821. Production and Inventory Planning and Control

Winter, Spring. 4(4-0) MGT 800 or approval of department. Interdepartmental with and administered by 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 8 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) MGT 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 actions.

853. Market Programming

Winter, Spring, Summer. 4(4-0) MTA 805.

Planning processes leading to programming the various elements of market cultivation. Major emphasis is given to the development of a total marketing strategy for the firm. Case analysis.

854. Problem-Solving Processes in Marketing

Fall, Spring. 4(4-0) MTA 853.

The problem-solving process is approached through the investigation and solution of current marketing problems by research teams.

855. Market Cost-Revenue Analysis

Winter. 4(4-0) One course in accounting and one in marketing. Interdepartmental with the Department of Finance and Insurance.

Analytical tools for use in planning and controlling marketing activities. Emphasis on the determination of factors causing marketing cost differences and the assignment of costs to those factors. Application of tools to determination of expenditure-revenue patterns and market potentials.

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 payments 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; MGT 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 the 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 growth. 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 812, 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.

941. Transportation-Distribution Development Policy

Spring. 4(4-0) MTA 909, MTA 912.

Applications in theory, principles, and proceses developed in MTA 909 and MTA 912 to the design of research processes and reports in signficant 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.

MATHEMATICS 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(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(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, simple factoring, simplifying algebraic expressions, parentheses, reciprocals, linear equations, integer exponents, applied problems, coordinate systems, graphing, solving equations by graphing.

Approved through Fall 1988.

1043. 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.

108. College Algebra and Trigonometry I

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; elementary theory of equations; binomial theorem; determinants, matrices and systems of equations.

109. College Algebra and Trigonometry II

Fall, Winter, Spring, Summer. 5(5-0) MTH 108; not open to students with credit in MTH 111.

Continuation of MTH 108 plus trigonometry including definition of circular functions, angular measure, fundamental identities.

110. Finite Mathematics with Applications

Fall, Winter, Spring, Summer. 5(5-0) MTH 108 or MTH 111.

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 in algebra placement test. Not open to students with credit in MTH 108 or MTH 109.

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 calculus and analytic geometry, covering derivatives, curve sketching, definite and indefinite integrals, area volume, transcendential functions, vector analysis, solid geometry, partial differentiation, multiple integrals, infinite series, power series.

113. Calculus and Analytic Geometry II

Fall, Winter, Spring, Summer. 5(5-0) MTH 112.

A continuation of MTH 112.

122. Calculus I

Fall, Winter, Spring. 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 and 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 0823-1043; 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 majors.

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. Approval of department.

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. 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; countability; connected and compact 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. 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. 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.

351. Introduction to Numerical Analysis

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 Solutions of Partial Differential Equation

Fall. 4(4-0) MTH 351.

Numerical solutions of boundary value problems, both two point and in the plane. Iterative methods for matrix equations. Introduction to stability and error analysis.

381. Chemical Engineering Analysis

Fall, Spring. 3(3-0) Students may not receive credit in both CHE 381 and MTH 341. MTH 310, CPS 112. Interdepartmental with and administered by the Department of Chemical Engineering.

Formulation of ordinary and partial differential equations describing chemical systems. Boundary value problems, numerical methods, matrices and applications, to chemical engineering systems.

382. Applied Discrete Mathematics I

(MTH 302.) Fall. 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, Summer. 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 hexidecimal 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.
Coordinate systems in Euclidean three-space. Basic configurations. Vectors and the geometry of n-space. Transformations. Elementary differential geometry of curves and surfaces.

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.
Power series solutions of ordinary differential equations, Fourier series and orthogonal functions, partial differential equations of second order.

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, Riemann 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 432 or approval of department.
Dirichlet series, distribution of primes, sums of squares, Pell's equation, continued fractions, Hurewicz Theorem.

450. *Mathematical Programming*
Fall of even-numbered years. 3(3-1) MTH 424 or concurrently, MTH 334, knowledge of FORTRAN 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. 4(4-0) 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.

461. *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.
Unicursal 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 nondeterministic computations; uncomputability; time bounded machines; classes NP and P; NP complete problems; complexity hierarchy.

471. *Mathematical Logic*
Winter. 3(3-0) MTH 470 or approval of department.
Propositional and predicate calculus; validity and satisfiability; compactness; Herbrand expansions; resolution methods; automated seasoning; 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.
Matrix algebra, determinants, quadratic forms, characteristic values. Partial derivatives, chain rule, Jacobian matrix, Taylor series, constrained optimization, linear differential equations. Mathematics introduced and developed using student's background in 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.

800. *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.

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

802. *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.

803. *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, pertinent issues; consideration of research models, designs and methods.

804. *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.

814B. Differential Geometry II
Winter. 3(3-0) MTH 814A.
The differential geometry of submanifolds including classical surface theory and conformal differential geometry.

814C. Differential Geometry III
Spring. 3(3-0) MTH 814B.
Complex differential geometry including some additional topics on submanifold theory, symplectic and contact manifolds and Dolbeault cohomology.

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 334, MTH 424, or approval of department.
Fundamental concepts of undirected and directed graphs, including connectivity, trees, blocks, partitions, isomorphism, Menger's theorem, line graphs, coverings, Kuratowski's theroem, chromatic numbers, incidence matrices, and automorphism groups.

818. Theory of Linear Graphs II
Spring. 3(3-0) MTH 817.
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 426 or MTH 804 or MTH 804 concurrently; or approval of department.
Set theory, Zorn's Lemma, topology of Rn 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 theory; 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 334.
Algebraic background; theory of linear and cyclic codes; advanced topics.

831. Applied Matrix Theory I
Fall, Winter, Summer. 3(3-0) MTH 334, MTH 424 or approval of department.
Row echelon form, inner products, quadratic forms; Gram, Unitary and Hermitian matricies; Gram Schmidt process, orthotriangular 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; diagonable 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 334 recommended.
Linear spaces, Fourier series. Boundary value problems for ordinary and partial differential equations. Variational methods. Fredholm integral equations. Integral transform. Distribution theory.

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 theorems; uniqueness and 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
Spring. 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 851.
Numerical methods with error analysis for: solutions of nonlinear algebraic equations; Lagrange and Hermite interpolation: finite differences; approximation theory, including least square and Chebyshev approximations.

853. Numerical Analysis III
Spring. 3(3-0) MTH 852.
Numerical methods with error analysis for: differentiation; quadrature including New Newton-Cotes and Gaussian-type; difference equations; solutions of ordinary differential equations using one-step and multi-step predictor-corrector methods.

854. Mathematics of Operations Research I
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.

855. *Mathematics of Operations Research II*

Winter. 3(3-0) MTH 854, MTH 805 or concurrently.

Continuation of MTH 854. Fixed point theorems, including Fan-Kakutani—Kuhn-Tucker theorems, duality theorems in nonlinear programming. Lagrangian conditions for constrained optima. Frobenius-Perron theory of non-negative matrices. Application to Economics and Business.

856. *Mathematics of Operations Research III*

Spring. 3(3-0) MTH 806 or concurrently.

Classical problems of variational calculus. Allocation and optimal control problems. Necessary conditions. Infinite dimensional programming and duality theory. Sufficiency conditions. Generalized Lagrange multipliers. Saddle point theory. Dynamic programming.

857. *Numerical Methods in Partial Differential Equations*

Spring. 4(4-0) MTH 422, knowledge of matrices recommended. Knowledge of computer programming desirable.

Numerical methods for solving initial and boundary value problems of partial differential equations.

858. *Numerical Solutions of Partial Differential Equations I*

Winter. 3(3-0) MTH 851 or approval of department.

Finite difference methods for solving partial differential equations.

859. *Numerical Solutions of Partial Differential Equations II*

Spring. 3(3-0) MTH 858.

Finite element method for solving partial differential equations.

861. *General Topology I*

Fall. 3(3-0) Approval of department.

An introductory course in the topology of point sets. Concepts studied include topological spaces, products, homotopy and isotopy, separation, compactness, connectedness and path connectedness, metrization and compactification.

862. *General Topology II*

Winter. 3(3-0) MTH 861.

Continuation of MTH 861 dealing with identification topology, covering axioms, partitions of unity, K spaces, Baire-spaces and function spaces.

863. *General Topology III*

Spring. 3(3-0) MTH 862.

Development of homotopy theory required for more advanced studies with applications to covering spaces and the fundamental group.

864. *Differential Topology*

Spring of odd-numbered years. 3(3-0) MTH 426, MTH 862.

Smooth manifolds and maps. Submanifolds and embeddings. Mappings and approximations. Smoothing of maps and manifolds. Manifolds with boundary.

870. *Foundations of Mathematics I*

Fall of even-numbered years. 3(3-0) MTH 424; MTH 471 recommended.

Axiomatic set theory. Operations on sets, relations and functions, axiom of choice, maximal principles, cardinal and ordinal numbers, generalized, continuum hypothesis, axiom of constructibility, inaccessible cardinals.

871. *Foundations of Mathematics II*

Winter of odd-numbered years. 3(3-0) MTH 870.

Problems in metamathematics. Topics include: axiomatic systems, predicate calculus, consistency, completeness, and independence results, model theoretics, decision procedures, Godel's incompleteness theorem, recursive functions.

872. *Foundations of Mathematics III*

Spring of odd-numbered years. 3(3-0) MTH 871.

Continuation of MTH 871.

881. *Foundations of Applied Mathematics I*

Fall. 3(3-0) MTH 426 or MTH 423.

Introduction to the mathematical theory of classical applied mathematics; properties and postulates of various theories such as ideal fluids and linear elasticity; derivation of field equations; formulation of initial and boundary value problems.

882. *Foundations of Applied Mathematics II*

Winter. 3(3-0) MTH 881.

Continuation of MTH 881.

883. *Foundations of Applied Mathematics III*

Spring. 3(3-0) MTH 882.

Continuation of MTH 882.

884. *Fluid Dynamics I*

Fall of even-numbered years. 3(3-0) MTH 426 or MTH 422 or approval of department.

Derivation of the equations of fluid mechanics. Comparisons of formulations, techniques and results in the basic disciplines of potential, viscous and gas dynamic flows.

885. *Fluid Dynamics II*

Winter of odd-numbered years. 3(3-0) MTH 884.

Continuation of MTH 884.

886. *Partial Differential Equations I*

Fall. 3(3-0) MTH 334, MTH 423, MTH 426.

Cauchy-Kowalewski theorem; classification, characteristics, normal forms; general theory of first order equations; potential theory.

887. *Partial Differential Equations II*

Winter. 3(3-0) MTH 886.

Elliptic type equations; Green's Neumann's and Kernel functions; boundary value problems and integral equations; hyperbolic equations, geometry of characteristics, Riemann's functions.

888. *Partial Differential Equations III*

Spring. 3(3-0) MTH 887.

Continuation of hyperbolic equations; application of functional analysis to existence theorems, theory of Leray and Schauder.

890. *Reading in Mathematics*

Fall, Winter, Spring, Summer. 1 to 6 credits. May reenroll for a maximum of 36 credits. Approval of department.

899. *Master's Thesis Research*

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

920. *Harmonic Analysis I*

Fall of even-numbered years. 3(3-0) MTH 823, MTH 862 or approval of department.

Fourier series, mean and point-wise convergence. Fourier-Stieltjes series. Maximal functions and a.e. convergence. Conjugate functions. Interpolation of operators. Hausdorff-Young Theorems.

924. *Functional Analysis I*

Fall of odd-numbered years. 3(3-0) MTH 826 or approval of department.

Topological groups and topological vector spaces, metrizability, locally convex spaces, Hahn-Banach and Krein-Milman theorems, dual spaces, Banach spaces, Hilbert spaces, Banach algebras.

925. *Functional Analysis II*

Winter of even-numbered years. 3(3-0) MTH 924 or approval of department.

Continuation of MTH 924.

926. *Functional Analysis III*

Spring of even-numbered years. 3(3-0) MTH 925.

Continuation of MTH 925.

928. *Harmonic Analysis II*

Winter of odd-numbered years. 3(3-0) MTH 920.

Fourier transforms on Rn and R. Tempered distribution, inversion formula, Plancherel Theorem, pseudo-measures, almost-periodic functions, spectral properties, Wiener Tauberian Theorem, Paley-Wiener Theorems.

929. *Harmonic Analysis III*

Spring of odd-numbered years. 3(3-0) MTH 928.

Selected topics from Fourier analysis on compact groups, singular integrals, harmonic analysis in Rn, Hp theory in one and several variables or differentiation of integrals.

934. *Advanced Group Theory I*

Fall. 3(3-0) MTH 836.

Permutation groups, characters, π properties, automorphisms, lattices of subgroups, classes of infinite groups, linear groups, recent literature.

935. *Advanced Group Theory II*

Winter. 3(3-0) MTH 934.

Continuation of MTH 934.

936. *Advanced Group Theory III*

Spring. 3(3-0) MTH 935.

Continuation of MTH 935.

948. *Fluid Dynamics III*

Spring of odd-numbered years. 3(3-0) MTH 885.

General theory of perfect fluids including motion of incompressible fluids in two and three dimensions and applications to problems of wing profiles. Viscous and compressible fluids discussed briefly.

964. *Algebraic Topology I*

Fall. 3(3-0) MTH 834, MTH 862.

Simplicial and singular homotopy theory, Eilenberg-Steenrod axioms, chain complexes, cell complexes, applications to Euclidean spaces.

965. *Algebraic Topology II*

Winter. 3(3-0) MTH 964.

Continuation of MTH 964 including category and functor theory, general coefficient and cohomology theory.

966. Algebraic Topology III
Spring. 3(3-0) MTH 965.
Continuation of MTH 965 including homology groups of products. Eilenberg-Zilber theorems, cohomology products, differential topology.

991. Advanced Topics in Geometry
Fall, Winter, Spring, Summer. 1 to 6 credits. May reenroll for a maximum of 36 credits. Approval of department.
Advanced topics in geometry.

992. Advanced Topics in Analysis
Fall, Winter, Spring, Summer. 1 to 6 credits. May reenroll for a maximum of 36 credits. Approval of department.
Advanced topics in analysis.

993. Advanced Topics in Algebra
Fall, Winter, Spring, Summer. 1 to 6 credits. May reenroll for a maximum of 36 credits. Approval of department.
Structure of rings and algebras, Lie Algebras, Jordan algebras, advanced algebraic number theory, advanced matrix theory, and advanced topics in group theory, Lattice theory.

994. Advanced Topics in Applied Mathematics
Fall, Winter, Spring, Summer. 1 to 6 credits. May reenroll for a maximum of 36 credits. Approval of department.
Nonlinear differential equations, asymptotic theory in differential equations, existence theorem, diffraction theory, Wiener-Hopf techniques.

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

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, hearing, scales, timbre, musical instruments. Room acoustics. Electronic reproduction and synthesis of music. Demonstrations emphasized.

303. Thermal-Fluid Phenomena
Winter. 3(3-0) MMM 201, MTH 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 303.
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) MTH 215 or concurrently.
Zeroth, first and second laws of thermodynamics. General energy equation. Process relations. Concepts of equilibrium, reversibility, and irreversibility. 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 principle 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) MMM 306 or concurrently.
Analysis of displacement, velocity, and acceleration in 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; MMM 306.
Fluid statics; Bernoulli equation; nondeformable control volume applied to conservation of mass, momentum and energy; derivation of differential equations of continuity and momentum; similtude.

333. Fluid Mechanics II
Fall, Spring, Summer. 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, refrigerator and combustion process.

351. Mechanical Engineering Analysis
Fall, Winter, Spring, Summer. 4(4-0) CPS 120 or concurrently, MTH 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(4-0) MMM 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 mechanics and hydraulics.

406. Automotive Engines
Spring. 3(3-0) M E 312.
Analysis of internal combustion engines for vehicular propulsion.

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

410. Thermomechanical Continua
Fall. 3(3-0) MMM 211.
Reexamination 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, Summer. 3(3-0) M E 311.
Analysis of steady-state and transient heat conduction; numerical solutions. Radiant heat transfer; principles and applications including radiation networks. Gaseous radiation exchange.

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, thermionic, 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.
Principles of solar radiation. Calculations of terrestrial difuse and direct-beam insolation. Analyses of flat-plate and focusing collectors and energy storage systems. Solar-assisted heat pumps. Photovoltaics. Biomass conversion.

416. Statistical Thermodynamics
(313.) Spring. 3(3-0) M E 311.
Kinetic theory, classical statistical mechanics, and quantum statistical mechanics. Derivation of transport coefficients. Applications of statistical mechanics.

421. Mechanical Design
Fall, Winter. 3(3-0) MMM 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 layers, 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, propellors, turboprops, and turbofans; a specific propulsion system will be designed.

434. Aerospace Engineering III
(471.) Spring. 3(3-0) MMM 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.