859. International Marketing
Fall. 4(4-0)

Presents an analytic framework for studying the development of marketing systems in the context of overall economic growth. Emphasis given to competitive marketing systems and the structure and operation of regional Common Market arrangements.

860. International Business
Winter, Summer. 4(4-0)

Case examination of United States business overseas organization and operations including administration in foreign settings, overseas personnel, marketing, financial and legal problems in conducting international business.

861. Seminar in International Business
Spring. 3(3-0)

Individual papers concerning international business problems with emphasis on administrative problems under conditions of cross cultural operations.

890. Special Problems
Fall, Winter, Spring, Summer. Variable credit. Approval of department.

905. Administration: Analysis of Business Enterprise Systems
Fall, Summer. 3 credits. 805; MGT 806.

Concepts and methods in the study of the development, functioning, and survival of business enterprise systems. Attention is directed to the elements of enterprise systems, the interaction of the elements, problems of equilibrium and growth, and strategies of business enterprise.

910. Advanced Research in Marketing
Winter. 4(4-0)

Advanced concepts and methods in the scientific investigation of market phenomena and the tools of market cultivation.

911. Advanced Seminar in Marketing
Fall, Winter, Spring. Variable credit. May re-enroll for a maximum of 15 credits.

921. Advanced Sampling and Estimation Techniques in Business Administration
Spring. 5(5-0)

Research design, estimation and decision criteria including Bayesian estimators, small sampling, stratified sampling, random and non-random sampling, information theory, powers of tests.

957. Dynamics in Marketing Theory
(857.) Spring, Summer. Variable credit. May re-enroll for a maximum of 6 credits.

Specific subject areas are selected for study where basic theoretical issues are at stake and where marketing thought is currently the most dynamic.

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.

082. Beginning Algebra II
Fall, Winter, Spring. 0(4-0) [4(4-0)]†. One year of high school algebra.

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.

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 or 120.

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.

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 or 120.

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.

190. Freshman Mathematics Seminar
Winter, Spring. 3(3-0) Freshman; 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(4-0) Open only to elementary education majors.

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

†See page A-2 item 3

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.

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.

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. Advanced Mathematics for Engineers I

Fall, 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. Advanced Mathematics for Engineers II

Fall, 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 I

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

Elementary set theory; equivalence relations; induction; construction of rationals; sequences; Cauchy sequences; construction of real numbers; order; denseness operations; least upper bounds.

325. Foundations of Analysis II

Winter, Spring. 4(4-0) 324.

Set theory; cardinal numbers; countability; index sets; mappings; open, closed, connected and compact sets; components, DeMorgans' Laws; Heine Borel Theorem; continuity; metric spaces.

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 I

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

Rings, integral domains, fields (rational and complex), properties of integers, polynomials, groups and vector spaces.

338. Concepts of Algebra II

Winter, Spring. 3(3-0) 337.

Continuation of 337.

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.

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 the calculus with a few applications; and infinite series.

416. Advanced Analytic Geometry

Fall. Summer of even-numbered years. 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.

417. Projective Geometry

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.

418. Axiomatic Geometry

Spring. 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.

420. Ordinary Differential Equations

Fall. 4(4-0) 325 or 424.

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

421. Applied Analysis I

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. Applied Analysis II

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. Applied Analysis III

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 or 325.

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

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. 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) 325 or 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 of odd-numbered years. 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.

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 325 or approval of department.

Axiomatic method; various formulations of the axiom of choice; cardinal and ordinal numbers.

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. 4(4-0) 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. 4(4-0) 821.

Continuation of 821.

823. Analysis III

Spring. 4(4-0) 822.

Continuation of 822.

824. Theory of Functions of a Real Variable

Fall. 4(4-0) 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. Theory of Functions of a Real Variable

Winter. 4(4-0) 824.

Continuation of 824.

826. Theory of Functions of a Real Variable

Spring. 4(4-0) 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. 4(4-0) 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. 4(4-0) 834.

Continuation of 834.

836. Algebra III

Spring. 4(4-0) 835.

Continuation of 835.

838. Analytic Number Theory

Fall of even-numbered years. 4(4-0) 821 or approval of department.

Solution of number theoretical problems by complex analysis. Zeta function, prime number theorem, partitions, irrational numbers, binary quadratic forms, geometry of numbers.

841. Boundary Value Problems I

Fall. Summer of even-numbered years. 4(4-0) 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. 4(4-0) 841.

Continuation of 841.

843. Boundary Value Problems III

Spring. 4(4-0) 842.

Continuation of 842.

847. Theory of Ordinary Differential Equations I

Fall. 4(4-0) 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. 4(4-0) 847.

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

851. Numerical Analysis I

Fall. 4(4-0) 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. 4(4-0) 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. 4(4-0) 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. 4(4-0) 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. 4(4-0) 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. 4(4-0) 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. 4(4-0) 424 or 325; 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. 4(4-0) 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. 4(4-0) 871.

Continuation of 871.

881. *Foundations of Applied Mathematics I*

Fall. 4(4-0) 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. 4(4-0) 881.

Continuation of 881.

883. *Foundations of Applied Mathematics III*

Spring. 4(4-0) 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.

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. 4(4-0) 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. 4(4-0) 921.

Continuation of 921.

923. *Theory of Functions of a Complex Variable III*

Spring. 4(4-0) 922.

Continuation of 922.

924. *Functional Analysis I*

Fall. 4(4-0) 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. 4(4-0) 924 or approval of department.

Continuation of 924.

926. *Functional Analysis III*

Spring. 4(4-0) 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 even-numbered years. 4 credits. 836.

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

932. *Non-Associative Algebras II*

Winter of odd-numbered years. 4 credits. 931.

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

933. *Non-Associative Algebras III*

Spring of odd-numbered years. 4 credits. 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. 4(4-0) 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. 4(4-0) 937.

Continuation of 937.

939. *Commutative Algebra III*

Spring of odd-numbered years. 4(4-0) 938.

Continuation of 938.

941. *Theory of Ordinary Differential Equations III*

Spring. 4(4-0) 848; approval of department.

Advanced topics in ordinary differential equations.

944. *Partial Differential Equations I*

Fall. 4(4-0) 823 or approval of department.

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

945. *Partial Differential Equations II*

Winter. 4(4-0) 944 or approval of department.

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

946. *Partial Differential Equations III*

Spring. 4(4-0) 945 or approval of department.

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

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. 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. 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. 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 of even-numbered years. 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 of odd-numbered years. 3(3-0) 964.

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

966. *Algebraic Topology III*

Spring of odd-numbered years. 3(3-0) 965.

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

967. *Homotopy Theory I*

Winter. 3(3-0) 964.

Sets of homotopy, fibrations, higher homotopy groups, CW complexes. homotopy functors.

968. *Homotopy Theory II*

Spring. 3(3-0) 965, 967.

Obstruction theory and the application of spectral sequences and cohomology operations to homotopy theory.

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.

990. *Introduction to Research*

Fall, Winter, Spring. 1 to 3 credits. May re-enroll for a maximum of 6 credits. Approval of department.

Introduction to mathematical research through the solution of challenging problems in a variety of fields of mathematics.

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

230. *Residence Heating*

Fall, Winter. 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.

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.

311. *Thermodynamics I*

Fall, Winter. 4(3-3) 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. 4(3-3) 311.

Continuation of 311; third law, gas and vapor relations, reactive and non-reactive mixtures. Introduction to combustion and equilibrium and to statistical mechanics and kinetic theory.

313. *Thermodynamics III*

Fall, Spring. 3(3-0) 312.

Thermodynamic principles as applied to gas and vapor power cycles for reciprocating and turbo machinery; nozzles and jets. Fundamental principles of energy conversion systems—electrical, chemical and thermal.

322. *Thermomechanical Continua*

Winter, Spring. 3(3-0) MMM 211; MTH 334.

Thermomechanical continua including energy principles, formulation and solution of boundary value problems in elasticity, plasticity, and viscoelasticity. Dynamic response of mechanical systems via Hamilton's Principle; Euler-Lagrange equations. Rayleigh, Ritz, and Galerkin approximations.

325. *Mechanical Vibrations*

Spring, Summer. 4(4-0) MMM 206; MTH 334 and 341.

Oscillatory phenomena for linear systems with one and two degrees of freedom, non-linear systems, time varying systems with deterministic excitation, and time invariant systems with non-deterministic excitations.

332. *Fluid Mechanics I*

Spring, Summer. 4(3-3) MMM 206.

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.

406. *Automotive Engines*

Winter. 3(2-3) 312, 424.

Analysis of internal combustion engines for vehicular propulsion.

407. *Automotive Vehicles*

Spring. 3(2-3) 421.

Analysis of the propulsion, braking, steering, and suspension requirements.

411. *Heat Transfer I*

Winter. 3(3-0) 311; MTH 215.

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*

Spring. 3(3-0) 411, 431.

Natural and forced convection based on boundary layer theory. Heat transfer in fluids with phase change. Heat exchangers, mass transfer.

420. *Kinematics of Machines I*

Fall. 4(3-3) MTH 214; MMM 206 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.

421. *Machine Design I*

Winter. 4(3-3) MMM 211.

Analysis and synthesis of mechanical systems; fatigue resistance; stress concentration; elasticity; non-linear elements.

422. *Machine Design II*

Spring. 3(2-3) 421.

Analysis and synthesis of elements of systems; hydrodynamic theory of lubrication; contact stresses; finite and infinite life design factors.

424. *Dynamics of Machines*

Winter. 3(3-0) 420.

Analysis of static and dynamic forces in rigid body systems; balancing of rotating and reciprocating system elements; inertial guidance; critical speeds.

428. *Control Theory*

Fall. 3(3-0) 325; MTH 322.

Closed-loop control systems; application of transfer function analysis; design for a definite degree of stability; on-and-off controllers.