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, parentheses, reciprocals, linear equations, integer exponents, applied problems, coordinate systems, graphing, solving equations by graphing. *Approved through Spring 1982.*

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, rational functions, exponents, roots and radicals, first and second degree equations, linear inequalities, complex numbers, word problems. *Approved through Spring 1982.*

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, parentheses, reciprocals, linear equations, integer exponents, applied problems, coordinate systems, graphing, solving equations by graphing. *Approved through Spring 1982.*

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, rational functions, exponents, roots and radicals, first and second degree equations, linear inequalities, complex numbers, word problems. *Approved through Spring 1982.*

108. College Algebra and Trigonometry I

Fall, Winter, Spring. 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. 5(5-0) 1-1/2 high school units in algebra and superior score on placement test, or MTH 108; 1 high school unit in geometry. Not open to students with credit in MTH 102 or 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. 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, satisfactory score in algebra placement examination, trigonometry or MTH 102 or concurrently. 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.

190. Freshman Mathematics Seminar

Winter, Spring. 3(3-0) Freshmen Mathematics majors; prior or concurrent calculus enrollment.

Intended to introduce mathematics majors to the type of mathematical reasoning and subject matter they can expect to encounter in advanced mathematics courses. Specific content will vary.

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.

202. Foundations of Algebra

Winter, Spring. 4(4-0) MTH 201; elementary education majors.

Fundamental concepts of algebra for elementary school teachers.

203. Foundations of Geometry

Spring. 4(4-0) MTH 201; elementary education majors.

Fundamental concepts of geometry for prospective elementary school 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.

216. *Mathematics of Finance*

Winter. 3(3-0) MTH 108 or MTH 111.

Mathematical theory of interest with application to such topics as ordinary, due, and deferred annuities, amortization of debts; depreciation; capitalized cost; purchase price of bonds.

290. *Special Topics in Mathematics*

Fall, Winter, Spring. 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 course.

302. *Introduction to Combinatorics and Its Applications*

Spring. 4(4-0) MTH 113.

Permutations combinations, the binomial and multinomial theorems, the principle of inclusion and exclusion, derangements, recurrence relations, Fibonacci sequences, generating functions, trees, graphs, chromatic polynomials, paths in networks.

305. *Elementary Mathematics Education*

Spring. 4(4-0) Elementary education mathematics minor and approval of department.

Professional organizations and their journals, mathematics curriculum in standard text series, new curriculum developments and projects, problems in assessments and evaluation.

309. *Theory of Equations*

Spring. 4(4-0) MTH 113 or approval of department.

Desirable for those preparing to teach mathematics in high schools. Mathematical induction, complex numbers, theorems in roots of polynomial equations, cyclotomic equations, ruler and compass constructions, solution of cubic and quartic equations, approximation to roots, theory of determinants, an introduction to matrices and some history of the theory of equations.

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, Summer. 3(3-0) MTH 113 or approval of department.

Diophantine equations, congruences, quadratic residues, finite fields.

334. *Theory of Matrices*

Fall, Winter, Spring. 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.

350. *Mathematical Modeling for Teachers*

Spring, Summer. 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.

351. *Introduction to Numerical Analysis*

(321.) 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 MTH 381 and MTH 341, MTH 310. 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.

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.

401. *Geometry for Teachers*

Summer. 3(3-0) Approval of department; not applicable to major or minor requirements.

Topics in geometry for junior and senior high school teachers.

405. *Mathematical Topics for Teachers*

Fall, Winter, Spring, Summer. 3(3-0) May reenroll for a maximum of 12 credits. Approval of department; open only to teachers participating in teacher institutes or special extension courses.

412. *Axiomatic Geometry*

Fall of odd numbered years. 4(4-0) MTH 215 or approval of department.

Euclid's and Hilbert's axioms; non-Euclidean geometries, the space concept, metric spaces and basic, topological concepts, the Erlanger Program.

413. *Projective Geometry*

Winter of even-numbered years. 4(4-0) MTH 215 or approval of department.

Axioms. Basic configurations. Synthetic and analytic treatment of projective transformations, duality, conics, poles, involution. Introduction of a metric.

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 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(3-0) 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(3-0) MTH 427.

Continuation of MTH 427.

429. *Real Analysis III*

Spring. 4(3-0) 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*

Spring. 4(4-0) MTH 451.

Continuation of MTH 451.

461. *Topology*

Winter, Spring. 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.

471. *Mathematical Logic*

Fall. 4(4-0) MTH 215 or approval of department.

Language of mathematics. Informal axiomatic method. Propositional logic, validity, axiom and rules of inference, introduction to algebra of sets. Predicate logic. Logic of identity.

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.

481. *Selected Mathematical Ideas in Biology*

Winter, Spring. 4(4-0) MTH 214 or MTH 123.

Matrix algebra, difference and differential equations, graphical and numerical methods, discrete and continous population models, compartmental analysis, enzyme kinetics, theory of chemostat, hormonal controls, diffusion processes, food chains, pollution problems.

490. *Mathematical Problems*

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

Individualized study adapted to the preparation and interests of the student.

800. *Set Theory and Foundations of Mathematics*

Spring. Summer. 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) Doctoral student in mathematical education or approval of department.

Historical origin of the content, methodology, forces, issues in mathematics education in the United States, Canada and Europe. Delineation of the important issues and problems.

802. *Mathematics Education II*

Winter. 3(3-0) MTH 801.

Consideration of the historical development, philosophy, and psychological considerations underlying the various contemporary mathematics curriculum projects for grades K-12. Examination of the 'forces' and 'issues' surrounding the projects.

803. *Mathematics Education III*

Spring. 3(3-0) MTH 802.

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.

811. *Theory of Relativity*

Winter of even-numbered years. 4(4-0) MTH 816.

Physical bases of theory of relativity. Introduction to space-time of two and four dimensions, and to relativistic dynamics, hydrodynamics and electromagnetism. Relativistic effects in solar gravitation field.

812. *Foundations of Geometry*

Fall. 4(4-0) MTH 426 or approval of department.

Incidence, affine and projective geometries. Finite projective planes, block designs. Lattice representations, coordination. Transformations Erlangen program, classical geometries. Metric topology, programs of Blumenthal and Busmann.

813. *Geometry of Linear Spaces*

Winter. 4(4-0) MTH 812.

Linear topological spaces, Banach spaces, locally convex spaces. Linear transformations and functionals, extension theorems, conjugate spaces, weak topologies. Convexity, Krien-Milman theorem. Minkowski spaces, Helly's theorem. Caratheodory's theorem. Extremal structure.

814. *Introduction to Differential Geometry*

Spring. 4(4-0) MTH 426 or approval of department.

Curves and surfaces in 3-space, curvature, torsion, Frenet formulas. Riemannian manifolds, Gauss and mean curvature, geodesics, theorem egregium, Gauss-Codazzi equations, Gauss-Bonnet and Hilbert theorems.

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 of even-numbered years. 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 426.
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*
Fall. 3(3-0) MTH 334.
Algebraic background; theory of linear and cyclic codes; advanced topics.

831. *Applied Matrix Theory*
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; orthotriangular factorization; least error, least effort problems; determinants, eigen values and eigen vectors, diagonalization methods, rank factorizations.

832. *Symmetry Groups and Their Applications*
Spring. 3(3-0) Matrix theory.
Elementary Group Theory, orthogonal and isometry groups; isometrices as translations, rotations; glide reflections, screw rotations; symbols for isometries, point and space groups, lattices, latice groups, Bravais lattices, crystals.

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. Summer of even-numbered years. 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 334, MTH 423, MTH 426.
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.

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.

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. Variable credit. 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 823, MTH 862 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.

927. *Theory of Measure and Integration*

Spring. 3(3-0) MTH 822. Interdepartmental with the Department of Statistics and Probability.

Introduction to the theory of integration over abstract spaces. Topics include: measure spaces; measurable and integrable functions; modes of convergence, theorems of Egroff, Lusin, Riesz-Fisher, Lebesgue absolute continuity, and the Radon-Nikodym theroem; product measures and Fubini's theorem. Applications to some of the classical theories of integration and summability.

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, ⅛-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.

951. *Approximation Theory I*

Fall of odd-numbered years. 3(3-0) MTH 823 or approval of department.

Tchebycheff, approximation with polynomials, rational functions and general linear families; the Uncity problem; degree of approximation; Berstein Polynomials; Remes algorithm, uniform approximation with constraints.

952. *Approximation Theory II*

Winter of even-numbered years. 3(3-0) MTH 951.

Continuation of MTH 951. Generalized methods of measuring error: Approximation in Li, and Lp norms, least-square approximation and orthogonal functions; spline functions; approximation in normed linear spaces.

953. *Approximation Theory III*

Spring of even-numbered years. 3(3-0) MTH 952.

Continuation of MTH 952.

961. *Topological Groups*

Winter of even-numbered years. 3(3-0) MTH 862.

General properties of topological groups, classical groups and Lie groups.

962. *Point Set Topology*

Fall of odd-numbered years. 3(3-0) MTH 823, MTH 861.

Hausdorff continua, Hahn-Mazurkiewicz cyclic element theory, monotone decompositions, indecomposable continua, homogeneity.

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. Variable credit.

992. *Advanced Topics in Analysis*

Fall, Winter, Spring, Summer. Variable credit.

993. *Advanced Topics in Algebra*

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

Nonlinear differential equations, asymptotic theory in differential equations, existence theorem, diffraction theory, Wiener-Hopf techniques.

996. *Advanced Topics in Topology*

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

Topological groups, topology of Euclidean spaces, axiomatic homology theory, homotopy theory, function spaces.

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. 3(3-0) or 4(4-0) Interdepartmental with and administered by the Department of Physics.

Man-sound relationship. Production, propagation, detection of sounds. Voice hearing, scales, timbre, musical instruments. Room acoustics. Electronic reproduction and synthesis of music. Demonstrations emphasized.

202. *The Science of Sound II*

Spring. 3(3-0) or 4(4-0) PHY 201. Interdepartmental with the Department of Physics.

Nature, generation, and progagation of sound. Acoustical phenomenon and measurements. Storage and manipulation of sound in numerical form. Music programming.

300. *Technology and Utilization of Energy*

Winter. 3(3-0) Initial course in any sequence of courses in the Department of Natural Science. Interdepartmental with the Department of Engineering.

Problems of energy technology and its impact: energy sources, conversions, waste and environmental effects, future outlook for mankind.

303. *Thermal-Fluid Phenomena*

Spring. 3(3-0) MMM 201 or approval of department.

Concepts and principles used to describe, predict, or explain thermal and fluid-flow phenomena. Constraints, approximations, engineering problem solving. Application to socio-technical questions.

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) EGR 260; 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.

341. *Computer Aided Manufacturing*

Fall. 4(3-2) CPS 110 or CPS 120. Interdepartmental with the Department of Computer Science.

Numerical control, Computer-Aided Numerical Control, Direct Numerical Control, and adaptive control applied in present day manufacturing. Use of the APT language to control NC machines.

346. *Mechanical Engineering Measurements Laboratory*

Winter, Spring. 2(1-3) E E 345.

Mechanical engineering experiments including accuracy, data reduction, and the measurement of pressure, velocity, temperature, heat flow and vibration.

347. *Thermosciences and Energy Systems Laboratory*

Fall, Spring, Summer. 2(1-3) M E 311, M E 346, 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 Anlysis*

Fall, Winter, 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) PHY 288, MTH 310.

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(2-3) 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*

Winter. 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.

417. *Propulsion*

Spring. 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.

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.