821. Production and Inventory Planning and Control
Winter, Spring. 4(4-0) MCT 800 or approval of department. Interdepartmental with the Department of Management.
Theory and practice of production and inventory planning and control. Focus on computer-based planning systems for material requirements including aggregate planning, master scheduling, capacity planning, shop floor control and inventory planning.

823. Seminar in Retailing
Winter. 4(4-0)
Critical analysis of available generalizations concerning the economic, social, and commercial role of retailing. Special attention to concepts of retail competition and productivity. Emphasis on research in improving retail efficiency.

824. Marketing Channel Management
Spring. 4(4-0) MTA 805.
Seminar in selected organizational, social, political, economic and cultural issues related to management in marketing channels.

831. Food Marketing Management
Fall. Spring. 4(4-0) May reenroll for a maximum of 6 credits. Interdepartmental with the Department of Agricultural Economics.
Food industry adjustment to changing social, economic and internal company environment. Managerial principles and techniques applied to food processing and distribution. Student interaction with industry, labor and government representatives.

841. Materials and Logistics Management Policy
Spring, Summer. 4(4-0) MCT 800 plus 30 credits in the MBA Program. Interdepartmental with the Department of Management.
Case course that integrates the materials and logistics management program. Emphasis on problem recognition, applying course materials and preparation of plans that improve total systems performance.

851. Market Behavior and Competitive Strategy
Fall, Winter, Summer. 4(4-0) MTA 805.
Industrial and consumer market structure and behavior and their impact upon the firm's competitive operations and actors.

860. International Business
Fall, Summer. 4(4-0) MTA 805.
The economic environment within which the international firm operates is presented. Special emphasis on relating trade and payment theory, regional analysis, and economic development to strategy formulation of the firm. Marketing, financial, and organizational factors are considered.

862. International Marketing
Winter. 4(4-0) MTA 860.
Models for headquarters planning and control of international marketing operations are developed. Social, cultural, institutional, and economic variables are considered in studying marketing operations in foreign environments.

863. Problems in International Business
Spring. 4(4-0) MTA 862.
Examination of strategies and organization for international business. In-depth consideration of headquarters and overseas personnel, marketing, financial, and legal issues.

890. Special Problems
Fall, Winter, Spring, Summer. 1 to 4 credits. May reenroll for a maximum of 8 credits. Approval of department.

905. Analysis of Business Enterprise Systems
Fall. 3 credits. MTA 805; MCT 806.
Research concepts and scientific methods for the study of business enterprise systems. The design of research, formulation of hypotheses, concepts of measurements and use of quantitative methods in the study of business systems.

909. Theory of Transportation-Distribution Systems
Fall. 4(4-0)
Examines the functions of transportation-distribution systems. Develops the relevant elements of networks, systems, and economic theory with empirical design. Applications to design evaluation, and control of representative macro and micro systems.

910A. Advanced Research in Marketing I
Winter. 4(4-0) Second-year doctoral students in marketing.
Advanced concepts and quantitative methods in the scientific investigation of market phenomena and the tools of market cultivation.

910B. Advanced Research in Marketing II
Spring. 5(5-0) MTA 910A.
Continuation of MTA 910A.

911A. History of Market Thought
Fall. 4(4-0) May reenroll for a maximum of 15 credits. MTA 851.
Traces the evolution of marketing institutions, techniques, theories and criticisms. The influence of changing environmental and technological factors on marketing practice and thought. Readings in retrospective and original materials, discussion and research paper.

911B. Seminar in Macro Marketing
Winter. 4(4-0) May reenroll for a maximum of 15 credits. MTA 911A.
Examines the relationships between competition, marketing and corporate and economic environments. Emphasis is given to a functional examination of competition and the central role of innovation in the process.

912. Research Methodology in Transportation-Distribution Systems
Winter. 4(4-0) MTA 912, MTA 909.
Research methodology in the design and administration of transportation-distribution systems. Emphasis on technique and methodology for conducting system design studies and evaluation of common implementational problems.

914. Transportation-Distribution Development Policy
Spring. 4(4-0) MTA 909, MTA 912.
Applicable theories and processes developed in MTA 906 and MTA 912 to the design of research processes and reports in significant transport and distribution problems.

957. Seminar in Micro Marketing
Spring, 4(4-0) MTA 911A.
Examines the current state of theory concerning the planning and implementation of marketing strategies and programs, and tries to identify where future research is needed and/or will be most useful to marketing and business managers.

999. Doctoral Dissertation Research
Fall, Winter, Spring, Summer. Variable credit. Approval of department.

MATHMATICS

MTH

College of Natural Science

One and one-half years of high school algebra and one year of geometry and a satisfactory score on the placement test are prerequisites for all courses in the Department of Mathematics which carry credit.

0813. Elements of Algebra
Fall, Winter, Spring. Summer. 0(3-0)
(3-0) See page A-1 item 3. Current enrollment in MTH 1033.
Fractions, decimals, real number properties, algorithms of arithmetic, simple factoring, simplifying algebraic expressions, parentheses, reciprocals, linear equations, integer exponents, applied problems, coordinate systems, graphing, solving equations by graphing. Approved through Fall 1988.

0823. Intermediate Algebra
Fall, Winter, Spring. Summer. 0(2-0)
(2-0) See page A-1 item 3. Current enrollment in MTH 1043, one year of high school algebra, satisfactory score on placement exam.
Properties of real numbers, polynomials, factoring, exponents, roots and radicals, first and second degree equations, linear inequalities, complex numbers, word problems, system of equations, operating on algebraic expressions, simplifying algebraic expressions. Approved through Fall 1988.

1033. Elements of Algebra
Fall, Winter, Spring. Summer. 2(2-0)
Current enrollment in MTH 0813.
Fractions, decimals, real number properties, algorithms of arithmetic, simplifying algebraic expressions, parentheses, reciprocals, linear equations, integer exponents, applied problems, coordinate systems, graphing, solving equations by graphing. Approved through Fall 1988.
104. Intermediate Algebra
Fall, Winter, Spring, Summer. 3(3-0)
Current enrollment in MTH 0823, one year of high school algebra, satisfactory score on placement exam.
Properties of real numbers, polynomials, factoring, exponents, roots and radicals, first and second degree equations, linear inequalities, complex numbers, word problems, system of equations, operations on algebraic expressions, simplifying algebraic expressions. Approved through Fall 1988.

105. College Algebra and Trigonometry
Fall, Winter, Spring, Summer. 5(5-0)
1-1/2 high school units in algebra and satisfactory score on placement test, or MTH 0823; 1 high school unit in geometry. Not open to students with credit in MTH 111.
Number systems; variables; functions and relations; mathematical induction; exponents and radicals; elementory theory of equations; binomial theorem; determinants, matrices and systems of equations.

109. College Algebra and Trigonometry II
Fall, Winter, Spring, Summer. 5(5-0)
Continuation of MTH 105, plus trigonometry including definition of circular functions, angular measure, fundamental identities.

110. Finite Mathematics with Applications
Fall, Winter, Spring, Summer. 5(5-0)
Elementary combinatorial analysis, binomial theorem, vectors and matrices, convex sets and linear programming, graph theory, applications to theory of games.

111. College Algebra with Trigonometry
Fall, Winter, Spring, Summer. 5(5-0)
1-1/2 years of high school algebra; 1 year of high school geometry; knowledge of trigonometry, satisfactory score on algebra placement test. Not open to students with credit in MTH 105 or MTH 111.
Sets and equations, simultaneous equations and matrices, vectors, inequalities, functions and relations, inverse functions, elementary theory of equations, trigonometric equations and identities, polar coordinates, parametric equations, straight line analytic geometry.

112. Calculus and Analytic Geometry I
Fall, Winter, Spring, Summer. 5(5-0)
MTH 109 or MTH 111.
The sequence MTH 112, MTH 113, MTH 214, MTH 215, is an integrated course in single variable calculus with an introduction to differential equations, applications. First and second order equations; solutions in series, higher order equations; systems of differential equations. Introduction to partial differential equations and initial and boundary value problems; emphasis on the wave equation, Laplace's equation and heat flow equations and their solutions by separation of variables.

113. Calculus and Analytic Geometry II
Fall, Winter, Spring, Summer. 5(5-0)
A continuation of MTH 112.

122. Calculus I
Fall, Winter, Spring, Summer. 5(5-0)
MTH 109 or MTH 111; not open to engineers, physical science or mathematics majors or to students with credit in MTH 112.
The first of a two-term course in primarily single variable calculus with an introduction to several variables for students who want only one or two terms of calculus.

123. Calculus II
Fall, Winter, Spring, 5(5-0)
MTH 122. not open to engineers, physical science or mathematics majors or to students with credit in MTH 113.
The second of a two-term course in primarily single variable calculus with an introduction to several variables for students who want only one or two terms of calculus.

201. Mathematical Foundations for Elementary School Teachers
Fall, Winter, Spring, Summer. 4(4-0)
1-1/2 high school units in algebra and satisfactory score on placement test, or MTH 0823; 1 high school unit in geometry. Open only to elementary education majors.
Fundamental concepts and processes of mathematics for prospective elementary school teachers.

204. Applied Mathematics in Elementary School
Winter, Spring, 4(4-0)
MTH 201, elementary education major.
Concepts and applications of algebra and geometry for prospective elementary teachers.

214. Calculus and Analytic Geometry III
Fall, Winter, Spring, Summer. 4(4-0)
MTH 113.
Continuation of MTH 113.

215. Calculus and Analytic Geometry IV
Fall, Winter, Spring, Summer. 4(4-0)
MTH 214.
Continuation of MTH 214.

290. Special Topics in Mathematics
Fall, Winter, Spring, Summer. 1 to 5 credits. May reenroll for a maximum of 9 credits.
Individualized study adapted to the preparation and interests of the student. Topics studied will generally supplement and enrich the regular courses.

310. Differential Equations
Fall, Winter, Spring, Summer. 3(3-0)
MTH 215 or concurrently.
First and second order equations; solutions in series, higher order equations; systems of differential equations, applications.

315. Concepts of Geometry I
Fall, Winter, Spring, Summer. 3(3-0) MTH 214 or approval of department.
Axiomatic structure of geometries including Euclidean, the classical non-Euclidean and projective geometries. Coordinate systems and geometric transformations.

316. Concepts of Geometry II
Winter, Spring, 3(3-0) MTH 315.
Continuation of MTH 315.

324. Foundations of Analysis
Fall, Winter, Spring. 4(4-0)
MTH 215.
Elementary set theory; functions, mappings, equivalence relations; sequences and series; Cauchy sequences; least upper bound; completeness, compact and connected sets; Bolzano-Weierstrass Theorem; continuity.

331. Theory of Numbers
Fall, Winter, Spring, 3(3-0) MTH 113 or approval of department.
Diophantine equations, congruences, quadratic residues, finite fields.

334. Theory of Matrices
Fall, Winter, Spring, Summer. 4(4-0)
MTH 214 or approval of department.
Algebra of matrices, vector spaces, rank, inverses, determinants, systems of equations, quadratic forms, Hermitian matrices, similarity transformations, characteristic values, linear transformations.

337. Concepts of Algebra
Winter, Spring. 3(3-0) MTH 214 or approval of department.
Rings, integral domains, properties of integers, fields, groups, polynomials.

341. Initial and Boundary Value Problems
Winter, Spring, Summer. 4(4-0) MTH 310.
Introduction to partial differential equations and initial and boundary value problems; emphasis on the wave equation, Laplace's equation and heat flow equations and their solutions by separation of variables.

352. Introduction to Numerical Solutions of Partial Differential Equations
Fall, Winter, Spring. 4(4-0)
MTH 315.
Numerical solutions of boundary value problems, both two point and in the plane. Iterative methods for matrix equations. Introduction to stability and error analysis.

351. Introduction to Numerical Analysis
Fall, Winter, Spring, 4(4-0) MTH 310 and knowledge of FORTRAN programming; students may not receive credit in both MTH 351 and MTH 451.
Introduction to numerical analysis; computer coding using a compiler language; approximation to roots of equations, interpolation, numerical quadrature, numerical solution of ordinary differential equations.

352. Introduction to Numerical Analysis
Fall, Winter, Spring. 4(4-0)
MTH 310 and knowledge of FORTRAN programming; students may not receive credit in both MTH 351 and MTH 451.
Introduction to numerical analysis; computer coding using a compiler language; approximation to roots of equations, interpolation, numerical quadrature, numerical solution of ordinary differential equations.

382. Applied Discrete Mathematics I
Fall, Winter, Spring. 3(3-0) MTH 215.
Basic counting; permutations, combinations, multinomial coefficients, binomial expansion. Introduction to graph theory: connectivity, coloring, trees, applications to sorting and searching.

383. Applied Discrete Mathematics II
Winter. 3(3-0) MTH 382.
Generating functions, recurrence relations and their solutions, divide and conquer algorithms; principle of inclusion and exclusion, pigeonhole principle.

400H. Honors Work
Fall, Winter, Spring. 1 to 16 credits. MTH 215 or approval of department.
Individualized reading and study in mathematics for students of high intellectual promise.

405. Mathematical Topics for Teachers
Fall, Winter, Spring. 1 to 4 credits. May reenroll for a maximum of 12 credits. Approval of department; open only to teachers participating in teacher institutes or special extension courses.
406. Mathematical Modeling for Teachers  
(350) Spring, 3(3-0) MTH 215. 
Mathematical topics covered include: binary, octal and hexadecimal arithmetic, Euclidean algorithm and prime number generators, root finding for polynomials, approximation of functions, difference equations, combinatorics and probability problems, topics from geometry, and mathematical modeling and simulation. 

414. Differential and Analytic Geometry  
Spring, 4(4-0) MTH 215 or approval of department. 

420. Ordinary Differential Equations  
Spring, 4(4-0) MTH 310, MTH 334. 
Existence and uniqueness theorems; linear systems, plane autonomous systems, introduction to stability theory, Lyapunov's second method, applications.

421. Vector and Tensor Analysis  
Fall, Winter, Summer. 4(4-0) MTH 310. MTH 334 recommended. 
Vector calculus, line and surface integrals, divergence and Stokes theorem, orthogonal coordinate systems, introduction to tensors; applications to the physical sciences.

422. Boundary Value Problems and Fourier Series  
Fall, Winter, Spring. 4(4-0) MTH 310, MTH 424. 

423. Complex Variables  
Winter, Spring. 4(4-0) MTH 310 or approval of department. 
Analytic functions, integrals, power series, residues, poles, conformal mapping and applications.

424. Advanced Calculus  
Fall, Winter, Spring, Summer. 4(4-0) MTH 215. 
Limits and continuity, function of several variables, ordinary and partial derivatives; theory of integration; multiple, line and surface integrals; infinite series, improper integrals, Beta and Gamma functions and other topics.

425. Advanced Calculus  
Winter, Spring, 3(3-0) MTH 334, MTH 424. 
Continuation of MTH 424.

426. Advanced Calculus  
Fall, Spring, 3(3-0) MTH 425. 
Continuation of MTH 425.

427. Real Analysis I  
Fall. 4(4-0) Approval of department. 
Topology, limits and continuity in En, functions of bounded variation, Rieman integration, calculus of several variables, linear transformations and derivatives.

428. Real Analysis II  
Winter. 4(4-0) MTH 427. 
Continuation of MTH 427.

429. Real Analysis III  
Spring. 4(4-0) MTH 428. 
Continuation of MTH 428.

430. Introduction to Error-Correcting Codes  
Winter. 3(3-0) MTH 334. 
Block codes and maximum likelihood decoding; Galois fields; encoding and decoding linear codes, cyclic codes (using shift registers), burst-error-correcting codes, convolutional codes.

432. Abstract Algebra I  
Fall, Winter. 4(4-0) MTH 215. 
Introduction to the concepts of basic algebraic structures; namely: group, ring, integral domain, field, polynomial ring, module, vector space, linear transformation, etc.

433. Abstract Algebra II  
Winter, Spring. 4(4-0) MTH 432. 
Continuation of MTH 432.

434. Abstract Algebra III  
Spring. 4(4-0) MTH 433. 
Continuation of MTH 433.

437. Theory of Numbers II  
Spring, 3(3-0) MTH 331 or MTH 452 or approval of department. 
Diverse series, distribution of primes, sums of squares, Pell's equation, continued fractions, Harewicz Theorem.

450. Mathematical Programming  
Fall of even-numbered years. 3(3-1) MTH 434 or concurrently, MTH 334, knowledge of FORTAN programming. 
Finite dimensional convexity, theorems of the alternative, LR factorization, simplex algorithm, quasi-Newton methods, nonlinear duality theory, dual algorithms.

451. Numerical Analysis I  
Winter, Spring, 3(3-0) MTH 310, MTH 334, MTH 424 or approval of department. 
Students may not receive credit in both MTH 351 and MTH 451.
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  
Fall, Spring. 4(4-0) MTH 451. 
Continuation of MTH 451.

460. Topology  
Winter. 3(3-0) MTH 424. 
Introduction to fundamental concepts in topology, to metric and topological spaces, connectedness, compactness, continuity and simple connectedness.

462. Combinatorial Topology  
Spring. 3(3-0) MTH 461 or MTH 424. 
Unions of graphs, surface topology, classification of surfaces, elementary set-theoretic topology, complexes.

470. Theory of Computation and Computational Complexity  
Fall. 3(3-0) MTH 334 or approval of department. 
Turing machines; deterministic and non-deterministic computations; incomputability; time bounded machines; classes NP and P; NP complete problems; complexity hierarchy.

471. Mathematical Logic  
Spring, 3(3-0) MTH 470 or approval of department. 
Propositional and predicate calculus; validity and satisfiability; compactness; Herbrand expansions; resolution methods; automated reasoning; Hoare logics and program verification.

480. Mathematics for Economists  
Fall. 5(5-0) MTH 113, graduate status in either economics, agricultural economics or College of Business, or approval of department. 
Interdepartmental with the Department of Economics.

484. Applied Discrete Mathematics III  
Spring, 3(3-0) MTH 334, MTH 383. 
Graph and network algorithms, depth first search, Eulerian and Hamiltonian paths, matching and covering problems, minimum spanning trees, network flows, shortest route.

490. Mathematical Problems  
Fall, Winter, Spring, Summer. 1 to 4 credits. May reenroll for a maximum of 12 credits. Approval of department.
Individualized study adapted to the preparation and interests of the student.

492. Advanced Topics in Mathematics (MTC)  
Fall, Winter, Spring, Summer. 3 to 6 credits. May reenroll for a maximum of 12 credits. Approval of department.
Advanced topics in mathematics not covered by current courses offered by the department.

500. Set Theory and Foundations of Mathematics  
Spring. 4(4-0) MTH 424 or approval of department. 
Axiomatic method; various formulations of the axiom of choice; cardinal and ordinal numbers.

501. Mathematics Education I  
Fall. 3(3-0) Graduate student in mathematics or approval of department.
Historical origin of the content, methodology, issues in mathematics education in the modern world. Delineation of the important issues and problems.

502. Mathematics Education II  
Winter. 3(3-0) Graduate student in mathematics or approval of department.
Contemporary mathematics curriculum issues and problems. Recent developments in curriculum development K-12.

503. Mathematics Education III  
Spring. 3(3-0) Graduate student in mathematics or approval of department.
Research in mathematics education; emphasis on identification of strengths and weaknesses in recent research practices, identification of specific crucial problems, potential issues; consideration of research models, designs and methods.

504. Linear Algebra and Analysis I  
Fall. 3(3-0) MTH 334, MTH 424. 
Linear and matrix algebra, Grassman algebra, differential and integral calculus in Rn, linear differential equations, differential forms, closed and exact forms, Stokes theorem and elements of differential manifolds.
805.  Linear Algebra and Analysis II
   Winter. 3(3-0) MTH 804.
   Continuation of MTH 804.

806.  Linear Algebra and Analysis III
   Spring. 3(3-0) MTH 805.
   Continuation of MTH 805.

814A.  Differential Geometry I
   Fall. 3(3-0) MTH 426 or approval of department.
   Differentiable manifolds, vector fields, Frobenius theorem, tensor algebra, differential forms, affine connections, Riemannian metrics, curvature, geodesics, arc length, Jacobi fields, conjugate and cut loci, topological implications of curvature.

816.  Tensor Calculus and Riemannian Geometry
   Fall of odd-numbered years. 4(4-0)
   MTH 426.
   Contravariant and covariant tensors, metric tensors, geodesics, Christoffel symbols, covariant differentiation, curvature, Ricci tensor, parallel propagation, relative tensors, extension, spaces with affine connection, Weyl spaces; applications to dynamics, hydrodynamics and electromagnetic radiation.

817.  Theory of Linear Graphs I
   Winter. 3(3-0) MTH 324, MTH 434, or approval of department.
   Fundamental concepts of undirected and directed graphs, including connectivity, trees, blocks, partitions, homomorphisms, Menger's theorem, line graphs, covering, Kuratowski's theorem, chromatic numbers, incidence matrices, and automorphism groups.

818.  Theory of Linear Graphs II
   Spring. 3(3-0) MTH 317.
   Advanced topics in the theory of linear graphs and combinatorial analysis. Polya's theorem and its application to enumeration problems.

821.  Topology and Analysis I
   Fall. 3(3-0) MTH 429 or MTH 804 or MTH 804 concurrently; or approval of department.
   Set theory, Zorn's Lemma, topology of R^n and metric spaces, topological spaces, Lebesgue integration, Hilbert and Banach spaces, linear operators.

822.  Topology and Analysis II
   Winter. 3(3-0) MTH 821.
   Continuation of MTH 821.

823.  Topology and Analysis III
   Spring. 3(3-0) MTH 822.
   Continuation of MTH 822.

824.  Real and Complex Analysis
   Fall. 3(3-0) MTH 823.
   Topics in this course, MTH 825 and MTH 826 selected from following: the real number system, linear point sets, theory of limits; continuity and differentiability properties of functions of one or more variables; sequences and series of functions; Riemann, Lebesgue and Stieltjes integrals, implicit function theorem; existence theorems for differential equations.

825.  Real and Complex Analysis
   Winter. 3(3-0) MTH 824.
   Continuation of MTH 824.

826.  Real and Complex Analysis
   Spring. 3(3-0) MTH 825.
   Continuation of MTH 825.

830.  Error-Correcting Codes
   Spring. 3(3-0) MTH 534.
   Algebraic background; theory of linear and cyclic codes; advanced topics.

831.  Applied Matrix Theory I
   Fall. Winter. Summer. 4(4-0) MTH 334, MTH 424 or approval of department.
   Row echelon form, inner products, quadratic forms; Gram, Unitary and Hermitian matrices; Gram-Schmidt process, orthonormal factorization; least error, least effort problems, pseudo inverses; determinants; applications.

832.  Applied Matrix Theory II
   Winter, Spring. 3(3-0) MTH 831.
   Linear transformations, eigenvalues, eigenvectors; Householder matrices; diagonalizable matrices; singular value decomposition; canonical forms and power series; applications.

834.  Algebra I
   Fall. 3(3-0) Approval of department.
   Elements of group theory, direct complement and chain decomposition, classification of groups; ring theory, integral domains, field theory, extensions, automorphisms. Galois theory: modules and vector spaces, Wedderburn structure theory, linear and multilinear algebra.

835.  Algebra II
   Winter. 3(3-0) MTH 834.
   Continuation of MTH 834.

836.  Algebra III
   Spring. 3(3-0) MTH 835.
   Continuation of MTH 835.

841.  Boundary Value Problems I
   Fall. 3(3-0) MTH 422, MTH 423; MTH 394 recommended.

842.  Boundary Value Problems II
   Winter. 3(3-0) MTH 841.
   Continuation of MTH 841.

843.  Boundary Value Problems III
   Spring. 3(3-0) MTH 842.
   Continuation of MTH 842.

844.  Methods of Applied Analysis I
   Fall. 3(3-0) MTH 823.
   Linear transformations on finite and infinite dimensional spaces. Fredholm and Hilbert-Schmidt theory, orthogonal polynomials, differential operators, Green's functions, Fourier transforms and distributions.

845.  Methods of Applied Analysis II
   Winter. 3(3-0) MTH 844.
   Continuation of MTH 844.

846.  Methods of Applied Analysis III
   Spring. 3(3-0) MTH 845.
   Continuation of MTH 845.

847.  Theory of Ordinary Differential Equations I
   Fall. 3(3-0) MTH 426; matrix theory.
   Existence and uniqueness, continuation of solutions, dependence of solutions on a parameter; linear systems; phase plane analysis.

848.  Theory of Ordinary Differential Equations II
   Winter. 3(3-0) MTH 847.
   Continuation of MTH 847; oscillation theory, asymptotic behavior. Lyapunov stability, boundary value problems.

849.  Theory of Ordinary Differential Equations III
   Fall. 3(3-0) MTH 848; approval of department.
   Advanced topics in ordinary differential equations.

850.  Numerical Solutions of Ordinary Differential Equations
   Fall. 3(3-0) MTH 851 or approval of department.
   Numerical methods for solving initial value problems for ordinary differential equations.

851.  Numerical Analysis I
   Fall. 3(3-0) MTH 426; FORTRAN programming and matrix theory recommended.
   Numerical methods for solving systems of linear equations with error analysis; linear programming, the simplex algorithm; numerical procedures for determining eigenvalues and eigenvectors of matrices. Emphasis on computer applications.

852.  Numerical Analysis II
   Winter. 3(3-0) MTH 852.
   Numerical methods with error analysis for: solutions of nonlinear algebraic equations; Lagrange and Hermite interpolation, finite differences; extrapolation theory, including least square and Chebyshev approximations.

853.  Numerical Analysis III
   Spring. 3(3-0) MTH 853.

   Fall. 3(3-0) MTH 804 or concurrently.
   An introduction to those aspects of convex sets and convex functions that are useful in applied mathematics, economics, and other areas together with applications to linear and nonlinear programming problems.
### Descriptions — Mathematics of Courses

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Course Title</th>
<th>Semester</th>
<th>Credits</th>
<th>Prerequisites</th>
</tr>
</thead>
<tbody>
<tr>
<td>855.</td>
<td>Mathematics of Operations Research II</td>
<td>Winter</td>
<td>3(3-0)</td>
<td>MTH 854, MTH 895 or concurrently.</td>
</tr>
<tr>
<td>856.</td>
<td>Mathematics of Operations Research III</td>
<td>Spring</td>
<td>3(3-0)</td>
<td>MTH 860 or concurrently.</td>
</tr>
<tr>
<td>858.</td>
<td>Numerical Solutions of Partial Differential Equations</td>
<td>Winter</td>
<td>3(3-0)</td>
<td>MTH 853 or approval of department.</td>
</tr>
<tr>
<td>859.</td>
<td>Numerical Solutions of Partial Differential Equations</td>
<td>Spring</td>
<td>3(3-0)</td>
<td>MTH 858.</td>
</tr>
<tr>
<td>861.</td>
<td>General Topology I</td>
<td>Fall</td>
<td>3(3-0)</td>
<td>Approval of department.</td>
</tr>
<tr>
<td>862.</td>
<td>General Topology II</td>
<td>Winter</td>
<td>3(3-0)</td>
<td>MTH 861.</td>
</tr>
<tr>
<td>863.</td>
<td>General Topology III</td>
<td>Spring</td>
<td>3(3-0)</td>
<td>MTH 862.</td>
</tr>
<tr>
<td>864.</td>
<td>Differential Topology</td>
<td>Spring</td>
<td>3(3-0)</td>
<td>MTH 426, MTH 892.</td>
</tr>
<tr>
<td>870.</td>
<td>Foundations of Mathematics I</td>
<td>Fall of even-numbered years</td>
<td>3(3-0) MTH 424; MTH 471 recommended.</td>
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</tr>
<tr>
<td>871.</td>
<td>Foundations of Mathematics II</td>
<td>Winter of odd-numbered years</td>
<td>3(3-0) MTH 870.</td>
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</tr>
<tr>
<td>872.</td>
<td>Foundations of Mathematics III</td>
<td>Spring of odd-numbered years</td>
<td>3(3-0) MTH 871.</td>
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</tr>
<tr>
<td>873.</td>
<td>Foundations of Applied Mathematics I</td>
<td>Fall of odd-numbered years</td>
<td>3(3-0) MTH 846 or MTH 843.</td>
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</tr>
<tr>
<td>874.</td>
<td>Fluid Dynamics I</td>
<td>Fall of even-numbered years</td>
<td>3(3-0) MTH 426 or MTH 822.</td>
<td>MTH 884 or approval of department.</td>
</tr>
<tr>
<td>875.</td>
<td>Fluid Dynamics II</td>
<td>Winter of odd-numbered years</td>
<td>3(3-0) MTH 884.</td>
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</tr>
<tr>
<td>876.</td>
<td>Partial Differential Equations I</td>
<td>Fall</td>
<td>3(3-0)</td>
<td>MTH 334, MTH 423.</td>
</tr>
<tr>
<td>877.</td>
<td>Partial Differential Equations II</td>
<td>Winter</td>
<td>3(3-0)</td>
<td>MTH 888.</td>
</tr>
<tr>
<td>878.</td>
<td>Partial Differential Equations III</td>
<td>Spring</td>
<td>3(3-0)</td>
<td>MTH 887.</td>
</tr>
<tr>
<td>880.</td>
<td>Reading in Mathematics</td>
<td>Fall, Winter, Spring, Summer</td>
<td>3(0-0) to 6 credits. May retake for a maximum of 36 credits. Approval of department.</td>
<td></td>
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<tr>
<td>890.</td>
<td>Master's Thesis Research</td>
<td>Fall, Winter, Spring, Summer</td>
<td>Variable credit. Approval of department.</td>
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### Additional Courses

- **Mathematics of Operations Research II**, Winter: 3(3-0) MTH 854, MTH 895 or concurrently.
- **Mathematics of Operations Research III**, Spring: 3(3-0) MTH 860 or concurrently.
- **Numerical Solutions of Partial Differential Equations I**, Winter: 3(3-0) MTH 853 or approval of department.
- **Numerical Solutions of Partial Differential Equations II**, Spring: 3(3-0) MTH 858.
- **General Topology I**, Fall: 3(3-0) Approval of department.
- **General Topology II**, Winter: 3(3-0) MTH 861.
- **General Topology III**, Spring: 3(3-0) MTH 862.
- **Differential Topology**, Spring of odd-numbered years: 3(3-0) MTH 426, MTH 892.
- **Foundations of Mathematics I**, Fall of even-numbered years: 3(3-0) MTH 424; MTH 471 recommended.
- **Foundations of Mathematics II**, Winter of odd-numbered years: 3(3-0) MTH 870.
- **Foundations of Mathematics III**, Spring of odd-numbered years: 3(3-0) MTH 871.
- **Foundations of Applied Mathematics I**, Fall of odd-numbered years: 3(3-0) MTH 426 or MTH 423.
- **Fluid Dynamics I**, Fall of even-numbered years: 3(3-0) MTH 426 or MTH 422 or approval of department.
- **Fluid Dynamics II**, Winter of odd-numbered years: 3(3-0) MTH 884.
- **Partial Differential Equations I**, Fall: 3(3-0) MTH 334, MTH 423.
- **Partial Differential Equations II**, Winter: 3(3-0) MTH 888.
- **Partial Differential Equations III**, Spring: 3(3-0) MTH 887.
- **Reading in Mathematics**, Fall, Winter, Spring, Summer: 1 to 6 credits. May retake for a maximum of 36 credits. Approval of department.
- **Master's Thesis Research**, Fall, Winter, Spring, Summer: Variable credit. Approval of department.

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**Harmonic Analysis I**
- Title: Harmonic Analysis I
- Credits: 3(3-0)
- Approval of department.
- Description: Fourier transforms on R^n and tempered distributions, inversion formula, Plancherel theorem, convolution, weak measures, almost-periodic functions, Fourier series, Wiener Fatou theorems, Paley-Wiener theorems.

**Harmonic Analysis III**
- Title: Harmonic Analysis III
- Credits: 3(3-0)
- Approval of department.
- Description: Selected topics from Fourier analysis, compact groups, singular integrals, harmonic analysis on R^n, L^p theory in one and several variables.

**Advanced Group Theory I**
- Title: Advanced Group Theory I
- Credits: 3(3-0)
- Approval of department.
- Description: Permutation groups, characters, properties, automorphisms, lattices, subgroups, classes of infinite groups, recent literature.

**Algebraic Topology I**
- Title: Algebraic Topology I
- Credits: 3(3-0)
- Approval of department.
- Description: Simplicial and singular homotopy theory, Eilenberg-Steenrod axioms, chain complexes, cell complexes, applications to Euclidean spaces.

**Algebraic Topology II**
- Title: Algebraic Topology II
- Credits: 3(3-0)
- Approval of department.
- Description: Continuation of MTH 964 including category and functor theory, general coefficient and cohomology theory.
MECHANICAL ENGINEERING M E

College of Engineering

201. The Science of Sound I: Rock, Bach and Oscillators (N)
Winter. 4(4-0) Interdepartmental with and administered by Physics.
Production, propagation, detection of sounds. Voice, bearing, scales, timbre, musical instruments.
Room acoustics. Electronic reproduction and synthesis of music. Demonstrations emphasized.

303. Thermal-Fluid Phenomena
Winter. 3(3-0) E E 301, M E 113.
Concepts and principles used to describe, predict, or explain thermal and fluid-flow phenomena.
Constraints, approximations, engineering problem solving. Application to socio-technical questions.

304. Technology and Utilization of Energy
(300.) Spring. 3(3-0) M E 393.
Problems of energy technology and its impact: energy sources, conversions, waste and environmental effects, future outlook.

311. Thermodynamics I
Fall, Winter, Spring. 3(3-0) M TH 215 or concurrently.
Zeroth, first and second laws of thermodynamics. General energy equation. Process relations. Concepts of equilibrium, reversibility, and entropy. Applications of these to systems describable by two independent properties.

312. Thermodynamics II
Winter, Spring. 3(3-0) M E 311.
Continuation of M E 311. Gas and vapor relations, reactive and non-reactive mixtures. Thermodynamic principles as applied to gas and vapor power and refrigeration cycles for reciprocating and turbo machinery.

320. Kinematics of Machines I
Fall, Spring, Summer. 4(3-3) M M M 360 or concurrently.
Analysis of displacement, velocity, acceleration; application to mechanical linkages; cam analysis and design; analysis of spur, helical, bevel, and worm gears, including planetary systems.

332. Fluid Mechanics I
Winter, Spring. 4(3-3) M E 311; M E 351 or concurrently; M M M 360.
Fluid statics; Bernouilli equation; nondeformable control volume applied to conservation of mass, momentum and energy, derivation of differential equations of continuity and momentum; similarity.

333. Fluid Mechanics II
Fall, Spring. 4(3-3) M E 332.
Fluid flow phenomena; laminar flow; turbulent flow, pipe flow, inviscid flows; boundary layers; external flow; an introduction to compressible flow.

347. Thermosciences and Energy Systems Laboratory
Winter, Spring. 1(0-3) M E 312 or concurrently.
Properties of pure substances; first law energy balances and second law analyses applied to a pump, turbine, refrigeration and combustion process.

351. Mechanical Engineering Analysis
Fall, Winter, Spring. 4(4-0) C P S 120 or concurrently, M T H 310.
Application of analytical and numerical methods to the solution of problems encountered in mechanical engineering.

352. Introduction to Systems and Control
Winter, Spring. 4(4-4) M M M 306, E E 345.
Modeling of a variety of physical systems, using state-variable concepts. Time and frequency response of low-order linear systems. Primary applications to mechanisms and hydraulics.

406. Automotive Engines
Spring. 3(3-0) M E 321.
Analysis of internal combustion engines for vehicular propulsion.

407. Automotive Vehicles
Fall. 3(3-0) M M M 306.
Analysis of the propulsion, braking, steering, and suspension requirements.

410. Thermomechanical Continua
Fall. 3(3-0) M M M 211.
Examination of the continuum concept in the modeling of the deformation of solids and the flow of fluids. Cartesian tensor formulation of the basic physical laws involving stress and strain.

411. Heat Transfer I
Fall, Winter. 3(3-0) M E 311.

412. Heat Transfer II
Winter. Spring. 3(3-0) M E 333.
Natural and forced convection based on boundary layer theory. Heat transfer in fluids with phase change. Heat exchangers, mass transfer.

414. Energy Conversion
Fall. 3(3-0) M E 312.
Fundamental principles of energy conversion systems. Direct energy conversion: Thermoelectric, thermonic, nuclear, fuel cells, magnetohydrodynamic, and other methods of power generation.

415. Solar Energy Conversion
Fall. 4(4-0) M E 311 or approval of department.

416. Statistical Thermodynamics
(313.) Spring. 3(3-0) M E 311.

421. Mechanical Design
Fall. Winter. 3(3-0) M M M 211.
Introduction to design, the design process, design considerations and design procedures. Application of design principles to machine elements.

422. Mechanical Design Projects
Winter. Spring. 3(3-0) M E 421.
Application of design concepts, such as optimization, economics and reliability, through several projects drawn from the basic areas of mechanical engineering (thermodynamics, heat transfer, fluid and solid mechanics).

424. Dynamics of Machines
Winter. 3(3-0) M E 320.
Analysis of static and dynamic forces in mechanical linkages; balancing of rotating and reciprocating machinery; flywheel requirements, gyroscopic forces, critical speeds.

432. Aerospace Engineering I
Fall. 3(3-0) M E 332.
Fundamentals of fluid mechanics, potential flows about bodies and airfoils, compressible flow, perturbation methods, viscous flow, boundary layer, transition, turbulence, separation, aerodynamics of wings and bodies.

433. Aerospace Engineering II
(417.) Winter. 3(3-0) M E 333.
Thermodynamics and fluid mechanics will be used to study rockets, turbojets, reciprocating engines, propellers, turboprops, and turbines; a specific propulsion system will be designed.

434. Aerospace Engineering III
(471.) Spring. 3(3-0) M M M 306.
Particle and rigid body dynamics; orbit theory; aerodynamic forces; propulsion; longitudinal, directional and lateral stability and control; range; payload; a specific vehicle will be designed.