863. *Problems in International Business*

(861.) Fall. 4(4-0) 860 or approval of department.

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. Variable credit. Approval of department.

905. *Analysis of Business Enterprise Systems*

Fall. 3 credits. 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*

(910.) 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*

(910.) Spring. 5(5-0) 910A.

Continuation of MTA 910A.

911A. *History of Market Thought*

(911.) Fall. 4(4-0) May re-enroll for a maximum of 15 credits. 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 restrospective and original materials, discussion and research paper.

911B. *Seminar in Macro Marketing*

(911.) Winter. 4(4-0) May re-enroll for a maximum of 15 credits. 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) 812, 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) 909, 912.

Applications in theory, principles, and processes developed in MTA 909 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) 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. *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 Mathematics Department which carry credit.

081. *Elements of Algebra*

Fall, Winter, Spring. 0(3-0) [3(3-0)]† Current enrollment in 103.

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.

082. *Intermediate Algebra*

Fall, Winter, Spring. 0(2-0) [2(2-0)]† Current enrollment in 104, one year of high school algebra.

Properties of real numbers, polynomials, factoring, rational functions, exponents, roots and radicals, first and second degree equations, linear inequalities, complex numbers, word problems.

102. *Trigonometry*

Fall, Winter, Spring. 3(3-0) 1½ high school units in algebra and satisfactory score on placement test, or 082; 1 high school unit in geometry. Not open to students who have had trigonometry in high school or credit in 109.

Trigonometric functions, identities, related angles, radian measure, graphs, sum and difference formulas, simple trigonometric equations, logarithms, solution of plane triangles, inverse functions.

103. *Elements of Algebra*

Fall, Winter, Spring. 2(2-0) Current enrollment in 081.

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.

104. *Intermediate Algebra*

Fall, Winter, Spring. 3(3-0) Current enrollment in 082, one year of high school algebra.

Properties of real numbers, polynomials, factoring, rational functions, exponents, roots and radicals, first and second degree equations, linear inequalities, complex numbers, word problems.

†See page A-2 item 3.

108. *College Algebra and Trigonometry I*

Fall, Winter, Spring. 5(5-0) 1½ high school units in algebra and satisfactory score on placement test, or 082; 1 high school unit in geometry. Not open to students with credit in 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) 1½ high school units in algebra and superior score on placement test, or 108; 1 high school unit in geometry. Not open to students with credit in 102 or 111.

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

110. *Finite Mathematics with Applications*

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

Elementary combinatorial analysis, binomial theorem, vectors and matrices, convex sets and linear programming, graph theory, applications to theory of games.

111. *College Algebra*

Fall, Winter, Spring, Summer. 5(5-0) 1½ years of high school algebra, 1 year of high school geometry, satisfactory score in algebra placement examination, trigonometry or 102 or concurrently. Not open to students with credit in 108 or 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 I with Analytic Geometry*

Fall, Winter, Spring, Summer. 5(5-0) 109 or 111.

The sequence 112, 113, 214, 215 is an integrated course in calculus, analytic geometry and differential equations covering derivatives, curve sketching, definite and indefinite integrals, area, volume, transcendental functions, vector analysis, solid geometry, partial differentiation, multiple integrals, infinite series, power series, differential equations.

113. *Calculus II with Analytic Geometry*

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

A continuation of 112.

122. *Calculus I*

Winter. 5(5-0) 109 or 111; not open to engineers, physical science or mathematics majors or to students with credit in 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*

Spring. 5(5-0) 122, not open to engineers, physical science or mathematics majors or to students with credit in 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) Freshman 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. Foundations of Arithmetic

Fall, Winter, Spring, Summer. 4(3-2) Open only to elementary education majors.

Fundamental concepts and structure of arithmetic for prospective elementary school teachers.

202. Foundations of Algebra

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

Fundamental concepts of algebra for elementary school teachers including properties of real numbers, equations, and inequalities, modular arithmetic, complex numbers, polynomials, algebraic structures, functions.

203. Foundations of Geometry

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

Fundamental concepts of geometry for prospective elementary school teachers.

214. Calculus III with Vectors

Fall, Winter, Spring, Summer. 5(5-0) 113.

Continuation of 113.

215. Calculus IV with Differential Equations

Fall, Winter, Spring, Summer. 5(5-0) 214.

Continuation of 214.

216. Mathematics of Finance

Winter. 3(3-0) 108 or 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.

227. Calculus for Social Scientists

Fall. 4(4-0) Graduate standing; 1½ years of high school algebra or high placement score; 1 year of high school geometry. Not open to students who have credit for calculus.

The sequence 227, 228 intended for social science graduate students is mainly calculus. Course 227 includes pre-calculus, differentiation and integration of elementary functions, applications.

228. Calculus for Social Scientists

Winter. 4(4-0) 227.

Mean value theorems, approximate integration, infinite series, Taylor series, partial derivatives, double and triple integration, and applications.

290. Special Topics in Mathematics

Fall, Winter, Spring. 1 to 5 credits. May re-enroll 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.

301. Foundations of Mathematics

Fall, Winter, Spring. 3(3-0) Approval of department.

Fundamental ideas underlying elementary mathematics. Basic set theory, relations, functions, mathematical induction, meaning of mathematical proof and the axiomatic method illustrated by examples from algebra, geometry and analysis.

302. Introduction to Combinatorics and Its Applications

Spring. 4(4-0) 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.

309. Theory of Equations

Fall, Winter, Spring, Summer. 4(4-0) 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.

315. Concepts of Geometry I

Fall, Winter, Spring. 3(3-0) 215 or 301 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) 315.

Continuation of 315

321. Introduction to Numerical Analysis

Winter, Spring. 4(4-0) 215 and knowledge of FORTRAN programming. Students may not receive credit in both 321 and 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.

322. Introduction to Complex Variables

Spring. 4(4-0) 215.

Elements of functions of a complex variable. Topics selected from complex number systems, infinite series, elementary functions, differentiation and integration, Taylor and Laurent series, conformal mapping, theory of residues.

324. Foundations of Analysis

Fall, Winter. 4(4-0) 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) 113 or approval of department.

Diophantine equations, congruences, quadratic residues, finite fields.

334. Theory of Matrices

Fall, Winter, Spring. 4(4-0) 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

Fall, Winter. 3(3-0) 301 or approval of department.

Rings, integral domains, properties of integers, fields, groups, polynomials.

341. Initial and Boundary Value Problems

Winter, Spring. 4(4-0) 215.

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.

381. Chemical Engineering Analysis

Fall, Spring. 3(3-0) Students may not receive credit in both 381 and 341. 215. Interdepartmental with and administered by the Chemical Engineering Department.

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. 215 or approval of department.

Individualized reading and study in mathematics for students of high intellectual promise.

401. Geometry for Teachers

Winter, Summer. 3(3-0) Approval of department; open only to participants in teachers institutes.

Topics in geometry for junior and senior high school teachers.

402. Algebra for Teachers

Fall, Summer. 3(3-0) Approval of department; open only to participants in teachers institutes.

Discussion of the historical and postulational development of the number system and other algebraic topics.

403. Concepts in Calculus

Spring, Summer. 3(4-0) One year of calculus; open only to participants in teachers institutes.

An introduction to advanced calculus, emphasizing concepts, derivation of formulas and proofs of theorems. Includes a discussion of functions, limits and continuity, the meaning of the derivative, the mean value theorem and Taylor's formula with remainder; partial derivatives; definite and indefinite integrals and their properties, the fundamental theorem of calculus with a few applications; and infinite series.

405. Mathematical Topics for Teachers

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

412. Axiomatic Geometry

(418.) Fall. 4(4-0) 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

(417.) Winter. Summer of odd-numbered years. 4(4-0) 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

(416.) Spring. 4(4-0) 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

Fall. 4(4-0) 424.

Linear differential equations, Wronskians, Green's functions, existence and uniqueness theorems, plane autonomous systems, approximate solutions, regular singular points. Sturm-Liouville systems.

421. Vector and Tensor Analysis

Fall, Winter, Summer. 4(4-0) 215, 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) 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) 424 or 427.

Analytic functions, integrals, power series, residues, poles, conformal mapping and applications.

424. Advanced Calculus

Fall, Winter, Spring, Summer. 4(4-0) 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

Fall, Winter, Spring, Summer. 3(3-0) 424.

Continuation of 424.

426. Advanced Calculus

Fall, Winter, Spring. 3(3-0) 425.

Continuation of 425.

427. Real Analysis I

Fall, Winter. 4(3-0) Approval of department.

Topology, limits and continuity in E^n, functions of bounded variation, Riemann integration, calculus of several variables, linear transformations and derivatives.

428. Real Analysis II

Winter, Spring. 4(3-0) 427.

Continuation of 427.

429. Real Analysis III

Fall, Spring. 4(3-0) 428.

Continuation of 428.

432. Abstract Algebra I

Fall, Winter. 4(4-0) 215.

Introduction to the concepts of basic algebraic structures, namely: group, ring, integral domain, field polynomial ring, module, vector space, linear transformations, etc.

433. Abstract Algebra II

Winter, Spring. 4(4-0) 432.

Continuation of 432.

434. Abstract Algebra III

Fall, Spring. 4(4-0) 433.

Continuation of 433.

437. Theory of Numbers II

Spring. 3(3-0) 331 or 432 or approval of department.

Dirichlet series, distribution of primes, sums of squares, Pell's equation, continued fractions, Hurewicz Theorem.

451. Numerical Analysis I

Winter, Spring. 4(4-0) 334, 424 or approval of department. Students may not receive credit in both 321 and 451.

Numerical solution of linear and non-linear 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) 451.

Continuation of 451.

461. Topology

Winter, Spring. 4(4-0) 424.

Introduction to fundamental concepts in topology, to metric and topological spaces, connectedness, compactness, continuity and simple connectedness.

462. Combinatorial Topology

Spring. 4(4-0) 461 or 424.

Unicursal graphs, surface topology, classification of surfaces, elementary set-theoretic topology, complexes.

471. Mathematical Logic

Fall. 4(4-0) 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) 113, graduate status in either economics, agricultural economics or College of Business, or approval of department. Interdepartmental with the Economics Department.

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.

490. Mathematical Problems

Fall, Winter, Spring. 1 to 4 credits. May re-enroll 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) 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) 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) 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.

811. Theory of Relativity

Winter of odd-numbered years. 4(4-0) 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) 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 Busemann.

813. Geometry of Linear Spaces

Winter. 4(4-0) 812.

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

814. Introduction to Differential Geometry

Spring. 4(4-0) 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 even-numbered years. 4(4-0) 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) 334, 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 theorem, chromatic numbers, incidence matrices, and automorphism groups.

818. *Theory of Linear Graphs II*

Spring of even-numbered years. 3(3-0) 817.

Advanced topics in the theory of linear graphs and combinatorial analysis. Polya's theorem and its application to enumeration problems.

821. *Analysis I*

Fall, Winter. 3(3-0) 426 or concurrently.

Real numbers, complex numbers, metric spaces, complex differentiation and integration, Cauchy's integral theorem and formula, power series, Laurent series, irregularities, theory of residues, Lebesgue measure and integration, L^p spaces.

822. *Analysis II*

Winter, Spring. 3(3-0) 821.

Continuation of 821.

823. *Analysis III*

Spring. 3(3-0) 822.

Continuation of 822.

824. *Real and Complex Analysis*

Fall. 3(3-0) 426.

Topics in this course, 825 and 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) 824.

Continuation of 824.

826. *Real and Complex Analysis*

Spring. 3(3-0) 825.

Continuation of 825.

827. *Calculus of Variations*

Spring. 4(4-0) 426.

Necessary conditions of Euler, Legendre, Weierstrass and Jacobi for minimizing integrals, sufficiency proofs, isoperimetric problems, general problems of Lagrange, Mayer, and Bolza and an introduction to optimal control theory.

828. *Hilbert Spaces*

Winter of even-numbered years. 4(4-0) 426.

Normed linear spaces, with particular emphasis on Hilbert spaces and linear operators in these spaces; linear functionals, conjugate spaces, operator algebra, spectral theory; and applications.

831. *Theory of Matrices and Groups*

Winter, Summer. 4(4-0) 334 or 421 or approval of department.

Vector spaces, matrices and linear transformations, groups of linear transformations, similarity and congruence, characteristic values and characteristic vectors, symmetric matrices and quadratic forms.

832. *Group Representations*

Spring. 4(4-0) 831.

Continuation of 831. Eigenvalues and eigenvectors of matrices; characters and matrix representations of groups. Symmetric and general linear group. Applications to topics such as crystal and molecular structures.

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) 834.

Continuation of 834.

836. *Algebra III*

Spring. 3(3-0) 835.

Continuation of 835.

841. *Boundary Value Problems I*

Fall. Summer of even-numbered years. 3(3-0) 422, 423; 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) 841.

Continuation of 841.

843. *Boundary Value Problems III*

Spring. 4(4-0) 842.

Continuation of 842.

844. *Methods of Applied Analysis I*

Fall. 3(3-0) 334, 423, 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) 844.

Continuation of 844.

846. *Methods of Applied Analysis III*

Spring. 3(3-0) 845.

Continuation of 845.

847. *Theory of Ordinary Differential Equations I*

Fall. 3(3-0) 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) 847.

Continuation of 847; oscillation theory, asymptotic behavior, Lyapunov stability, boundary value problems.

849. *Theory of Ordinary Differential Equations III*

(941.) Spring. 3(3-0) 848; approval of department.

Advanced topics in ordinary differential equations.

851. *Numerical Analysis I*

Fall. 3(3-0) 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) 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) 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.

857. *Numerical Methods in Partial Differential Equations*

Spring. 4(4-0) 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) 861.

Continuation of 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) 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) 426, 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) 424; 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) 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) 871.

Continuation of 871.

881. *Foundations of Applied Mathematics I*
Fall. 3(3-0) 426 or 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) 881.

Continuation of 881.

883. *Foundations of Applied Mathematics III*
Spring. 3(3-0) 882.

Continuation of 882.

884. *Fluid Dynamics I*
Winter of odd-numbered years. 3(3-0) 881 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*
Spring of odd-numbered years. 3(3-0) 884.

Continuation of 884.

886. *Partial Differential Equations I*
(944.) Fall. 3(3-0) 334, 423, 426.

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

887. *Partial Differential Equations II*
(945.) Winter. 3(3-0) 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*
(946.) Spring. 3(3-0) 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. *Research*
Fall, Winter, Spring, Summer. Variable credit. Approval of department.

921. *Theory of Functions of a Complex Variable I*
Fall. 3(3-0) 823.

Conformal mapping, Riemann's theorem, reflection principle, mapping of boundary points, entire and meromorphic functions, order of a function, theorems of Picard-Nevanlinna, power series with finite radius of convergence, Abel's theorem and its converses.

922. *Theory of Functions of a Complex Variable II*
Winter. 3(3-0) 921.

Continuation of 921.

923. *Theory of Functions of a Complex Variable III*
Spring. 3(3-0) 922.

Continuation of 922.

924. *Functional Analysis I*
Fall. 3(3-0) 823, 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. 3(3-0) 924 or approval of department.

Continuation of 924.

926. *Functional Analysis III*
Spring. 3(3-0) 925.

Continuation of 925.

927. *Theory of Measure and Integration*
Spring. 4(4-0) 861. Interdepartmental with the Statistics and Probability Department.

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

931. *Non-Associative Algebras I*
Fall of odd-numbered years. 3(3-0) 836.

Non-associative algebras, radicals, idempotent decomposition of simple algebras.

932. *Non-Associative Algebras II*
Winter of even-numbered years. 3(3-0) 931.

Continuation of 931. Nil algebras, structure and representations, Lie algebras.

933. *Non-Associative Algebras III*
Spring of even-numbered years. 3(3-0) 932.

Continuation of 932. Relations between non-associative algebras, representations and cohomology theory.

934. *Advanced Group Theory I*
Fall. 3(3-0) 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) 934.

Continuation of 934.

936. *Advanced Group Theory III*
Spring. 3(3-0) 935.

Continuation of 935.

937. *Commutative Algebra I*
Fall of even-numbered years. 3(3-0) 836.

Algebraic number theory, Noetherian rings, Dedekind domains and classical ideal theory, valuation theory, power series rings, local rings.

938. *Commutative Algebra II*
Winter of odd-numbered years. 3(3-0) 937.

Continuation of 937.

939. *Commutative Algebra III*
Spring of odd-numbered years. 3(3-0) 938.

Continuation of 938.

948. *Fluid Dynamics III*
Fall of odd-numbered years. 3(3-0) 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) 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) 951.

Continuation of 951. Generalized methods of measuring error: Approximation in L^1 and L^p 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) 952.

Continuation of 952.

961. *Topological Groups*
Winter of even-numbered years. 4 credits. 862.

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

962. *Point Set Topology*
Fall of odd-numbered years. 3(3-0) 823, 861.

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

964. *Algebraic Topology I*
Fall. 3(3-0) 834, 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) 964.

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

966. Algebraic Topology III

Spring. 3(3-0) 965.

Continuation of 965 including homology groups of products, Eilenberg-Zilber theorems, cohomology products, differential topology.

981. Methods of Complex Analysis I

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

Application of functions of a complex variable to contour integrals, conformal mapping, asymptotic methods, integral transform methods, Weiner-Hopf methods and special functions.

982. Methods of Complex Analysis II

Winter of odd-numbered years. 3(3-0) 981.

Continuation of 981.

983. Methods of Complex Analysis III

Spring of odd-numbered years. 3(3-0) 982.

Continuation of 982.

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. 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

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

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 Physics Department.

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

230. Residence Heating

Fall. 4(3-2) Building construction majors.

Calculation of heat losses and heat gains for typical residences, and system design and layout for both heating and air-conditioning.

255. Computer Models in Science and Engineering

Spring. 3(3-0) CPS 110 or 120 or equivalent FORTRAN. Interdepartmental with the Computer Science Department.

Problem-solving; development of student's ability to formulate computable models based on finite physical elements, examples from statics, dynamics, electrical resistance, and conduction heat transfer.

280. Manufacturing Processes

Fall, Winter, Spring. 3(3-0)

An introduction to the materials and processes used in manufacturing, to convert ideas into products, machines, and structures for the use of mankind. Extensive use is made of audio-visual techniques.

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 Engineering Department.

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. 3(3-0) MTH 215 or concurrently.

Zeröth, 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) 311.

Continuation of 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.

315. Thermodynamics Laboratory I

Fall, Winter. 1(0-3) 311 concurrently.

Laboratory experiments applying the basic laws of thermodynamics.

316. Thermodynamics Laboratory II

Winter, Spring. 1(0-3) 312 concurrently.

Laboratory experiments investigating gases and liquid behavior and combustion from a thermodynamic viewpoint.

320. Kinematics of Machines I

(420.) Fall, Spring. 4(3-3) MMM 306 or concurrently; EGR 260.

Absolute and relative displacements, velocities, and accelerations in rigid body systems; analysis and synthesis of multi-bar linkages and rotational mechanisms.

332. Fluid Mechanics I

Winter, Spring. 4(3-3) 311, MMM 306.

Fluid statics. Fundamental concepts and analysis techniques. Deformable and non-deformable control volume approach to conservation of mass, linear and moment of momentum, energy. Dimensional analysis, similitude and examples of engineering usage.

333. Fluid Mechanics II

(431.) Fall, Spring. 4(3-3) 332, 351 concurrently.

Field descriptions, stress-strain relations for a fluid, circulation, vorticity, field equations for continuity and momentum, boundary layers, basic concepts of turbulence, Reynolds equations, phenomeno-logical theories, one-dimentional gas dynamics.

351. Mechanical Engineering Analysis

Fall, Winter. 4(4-0) MTH 215; CPS 120 or concurrently.

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) MTH 215 concurrently.

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.

380. The Modern Automobile

Fall. 3(3-0)

Characteristics of the automobile that affects society: safety, pollution, substitutes for the present engine, substitutes for the automobile, economic problems, manufacturing techniques; quality control, sales and distribution.

406. Automotive Engines

Spring. 3(2-3) 312.

Analysis of internal combustion engines for vehicular propulsion.