1965 – 1966

senior level) course in logic. In addition, one upper division course in some science division course in mathematics (other tha was philosophy, or in philosophy (other th was mathematics. Exceptions to these req discretion of the graduate adviser.

Further Information. Further informati... about the program, including a statement of the requirements for advancement to candidacy, is given in the Announcement of the Group in Logic and the Methodology of Science, which is available upon request from the Group Office.

Courses

Courses are chosen with the advice of the graduate adviser from among the offerings of the various departments of the University. In addition to the Departments of Mathematics and Philosophy, attention is especially directed to courses in the various science departments, in statistics, and in linguistics.

Logic Colloquium. (No Credit) I and II. The Staff

Reports on current research and scholarly work by members of the staff, visitors, and graduate students.

Other Departments with Related Programs

Department of Mathematics and Department of Philosophy

MATHEMATICS

(Department Office, 301 Campbell Hall)

‡William G. Bade, Ph.D., *Professor of Mathematics.*
Paul L. Chambré, Ph.D., *Professor of Mathematics and of Nuclear Engineering.*
Shiing-Shen Chern, D.Sc., *Professor of Mathematics.*
Heinz O. Cordes, Ph.D., *Professor of Mathematics.*
René J. De Vogelaere, Ph.D., *Professor of Mathematics.*
Stephen P. Diliberto, Ph.D., *Professor of Mathematics.*
István Fáry, Ph.D., *Professor of Mathematics.*
Jacob Feldman, Ph.D., *Professor of Mathematics.*
Alfred L. Foster, Ph.D., *Professor of Mathematics.*
Bernard Friedman, Ph.D., *Professor of Mathematics.*
Henry Helson, Ph.D., *Professor of Mathematics.*
Leon A. Henkin, Ph.D., *Professor of Mathematics.*
²Morris W. Hirsch, Ph.D., *Professor of Mathmatics.*
Gerhard P. Hochschild, Ph.D., *Professor of Mathematics.*
Harry D. Huskey, Ph.D., *Professor of Mathematics and of Electrical Engineering.*

‡ Appointment in the Miller Institute for Basic Research in Science, 1965–1966.
² In residence spring semester only, 1965–1966.

²Tosio Kato, D.Sc., *Professor of Mathematics.*
John L. Kelley, Ph.D., *Professor of Mathematics.*
°Derrick H. Lehmer, Ph.D., *Professor of Mathematics.*
Hans Lewy, Ph.D., *Professor of Mathematics.*
Michel Loève, Docteur ès Sciences, *Professor of Mathematics and of Statistics.*
Charles B. Morrey, Jr., Ph.D., *Professor of Mathematics.*
Anthony P. Morse, Ph.D., *Professor of Mathematics.*
¹Edmund Pinney, Ph.D., *Professor of Mathematics.*
°Murray H. Protter, Ph.D., *Professor of Mathematics.*
Raphael M. Robinson, Ph.D., *Professor of Mathematics.*
Maxwell A. Rosenlicht, Ph.D., *Professor of Mathematics.*
Abraham Seidenberg, Ph.D., *Professor of Mathematics.*
Stephen Smale, Ph.D., *Professor of Mathematics.*
Edwin H. Spanier, Ph.D., *Professor of Mathematics.*
Alfred Tarski, Ph.D., *Professor of Mathematics.*
Abraham H. Taub, Ph.D., *Professor of Mathematics and Director of the Computer Center.*
P. Emery Thomas, Ph.D., *Professor of Mathematics.*
Robert L. Vaught, Ph.D., *Professor of Mathematics.*
František Wolf, Ph.D., *Professor of Mathematics.*
Thomas Buck, Ph.D., *Professor of Mathematics, Emeritus.*
Griffith C. Evans, Ph.D., LL.D., *Professor of Mathematics, Emeritus.*
Raymond H. Sciobereti, Ph.D., *Associate Professor of Mathematics, Emeritus.*
Pauline Sperry, Ph.D., *Associate Professor of Mathematics, Emeritus.*
²John W. Addison, Jr., Ph.D., *Associate Professor of Mathematics.*
²Glen E. Bredon, Ph.D., *Associate Professor of Mathematics.*
¹Hans J. Bremermann, Ph.D., *Associate Professor of Mathematics.*
Lester E. Dubins, Ph.D., *Associate Professor of Mathematics and of Statistics.*
Phillip A. Griffiths, Ph.D., *Associate Professor of Mathematics.*
¹Shoshichi Kobayashi, Ph.D., *Associate Professor of Mathematics.*
Antoni A. Kosinski, Ph.D., *Associate Professor of Mathematics.*
R. Sherman Lehman, Ph.D., *Associate Professor of Mathematics.*
Jerome P. Levine, Ph.D., *Associate Professor of Mathematics.*
¹Calvin C. Moore, Ph.D., *Associate Professor of Mathematics.*
°Joseph A. Wolf, Ph.D., *Associate Professor of Mathematics.*
Robert B. Brown, Ph.D., *Assistant Professor of Mathematics.*
Lutz Bungart, Ph.D., *Assistant Professor of Mathematics.*
P. Nicholas Burgoyne, Ph.D., *Assistant Professor of Mathematics.*
Richard M. Dudley, Ph.D., *Assistant Professor of Mathematics.*
Herbert B. Enderton, Ph.D., *Assistant Professor of Mathematics.*
Alfred Gray, Ph.D., *Assistant Professor of Mathematics.*
Frederick P. Greenleaf, Ph.D., *Assistant Professor of Mathematics.*

° Absent on leave, 1965–1966.
¹ In residence fall semester only, 1965–1966.
² In residence spring semester only, 1965–1966.

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Bernard R. Kripke, Ph.D., *Assistant Professor of Mathematics.*
C. Keith Miller, *Assistant Professor of Mathematics.*
Robert T. Moore, Ph.D., *Assistant Professor of Mathematics.*
[1]Andrew P. Ogg, Ph.D., *Assistant Professor of Mathematics.*
Beresford N. Parlett, Ph.D., *Assistant Professor of Mathematics.*
John L. Rhodes, Ph.D., *Assistant Professor of Mathematics.*
Marc A. Rieffel, Ph.D., *Assistant Professor of Mathematics.*
Donald E. Sarason, Ph.D., *Assistant Professor of Mathematics.*
Robert M. Solovay, Ph.D., *Assistant Professor of Mathematics.*
Hung Hsi Wu, Ph.D., *Assistant Professor of Mathematics.*
William W. Adams, Ph.D., *Instructor in Mathematics.*
Christopher T. H. Baker, Ph.D., *Instructor in Mathematics.*
Bruce A. Barnes, Ph.D., *Instructor in Mathematics.*
Ralph J. Faudree, Jr., Ph.D., *Instructor in Mathematics.*
Marvin I. Freedman, Ph.D., *Instructor in Mathematics.*
John B. Lewis, Ph.D., *Instructor in Mathematics.*
Stuart M. Newberger, Ph.D., *Instructor in Mathematics.*

Fred Galvin, M.A., *Acting Instructor in Mathematics.*
Christian M. Gram, M.S., *Lecturer in Mathematics.*
Nagayoshi Iwahori, Dr.Sc., *Visiting Professor of Mathematics.*
Ivan A. K. Kupka, Ph.D., *Acting Assistant Professor of Mathematics.*
O. Carruth McGehee, M.A., *Acting Instructor in Mathematics.*
Charles C. Pugh, Ph.D., *Acting Assistant Professor of Mathematics.*
Alan Schumitzky, M.S., *Acting Instructor in Mathematics.*
Shigeaki Tôgô, Ph.D., *Visiting Professor of Mathematics.*
Philippe Tondeur, Ph.D., *Lecturer in Mathematics.*
Frank W. Warner, 3rd, Ph.D., *Acting Assistant Professor of Mathematics.*
Harold Widom, Ph.D., *Visiting Professor of Mathematics.*
Eduardo H. Zarantonello, Ph.D., *Visiting Professor of Mathematics for the spring semester.*

Letters and Science List. All undergraduate courses in mathematics are included in the Letters and Science List of Courses. For regulations governing this list, see page 94.

Departmental Major Advisers: See departmental office.

The Major in Mathematics. The major in mathematics consists of Mathematics 1A–1B, 2A–2B, 104, 113A, 135A or 185, 130A or 140, and 12 additional units of upper division mathematics. Students who have completed H2B do not take 104. Courses 111, 120A–120B, 190A–190B are not acceptable for the major in mathematics.

[1] In residence spring semester only, 1965–1966.

Mathematics 105 is a desirable part of the major program. Courses in number theory, 115A–115B, and numerical analysis, 128A, 128B (relating to large-scale digital computers), are also available. Attention is directed to Philosophy 12 and Mathematics 125A–125B, for those who are interested in logic. Statistics 112 and 113 will be of interest to many students. Special attention is also directed to the course in analytic mechanics, Physics 105A–105B.

Subject to the requirement of competence in the major, and with the approval of the adviser, the student is at liberty to take not more than 6 units of theoretical courses in astronomy, physics, statistics, or other sciences as part of his major in mathematics.

Mathematics majors who expect to work in digital computing or to undertake further study in computer sciences are advised to take Mathematics 113B, 128A, 128B, 128C, 128D, and both 135A and 185. Statistics 112 and 113 are especially recommended, as are Electrical Engineering 148 and 153.

The Major in Mathematics for Teachers. This major prepares students for the profession of secondary teaching. Enrollment in the major is limited to 30 new students per year. Attention of students in this major is called to the ANNOUNCEMENT OF THE SCHOOL OF EDUCATION; a teaching minor also is required for the secondary teaching credential. No education courses are required for graduation.

The major in mathematics for teachers consists of Mathematics 1A–1B, 2A–2B, Philosophy 12, and special sections of 113A–113B, 115A, 130A–130B, 135A, 160, and Statistics 112. Special arrangements for transfer students can be made with the adviser.

Honors Program. In addition to completing the established requirements for the major, a student must: (a) earn a grade-point average greater than 3 in upper division mathematics courses; (b) complete two of the following three requirements, (1) Mathematics 117, (2) Mathematics 118, (3) a graduate course or seminar; (c) either pass a comprehensive examination at the end of his senior year or write a thesis—the choice to be made by the student. At the discretion of the major adviser, 3 units credit in Mathematics 199 may be given for passing the comprehensive examination or writing the thesis. (d) At the discretion of the major adviser, 6 units of the regular major requirements may be waived for honor students.

Computer Science. See the listing at end of the Department of Mathematics section and see ANNOUNCEMENT OF THE COLLEGE OF LETTERS AND SCIENCE for a description of the Group Major in Computer Science.

1A–1B. Calculus with Analytic Geometry, First Course. (4–4) Yr.

Beginning each semester.

Prerequisite: two years of high school algebra, plane geometry, plane trigonometry. Beginning calculus for mathematics majors, most physical science students, and others who wish to continue with mathematics.

Elements of analytic geometry, introduction to differential and integral calculus with applications. (1A–1B covers the material of 3A–3B and two-thirds of 4A.)

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H1A–H1B. Calculus with Analytic Geometry, First Course. (4–4) Yr.
(Formerly numbered 1C–1D.)
Prerequisite: two years of high school algebra, plane geometry, plane trigonometry.
Honors course, corresponding to 1A–1B, for able students with strong mathematical background and interest. Emphasis on theory, rigor, and hard problems. Recommended as preparation for the major, particularly for honors candidates.

2A–2B. Calculus with Analytic Geometry, Second Course. (4–4) Yr.
Beginning each semester.
Prerequisite: course 1A–1B.
Thorough technique of differential and integral calculus. Analysis of functions of several variables. Partial differentiation, multiple integrals. Differential equations. (Covers the material of one-third of 4A, all of 4B and two-thirds of 119 and 122.)

H2A–H2B. Calculus with Analytic Geometry, Second Course. (4–4) Yr.
Prerequisite: course H1A–H1B or 1A–1B and permission of instructor. Course H2B can be substituted for course 104 in the requirements for the major and in prerequisites for more advanced courses.
Honors course, corresponding to 2A–2B, for able students with strong mathematical background and interest. Emphasis on theory, rigor, and hard problems. Recommended as preparation for the major, particularly for honors candidates.

3A–3B. Calculus with Analytic Geometry, First Course. (3–3) Yr.
Beginning each semester.
Prerequisite: two years of high school algebra, plane geometry, plane trigonometry. Students may not receive credit for 3A after having completed 3R or 16A–16B. 3A–3B covers the first 6 units of 1A–1B.
Elements of analytic geometry, introduction to differential and integral calculus, with applications.

4. Calculus with Analytic Geometry, Second Course. (3) I and II.
(Formerly numbered 4A.)
Prerequisite: course 3B. Course 4 can be followed by 2A for 3 units credit.
Continuation of differential and integral calculus with application to hyperbolic functions, polar coordinates, solid analytic geometry and vectors.

6. Computers and Data Processing. (3) I.
An introductory course on automation of data processing structure of simple computers and its application to automatic control and pattern recognition. Algorithmic languages and translation to computers and their use in problem solving.

10. Mathematics for Liberal Arts Students. (3) I and II.
(Formerly numbered 5.)
Not open to students who have had 1A, 3A or 16A.
Conceptions of modern mathematics for students who have no technical background. The content varies among the following topics: algebra, geometry, set theory, logic, number theory, statistics, mathematical methods in science.

Introduction to Logic (Philosophy 12.)
This course, given in the Department of Philosophy, may be used as a prerequisite to course 125A–125B and is recommended for students taking 135A.

15. Concepts of Mathematics for Elementary School Teachers. (3) I and II.
Development and structure of the real number system and its subsystems. Elementary concepts of set theory, numeration, factoring and divisibility, nonmetric geometry, measurement. Course is intended for prospective elementary school credential candidates.

16A–16B. Analytic Geometry and Calculus. (3–3) Yr.
16A. I and II.
Prerequisite: two years of high school algebra; plane geometry, plane trigonometry. 16A–16B is a terminal course for students who do not plan to take further work in mathematics. Students may not receive credit for 16A taken concurrently with or following 1A or 3A, nor for 16B taken concurrently with or following 1B or 3B. Students may not remove deficiencies in 1A or 3A by taking 16A, nor in 3B by taking 16B.

16A. Elements of analytic geometry and calculus.

16B. Continuation of calculus, vectors, and matrices.

17. Elementary Computer Programming. (3) I and II.
Prerequisite: course 1A or concurrent registration.
Computers and their logical structure, binary arithmetic, codes, programming languages, problem solving by machine. Introductory course for students wishing to study computing.

Upper Division Courses

104. Introductory Analysis. (3) I and II.
Prerequisite: course 2B or 14B or consent of instructor.
Point sets on the line and in Euclidean spaces, metric spaces, spaces of functions, differentiation, Riemann integration, interchange of order of limit operations, methods of successive approximations, existence theorems.

105. Integration. (3) I and II.
Prerequisite: course 104.
Functions of bounded variation, Riemann-Stieltjes integration, measure theory, Lebesgue-Stieltjes integration, Fubini and Radon-Nikodym theorems.

111. Introduction to Linear Algebra. (3) I and II.
Prerequisite: course 2A. For students in engineering, physical sciences, social sciences, statistics.
Vector spaces, linear transformations, matrices, characteristic values, quadratic forms.

112. Linear Geometry. (3) II.
Prerequisite: course 1B.
Linear equations, matrices, determinants, groups of transformations, analytic affine and Euclidean geometry of 2 and 3 dimensions, quadratic forms and the principal axis theorem, analytic projective geometry.

Discrete Probability (Statistics 112). (3) I and II.

Introduction to Theory of Statistics (Statistics 113). (3) II.

113A. Abstract Algebra. (3) I and II.
Prerequisite: course 2A or 112.
Sets, equivalence relations, integral domains, mathematical induction, rings, fields, field of quotients, unique factorization for integers and polynomials, real and complex numbers, elementary group theory.

113B. Linear Algebra. (3) I and II.
Prerequisite: course 113A or 112.
Vector spaces and linear transformations, matrices, rank, determinants, duality, bilinear and quadratic forms, unitary spaces, similarity and unitary similarity, canonical forms.

115A–115B. The Theory of Numbers. (3–3) Yr.
Prerequisite: one year of calculus.
Divisibility, congruences, theory of prime numbers, Diophantine analysis, partitions.

117. Analysis of Mathematical Problems. (3) I.
Prerequisite: upper division standing in mathematics and consent of instructor. Intended primarily for honor students. Enrollment limited to fifteen students.
An undergraduate seminar in methods of attack on mathematical problems, without regard to particular field.

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118. Analysis of Mathematical Problems. (3) II.

Prerequisite: upper division standing in mathematics and consent of instructor. Intended primarily for honor students. Enrollment limited to fifteen students.

An undergraduate seminar in methods of attack on mathematical problems, without regard to particular field.

120A–120B. Advanced Calculus for the Applied Sciences. (3–3) Yr.

Beginning each semester.

Prerequisite: course 14B or 2B. Primarily for students in the physical sciences. One unit of credit is given for 120B taken after 185.

120A. Boundary value problems and orthogonal functions. Laplace transforms.

120B. Partial differential equations of mathematical physics. Functions of a complex variable.

123. Ordinary Differential Equations. (3) I.

Prerequisite: courses 104, 185 (may be taken concurrently). Some background in Linear Algebra is recommended.

Existence and uniqueness of solutions; linear systems. Other topics selected from: boundary value problems, analytic systems, autonomous systems, Sturm-Liouville theory.

125A–125B. Mathematical Logic. (3–3) Yr.

Prerequisite: one year of calculus or Philosophy 12 or consent of instructor.

Sentential and predicate logics: formula, construction and semantical interpretation, deductive calculi, normal forms, completeness. Elements of the theory of models. Applications to formalized mathematical theories.

126. Introduction to Partial Differential Equations. (3) I.

Prerequisite: course 104. This course will emphasize theory and should serve as a preparation for Mathematics 222A–222B.

Classification of second order equations. Boundary value problems for elliptic and parabolic equations. Initial value problems for hyperbolic equations. Existence and uniqueness theorems in simple cases. Maximum principles and a priori bounds. The Fourier transform.

128A. Numerical Analysis. (3) I and II.

Prerequisite: courses 2A–2B, or 4A–4B and 119, or 14B.

Interpolation, polynomial approximation of functions, operational calculus, numerical integration and summation, numerical solution of ordinary differential equations. Emphasis is on material appropriate for programming large computers.

128B. Numerical Analysis. (3) II. The Staff

Prerequisite: courses 2A or 4A–4B, 111 or 113B, 119. 128A is not prerequisite for 128B.

Numerical methods for solving systems of linear equations and inverting matrices. Solution of nonlinear equations. Characteristic roots and vectors of matrices. Numerical method for partial differential equations. Emphasis is on material appropriate for programming large computers.

128C. Laboratory for Numerical Analysis. (2) I and II.

Prerequisite: may be taken only in conjunction with course 128A.

128D. Laboratory for Numerical Analysis. (2) II.

Prerequisite: may be taken only in conjunction with course 128B.

130A–130B. Projective Geometry. (3–3) Yr.

130A. I and II.

Prerequisite: course 2A.

Projective geometry as an extension of high school geometry. Projective invariants: harmonic tetrads; cross-ratio. Desargues' and Pappus' theorem. Axiomatic foundation of projective geometry. Introduction of coordinates in the plane. Synthetic and analytic treatment of conics. Higher dimensional spaces.

131. Algebraic Curves. (3) I.

Prerequisite: course 130A, 113A, or consent of instructor.

The role of the complex number field and of the projective plane in algebraic geometry. Simple and singular points of plane curves. The resultant. Bezout's theorem. The plane cubic as abelian variety. Branches of plane curves. General points. Linear series.

135A–135B. Foundations of Mathematics. (3–3) Yr.

135A. I and II.

Prerequisite: one year of calculus or consent of the instructor. Recommended: Philosophy 12.

135A. Arithmetic of natural numbers based on Peano's axioms. Inductive proofs and recursive definitions. Extension to the integers, rational numbers, and real numbers. Various characterizations of the field of real numbers.

135B. Axiomatic development of set theory. Finite and infinite sets, set-theoretical equivalence, cardinal numbers. Ordinal numbers, well-ordering, proof by transfinite induction, definition by transfinite recursion.

140. Metric Differential Geometry. (3) I and II.

Prerequisite: course 104 or consent of instructor.

Frenet formulas for curves; first and second fundamental forms of a surface, principal curvatures, geometry on a surface; some global theorems on curves and surfaces.

145. Theory of Boolean Algebras. (3) II.

Prerequisite: course 125A.

Postulates, treatment as rings or lattices; relation to sentential calculus and calculus of classes; elementary development from the axioms; infinite operations, atoms; subalgebras, homomorphisms, direct products; representation theorem and its connection with completeness theorems of logic.

Introduction to Continuous Probability (Statistics 155). (3) II.

160. History of Mathematics. (3) II.

Prerequisite: courses 2B and 113A.

History of algebra, geometry, analytic geometry, and calculus from ancient times through the seventeenth century and selected topics from more recent mathematical history. Recommended for the teaching major.

175. Calculus of Variations. (3) II.

Prerequisite: course 104.

Euler equations for variational problems; problems of mathematical physics; application of direct methods; Hamilton-Jacobi theory.

185. Introduction to the Theory of Functions of a Complex Variable. (3) I and II.

Prerequisite: course 2B or 14B or 122. Special sections will be arranged for students who have completed course 104.

Differentiability of complex functions. Cauchy's integral. Power series. Laurent series. Analytic continuation. Singularities of analytic functions. Residue theorem; applications to definite integrals. Conformal mapping. Concepts and theorems as well as manipulation will be stressed.

188. Mathematical Models in Physics and Engineering. (3) II.

Prerequisite: course 104, 113A, 113B, 185, or consent of instructor. Designed primarily for mathematics majors with little or no background in physical sciences.

Study of the relationship between such mathematical concepts as discrete and continuous spectra, resolvents of linear operators, group invariance and some of the physical concepts which arise in the study of dynamical systems and wave propagation.

190A–190B. Survey of Algebra and Analysis. (3–3) Yr.

190A. I and II.

For upper division and graduate students in social sciences. Not to be taken in place of 1A–1B.

The first semester covers analytic geometry, calculus, and partial differentiation. The second semester includes difference equations, matrices, and selected topics related to current literature in social science.

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199. Special Study for Advanced Undergraduates. (1–5) I and II.
Investigation of special problems under the direction of members of the department. In particular, this course offers an opportunity to students with facility for mathematics to anticipate some of the advanced courses by individual study. Restricted to senior honor students.

Graduate Courses

(Concerning conditions for admission to graduate courses, see page 169)

202. Foundations of Analysis. (3) I and II.
Prerequisite: course 104 and 113A.
Set theory, the real number system, topological spaces, metric spaces, compactness, completeness, function spaces.

Theory of Probability and Statistics (Statistics 202A–202B). Yr.

203. Measure and Integration. (3) I and II.
Prerequisite: course 105 and 202 (202 may be taken concurrently), or consent of instructor.
General theory of measure and integration, including the Fubini theorem on product measures and the Radon-Nikodym theorem on absolutely continuous set functions.

205A–205B. Theory of Functions of a Complex Variable. (3–3) Yr.
Prerequisite: course 104 and 185, or equivalent.
The theory of analytic functions and topics such as meromorphic functions, entire functions, modular functions, and Abelian integrals, analytic theory of differential equations, inequalities, etc., to be selected by the instructor.

206. Linear Spaces. (3) I.
Prerequisite: course 105, 185, and 202.
Elementary theory of Banach and Hilbert spaces; linear functionals and operators; weak convergence; L^p spaces and C; spectral theorem for bounded self-adjoint operators.

207. Linear Operations. (3) II.
Prerequisite: course 206 or consent of instructor.
Completely continuous operators, differential operators, unbounded symmetric operators, perturbation theory and additional topics selected by the instructor.

208. Functional Analysis. (3) II.
Prerequisite: course 206.
Locally convex linear topological spaces; distributions; Banach algebras; Fourier transforms; Riesz theory of compact operators.

212. Several Complex Variables. (3) II.
Prerequisite: course 205A.
Power series and analytic functions of several variables; analytic sets and ideals of holomorphic functions; analytic continuation and envelopes of holomorphy; analytic spaces; global problems and sheaf theory.

215A. Algebraic Topology. (3) I and II.
Prerequisite: course 113B and 202.
Fundamental group, covering spaces; simplicial complexes, homology and cohomology groups; homotopy; applications to fixed point theorems and classification problems.

215B. Homotopy Theory. (3) II.
Prerequisite: course 215A.
Homotopy groups, fiber spaces, loop spaces; relations between homotopy and homology, obstruction theory; theorems of Hopf, Hurewicz and Whitehead.

217. Special Functions and Asymptotic Integration. (3) I.
Prerequisite: course 185.
Properties of the Bessel, Legendre, and hypergeometric functions and the asymptotic evaluation of integrals by the methods of stationary phase and steepest descents.

219A–219B. Ordinary Differential Equations. (3–3) Yr.
Prerequisite: course 111 or 113B, and 185 (which may be taken concurrently).
Ordinary differential equations in the real and complex domains. Existence, differentiability of solutions. Linear systems with constant and periodic coefficients. Analysis of singular points, Poincaré-Bendixson theorem, perturbation theory. Sturm-Liouville theory. Fuchsian equations, asymptotic expansions.

220A–220B. Higher Mathematics for Physical Sciences and Engineering. (3–3) Yr.
Prerequisite: course 2B or 14B, 104, and 185, or consent of instructor. 185 may be taken concurrently. Primarily for students in engineering.
Boundary value problems for the heat, potential and wave equations. Laplace and Fourier transforms. Bessel and Legendre functions. Green's functions. Integral equations, variational methods.

*221. Logarithmic and Newtonian Potential. (3) I.
Prerequisite: course 105, 185 or equivalent.
Harmonic and superharmonic functions. Dirichlet problem. Capacity of sets. General potentials.

222A–222B. Partial Differential Equations. (3–3) Yr.
Prerequisite: course 105, 185, 206, or equivalent.
Theory of initial value and boundary value problems for hyperbolic, parabolic, and elliptic partial differential equations, with emphasis on nonlinear equations.

223A–223B. Differential Equations and Operator Theory for Physical Sciences. (3–3) Yr. Beginning each semester.
(Formerly numbered 220C–220D.)
Prerequisite: courses 2B or 14B, 104 and 185, or their equivalents, or consent of instructor.
Introduction to Hilbert space and linear operators. Spectral theory of matrices and ordinary differential operators. Green's functions and solution of partial differential equations.

225A–225B. Metamathematics. (3–3) Yr.
Prerequisite: courses 125A–125B and 135A.
Formalized mathematical theories. Symbols, concatenation, formulas, sentences, derivability, axiomatic basis. Consistency and completeness. Notions of model and consequence—their relations to consistency and derivability. Application to formalized number theory. Truth and provability—their mutual relations. Introduction to the decision problem.

226. Mathematical Logic and Computers. (3) II.
Prerequisite: course 125A or consent of instructor.
Boolean functions and switching circuits, deterministic computing elements, finite automata, Turing machines, introduction to recursive functions and unsolvable combinatorial problems, selected topics on general algorithmic languages.

227. Theory of Recursive Functions. (3) I.
Prerequisite: course 225B or consent of instructor.
Recursive and recursively enumerable sets of natural numbers; characterizations, significance, and classification. Relativization, degrees of unsolvability. The recursion theorem. Constructive ordinals, the hyperarithmetical and analytical hierarchies. Recursive objects of higher type.

* Not to be given, 1965–1966.

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228A–228B. Advanced Numerical Analysis. (3–3) Yr.

Prerequisite: course 128A–128B and 111 or 113B, or consent of instructor. 228A is not prerequisite to 228B.

228A. Interpolation, discretization, optimum discretization methods. Approximation of functions, integration of ordinary differential equations, including convergence, stability and error analysis, nonlinear boundary and eigenvalue problems, partial differential equations and integral equations. Generality of methods emphasized, practical aspects will not be neglected.

228B. Iteration methods, algorithms, relaxation and over-relaxation methods, Newton's method, iteration of higher order, iteration with fixed initial condition. Systems of linear and nonlinear equations, linear and nonlinear eigenvalue problems. Generality of methods emphasized, practical aspects will not be neglected.

230A–230B. Algebraic Geometry. (3–3) Yr.

Prerequisite: course 250A or 131.

Algebraic varieties. Dimension. Correspondences. Normalization. Simple points. Linear systems. Riemann-Roch theorems for curves. Cohomology of coherent sheaves and theory of schemes, as time permits.

***235A–235B. Set Theory.** (3–3) Yr. ———

Prerequisite: courses 125A and 135A–135B.

Fundamental notions and axioms. Sets, their families, rings, fields. Finiteness and infinity. Relations, functions, images. One-to-one correspondence, set-theoretical equivalence, cardinal numbers. Similarity of relations, relation numbers. Partial and simple order. Well-ordering, arithmetic of ordinals. Applications of set theory, selected topics.

240A. Differential Geometry. (3) I and II.

Prerequisite: course 104, 113B; 202 (taken concurrently).

Multilinear algebra, differentiable manifolds, tensor bundles, exterior forms; theorems of Stokes and Frobenius; imbedding theorem, connections, curvature, introduction to Riemannian geometry.

240B. Riemannian Geometry. (3) II. ———

Prerequisite: course 215A and 240A.

Affine connections, curvature tensor, manifolds of constant curvature, completeness. Additional topics selected by the instructor.

241. Complex Manifolds. (3) I.

Prerequisite: course 185 and 240A.

Compact Riemann surfaces, Kahler manifolds; sheaves; theorems of Dolbeault and Hodge.

245A–245B. General Algebraic Systems. (3–3) Yr.

Prerequisite: course 113A, 113B, 125A–125B, and 135A.

General notion of an algebraic system. Subalgebras. Isomorphism. Homomorphism and equivalence relations. Direct products. Free algebras. Applications of general notions to special algebraic systems: groups, rings, fields, lattices, Boolean algebras.

250A. Groups, Rings and Fields. (3) I and II.

Prerequisite: course 113B.

Group theory through the Jordan-Hölder-Schreier theorem, homomorphism theorems for rings and modules, unique factorization domains, structure of modules over principal ideal domains, field theory through Galois theory.

250B. Topics in Algebra. (3) I and II.

Prerequisite: course 250A.

Multilinear algebra and additional topics selected from the following: field theory, valuation theory, ring theory, homological algebra.

251. Ring Theory. (3) II. ———

Prerequisite: course 250A.

Topics chosen from Noetherian rings, rings with descending chain condition, theory of the radical, homological methods.

* Not to be given, 1965–1966.

252. Representation Theory. (3) I.

Prerequisite: course 250A.

Structure of finite dimensional algebras, applications to representations of finite groups, the classical linear groups.

253. Homological Algebra. (3) II. ———

Prerequisite: course 250A.

Modules over a ring, homomorphisms and tensor products of modules, functors and derived functors, homological dimension of rings and modules.

254. Algebraic Number Theory. (3) I.

Prerequisite: course 250A.

Valuation theory in number fields and relation to ideal theory, local fields, unit theorem and finiteness of class number, ramification theory.

255A–255B. Foundations of Geometry. (3–3) Yr. ———

Prerequisite: course 125A, 130A and 135A.

Historical introduction. Primitive terms and axioms of Euclidean geometry. Main consequences of the axioms; introduction of Cartesian coordinates. Completeness, categoricity, and independence of axioms. Alternative systems of primitive terms and axioms. Non-Euclidean geometries.

Probability Theory and Its Analytic Basis (Statistics 255A–255B). (3–3) Yr. ———

259. Transformation Groups. (3) II. ———

Prerequisite: course 215A; 240A (taken concurrently) or consent of instructor.

Topological groups, Haar measure; general theory of topological transformation groups; the existence of slices and applications; the Smith theory of periodic transformations.

260. Topological Groups. (3) I.

Prerequisite: course 250A and 202.

Haar measure, locally compact Abelian groups, compact groups.

261A–261B. Lie Groups. (3–3) Yr.

Prerequisite: course 240A.

Lie groups and Lie algebras, general structure theory; compact, solvable, complex, and semisimple groups; classification of simple groups, representation theory.

265. Differential Topology. (3) I.

Prerequisite: course 215A and 240A.

The imbedding theorem; characteristic classes; Morse theory; additional topics from cobordism, immersion theory, singularities of maps, and the structure of manifolds.

Advanced Probability (Statistics 265A–265B). (3–3) Yr. ———

270. Mathematical Theory of Fluid Dynamics. (3) I. ———

Development of the fundamental equations describing the behavior of a fluid continuum followed by the treatment of special topics selected to exhibit different physical situations, analytical techniques and approximate methods of solution.

275. Special Topics in Applied Mathematics. (3) II. ———

Operator theory, boundary-value problems, and integral equations applied to problems arising from electromagnetic theory, quantum theory, and statistical mechanics.

276A–276B. Special Topics in Topology. (3–3) Yr.

Prerequisite: course 215A.

Topics of current interest in topology such as: homotopy theory, fiber bundles, sheaves, cohomology operations, theory of manifolds.

277A–277B. Selected Topics in Differential Geometry. (3–3) Yr. ———

Prerequisite: course 240A.

Study of deformation problem in differential geometry; deformation of Riemannian, complex, and other structures, including extrinsic problems. Recent developments in global differential geometry.

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278. Selected Topics in Analysis. (3) I.
Prerequisite: Real and Complex Variables.
Elements of harmonic analysis; conjugate function; boundary values of analytic functions; prediction theory.

280A–280B. Mathematical Theory of Relativity. (3–3) Yr.
Prerequisite: course 140 or consent of instructor.
Special theory of relativity, spinor representation of the Lorentz group, reformulation of classical physical theories in relativistic form, principle of equivalence, Einstein theory of gravitation, cosmological problems.

290. Seminars. (2–6) I and II. The Staff
Topics in foundations of mathematics, theory of numbers, numerical calculation, analysis, geometry, topology, algebras, and their applications, by means of lectures and informal conferences; work based largely on original memoirs.

295. Individual Research. (2–6) I and II.
Intended for candidates for the Ph.D. degree.

297. Individual Study. (1–9) I and II. The Staff
Prerequisite: one year of full-time graduate study and permission of the graduate adviser.
Individual study, in consultation with the graduate adviser, intended to provide opportunity for qualified students to prepare themselves for the various examinations required of candidates for the Ph.D. Course to be taken on the pass or fail basis.

299. Reading Course for Graduate Students. (2–6) I and II. The Staff
Investigation of special problems under the direction of members of the department.

Mathematical Colloquium. (No credit) I and II. The Staff
Meetings for the presentation of original work by members of the staff and graduate students.

Logic Colloquium. (No credit) I and II. The Staff
Reports on current research and scholarly work by members of the staff, visitors, and graduate students.

Related Courses and Programs

Computer Science: Mathematics 6, 17, 128A, 128B, 128C, 128D, 226, 227, 228A–228B; Statistics 134; Electrical Engineering 148, 150, 152, 153; Linguistics 100; Economics 103A; Industrial Engineering 162.
Logic. See Group in Logic and Methodology of Science and Department of Philosophy.
Statistics. See Department of Statistics.

MILITARY SCIENCE

(Department Office, 149 Harmon Gymnasium)

James D. Land, Colonel, Artillery; *Professor of Military Science (Chairman of the Department).*
Don S. Fletcher, Lieutenant Colonel, Transportation Corps; *Associate Professor of Military Science.*

Vinton L. Rathburn, Major, Corps of Engineers; *Associate Professor of Military Science.*
Howell F. Stewart, Major, Artillery; *Associate Professor of Military Science.*
William R. Flick, Captain, Quartermaster Corps; *Assistant Professor of Military Science.*
Norman R. Kyle, Captain, Ordnance Corps; *Assistant Professor of Military Science.*

Lower Division Courses

The Army R.O.T.C. Program is a four-year program comprised of a two-year lower division basic course which is a preparatory program for the enrollment selection in the two-year advanced course. Any male student may enroll in the lower division basic courses provided that he meets the appropriate medical and administrative criteria, is a citizen of the United States, is at least fourteen years of age, and can qualify for appointment as a second lieutenant prior to reaching twenty-eight years of age in connection with the completion of the four-year program. These courses consist of three hours of formal instruction per week for two academic years. Instruction is given in subjects common to all branches of the Army. Uniforms and textbooks, as required, are provided by the Government and must be returned in good condition.

The A part of a course is not a prerequisite for the B part of a course in either basic or advanced military science.

1A. Military Science I. (2) I. The Staff (Mr. Stewart in charge)
Organization of the Army and R.O.T.C.; individual weapons and marksmanship; leadership laboratory; appropriate academic or military subjects.

1B. Military Science I. (2) II. The Staff (Mr. Stewart in charge)
U. S. Army and national security; American military history; leadership laboratory; appropriate academic or military subjects.

21A. Military Science II. (2) I. The Staff (Mr. Flick in charge)
American military history; leadership laboratory; appropriate academic or military subjects.

21B. Military Science II. (2) II. The Staff (Mr. Flick in charge)
Introduction to operations and basic tactics; map and aerial photograph reading; leadership laboratory; appropriate academic or military subjects.

Upper Division Courses

Students who successfully complete the basic course or who have received credit in lieu thereof may apply for enrollment in the advanced course. For admission to the upper division or advanced course, a student must:

1. Be a male citizen of the United States and be regularly enrolled in the University.
2. Be able to complete the course before the age of twenty-eight years.
3. Have attained junior standing in the University.