Benson Mates, Ph.D. (*Philosophy*)
J. Frits Staal, Ph.D. (*Philosophy and of South Asian Languages*)
Robert L. Vaught, Ph.D. (*Mathematics*)
Yuen Ren Chao, Ph.D., Litt.D. (*Oriental Languages, Emeritus*)
Raphael M. Rob... Ph.D. (*Emeritus*)
Alfred Tarski, P...

Associate Prof...
Charles S. Chi...
Ronald B. J...
Ralph N. McK...
George Myro, ...
I. Silver
Sluga, F...

Chairman: M...
Graduate Ad...

The Group ... Science offers an interdisciplinary program of stu... degree. Although the Department of Mathematics ... each offers a Ph.D. degree toward which a studer... c, the interdisciplinary program is designed for th... ... logic and the methodology of science who wish to explore the subject in both its mathematical and philosophical aspects. "Methodology of science" is here understood to mean "metascience," the study of the methods of the sciences by logical and mathematical means. The program is administered by an interdepartmental group which cooperates closely with both the Department of Mathematics and the Department of Philosophy.

Preparation For admission to the graduate program the student shall have completed an undergraduate major in philosophy, *or* in mathematics, *or* a joint major in both, including at least one full year upper division course in logic. In addition, he or she shall have completed (a) at least one upper division course in some science, and (b) at least one full year upper division course in mathematics (other than logic) if his or her undergraduate major was philosophy, or in philosophy (other than logic) if his or her undergraduate major was mathematics. Exceptions to these requirements are permitted only at the discretion of the graduate adviser. Before advancement to candidacy, and preferably early in the student's doctoral career, written examinations in two foreign languages must be passed; students may choose from the following: French, German, or Russian. Students should prepare themselves for the language requirement in their undergraduate years.

Further information about the program, including a full 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)

Reports on current research and scholarly work by members of the staff, visitors, and graduate students. The Staff (F, W, Sp, Su)

Other Departments with Related Programs

Department of Mathematics and Department of Philosophy.

MATHEMATICS

(Department Office, 970 Evans Hall)

Professors:
John W. Addison, Jr., Ph.D.
William B. Arveson, Ph.D.
William G. Bade,† Ph.D.
Elwyn R. Berlekamp, Ph.D.

NOTE: For key to footnote symbols, see page 92.

David Blackwell, Ph.D.
Hans J. Bremermann, Ph.D.
Paul L. Chambré, Ph.D.
Shiing-shen Chern, D.Sc., LL.D.
Heinz O. Cordes, Ph.D.
René J. De Vogelaere, Ph.D.
Stephen P. Diliberto,† Ph.D.
Lester E. Dubins, Ph.D.
István Fáry, Ph.D.
Jacob Feldman,†[5] Ph.D.
David A. Freedman, Ph.D.
David Gale, Ph.D.
Henry Helson, Ph.D.
Leon A. Henkin, Ph.D.
Morris W. Hirsch, Ph.D.
Gerhard P. Hochschild, Ph.D.
Wu-Yi Hsiang,†[5] Ph.D.
William Kahan, Ph.D.
Tosio Kato,†[1] D.Sc.
John L. Kelley, Ph.D.
Robion C. Kirby, Ph.D.
Shoshichi Kobayashi, Ph.D.
Lucien Lecam, Ph.D.
R. Sherman Lehman, Ph.D.
Calvin C. Moore, Ph.D.
Andrew P. Ogg,†[4] Ph.D.
Beresford N. Parlett, Ph.D.
Edmund J. Pinney, Ph.D.
Murray H. Protter, Ph.D.
Charles C. Pugh, Ph.D.
John L. Rhodes, Ph.D.
Marc A. Rieffel, Ph.D.
Maxwell A. Rosenlicht, Ph.D.
Rainer K. Sachs, Ph.D.
Donald E. Sarason, Ph.D.
Ichiro Satake, Ph.D.
Abraham Seidenberg,†[3] Ph.D.
Stephen Smale,†[1] Ph.D.
Robert M. Solovay,† Ph.D.
Edwin H. Spanier, Ph.D.
John R. Stallings, Jr., Ph.D.
Abraham H. Taub,†[3] Ph.D.
P. Emery Thomas, Ph.D.
Robert L. Vaught, Ph.D.
Joseph A. Wolf,† Ph.D.
Hung-Hsi Wu, Ph.D.
Alfred L. Foster, Ph.D. (*Emeritus*)
Derrick H. Lehmer, Ph.D. (*Emeritus*)
Hans Lewy, Ph.D. (*Emeritus*)
Michel Loeve, Docteur ès Sciences (*Emeritus*)
Charles B. Morrey, Jr., Ph.D. (*Emeritus*)
Anthony P. Morse, Ph.D. (*Emeritus*)
Raphael M. Robinson, Ph.D. (*Emeritus*)
Alfred Tarski, Ph.D. (*Emeritus*)
Frantisek Wolf, Ph.D. (*Emeritus*)

Associate Professors:
George M. Bergman, Ph.D.
Robert E. Bowen,†[5] Ph.D.
Paul R. Chernoff,†[5] Ph.D.
Alexandre J. Chorin, Ph.D.
David H. Goldschmidt,†[1] Ph.D.
Robert G. Hartshorne, Ph.D.
Ronald B. Jensen, Ph.D.
Tsit-Yuen Lam,†[4] Ph.D.
Oscar E. Lanford, III,†[3] Ph.D.
H. Blaine Lawson, Ph.D.
Jerrold E. Marsden,†[5] Ph.D.
Ralph N. McKenzie, Ph.D.
Keith Miller, Ph.D.
Jack H. Silver, Ph.D.
John B. Wagoner,†[2] Ph.D.
Alan D. Weinstein, Ph.D.

Assistant Professors:
F. Alberto Grunbaum, Ph.D.
Ole H. Hald, Ph.D.
Arthur E. Ogus,† Ph.D.

Armand M. Borel, Docteurès Sciences *(Visiting)*

Lecturers:
Eloise H. Carlton, Ph.D.
Jill Mesirov-Kazdan, Ph.D.
Michael D. Miller, Ph.D.
Shi-shyr Roan, Ph.D.
Nancy K. Stanton, Ph.D.

Undergraduate Programs

The department offers the undergraduate student a choice of three programs leading to the A.B. degree. The basic major program in mathematics gives the student the opportunity to obtain a strong, well-rounded mathematical background. The faculty of the department is strongly oriented toward research, and courses required for the major are oriented toward theory. For students with particular interest in the applications of mathematics, a special major program in applied mathematics is available. For prospective school teachers of mathematics there is a small, selective major program in mathematics for teachers.

General Major Requirements Each of the three major programs requires a minimum

of 36 upper division units in the major in addition to a lower division base of 1A–1B–1C, 51A–51B–51C. Courses 111, 190A, 190B, 190C, and 190D are not acceptable toward the upper division major requirements. Additional requirements for these programs are as follows.

Major in Mathematics 113A–113B; 104A; 104B or 185; 130 or 140 or 142; 135; three additional upper division mathematics courses. Only one of courses 120A and 185 can be offered as part of the major.

The attention of students interested in logic is directed to Philosophy 12A–12B and Mathematics 125A–125B.

Courses in Computer Science, Physics and Statistics 100A–100B–100C are of interest to mathematics majors.

Subject to the requirement of competence in the major, and with the approval of the major adviser, the student may count not more than two mathematically theoretical courses in computer science, statistics, astronomy, physics, mathematical economics, or other sciences toward his requirements for the major in mathematics.

Major in Applied Mathematics 120A–120B–120C or three courses from 104A, 104B, 185, 105; 113A and 112; 128A, 128B, 129A or 129B; three additional upper division courses in mathematics or in an applied field (all subject to the approval of the major adviser), of which at least two must be in an applied field.

Major in Mathematics for Teachers Philosophy 12A; Statistics 20; 113A–113B–113C, 115A, 130, 132, 134, and 160; one additional upper division mathematics course.

Honors Program In addition to completing the requirements for the major in mathematics or major in applied mathematics, a student in the honors program must (a) earn a grade-point average of at least 3.3 in upper division and graduate courses in mathematics; (b) pass a graduate mathematics course with a grade of at least A–; (c) complete the course H196 in which he will write a senior thesis, or pass a second graduate course with a grade of at least A–; (d) receive the recommendation of his major adviser. Students interested in the honors program should consult with their major adviser at least two quarters before graduation.

Preparation for Graduate Study Students preparing for graduate work in mathematics are strongly advised to acquire a reading knowledge of two foreign languages from among French, German, and Russian. This proficiency is required for most Ph.D. programs, but the graduate programs do not leave a large amount of time for language study. There is usually no language requirement for an M.A. degree.

Course 117, designed to challenge the student's ability to do creative thinking, is useful for students preparing for graduate work. It is also desirable for such students to take some graduate courses while still in undergraduate status; courses 202A–202B–202C, 214, 250A–250B are recommended.

Graduate Programs

The department offers the M.A. degree in mathematics and the Cand.Phil. and Ph.D. degrees in both mathematics and applied mathematics. Detailed information concerning admission, teaching assistantships and fellowships, and degree requirements is given in the GRADUATE ANNOUNCEMENT OF THE DEPARTMENT OF MATHEMATICS, which is available upon request from the Graduate Secretary, Department of Mathematics.

Courses and Seminars

Courses and seminars are listed below. Statements of instructors commenting on their methods of teaching, emphasis in presenting material, and other characteristics of their courses are posted at the Department Office, 970 Evans, at the beginning of each quarter. Detailed descripitions of seminars and names of instructors offering them are also available.

Letters and Science List: for regulations governing this list, see the ANNOUNCEMENT OF THE COLLEGE OF LETTERS AND SCIENCE.

Lower Division Courses

P. Algebra and Trigonometry. (2)

Four hours of lecture per week. Intended for students who wish to take 1A or 16A but lack the prerequisites. A screening test will be given during the pre-enrollment period. May not be used to satisfy the Letters and Science breadth requirement. After receiving credit for 6B, 1A, 16A or the equivalent, students will not receive credit for course P. Review of algebra, graphs, functions, polynominals, exponential and logarithmic functions, inverse functions. Trigonometric functions and their properties, mathematical induction, binomial theorem, sequences and series. (F, W, Sp)

1A–1B–1C. Calculus. (4–4–4)

Four hours of lecture per week. *Prerequisite: at least three and one-half years of high school mathematics including algebra, geometry, trignometric and other elementary functions, and some coordinate geometry; students lacking the prerequisites may enroll after completing course P or 6A–6B.* A screening test will be given at the first section meeting. This is the usual sequence for students who plan additional study of mathematics. Students who have received credit for 16A or 190A will receive one unit of credit for 1A; students who have received credit for 16B will receive two units of credit for 1B. Introduction to differential and integral calculus of functions of one variable with applications, transcendental functions, techniques of intergation, introduction to differential equations and infinite series, vectors, introduction to differential and integral calculus of several variables.

Mr. Arveson, Mr. Addison, Mr. Hirsch, Mr. Weinstein, Mr. Vaught (each part offered each quarter)

1S. Self-Paced Study in Introductory Calculus. (2–12)

Four hours of lecture and two to six hours of laboratory per week. *Prerequisite: 3½ years of high school mathematics, including algebra, geometry, trigonometric and other elementary functions, and some coordinate geometry.* Self-paced instruction covering the material of course 1A–1B–1C. May be repeated for credit up to a total of 12 units. Reduced credit for students who have taken part(s) of course 1A–1B–1C. Unit credit and grades assigned at the end of each quarter, depending on the number of study units completed. Mr. Rieffel (F, W, Sp)

H1A–H1B–H1C. Calculus. (5–5–5)

Five hours per week. *Prerequisite: same as 1A plus A's or B's in high school mathematics and English, and the consent of instructor.* No screening exam. Honors course corresponding to 1A, 1B, 1C, 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.

Mr. Sarason (sequence beginning F)

5A. Finite Mathematics. (4)

Four hours of lecture per week. *Prerequisite: 3 years of high school mathematics, including at least 2 years of high school algebra, or course P.* A short screening test will be given at the first class meeting. Not open to students who have completed 51A or 111. Sets, functions, logic, probability, vectors and matrices, with applications.

Mr. M. Miller, Mr. Henkin (F, W)

5B. Finite Mathematics. (4)

Four hours of lecture per week. *Prerequisite: course 5A or a course in linear algebra.* Linear programming, graph theory and combinatorics, game theory, and model theory. Mr. M. Miller (Sp)

***6A–*6B. Elementary Mathematical Planning. (4–4)**

Three hours of lecture and three hours of laboratory per week. No credit for 6A following courses P, 1A or 16A. A problem-oriented course. Elementary versions of advanced mathematical ideas are studied so as to simultaneously prepare students for calculus and rebuild their high school algebra, geometry, and trigonometry by adding new foundational material and examples from the life, social, and natural sciences. Students with low scores on a placement examination will be required to do extra laboratory work. Course 6A alone prepares students for Statistics 2 and Chemistry 1A.

10. Mathematics for Liberal Arts Students. (4)

Four hours of lecture per week. *Prerequisite: not open to students who have had 1A, 16A, or a more advanced course, but course 10 may be followed by one of these courses.* Concepts of modern mathematics for students who have no technical background. The topics are chosen by the instructor and vary from quarter to quarter. Course 10 is *not* a remedial course in algebra and trigonometry.

Mr. Rhodes (W)

15. Concepts of Mathematics for Elementary School Teachers. (5)

Five hours of lecture per week. Intended only for prospective elementary school teachers. Restricted to seniors and students in the elementary credential program. No credit for 15 taken concurrently with or after any other mathematics course except P, 6A–6B, or 10. Development and structure of the real number system and its subsystems. Elementary concepts of set theory, numeration, factoring and divisibility, nonmetric geometry, measurement. (W, Sp)

16A–16B. Analytic Geometry and Calculus. (4–4)

Four hours of lecture per week. *Prerequisite: two years of high school algebra plus plane trigonometry; students lacking the prerequisites may enroll after completing course P or 6A–6B.* A screening test will be given at the first section meeting. For students in the social and biological sciences. Course 16A–16B is a terminal course for lower division students whose program does not require more than one year of mathematics. Students do not receive credit for both 16A and 190A, nor for either 16A or 190A after 1A. After receiving credit for 1B, students may receive two units for 16B. They may not receive credit for both 16B and 190C.

16A. Inequalities, absolute value; graphs of simplest functions; the derivative; extreme values;

rates of change and differentials; increasing and decreasing functions (mean value theorem); basic properties of log, exp, cos, sin; introduction to integration.

16B. Fundamental theorem of calculus, properties of the intergal; integration by substitution and by parts; volumes of solids of revolution and arc length; vector spaces and linear algebra.

Mr. Spanier, Mr. Thomas, Mr. Parlett, Mr. Pugh, Mr. Wu (each part offered each quarter)

41. Introduction to Linear Algebra and Vector Analysis. (4)

Four hours of lecture per week. *Prerequisite: course 1C.* Primarily for certain students in Mechanical Engineering. May not be taken for credit after Math 51A or Math 51B. May not replace Math 51A or Math 51B as part of the Mathematics Major. Determinants, linear equations, n-dimensional Euclidean space, matrices, linear independence, linear transformations, review of partial differentiation, application of partial differentiation to maximum and minimum problems, multiple integrals and applications, surface and line integrals, Green's theorem, divergence theorem, Stokes' theorem.

Mr. Laitone (F, W)

51A. Introduction to Linear Algebra. (4)

Four hours of lecture per week. *Prerequisite: 1C.* Students may not receive credit for both 51A and 111. Matrix algebra, simultaneous linear equations, vector spaces, linear transformations, determinants.

Mr. K. Miller, Mr. DeVogelaere (F, W, Sp)

51B. Calculus of Vector Functions. (4)

Four hours of lecture per week. *Prerequisite: course 51A.* Review of partial differentiation and multiple integration. Vector differential and integral calculus, including theorems of Green and Stokes. Implicit function theorem if time permits.

Mr. K. Miller, Mr. DeVogelaere, Mr. Kirby,

51C. Differential Equations and Related Topics. (4)

Four hours of lecture per week. *Prerequisite: courses 1A–1B–1C.* Ordinary differential equations of first and second order, series solutions and higher order equations. An introduction to Fourier series and separation of variables in simple partial differential equations with some applications.

Mr. K. Miller, Mr. Cordes (F, W, Sp)

H51A–H51B–H51C. Linear Algebra, Calculus of Vector Functions, and Differential Equations. (5–5–5)

Five hours of lecture per week. *Prerequisite: H1C, or 1C and consent of instructor.* Honors sequence corresponding to 51A–51B–51C 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.

Mr. Bergman (Sequence beginning F)

Related Courses in Another Department

Computer Science 1. Introduction to Computing.

Philosophy 12A–12B–12C. Introduction to Logic.

Statistics 20. Introduction to Probability and Statistics.

Upper Division Courses

104A–104B. Introductory and Intermediate Analysis. (4–4)

Three hours of lectures per week. *Prerequisite: courses 51B and 51C or consent of instructor.*

104A. Sets and functions, the topology of R^n, the Riemann integral, continuous functions, uniform convergence, the elementary transcendental functions sin x, log x, interchange of limit operations, and some discussion of metric spaces.

104B. The Frechet derivative, chain rule, implicit function theorems and existence theorems for differential equations by the method of successive approximations, integration in several variables, and further topics.

Mr. Protter, Mr. Kelley, Mr. Fáry (each part offered each quarter)

H104A–H104B. Introductory and Intermediate Analysis. (4–4)

Three hours of lecture per week. *Prerequisite: courses 51B, 51C, and consent of instructor.* Not open to students who have taken 104A–104B. Honors sequence corresponding to 104A–104B for exceptional students with strong mathematical background and interest. Emphasis is on rigor, depth, and hard problems.

Mr. Lanford (sequence beginning F)

105. Integration. (4)

Three hours of lecture per week. *Prerequisite: course 104A.* Null sets and the Riemann integral, construction and properties of Lebesgue measure, the Lebesgue integral and convergence theorems, Fubini's theorem, absolutely continuous functions and differentiation, completeness of L^1, L^2, and Fourier series. Mr. Marsden (F, W, Sp)

111. Introduction to Linear Algebra. (4)

Three hours of lecture per week. *Prerequisite: two quarter courses in calculus and upper division or graduate standing. Students may not receive credit for both 51A and 111.* Same mathematical content as 51A but intended for advanced students who did not have linear algebra in their lower division calculus sequence.

Mr. Hochschild, Mr. Freedman (F, W)

112. Linear Algebra. (4)

Three hours of lecture per week. *Prerequisite: course 51A or 111. Students may not receive credit for both 112 and 113C.* For students in engineering or mathematical, natural, or social sciences. The course is oriented more toward a concrete knowledge of matrix theory than is 113C. Characteristic equations, values, and vectors; orthogonal and unitary vector spaces; orthogonal, unitary, and hermitian matrices; quadratic forms, hermitian forms, and diagonalization of normal matrices; introduction to infinite-dimensional spaces.

Mr. Cordes, Mr. Gale, Mr. Kato, Mr. Kahan (F, W, Sp)

113A–113B. Introduction to Abstract Algebra. (4–4)

Three hours of lecture per week. *Prerequisite: course 51A.* Sets, groups, rings, fields, polynomials, vector spaces, linear transformations and matrices. (Each part offered each quarter)

Mr. Kelley, Mr. Satake, Mr. Hochschild, Mr. Stallings, Mr. Lam, Mr. Bremermann

113C. Abstract Linear Algebra. (4)

Three hours of lecture per week. *Prerequisite: course 113B. Students may not receive credit for both 113C and 112.* Dual vector spaces, determinants, characteristic values, similarity, canonical forms, unitary spaces, unitary similarity, quadratic forms.

Mr. Kelley, Mr. Freedman, (F, W, Sp)

H113A–H113B–H113C. Introduction to Abstract Algebra and Abstract Linear Algebra. (4–4–4)

Three hours of lecture per week. *Prerequisite: course 51A and consent of instructor.* Not open to students who have taken 113A–113B–113C. Honors sequence corresponding to 113A–113B–113C for exceptional students with strong mathematical background and interest. Emphasis is on rigor, depth, and hard problems. Mr. Wu (Sequence beginning F)

115A. Introduction to Number Theory. (4)

Three hours of lecture per week. *Prerequisite: course 51A.* Divisibility, congruences, numerical functions, theory of primes.

Mr. Hartshorne, Mr. Lennan, Mr. DeVogelaere (F, W, Sp)

115B. Topics in Number Theory. (4)

Three hours of lecture per week. *Prerequisite: course 115A.* Topics selected from: Diophantine analysis, continued fractions, partitions, quadratic fields, asymptotic distributions, additive problems.

Mr. Hartshorne (W)

117. Mathematical Problems Seminar. (4)

Three hours of lecture per week. *Prerequisite: consent of the instructor. Upper division standing advisable.* The student is given the opportunity to exercise his mathematical abilities on problems calling for original thought, and to discuss methods of attack on mathematical questions. Material used may include isolated problems, advanced topics developed through problems, and open research topics. Approach varies with the instructor. For the most part, only material covered in undergraduate courses will be assumed. May be repeated for credit.

Mr. Bergman (F)

120A–120B–120C. Analysis for Applied Mathematics. (4–4–4)

Three hours of lecture per week. *Prerequisite: courses 51B and 51C.* Primarily for students in applied mathematics and those students in the physical sciences who are likely to pursue more advanced work. No credit for 120A following 185.

120A. Sets, sequences, and series. Continuity, differentiability, and Riemann integration, theory of a function of a complex variable. Conformal mapping. (F, W)

120B. Holomorphic functions, singularities. Contour integration and residue theory. Analytic continuation and Riemann surfaces. (W, Sp)

120C. Ordinary differential equations. Sturm-Liouville problems, Fourier and Laplace transform theory. Special functions and partial differential equations of mathematical physics.

Mr. Pinney, Mr. Chambré, Mr. Lehman (F, Sp)

121A–121B. Mathematical Tools for the Physical Sciences. (4–4)

Three hours of lecture per week. *Prerequisite: courses 51B and 51C.* Primarily for students in the physical sciences. Students who wish to prepare for advanced work in applied mathematics should take courses 112 or 113C, 104A, and 185 or 120A–120B–120C.

121A. Orthogonal functions and eigenfunction representations, ordinary differential equations, special functions of mathematical physics. (F, W)

121B. Partial differential equations: Laplace equation, wave equation, diffusion equation, Green's function. Functions of a complex variable.

Mr. Chernoff, Mr. Sachs (W, Sp)

123. Ordinary Differential Equations. (4)

Three hours of lecture per week. *Prerequisite: course 104A. 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. Mr. K. Miller (W)

125A–125B. Mathematical Logic. (4–4)

Three hours of lecture per week. *Prerequisite: course 113A or consent of instructor.* Sentential and quantificational logic. Formal grammar, semantical interpretation, formal deduction, and their interrelation. Applications to formalized mathematical theories. Selected topics from model theory or proof theory. Mr. Henkin (125A: F, W; 125B: Sp)

126. Introduction to Partial Differential Equations. (4)

Three hours of lecture per week. *Prerequisite: course 104A.* 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. Mr. K. Miller (Sp)

128A. Numerical Analysis. (5)

Three hours of lecture per week and one 4-hour laboratory. *Prerequisite: courses 51B and 51C.* Students do not receive credit for both 128A and 129B. Syntax and semantics of ALGOL, interpolation and approximation, discretization of operators, numerical solution of ordinary differential equations. Emphasis on methods appropriate for use with computers.

Mr. DeVogelaere, Mr. Lehman (F, W)

128B. Numerical Analysis. (5)

Three hours of lecture per week and one 4-hour laboratory. *Prerequisite: courses 128A, and 112 or 113C.* Students do not receive credit for both 128B and 129A. Solution of nonlinear equations. Numerical methods for solving systems of linear equations and inverting matrices. Characteristic roots and vectors of matrices. Introduction to numerical solution of partial differential equations. Emphasis on methods appropriate for use with computers.

Mr. Lehman (Sp)

129A. Computational Algebra. (4)

Three hours of lecture and one hour of problem section per week. *Prerequisite: course 51A or 111 and a working knowledge of either ALGOL or FORTRAN.* Round off errors. Approximation by interpolation. Solution of nonlinear equations in one unknown. Systems of linear equations, least squares fitting, eigenvalues. Systems of nonlinear equations. Students may not receive credit for both 129A and 128B. Mr. Chorin (F, W)

129B. Computational Analysis. (4)

Three hours of lecture and one hour of problem section per week. *Prerequisite: courses 51B and 51C*

and a working knowledge of either ALGOL or FORTRAN. Interpolation, quadrature, ordinary differential equations, difference methods for initial value and boundary value problems. Variational methods, elliptic partial differential equations. Students may not receive credit for both 129B and 128A.
Mr. Chorin (W, Sp)

130. The Classical Geometries. (4)

Three hours of lecture per week. *Prerequisite: course 113B.* Topics chosen from the following list: axioms for affine and projective planes, planes over a division ring, duality, the coordinatization theorem, *n*-dimensional projective geometry over a field, collineations and correlations, classification of hyperquadrics, the projective group and its subgroups, non-Euclidean geometry, inversive geometry.
Mr. Rhodes, Mr. Lawson, Mr. Gale (F, W, Sp)

132. Topics in Geometry. (4)

Three hours of lecture per week. *Prerequisite: course 113A and consent of instructor.* Topics selected from such areas as classical projective geometry, inversive geometry, symplectic geometry, geometric algebra, integral geometry, convexity, and elementary topology. Mr. Seidenberg (W)

*133. Algebraic Curves. (4)

Three hours of lecture per week. *Prerequisite: course 113A.* The complex projective plane, simple and singular points of plane algebraic curves, Bezout's theorem, branches, linear series, cubic curves.

134. Number Systems. (4)

Three hours of lecture per week. *Prerequisite: course 1C.* Especially recommended for prospective teachers. Systems of natural numbers, integers, rational numbers, and real numbers developed both axiomatically and through set-theoretical construction. Proof by induction and definitions by recursion. Mr. Henkin, Mr. Fáry (W, Sp)

135. Introduction to the Theory of Sets. (4)

Three hours of lecture per week. *Prerequisite: courses 113A and 104A.* Set-theoretical paradoxes and means of avoiding them. Sets, relations, functions, order and well-order. Proof by transfinite induction and definition by transfinite recursion. Cardinal and ordinal numbers and their arithmetic. Construction of the real numbers. Axiom of choice and its consequences. Mr. Henkin, Mr. Kelley, (F, W, Sp)

140. Metric Differential Geometry. (4)

Three hours of lecture per week. *Prerequisite: courses 104B or 120B.* Frenet formulas, isoperimetric inequality, local theory of surfaces in Euclidean space, first and second fundamental forms, Gaussian and mean curvature, isometries, geodesics, parallelism, the Gauss-Bonnet-Von Dyck Theorem.
Mr. Weinstein, Mr. Chern (F, W)

142. Elementary Algebraic Topology. (4)

Three hours of lecture per week. *Prerequisite: courses 104A and 113A.* The topology of one and two dimensional spaces: manifolds and triangulation, classification of surfaces, Euler characteristic, fundamental groups, plus further topics at the discretion of the instructor. Mr. Chern (Sp)

*145. Boolean Algebras. (4)

Three hours of lecture per week. *Prerequisite: course 125A.* Postulates, treatment as rings or lattices; relation to sentential calculus and calculus of classes; infinite operations, atoms; subalgebras, ideals, direct products; representation theorem.

*151. Generalized Functions (Distributions). (4)

Three hours of lecture per week. *Prerequisite: course 104A.* Motivation. Distribution solutions of differential equations. Test functions, functionals, continuity. Generalized functions. The spaces (D_K^m), (D), and (E) and their duals. Distribution derivatives. Fourier transform. Convolution. Differential equations with constant coefficients. Green's function. Application to partial differential equations.

160. History of Mathematics. (4)

Three hours of lecture per week. *Prerequisite: courses 51B, 51C, 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. Mr. Silver (F)

163. Tutorial in Upper Division Mathematics. (4)

Four hours per week. *Prerequisite: consent of instructor.* Emphasis is placed on the individual's experience in discovering and explaining mathematics. Examples of subjects which may be covered are game theory, category theory, differential topology, mathematical foundations of quantum mechanics, global theory of ordinary differential equations, and classical linear groups. Content varies: may be repeated for credit with consent of instructor. (Sp)

*175. Calculus of Variations. (4)

Three hours of lecture per week. *Prerequisite: course 51B or equivalent knowledge of the calculus.* Euler equations for variational problems; differential equations of mathematical physics derived from integral principles; solutions of variational problems by direct methods.

185. Introduction to the Theory of Functions of a Complex Variable. (4)

Three hours of lecture per week. *Prerequisite: course 104A. No credit for 185 following 120B.* Analytic functions of a complex variable, Cauchy's integral theorem, power series, Laurent series, singularities of analytic functions, the residue theorem with application to definite integrals. Some additional topics such as conformal mapping.
Mr. Goldschmidt, Mr. Lawson (F, W, Sp)

188. Mathematical Models in Physics and Engineering. (4)

Three hours of lecture per week. *Prerequisite: courses 113B and 185.* Designed primarily for mathematics majors with little or no background in physical sciences. Study of the relationship between mathematical concepts such as discrete and continuous spectra, resolvents of linear operators, group invariance, and physical concepts which arise in the study of dynamical systems and wave propagation. Mr. Rhodes (Sp)

190A–190B–190C–190D. Survey of Algebra and Analysis. (4–4–4–4)

Three hours of lecture per week. *Prerequisite: upper division or graduate standing with specialization outside mathematics and physical science. Students who have studied calculus should not take 190A but may enter 190B or 190C.* Students receive 2 units for 190C following 16B. Course 190D prepares students for course 104A.

190A. Analytic geometry, differential and integral calculus. (F, W)

190B. Calculus of several variables (partial differentiation, extremum problems), complex numbers and trigonometry, vectors and vector spaces. (W, Sp)

190C. Linear algebra. (F, Sp)

190D. Infinite series, differential and difference equations, multiple integration, Kuhn-Tucker theorem. Mr. Helson, Mr. Silver (F)

*191. Experimental Courses in Mathematics.

The topics to be covered and the method of instruction to be used will be announced at the beginning of each quarter that such courses are offered. See departmental bulletins.

195. Special Topics in Mathematics. (4)

Three hours of lecture per week. *Prerequisite: consent of instructor.* Lectures on special topics, which will be announced at the beginning of each quarter that the course is offered. May be repeated for credit. Mr. Marsden (F)

H196. Honors Thesis. (4)

Meetings to be arranged.
Prerequisite: admission to the Honors Program in Mathematics: a grade-point average of 3.00 overall and a grade-point average of 3.30 in the major. Independent study of an advanced topic leading to an honors thesis. The Staff (F, W, Sp)

199. Supervised Independent Study and Research. (1–5)

Enrollment is restricted by regulations listed on page 93. Must be taken on a *passed* or *not passed* basis. The Staff (F, W, Sp)

Related Courses in Other Departments

Computer Science 167. Graph Theory.
Computer Science 169. Introduction to Combinatorics.
Economics 191A. Introduction to Mathematical Economics.
Statistics 100A–100B–100C. Introduction to Probability and Statistics.
Statistics 141. Introduction to Continuous Parameter Stochastic Processes.
Statistics 142. Introduction to Discrete Parameter Stochastic Processes.
Statistics 168. Game Theory.

Graduate Courses

202A–202B–202C. Introduction to Topology and Analysis. (4–4–4)

Three hours of lecture per week. *Prerequisite: course 104A; also linear algebra for 202B and 105 for 202B and 202C.*

202A. General topology; theorems of Tychonoff, Urysohn, Tietze, Arzela-Ascoli, Baire. Stone-Weierstrass theorem. (F, W, Sp)

202B. Bounded linear maps on Banach spaces. Spectral theorem in Hilbert space. Derivative on Banach spaces. (W, Sp)

202C. Measure and integration. The Fourier transform. (Sp)
Mr. Helsen, Mr. Smale

203. Measure and Integration. (4)

Three hours of lecture per week. *Prerequisite: course 202A (may be taken concurrently).* General theory of measure and integration, including the Fubini theorems and the Radon-Nikodym theorem.
Mr. Dubins Mr. Kirby (F, W)

204A–204B–204C. Ordinary and Partial Differential Equations. (4–4–4)

Three hours of lecture per week. *Prerequisites: courses 105 and 185 or permission of instructor.* Fundamental existence theorem for ordinary differental equations. Properties of linear systems with constant and periodic coefficients. Sturm-Liouville theory; Poincare-Bendixson Theorem. Cauchy-Kowalewski theory for systems of partial differential equations. Initial and boundary value problems for elliptic, parabolic, and hyperbolic second order equations. Nonlinear equations and systems. Mr. Protter (Sequence beginning F)

205A–*205B. Theory of Functions of a Complex Variable. (4–4)

Three hours of lecture per week. *Prerequisite: course 185 or 120B.* Normal families, the Riemann mapping theorem, Picard's and related theorems, and additional topics chosen by the instructor from classical complex variable theory.
Mr. Fáry, Mr. Sarason (F, W)

206A. Linear Spaces. (4)

Three hours of lecture per week. *Prerequisite: courses 105 and 202A, or course 203.* Elementary theory of Banach and Hilbert spaces, Hahn-Banach theorem, closed graph theorem, principle of uniform boundedness, linear functionals and operators, weak convergence, spaces L_p and C.
Mr. Arveson (F, W, Sp)

206B. Linear Operators. (4)

Three hours of lecture per week. *Prerequisite: course 206A.* Spectrum and resolvent, Fredholm theory of compact operators, spectral theorem for bounded self-adjoint operators, commutative Banach algebras. Mr. Arveson (Sp)

207. Differential Operators. (4)

Three hours of lecture per week. *Prerequisite: course 206B.* Differential operators, unbounded symmetric operators, perturbation theory, additional topics selected by the instructor. Mr. Chernoff (F)

208. Functional Analysis. (4)

Three hours of lecture per week. *Prerequisite: course 206A.* Locally convex linear topological spaces, distributions, further topics selected by the instructor. (W)

212A–212B. Several Complex Variables. (4–4)

Three hours of lecture per week. *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. Further topics such as pseudoconvexity and the E. Levi problem, embedding theorems for Stein manifolds, proper mapping theorem, normalization theorem, bounded domains in C^n. (Sequence beginning W)
Mr. Kobayachi

214. Differentiable Manifolds. (4)

(Formerly numbered 240A)
Three hours of lecture per week. *Prerequisite:*

courses 202A, 140, or their equivalents are recommended. Smooth manifolds and smooth mappings, tangent and normal bundles, Sard theorem and transversality, Whitney imbedding theorem, Morse functions, Stokes' theorem, Frobenius theorem.
Mr. Thomas, Mr. Hirsch (F, W)

215A–215B–215C. Algebraic Topology. (4–4–4)

Three hours of lecture per week. *Prerequisite: courses 113B and 202A.* Fundamental group, covering spaces, simplicial complexes, homology theory and applications. Homotopy groups, fibrations, relations between homotopy and homology, obstruction theory, classification theorems, spectral sequences nad applications. Mr. Stallings,
Mr. Freedman (215A: F, W; 215B: W, Sp; 215C: Sp)

219A–*219B–*219C. Ordinary Differential Equations. (4–4–4)

Three hours of lecture per week. *Prerequisite: courses 112 or 113C, and 185 or 120A (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. Mr. Pugh (F)

219D–219E. Modern Flow Theory and Structural Stability. (4–4)

Three hours of lecture per week. *Prerequisite: course 219A.* Group actions and orbits, classification, special cases of Z and R; structural stability in low dimensions, characterization of stable fields in two dimensional manifolds. Higher dimensional theory, generic properties of fields and diffeomorphisms; closing lemma, structural stability, flows and diffeomorphisms; special topics. Mr. Pugh (W, Sp)

220A–220B–220C. Applied Mathematics for Physical Sciences and Engineering. (4–4–4)

Three hours of lecture per week. *Prerequisite: courses 120A–120B–120C, or 104A and 185, or equivalent.*

220A–220B. Ordinary and partial differential equations of mathematical physics and engineering. Special functions, integral transforms.

220C. Integral equations. Variational methods for partial differential equations. Mr. Pinney
(Sequence beginning F)

222A–222B–*222C. Partial Differential Equations. (4–4–4)

Three hours of lecture per week. *Prerequisite: courses 105 or 203; and 185.* The theory of initial value and boundary value problems for hyperbolic, parabolic, and elliptic partial differential equations, with emphasis on nonlinear equations. More general types of equations and systems of equations.
Mr. Cordes (Sequence beginning F)

224A–224B–224C. Mathematical Methods for the Physical Sciences. (4–4–4)

Three hours of lecture per week. *Prerequisite: courses 112 or 113C; and either 104A and 185, or 121A–B, or 120A–B.*

224A–224B. Introduction to the theory of distributions. Fourier and Laplace transforms. Partial differential equations. Green's function. Operator theory, with applications to one-parameter unitary groups, eigenfunction expansions, perturbation theory.

224C. Special topics chosen by students and instructor. Mr. Taub, Mr. Grunbaum
(Sequence beginning F)

225A–225B–225C. Metamathematics. (4–4–4)

Three hours of lecture per week. *Prerequisite: courses 125B and 135.* Metamathematics of predicate logic. Completeness and compactness theorems. Interpolation theorem, definability, theory of models. Metamathematics of number theory, recursive functions, applications to truth and provability. Undecidable theories. Mr. Vaught (225A: F, W; 225B: W, Sp; 225C: Sp)

226A. Functions and Abstract Machines. (4)

Three hours of lecture per week. *Prerequisite: courses 113B and 135 or consent of instructor.* Functions computed by finite state devices, algebraic characterizations, regular sets. Turing machines, recursive functions, decision problems. Mr. Spanier (F)

226B. Power Series and Languages. (4)

Three hours of lecture per week. *Prerequisite: course 226A.* Power series in non-commuting variables, rational and algebraic power series, applications to context-free languages, grammars, special families of languages. Mr. Spanier (W)

226C. Semigroups and Machines. (4)

Three hours of lecture per week. *Prerequisite: courses 226A and 250A.* Finite semigroups, wreath products, prime decomposition theorem, application to finite state machines, algebraic theory of complexity. (Sp)

227A–227B. Theory of Recursive Functions. (4–4)

Three hours of lecture per week. *Prerequisite: course 225C.* 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.
(Sequence beginning F)

228A–228B. Advanced Numerical Analysis. (5–5)

Three hours of lecture and two hours of laboratory per week. *Prerequisite: courses 111 or 113B, and 128B.* Discretization and optimum discretization. Iteration methods. Applications to systems of linear, differential, and integral equations. Discussion of convergence, stability, and errors. Additional topics selected by the instructor.
(Sequence beginning F) Mr. Kahan, Mr. Chorin

229A–229B. Theory of Models. (4–4)

Three hours of lecture per week. *Prerequisite: course 225C.* Syntactical characterization of classes closed under algebraic operations. Ultraproducts and ultralimits, saturated models. Methods for establishing decidability and completeness. Model theory of various languages richer than first-order.
(Sequence beginning F)

235A–235B–*235C. Theory of Sets. (4–4–4)

Three hours of lecture per week *Prerequisite: courses 125A and 135.*

235A–235B. Axiomatic foundations. Operations on sets and relations. Images and set functions. Ordering, well-ordering, and well-founded relations; general principles of induction and recursion. Ranks of sets, ordinals and their arithmetic. Set-theoretical equivalence, similarity of relations; definitions by abstraction. Arithmetic of cardinals. Axiom of choice, equivalent forms, and consequences.

235C. Selected topics such as: arithmetic of relation types, generalized continuum hypothesis, inaccessible numbers, constructible sets. (F, W)

*236A–*236B. Metamathematics of Set Theory. (4–4)

Three hours of lecture per week. *Prerequisite: courses 225C and 235A.* Various set theories: comparison of strength, transitive and natural models, finite axiomatizability. Independence and consistency of axiom of choice, continuum hypothesis, etc. The measure problem and axioms of strong infinity.

240A–240B. Riemannian Geometry. (4–4)

(Formerly 240B–240C)

Three hours of lecture per week. *Prerequisite: course 214.* Riemannian manifolds, parallelism, geodesics, structure, equations, completeness, curvature, relations between curvature and topology. Further topics such as: general theory of connections, holonomy groups and de Rham decomposition, pinched manifolds, submanifolds. Riemannian geometry of Lie groups.
Mr. Fáry (240A: W, Sp; 240B: Sp)

241A. Riemann Surfaces. (4)

Three hours of lecture per week. *Prerequisite: courses 205A and 214.* Compact Riemann surfaces, Riemann surface of an algebraic function, Riemann-Roch theorem, Abel's theorem, Jacobian variety and linear systems, integrals of 1st, 2nd, and 3rd kind, and period relations. Mr. Lawson (W)

241B. Complex Manifolds. (4)

Three hours of lecture per week. *Prerequisite: course 241A.* Transcendental methods in algebraic geometry, Kähler manifolds, Hodge and Dolbeault theorems, fiber bundles and characteristic classes in algebraic geometry, abelian varieties and analytic surfaces. Mr. Lawson (Sp)

*245A–*245B–*245C. General Theory of Algebraic Structures. (4–4–4)

Three hours of lecture per week. *Prerequisite: courses 113C and 135.* General notion of an algebraic structure. Subalgebras; isomorphism; homomorphisms and congruence relations; direct products, reduced products, and ultraproducts; free algebras. Applications of general notions to groups, rings, fields, lattices, Boolean algebras, etc.

250A. Groups, Rings, and Modules. (4)

Three hours of lecture per week. *Prerequisite: courses 113A, 113B, and 113C or their equivalent.* Group theory; direct and semidirect products, composition series, permutation groups, groups with operators. Ring theory: homomorphisms and ideals, unique factorization and principal ideal domains. Modules over rings: maximum and minimum conditions, free modules, duality, tensor product and homomorphism modules. Mr. Seidenberg,
Mr. Rhodes (F, W, Sp)

250B. Field Theory. (4)

Three hours of lecture per week. *Prerequisite: course 250A.* Extensions and composites of fields. Transcendental and algebraic extensions. Algebraic closure. Separable and purely inseparable extensions and automorphisms of fields, Galois theory. Finite fields. Isomorphisms. Mr. Seidenberg,
Mr. Rhodes, Mr. Stallings (F, W, Sp)

250C. Multilinear Algebra and Commutative Algebra. (4)

Three hours of lecture per week. *Prerequisite: course 250B.* Tensor algebra and exterior algebra of a module, with application to linear transformations. Elementary commutative ideal theory, rings of fractions, local rings. Elementary specialization and valuation theory. Related topics in commutative algebra. (Sp)

251. Ring Theory. (4)

Three hours of lecture per week. *Prerequisite: course 250B.* Topics such as: Noetherian rings, rings with descending chain condition, theory of the radical, homological methods. (F)

252. Representation Theory. (4)

Three hours of lecture per week. *Prerequisite: course 250B.* Structure of finite dimensional algebras, applications to representations of finite groups, the classical linear groups. Mr. Moore (F)

*253. Homological Algebra. (4)

Three hours of lecture per week. *Prerequisite: course 250B.* Modules over a ring, homomorphisms and tensor products of modules, functors and derived functors, homological dimension of rings and modules.

254. Algebraic Number Theory. (4)

Three hours of lecture per week. *Prerequisite: course 250B.* Valuation theory in number fields and relation to ideal theory, local fields, unit theorem and finiteness of class number, ramification theory.
Mr. Lam (Sp)

*255A–*255B–*255C. Foundations of Geometry. (4–4–4)

Three hours of lecture per week. *Prerequisite: courses 125B and 130.* Historical introduction. Primitive terms and axioms of Euclidean geometry. Principal consequences of axioms; introduction of Cartesian coordinates. Completeness, categoricity, decidability; independence of axioms. Alternative systems of primitive terms and axioms. Non-Euclidean geometries—parallel development to Euclidean geometry.

256A–256B–256C. Algebraic Geometry. (4–4–4)

Three hours of lecture per week. *Prerequisite: course 250B.* Algebraic varieties, dimension, correspondences, normalization, simple points, linear systems, Riemann-Roch theorems for curves, cohomology of coherent sheaves and theory of schemes.
(Sequence beginning F) Mr. Satake

*259. Transformation Groups. (4)

Three hours of lecture per week. *Prerequisite: courses 215A and 214.* Topological groups, Haar measure, general theory of topological transformation groups, the existence of slices and applications, the Smith theory of periodic transformations.

260A. Topological Groups. (4)

Three hours of lecture per week. *Prerequisite: courses 202A and 250A.* General topological groups, Haar measure, compact groups. Mr. Rieffel (F)

260B. Abstract Harmonic Analysis. (4)

Three hours of lecture per week. *Prerequisite: courses 206A and 260A.* Banach algebras, convolution algebras, group repersentations. Mr. Rieffel (W)

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261A–261B–261C. Lie Groups. (4–4–4)

Three hours of lecture per week. *Prerequisite: course 214.* Lie groups and Lie algebras, general structure theory; compact, solvable, complex, and semi-simple groups; classification of simple groups, representation theory; further topics such as the theory of symmetric spaces. Mr. Hochschild (Sequence beginning F)

265. Differential Topology. (4)

Three hours of lectures per week. *Prerequiusite: course 214.* Vector bundles, tubular neighborhoods, approximation theorems, Morse theory, handlebodies, surgery and cobordism. Mr. Hirsch (Sp)

270. Mathematical Theory of Fluid Dynamics. (4)

Three hours of lecture per week. 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. Mr. Chorin (Sp)

271. Topics in Foundations. (4)

Three hours of lecture per week. Advanced topics chosen by the instructor. The content of this course changes, as in the case of seminars. Hence it may be repeated for credit. Mr. Addison (F); Mr. Silver (W)

*272. Topics in Differential Topology. (4)

Three hours of lecture per week. Advanced topics chosen by the instructor. The content of this course changes as in the case of seminars. Hence it may be repeated for credit.

273. Topics in Advanced Numerical Analysis. (4)

(Formerly 228C)

Three hours of lecture per week. Advanced topics chosen by the instructor. Content of this course changes. Hence, may be repeated for credit. Mr. Parlett (W)

274. Topics in Algebra. (4)

Three hours of lecture per week. Advanced topics chosen by the instructor. The content of this course changes, as in the case of seminars. Hence it may be repeated for credit. Mr. Hartshorne (F, W); Mr. Bergman (W); Mr. Ogg (Sp)

275. Topics in Applied Mathematics. (4)

Three hours of lecture per week. Advanced topics chosen by the instructor. The content of this course changes, as in the case of seminars. Hence it may be repeated for credit. Mr. Bremermann (F); Mr. Gale (W)

276. Topics in Topology. (4)

Three hours of lecture per week. Advanced topics chosen by the instructor. The content of this course changes, as in the case of seminars. Hence it may be repeated for credit. Mr. Stallings (Sp)

277. Topics in Differential Geometry. (4)

Three hours of lecture per week. Advanced topics chosen by the instructor. The content of this course changes, as in the case of seminars. Hence it may be repeated for credit. Mr. Weinstein (Sp)

278. Topics in Analysis. (4)

Three hours of lecture per week. Advanced topics chosen by the instructor. The content of this course changes, as in the case of seminars. Hence it may be repeated for credit. Mr. Arveson (F); Mr. Kato (W); Mr. Rieffel (Sp)

*279. Topics in Partial Differential Equations. (4)

Three hours of lecture per week. Advanced topics chosen by the instructor. The content of this course changes, as in the case of seminars. Hence it may be repeated for credit.

*280A–*280B–*280C. Mathematical Theory of Relativity. (4–4–4)

Three hours of lecture per week. *Prerequisite: course 140 or consent of instructor.* Special theory of relativity, spinor representation of the Lorentz group, reformation of classical physical theories in relativistic form, principle of equivalence, Einstein theory of gravitation, cosmological problems.

290. Seminars. (2–8)

One 2-hour lecture per week. Credit and grade will be awarded at termination of seminar. Topics in foundations of mathematics, theory of numbers, numerical calculations, analysis, geometry, topology, algebra, and their applications, by means of lectures and informal conferences; work based largely on original memoirs.

295. Individual Research. (2–8)

By appointment. Intended for candidates for the Ph.D. degree. Sections 1–20 must be taken on a letter grade basis. Sections 21–60 must be taken on a *satisfactory/unsatisfactory* basis. The Staff (F, W, Sp)

299. Reading Course for Graduate Students. (2–8)

By appointment. Investigation of special problems under the direction of members of the department. Sections 1–20 must be taken on a letter grade basis. Sections 21–60 must be taken on a *satisfactory/unsatisfactory* basis. The Staff (F, W, Sp)

300. Teaching Workshop. (3)

Three to four hours of lecture per week. Designed for new teaching assistants in mathematics. The course consists of: microteaching sessions for the development of elementary teaching skills, lesson planning and alternatives to standard classroom methods, a program of guided group and self-analysis, and a schedule of reciprocal classroom visitations. Must be taken on a *passed/not passed* basis. Mr. Lawson (F)

601. Individual Study for Master's Students. (1–6)

Individual study for the comprehensive or language requirements in consultation with the field adviser. *Units may not be used to meet either unit or residence requirements for a master's degree. Must be taken on a satisfactory/unsatisfactory basis.* The Staff (F, W, Sp)

602. Individual Study for Doctoral Students. (1–8)

Individual study in consultation with the major field adviser, intended to provide an opportunity for qualified students to prepare themselves for the various examinations required of candidates for the Ph.D. *May not be used for unit or residence requirements for the doctoral degree. Must be taken on a satisfactory/unsatisfactory basis.* The Staff (F, W, Sp)

IDS* 7. Self-Paced Study in Introductory Physics and Calculus. (1–12)

See Interdepartmental Studies for the complete description of this course.

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IDS 289A–289B. Turbulence and Its Mathematical Analysis. (4–4)

See Interdepartmental Studies for the complete description of this course.

Logic Colloquium. (No credit)

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

Mathematics Colloquium. (No credit)

Meetings for the presentation of original work by members of the staff, visiting mathematicians, and graduate students.

Related Courses In Other Departments

Statistics 200A–200B–200C. Introduction to Probability and Statistics at an Advanced Level.

Statistics 205A–205B–205C. Probability Theory.

Statistics 261. Foundations of Random Analysis.

Statistics 262. Information Theory.

Statistics 263. Decomposable Processes.

Statistics 265. Markov Processes.

Related Programs

Computer Science See Department of Electrical Engineering and Computer Sciences, Computer Science Division.

Logic See Group in Logic and the Methodology of Science and Department of Philosophy.

Mathematics Education See Group in Science and Mathematics Education.

Statistics See Department of Statistics.

MEDICAL PHYSICS

(Division Office, 103 Donner Laboratory)

Professors:
Hans J. Bremermann, Ph.D.
Hardin B. Jones, Ph.D.
Robert K. Mortimer, Ph.D. (*Chairman*)
Alexander V. Nichols, Ph.D.
Cornelius A. Tobias,† Ph.D.
John W. Gofman, M.D., Ph.D. (*Emeritus*)
Thomas H. Jukes, Ph.D., D.Sc. (*in Residence*) (*Emeritus*)
John H. Lawrence, M.D. Sc.D. (*Emeritus*)
John H. Northrop, Ph.D., Sc.D., LL.D. (*Emeritus*)

Associate Professors:
Robert M. Glaeser, Ph.D.
Howard C. Mel,† Ph.D.

Assistant Professor:
H. John Burki, Ph.D.

Professors:
Thomas L. Hayes, Ph.D. (*Adjunct*)
A. Douglas McLaren,† Ph.D.

Associate Professor:
Alan J. Bearden, Ph.D. (*Adjunct*)

Undergraduate Advisers: Mr. Bearden, Mr. Glaeser, Mr. Nichols.

The courses of the division are designed to meet several objectives: (1) to prepare students for advanced work in biophysics, medical physics, and allied fields; (2) to offer for physical science and engineering students selected topics and concepts of biological sciences; and (3) to provide biomedically oriented students an introduction to some of the quantitative physical problems and approaches in biology and medicine. Courses 10, 11, and 103 are designed to provide background and perspective in their specified fields.

Individual Major in Biophysics

An individual major in *biophysics* (physics and biology) may be arranged in consultation with one of the major advisers. Lower division course sequences in physics, mathematics, chemistry and biology are required as preparation for the major. In addition, 45 units of upper division courses in physics, physical chemistry, and biology are required for completion of the major. Recommended courses include atomic and

Note: For key to footnote symbols, see page 92.