in Applied Mathematics*  
Fall, Spring. 3 to 6 credits in increments of 3 credits. May reenroll for a maximum of 18 credits.  
P: Approval of department  
Advanced topics in Applied Mathematics.  
QA: MTH 994
- 995\*.** *Special Topics in Numerical Analysis and Operations Research*  
Fall, Spring. 3 to 6 credits in increments of 3 credits. May reenroll for a maximum of 18 credits.  
P: Approval of department  
Advanced topics in numerical analysis or operations research.
- 996\*.** *Special Topics in Topology*  
Fall, Spring. 3 to 6 credits in increments of 3 credits. May reenroll for a maximum of 18 credits.  
P: Approval of department  
Advanced topics in topology.
- 998\*.** *Special Topics in Combinatorics and Graph Theory*  
Fall, Spring. 3 to 6 credits in increments of 3 credits. May reenroll for a maximum of 18 credits.  
P: Approval of department  
Advanced topics in combinatorics and graph theory.
- 999\*.** *Doctoral Dissertation Research*  
Fall, Spring, Summer. 1 to 9 credits. May reenroll for a maximum of 99 credits.  
P: Approval of department R: Mathematics  
QA: MTH 999

**MECHANICAL ENGINEERING**

- 201.** *Thermodynamics*  
Fall, Spring. 3(3-0)  
P: CEM 141, MTH 234 or concurrently.  
R: Not open to students with credit in CHE 311 or MMM 351.  
Basic concepts of thermodynamics. Property evaluation of ideal gases and incompressible substances. Theory and application of the first and second laws of thermodynamics. Entropy and Carnot efficiency.  
QP: MTH 215 CEM 141 QA: ME 311

- 332\*.** *Fluid Mechanics*  
Fall, Spring. 4(3-3)  
P: MMM 306; CHE 311 or ME 201 or MMM 351; ME 391 or concurrently. R: Open only to Mechanical Engineering and Mechanics students.  
Statics, control volume equations, similitude, exact fluid solutions. Turbulence, pipe flow, boundary layer flow, external flow.  
QP: ME 311 MMM 306 ME 351 QA: ME 332
- 371\*.** *Mechanical Design I*  
Fall, Spring. 3(3-0)  
P: MMM 306 or concurrently. R: Open only to Mechanical Engineering and Mechanics majors.  
Analysis of displacement, velocity and acceleration in mechanical linkages. Kinematics and dynamics of machines.  
QP: MMM 306 QA: ME 320
- 410\*.** *Heat Transfer*  
Fall, Spring. 3(3-0)  
P: ME 332. R: Open only to Mechanical Engineering and Mechanics majors.  
Steady state and transient heat conduction. Natural and forced convection based on boundary layer theory. Application of Nusselt number correlations. Radiant heat transfer principles and applications including radiation networks.  
QP: ME 332 QA: ME 411
- 411\*.** *Applied Thermal Science*  
Fall, Spring. 3(3-0)  
P: ME 410 or concurrently. R: Open only to Mechanical Engineering majors.  
Thermodynamic principles as applied to gas and vapor power and refrigeration cycles for reciprocating and turbo machinery. Combustion. Analysis and design of heat exchangers. Numerical analysis of heat conduction.  
QP: ME 411 QA: ME 312
- 412\*.** *Heat Transfer Laboratory*  
Fall, Spring. 1(1-2)  
P: ME 411 or concurrently. R: Open only to Mechanical Engineering majors.  
Practices and measurement techniques for heat transfer and thermal systems. Experimental problem solving applied to heat transfer.  
QP: ME 312 ME 411 QA: ME 413
- 415\*.** *Solar Energy Conversion*  
Spring. 3(3-0)  
P: ME 410. R: Open only to Mechanical Engineering majors.  
Solar radiation: terrestrial diffuse and direct-beam insolation. Flat-plate and focusing collectors. Energy storage systems. Solar-assisted heat pumps. Photovoltaic, biomass and wind energy conversions.  
QP: ME 411 QA: ME 415
- 416\*.** *Computer Assisted Design of Thermal Systems*  
Fall. 3(4-0)  
P: ME 411. R: Open only to Mechanical Engineering majors.  
Classifying, cataloging and processing design information. Modeling of thermal equipment. Simulation and optimization of thermal systems. Computer based design projects.  
QP: ME 312
- 422\*.** *Introduction to Combustion*  
Fall. 3(3-0)  
P: ME 332. R: Open only to Mechanical Engineering majors.  
Thermodynamics, chemistry, fluid mechanics, and heat transfer principles applied to combustion.  
QP: ME 332

- 432\*.** *Intermediate Fluid Mechanics*  
Spring. 3(3-0)  
P: ME 332. R: Open only to Mechanical Engineering majors.  
Deformable control volumes, Navier-Stokes equations, vorticity and circulation. Exact solutions. Turbulence, boundary layer flows, compressible flows.  
QP: ME 332 QA: ME 333
- 433\*.** *Intermediate Fluid Mechanics Laboratory*  
Spring. 1(0-3)  
P: ME 432 or concurrently. R: Open only to Mechanical Engineering majors.  
Visualization and measurement of flow, jets and wakes. Flow separation and boundary layers.  
QP: ME 333
- 440\*.** *Aerospace Engineering I*  
Fall. 3(3-0)  
P: ME 332. R: Open only to Mechanical Engineering and Mechanics majors.  
Aerodynamics, propulsion and flight mechanics. Vehicle and propulsion engine performance and design characteristics.  
QP: ME 332 QA: ME 432
- 441\*.** *Aerospace Engineering II*  
Spring. 3(3-0)  
P: ME 440. R: Open only to Mechanical Engineering and Mechanics majors.  
Computer analysis experiments associated with aerospace vehicle design. Application of aerospace engineering principles in design such as propulsion, aerodynamics, stability and control.  
QP: ME 432 QA: ME 434
- 451\*.** *Control Systems*  
Fall, Spring. 4(3-3)  
P: ME 391, MMM 306, EE 345. R: Open only to Mechanical Engineering and Mechanics majors.  
Mathematical modeling of dynamic systems. Standard feedback control formulation. Transient and sinusoidal steady state analysis. Time and frequency domain controller synthesis.  
QP: MMM 306 ME 351 EE 345 QA: ME 458
- 461\*.** *Mechanical Vibrations*  
Fall, Spring. 4(3-3)  
P: ME 451. R: Open only to Mechanical Engineering and Mechanics majors.  
Modeling and analysis of oscillatory phenomena found in linear discrete and continuous mechanical systems.  
QP: ME 458 QA: ME 455
- 463\*.** *Computer Aided Design of Dynamic Systems*  
Spring. 3(3-0)  
P: ME 451. R: Open only to Mechanical Engineering and Mechanics majors.  
Modeling and design of mechanical and mixed-energy dynamic systems. State-space equation representation. Simulation methods.  
QP: ME 458 QA: ME 352
- 465\*.** *Computer Aided Optimal Design*  
Fall. 3(3-0)  
P: ME 471 or concurrently. R: Open only to Mechanical Engineering majors.  
Modeling for mechanical design optimization. Algorithms for constrained and unconstrained optimization. Optimality criteria. Optimization using finite element models. Design projects.  
QP: ME 421 QA: ME 465
- 471\*.** *Mechanical Design II*  
Fall, Spring. 3(3-0)  
P: ME 371, ME 391. R: Open only to Mechanical Engineering and Mechanics majors.  
Engineering design of machine elements and mechanical systems. Computer based analysis in support of design. Design for static and fatigue strength, deflection and reliability.  
QP: ME 351 ME 320 QA: ME 421