Berkeley 2003-2005

Mathematics

(College of Letters and Science)

Department Office: 970 Evans Hall, (510) 642-6550

University Professor

Alexandre J. Chorin, Ph.D. New York University. Applied mathematics, turbulence, numerical methods, nonlinear PDEs

Professors

David Aldous, Ph.D. University of Cambridge. Theoretical and applied probability
Robert M. Anderson, Ph.D. Yale University. Mathematical economics, nonstandard analysis, probability theory
William B. Arveson, Ph.D. University of California at Los Angeles. Functional analysis, operator algebras
George M. Bergman, Ph.D. Harvard University. Associative rings, universal algebra and category theory, counterexamples
Richard E. Borcherds, Ph.D. Trinity College, Cambridge. Lie algebras, vertex algebras, automorphic forms
Paul R. Chernoff, Ph.D. Harvard University. Functional analysis, operator theory
F. Michael Christ, Ph.D. University of Chicago. Harmonic analysis, partial differential equations, complex analysis in several variables
Robert F. Coleman, Ph.D. Princeton University. P-adic analysis and algebraic geometry
James W. Demmel, Ph.D. University of California, Berkeley. Numerical analysis, high performance computing
Lester E. Dubins, Ph.D. University of Chicago. Probability, gambling theory, geometry
David Eisenbud, Ph.D. University of Chicago. Algebraic geometry, commutative algebra, computation
L. Craig Evans, Ph.D. University of California at Los Angeles. Partial differential equations
Steve Evans, Ph.D. University of Cambridge. Probability and stochastic processes
David A. Freedman, Ph.D. Princeton University. Foundations of statistics
Edward Frenkel, Ph.D. Harvard University. Representation theory, integrable systems, mathematical physics
Alexander Givental, Ph.D. Moscow State University. Symplectic and contact geometry, singularity theory, mathematical physics
F. Alberto Grünbaum, Ph.D. Rockefeller University. Analysis, probability, integrable systems, medical imaging
Mark Haiman, Ph.D. Massachusetts Institute of Technology. Algebra, combinatorics, algebra geometry
†Ole H. Hald, Ph.D. New York University. Numerical analysis
Leo A. Harrington, Ph.D. Massachusetts Institute of Technology. Recursion theory, model theory, set theory
Jenny C. Harrison, Ph.D. University of Warwick. Dynamical systems, integration theory
Robert C. Hartshorne, Ph.D. Princeton University. Algebraic geometry
Vaughan F. R. Jones, Ph.D. Docteur es Sciences, School of Mathematics, Geneva. Von Neumann algebras
William M. Kahan, Ph.D. University of Toronto. Error analysis, numerical computations, computers, convexity, large matrices, trajectory problems
†Richard M. Karp, Ph.D. Harvard University. Computer science and bioengineering
Robion C. Kirby, Ph.D. University of Chicago. Topology of manifolds
Michael J. Klass, Ph.D. University of California at Los Angeles. Probability theory, combinatorics
Tsit-Yuen Lam, Ph.D. Columbia University. Algebra
Hendrik W. Lenstra, Jr., Ph.D. University of Amsterdam. Algebraic number theory, algorithms
C. Keith Miller, Ph.D. Rice University. Partial differential equations, numerical methods for PDEs
Calvin C. Moore, Ph.D. Harvard University. Representations and actions of topological groups, operator algebras
John C. Neu, Ph.D. California Institute of Technology. Applied mathematics
Arthur E. Ogus, Ph.D. Harvard University. Algebraic geometry
Andrei Okounkov, Ph.D. Moscow State University. Representation theory, combinatorics
Yuval Peres, Ph.D. Hebrew University. Probability theory and Hausdorff dimension
James Pitman, Ph.D. Sheffield University. Probability and stochastic processes
Charles C. Pugh, Ph.D. Johns Hopkins University. Global theory of differential equations
Marina Ratner, Ph.D. Moscow State University. Ergodic theory
Nicolai Reshetikhin, Ph.D. Steklov Institute. Mathematical physics, low-dimensional topology, representation theory
Kenneth A. Ribet, Ph.D. Harvard University. Algebraic number theory, algebraic geometry
Marc A. Rieffel, Ph.D. Columbia University. Noncommutative harmonic analysis, operator algebras, quantum geometry
Donald E. Sarason, Ph.D. University of Michigan. Complex function theory, operator theory
Vera Serganova, Ph.D. Leningrad University. Super-representation theory
James A. Sethian, Ph.D. University of California, Berkeley. Applied mathematics, computational physics, partial differential equations
Christina Shannon, Ph.D. Stanford University. Economic theory, mathematical economics
Jack H. Silver, Ph.D. University of California, Berkeley. Mathematical logic, theory of sets
Theodore Slaman, Ph.D. Harvard University. Recursion theory
John Steel, Ph.D. University of California, Berkeley. Set theory, descriptive set theory, fine structure
John Strain, Ph.D. University of California, Berkeley. Applied mathematics, numerical analysis, fast algorithms, materials science
Bernd Sturmfels, Ph.D. University of Washington, Seattle. Combinatorics, computational algebraic geometry
Daniel Tartaru, Ph.D. University of Virginia, Charlottesville. Partial differential equations
Dan-Virgil Voiculescu, Ph.D. University of Bucharest. Operator algebras
Paul A. Vojta, Ph.D. Harvard University. Number theory
John B. Wagoner, Ph.D. Princeton University. Differential topology, algebraic K-theory, dynamical systems
Alan D. Weinstein, Ph.D. University of California, Berkeley. Symplectic geometry, mathematical physics
Mariusz Wodzicki, Ph.D. Steklov Mathematical Institute. Noncommutative and algebraic geometry, analysis, K-theory
W. Hugh Woodin, Ph.D. University of California, Berkeley. Set theory, large cardinals
Hung-Hsi Wu, Ph.D. Massachusetts Institute of Technology. Riemannian geometry, complex manifolds
Maciej Zworski, Ph.D. Massachusetts Institute of Technology. Linear partial differential equations, microlocal analysis
John W. Addison, Jr. *(Emeritus)*, Ph.D. University of Wisconsin. Theory of definability, descriptive set theory, model theory, recursive function theory
William G. Bade *(Emeritus)*, Ph.D. University of California at Los Angeles. Functional analysis, Banach algebras
Elwyn R. Berlekamp *(Emeritus)*, Ph.D. Massachusetts Institute of Technology. Combinatorial game theory, algebraic coding theory, electrical engineering, computer science
David H. Blackwell *(Emeritus)*, Ph.D. University of Illinois, Urbana. Set theory, recursive functions, measure theory, stochastic processes, game theory, information theory, linear programming
Paul L. Chambré *(Emeritus)*, Ph.D. University of California, Berkeley. Applied mathematics
Shiing-Shen Chern *(Emeritus)*, D.Sc., LL.D. University of Hamburg. D.Sc. University of Chicago. LL.D. Chinese University of Hong Kong. Differential and integral geometry, topology
Heinz O. Cordes *(Emeritus)*, Ph.D. University of Göttingen. Classical analysis
Gerard Debreu *(Emeritus)*, D.Sc. University of Paris. Mathematical economics
Stephen P. L. Diliberto *(Emeritus)*, Ph.D. Princeton University. Ordinary differential equations, celestial mechanics
Jacob Feldman *(Emeritus)*, Ph.D. University of Chicago. Ergodic theory, stochastic processes
David Gale *(Emeritus)*, Ph.D. Princeton University. Mathematical economics
Henry Helson *(Emeritus)*, Ph.D. Harvard University. Harmonic analysis, function theory
Leon A. Henkin *(Emeritus)*, Ph.D. Princeton University. Logic and foundations of mathematics, mathematics education
Morris W. Hirsch *(Emeritus)*, Ph.D. University of Chicago. Dynamical systems, neural networks, stochastic approximation
Gerhard P. Hochschild *(Emeritus)*, Ph.D. Princeton University. Lie groups, algebraic groups, homological algebra
Wu-Yi Hsiang *(Emeritus)*, Ph.D. Princeton University. Transformation groups, differential geometry
Irving Kaplansky *(Emeritus)*, Ph.D. Harvard University. Algebra
Shoshichi Kobayashi *(Emeritus)*, Ph.D. University of Washington. Differential geometry, Riemannian and complex manifolds, several complex variables
R. Sherman Lehman *(Emeritus)*, Ph.D. Stanford University. Number theory, numerical analysis
Jerrold E. Marsden *(Emeritus)*, Ph.D. Princeton University. Mechanics, applied dynamics, control theory
Ralph N. McKenzie *(Emeritus)*, Ph.D. University of Colorado. Logic, universal algebra
Andrew P. Ogg *(Emeritus)*, Ph.D. Harvard University. Number theory, elliptic curves, modular forms
Beresford N. Parlett *(Emeritus)*, Ph.D. Stanford University. Numerical analysis, scientific computation
Murray H. Protter *(Emeritus)*, Ph.D. Brown University. Partial differential equations
John L. Rhodes *(Emeritus)*, Ph.D. Massachusetts Institute of Technology. Algebra, semigroups, automata
Rainer K. Sachs *(Emeritus)*, Ph.D. Syracuse University. Relativity, mathematical biology
Ichiro Satake *(Emeritus)*, Ph.D. University of Tokyo. Symmetric spaces, automorphic functions
Isadore M. Singer *(Emeritus)*, Ph.D. University of Chicago, Dr. Sc. Tulane University. Geometry, partial differential equations, physics
Stephen Smale *(Emeritus)*, Ph.D. University of Michigan. Dr. Sc. University of Warwick. Algorithms, numerical analysis, global analysis
Robert M. Solovay *(Emeritus)*, Ph.D. University of Chicago. Mathematics of set theory, large cardinals
John R. Stallings *(Emeritus)*, Jr., Ph.D. Princeton University. Topology, group theory
P. Emery Thomas *(Emeritus)*, Ph.D. Princeton University. Number theory, diophantine equations
Joseph A. Wolf *(Emeritus)*, Ph.D. University of Chicago. Differential geometry, lie groups, harmonic analysis

Associate Professors

Ming Gu, Ph.D. Yale University. Numerical linear algebra, scientific computing
Bjorn Poonen, Ph.D. University of California, Berkeley. Number theory, algebraic geometry
Fraydoun Rezakhanlou, Ph.D. New York University. Probability theory, partial differential equations

Assistant Professors

Tom Graber, Ph.D. University of California, Los Angeles. Algebraic geometry
Michael Hutchings, Ph.D. Harvard University. Low dimensional and symplectic topology, geometry
Allen Knutson, Ph.D. Massachusetts Institute of Technology. Symplectic geometry and combinatorics
Ai-ki Liu, Ph.D. Harvard University. Algebraic and differential geometry, symplectic topology
Lior Pachtor, Ph.D. Massachusetts Institute of Technology. Applications of statistics and combinatorics to problems in biology
Thomas Scanlon, Ph.D. Harvard University. Model theory and applications to number theory

Adjunct Professor

Paul Concus, Ph.D. Harvard University. Fluid dynamics, numerical analysis, applied mathematics

Affiliated Professor

Alan H. Schoenfeld *(Education)*, Ph.D. Stanford University. Psychology of problem solving

Professor-in-Residence

Grigory Barenblatt, Applied mechanics, mechanics of solids

The Major Programs

The department offers undergraduate major programs in mathematics and applied mathematics leading to the B.A. degree. These programs provide excellent preparation for advanced degrees in math, physical sciences, economics, and industrial engineering as well as graduate study in business, education, law, and medicine. They also prepare students for post-baccalaureate positions in business, technology, industry, teaching, government, and finance. The requirements for both majors are summarized below. More detailed information is given in the "Undergraduate Handbook," available from the undergraduate advising office in 965 Evans Hall and at http://math.berkeley.edu/undergrad/announcement.html.

General Major Requirements. Both major programs require a lower-division base of Mathematics 1A-1B and 53 and 54. Courses 16A-16B are not an acceptable alternative. Math 1A-1B must be completed with average grades of C or better; Math 53 and 54 must be completed with minimum grades of C in each. Transfer students should contact the undergraduate adviser in 965 Evans Hall about requirements for admission to the major. Eight upper-division courses are required for either major. Specific course requirements follow.

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Major in Mathematics. (a) Four core courses 104, 110, 113 and 185; (b) two semi-electives: select one course from each of two of the following three subject areas: I. Computing (128A); II. Geometry (130, 140, 141, 142); III. Logic and foundations (125A, 135); (c) Two upper division math electives. With the approval of the major adviser, students may count two mathematically theoretical courses in computer science, statistics, physics, astronomy, mathematical economics, or other sciences toward requirements for the major in mathematics.

Major in Applied Mathematics. (a) 104, 110, 113, 128A, and 185; (b) Three additional upper division courses, approved by a major adviser, which form a coherent cluster in some applied area such as actuarial science, biophysics, classical mechanics, computer science, decision theory, economics, fluid mechanics, geophysics, mathematical biology, numerical analysis, operations research, probability theory, quantum mechanics, systems theory. Many other clusters are also possible.

Honors Program. In addition to completing the requirements for the major in mathematics or applied mathematics, students in the honors program must (a) earn a grade-point average of *at least* 3.5 in upper division and graduate courses in the major and *at least* 3.3 in all courses taken at the University; (b) complete course 196 in which they will write a senior honors thesis, or pass two graduate mathematics courses with a grade of at least A-; (c) receive the recommendation of their major adviser. Students interested in the honors program should consult with their major adviser early in their program, preferably by their junior year.

B prefix=language course for business majors
C prefix=cross-listed course
H prefix=honors course

R prefix=course satisfies R&C requirement
AC suffix=course satisfies American cultures requirement

*Professor of the Graduate School
†Recipient of Distinguished Teaching Award

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Undergraduate Research Seminar. Math 191 is intended to initiate undergraduates into the research experience. This small seminar is led by a ladder-rank faculty member, and topics vary each semester.

The Minor Program

Students in the College of Letters and Science may complete one or more minors of their choice, normally in a field both academically and administratively distinct from their major. The minor program in the Department of Mathematics consists of the following course work:

Prerequisites: Mathematics 1A-1B and 53 and 54 (or their equivalents). These courses must be taken for a letter grade and must be passed with *average* grades of C or better.

Minor Requirements: Mathematics 104, 110, 113, and 185, plus one additional upper division mathematics course. These five courses must each be taken for a letter grade, and a minimum grade-point average of 2.0 is required for upper division courses applied to the minor program. At least three of the five courses must be completed at Berkeley.

For more information about this program, please contact the undergraduate adviser in 965 Evans Hall.

Preparation for Graduate Study

Students preparing for the Ph.D. in mathematics are strongly advised to acquire a reading knowledge of two foreign languages from among French, German, and Russian. Undergraduate students also often take one or more of the following introductory graduate courses: 202A-202B, 214, 225A-225B, 228A-228B, 250A-250B.

Graduate Programs

The department offers the M.A. degree in mathematics and Ph.D. degrees in mathematics and applied mathematics. Detailed information concerning admission, graduate student instructorships and fellowships, and degree requirements is given in the *Graduate Announcement of the Department of Mathematics*, which is available upon request from the graduate office, 910 Evans Hall and at http://math.berkeley.edu/graduate/graduate.html

Courses and Seminars

Courses and seminars are listed below. More detailed and up-to-the-minute information on semester offerings, instructors, textbooks, course and seminar content, teaching and grading methods, and schedules are posted on the ninth floor of Evans Hall and are available on the web at http://math.berkeley.edu.

Math 1A-1B is the calculus sequence intended for students planning majors in mathematics, engineering, or the sciences. The sequence is also acceptable as a substitute for Math 16A-16B. It is designed to prepare students for further courses in mathematics.

Math 16A-16B is a terminal calculus sequence intended for students planning majors in the life or social sciences.

Math 32 is intended for students who wish to take Math 1A or 16A but have not met the prerequisites.

Lower Division Courses

1A. Calculus. (4) Students will receive no credit for 1A after taking 16B and 2 units after taking 16A. Three hours of lecture and two hours of discussion/workshop per week; at the discretion of the instructor, an additional hour of discussion/workshop or computer laboratory per week. *Prerequisites: Three and one-half years of high school math, including trigonometry and analytic geometry, plus a satisfactory grade in one of the following: CEEB MAT test, an AP test, the UC/CSU math diagnostic test, or 32. Consult the mathematics department for details. Students with AP credit should consider choosing a course more advanced than 1A.* This sequence is intended for majors in engineering and the physical sciences. An introduction to differential and integral calculus of functions of one variable, with applications and an introduction to transcendental functions. (F,SP)

1B. Calculus. (4) Students will receive 2 units of credit for 1B after taking 16B. Three hours of lecture and two hours of discussion/workshop per week; at the discretion of the instructor, an additional hour of discussion/workshop or computer laboratory per week. *Prerequisites: 1A.* Continuation of 1A. Techniques of integration; applications of integration. Infinite sequences and series. First-order ordinary differential equations. Second-order ordinary differential equations; oscillation and damping; series solutions of ordinary differential equations. (F,SP)

H1B. Honors Calculus. (4) Students will receive 2 units of credit for H1B after taking 16B. Three hours of lecture and two hours of discussion/workshop per week; at the discretion of the instructor, an additional hour of discussion/workshop or computer laboratory per week. *Prerequisites: 1A.* Honors version of 1B. Continuation of 1A. Techniques of integration; applications of integration. Infinite sequences and series. First-order ordinary differential equations. Second-order ordinary differential equations; oscillation and damping; series solutions of ordinary differential equations. (F)

16A. Analytic Geometry and Calculus. (3) Students will receive no credit for 16A after taking 1A. Two hours of lecture and one hour of discussion/workshop per week; at the discretion of the instructor, an additional hour of lecture or discussion/workshop per week. *Prerequisites: Three years of high school math, including trigonometry, plus a satisfactory grade in one of the following: CEEB MAT test, an AP test, the UC/CSU math diagnostic exam, or 32. Consult the mathematics department for details.* This sequence is intended for majors in the life and social sciences. Calculus of one variable; derivatives, definite integrals and applications, maxima and minima, and applications of the exponential and logarithmic functions. (F,SP)

16B. Analytic Geometry and Calculus. (3) Students will receive no credit for 16B after 1B, 2 units after 1A. Two hours of lecture and one hour of discussion/workshop per week; at the discretion of the instructor, an additional hour of lecture or discussion/workshop per week. *Prerequisites: 16A.* Continuation of 16A. Application of integration of economics and life sciences. Differential equations. Functions of many variables. Partial derivatives, constrained and unconstrained optimization. (F,SP)

24. Freshman Seminars. (1) Course may be repeated for credit as topic varies. One hour of seminar per week. Sections 1-2 to be graded on a letter-grade basis. Sections 3-4 to be graded on a *passed/not passed* basis. The Berkeley Seminar Program has been designed to provide new students with the opportunity to explore an intellectual topic with a faculty member in a small-seminar setting. Berkeley Seminars are offered in all campus departments, and topics vary from department to department and semester to semester. (F,SP)

32. Precalculus. (4) Students will receive no credit for 32 after taking 1A-1B or 16A-16B and will receive 3 units after taking 96. Two hours of lecture and two hours of discussion per week, plus, at the instructor's option, an extra hour of lecture/discussion per week. *Prerequisites: Three years of high school mathematics, plus satisfactory score on one of the following: CEEB MAT test, math SAT, or UC/CSU diagnostic examination.* Polynomial and rational functions, exponential and logarithmic functions, trigonometry and trigonometric functions. Complex numbers, fundamental theorem of algebra, mathematical induction, binomial theorem, series, and sequences. (F,SP)

39. Freshman/Sophomore Seminar. Course may be repeated for credit as topic varies. Seminar format. *Prerequisites: Priority given to freshmen and sophomores.* Freshman and sophomore seminars offer lower division students the opportunity to explore an intellectual topic with a faculty member and a group of peers in a small-seminar setting. These seminars are offered in all campus departments; topics vary from department to department and from semester to semester.

49. Supplementary Work in Lower Division Mathematics. (1-3) Course may be repeated for credit. Meetings to be arranged. *Prerequisites: Some units in a lower division Mathematics class.* Students with partial credit in lower division mathematics courses may, with consent of instructor, complete the credit under this heading. (F,SP)

53. Multivariable Calculus. (4) Students will receive 1 unit of credit for 53 after taking 50B and 3 units of credit after taking 50A. Three hours of lecture and two hours of discussion/workshop per week; at the discretion of the instructor, an additional hour of discussion/workshop or computer laboratory per week. *Prerequisites: 1B.* Parametric equations and polar coordinates. Vectors in 2-and 3-dimensional Euclidean spaces. Partial derivatives. Multiple integrals. Vector calculus. Theorems of Green, Gauss, and Stokes. (F,SP)

H53. Honors Multivariable Calculus. (4) Students will receive 1 unit for H53 after taking 50B and 3 units after taking 50A. Three hours of lecture and two hours of discussion/workshop per week; at the discretion of the instructor, an additional hour of discussion/workshop or computer laboratory per week. *Prerequisites: 1B.* Honors version of 53. Parametric equations and polar coordinates. Vectors in 2-and 3-dimensional Euclidean spaces. Partial derivatives. Multiple integrals. Vector calculus. Theorems of Green, Gauss, and Stokes. (F,SP)

53M. Multivariable Calculus with Computers. (4) Students will receive no credit for 53M after taking 53, 1 unit after 50B, and 3 units after 50A. Three hours of lecture and three hours of discussion/microcomputer laboratory per week. *Prerequisites: 1BM or 1B.* This course will cover the same topics as 53; parametric equations and polar coordinates, vectors in 2-and 3-dimensional Euclidean spaces; partial derivatives, multiple integrals; vector calculus. Theorems of Green, Gauss, and Stokes. No prior computer experience is necessary. (F,SP)

54. Linear Algebra and Differential Equations. (4) Students will receive 1 unit of credit for 54 after taking 50A and 3 units of credit after taking Math 50B. Three hours of lecture and two hours of discussion/workshop per week; at the discretion of the instructor, an additional hour of discussion/workshop or computer laboratory per week. *Prerequisites: 1B.* Basic linear algebra; matrix arithmetic and determinants. Vector spaces; inner product as spaces. Eigenvalues and eigenvectors; linear transformations. Homogeneous ordinary differential equations; first-order differential equations with constant coefficients. Fourier series and partial differential equations. (F,SP)

H54. Honors Linear Algebra and Differential Equations. (4) Students will receive 1 unit for H54 after taking 50A and 3 units after taking 50B. Three hours of lecture and two hours of discussion/workshop per week; at the discretion of the instructor, an additional hour of discussion/workshop or computer laboratory per week. *Prerequisites: 1B.* Honors version of 54. Basic linear algebra: matrix arithmetic and determinants. Vectors spaces; inner product spaces. Eigenvalues and eigenvectors; linear transformations. Homogeneous ordinary differential equations; first-order differential equations with constant coefficients. Fourier series and partial differential equations. (F,SP)

54M. Linear Algebra and Differential Equations with Computers. (4) Students will receive no credit for 54M after taking 54, 1 unit after 50A, and 3 units after 50B. Three hours of lecture and three hours of discussion/microcomputer laboratory per week. *Prerequisites: 1BM or 1B.* This course will cover the same topics as 54: basic linear algebra; matrix arithmetic and determinants. Vector spaces, inner product spaces. Eigenvalues and eigenvectors; linear transformations. Homogenous ordinary differential equations; first-order differential equations with constant coefficients. Fourier series and partial differential equations. No prior computer experience is necessary. (F,SP)

55. Discrete Mathematics. (4) Students will receive no credit for 55 after taking Computer Science 70. Three hours of lecture and two hours of discussion/workshop per week; at the discretion of the instructor, an additional hour of discussion/workshop or computer laboratory per week. *Prerequisites: Mathematical maturity appropriate to a sophomore math class. 1A-1B recommended.* Logic, mathematical induction sets, relations, and functions. Introduction to graphs, elementary number theory, combinatorics, algebraic structures, discrete probability, theory, and statistics. Emphasis on topics of interest to students in computer science. (F,SP)

74. Transition to Upper Division Mathematics. (3) Three hours of lecture per week. *Prerequisites: 53 and 54.* The course will focus on reading and understanding mathematical proofs. It will emphasize precise thinking and the presentation of mathematical results, both orally and in written form. The course is intended for students who are considering majoring in mathematics but wish additional training. (F,SP)

84. Sophomore Seminar. (1) One hour of seminar per week. Sections 1-2 to be graded on a *passed/not passed* basis. Sections 3-4 to be graded on a letter-grade basis. Sophomore seminars are designed for students considering a major in the sponsoring department. They are small, interactive courses in which students will encounter a topic typical of the discipline and become acquainted with the approaches and methods of scholars in that field. Sophomore seminar instructors will become faculty mentors for the students from the time they declare the major until the time they graduate. (F,SP)

H90. Honors Undergraduate Seminar in Mathematical Problem Solving. (1) Course may be repeated for credit. Two hours of seminar per week. *Prerequisites: Consent of instructor; undergraduate standing.* This seminar is designed especially, but not exclusively, to prepare students for the annual national Putnam Mathematical Competition in December. Students will develop problem solving skills and experience by attempting the solution of challenging mathematical problems that require insight more than knowledge. (F)

98. Supervised Group Study. (1-4) Must be taken on a *passed/not passed* basis. Directed Group Study, topics vary with instructor. (F,SP)

Upper Division Courses

C103. Introduction to Mathematical Economics. (3) Three hours of lecture per week. *Prerequisites: 53 and 54. Formerly 103.* Selected topics illustrating the application of mathematics to economic theory. This course is intended for upper-division students in Mathematics, Statistics, the Physical Sciences, and Engineering, and for economics majors with adequate mathematical preparation. No economic background is required. Also listed as Economics C103.

104. Introduction to Analysis. (4) Three hours of lecture per week. *Prerequisites: 53 and 54.* The real number system. Sequences, limits, and continuous functions in R and R^n. The concept of a metric space. Uniform convergence, interchange of limit operations. Infinite series. Mean value theorem and applications. The Riemann integral. (F,SP)

H104. Introduction to Analysis. (4) Three hours of lecture per week. *Prerequisites: 53 and 54.* Honors section corresponding to 104. Recommended for students who enjoy mathematics and are good at it. Greater emphasis on theory and challenging problems.

105. Second Course in Analysis. (4) Three hours of lecture per week. *Prerequisites: 104.* Differential calculus in R^n: the derivative as a linear map; the chain rule; inverse and implicit function theorems. Lebesgue integration on the line; comparison of Lebesgue and Riemann integrals. Convergence theorems. Fourier series, L^2 theory. Fubini's theorem, change of variable. (SP)

110. Linear Algebra. (4) No credit allowed after completion of Math 112 or 113B. Three hours of lecture per week and an additional two hours of discussion at the discretion of the instructor. *Prerequisites: 54 or a course with equivalent linear algebra content.* Matrices, vector spaces, linear transformations, inner products, determinants. Eigenvectors. QR factorization. Quadratic forms and Rayleigh's principle. Jordan canonical form, applications. Linear functionals. (F,SP) *Staff*

H110. Linear Algebra. (4) No credit allowed after completion of Math 112 or 113B. Three hours of lecture per week. *Prerequisites: 54 or a course with equivalent linear algebra content.* Honors section corresponding to course 110 for exceptional students with strong mathematical inclination and motivation. Emphasis is on rigor, depth, and hard problems. (SP)

113. Introduction to Abstract Algebra. (4) Three hours of lecture per week. *Prerequisites: 54 or a course with equivalent linear algebra content.* Sets and relations. The integers, congruences and the Fundamental Theorem of Arithmetic. Groups and their factor groups. Commutative rings, ideals and quotient fields. The theory of polynomials: Euclidean algorithm and unique factorizations. The Fundamental Theorem of Algebra. Fields and field extensions. (F,SP)

H113. Introduction to Abstract Algebra. (4) Three hours of lecture per week. *Prerequisites: 54 or a course with equivalent linear algebra content.* Honors section corresponding to 113. Recommended for students who enjoy mathematics and are good at it. Greater emphasis on theory and challenging problems. (F)

114. Second Course in Abstract Algebra. (4) Three hours of lecture per week. *Prerequisites: 113.* Further topics on groups, rings and fields not covered in Math 113. Possible topics include: the Sylow Theorems and their applications to group theory; classical groups; abelian groups and modules over a principal ideal domain; algebraic field extensions; splitting fields and Galois theory; construction and classification of finite fields. (SP)

115. Introduction to Number Theory. (4) Three hours of lecture per week. *Prerequisites: 53 and 54.* Divisibility, congruences, numerical functions, theory of primes. Topics selected: Diophantine analysis, continued fractions, partitions, quadratic fields, asymptotic distributions, additive problems. (F,SP)

118. Wavelets and Signal Processing. (4) Three hours of lecture per week. *Prerequisites: 53 and 54.* Introduction to signal processing including Fourier analysis and wavelets. Theory, algorithms, and applications to one-dimensional signals and multidimensional images. (F,SP)

119. Introduction to Applied Mathematics. (4) Three hours of lecture per week. *Prerequisites: 53 and 54.* A sample of ideas important in the mathematical sciences. Topics: duality in constrained optimization, structure of equilibrium equations (both discrete and continuous), initial value problems, conservation laws, uses of (fast) Fourier transform, calculus of variations, use of complex analysis, chaos. (F)

121A-121B. Mathematical Tools for the Physical Sciences. (4;4) Three hours of lecture per week. *Prerequisites: 53 and 54.* Functions of a complex variable, Fourier series, finite-dimensional linear systems. Infinite-dimensional linear systems, orthogonal expansions, special functions, partial differential equations arising in mathematical physics. Intended for students in the physical sciences who are not planning to take more advanced mathematics courses. (F,SP)

123. Ordinary Differential Equations. (4) Three hours of lecture per week. *Prerequisites: 104.* Existence and uniqueness of solutions, linear systems, regular singular points. Other topics selected from analytic systems, autonomous systems, Sturm-Liouville Theory. (F)

125A. Mathematical Logic. (4) Three hours of lecture per week. *Prerequisites: 113 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. (F,SP)

126. Introduction to Partial Differential Equations. (4) Three hours of lecture per week. *Prerequisites: 104.* 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, *a priori* bounds, the Fourier transform. (SP)

127. Mathematical and Computational Methods in Molecular Biology. (4) Three hours of lecture per week. *Prerequisites: 53, 54, and 55; Statistics 20 recommended.* Introduction to mathematical and computational problems arising in the context of molecular biology. Theory and applications of combinatorics, probability, statistics, geometry, and topology to problems ranging from sequence determination to structure analysis. (F,SP)

128A. Numerical Analysis. (4) Three hours of lecture and one hour of discussion per week. At the discretion of instructor, an additional hour of discussion/computer laboratory per week. *Prerequisites: 53 and 54.* Programming for numerical calculations, round-off error, approximation and interpolation, numerical quadrature, and solution of ordinary differential equations. Practice on the computer. (F,SP)

128B. Numerical Analysis. (4) Three hours of lecture and one hour of discussion per week. At the discretion of the instructor, an additional hour of discussion/computer laboratory per week. *Prerequisites: 110 and 128A.* Iterative solution of systems of nonlinear equations, evaluation of eigenvalues and eigenvectors of matrices, applications to simple partial differential equations. Practice on the computer. (F,SP)

130. The Classical Geometries. (4) Three hours of lecture per week. *Prerequisites: 110 and 113.* A critical examination of Euclid's Elements; ruler and compass constructions; connections with Galois theory; Hilbert's axioms for geometry, theory of areas, introduction of coordinates, non-Euclidean geometry, regular solids, projective geometry. (F,SP)

135. Introduction to the Theory of Sets. (4) Three hours of lecture per week. *Prerequisites: 113 and 104.* Set-theoretical paradoxes and means of avoiding them. Sets, relations, functions, order and well-order. Proof by transfinite induction and definitions by transfinite recursion. Cardinal and ordinal numbers and their arithmetic. Construction of the real numbers. Axiom of choice and its consequences. (F,SP)

140. Metric Differential Geometry. (4) Three hours of lecture per week. *Prerequisites: 104 or 121B.* 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. (SP)

141. Elementary Differential Topology. (4) Three hours of lecture per week. *Prerequisites: 104 or equivalent and linear algebra.* Manifolds in n-dimensional Euclidean space and smooth maps, Sard's Theorem, classification of compact one-manifolds, transversality and intersection modulo 2.

142. Elementary Algebraic Topology. (4) Three hours of lecture per week. *Prerequisites: 104 and 113.* 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. (F)

160. History of Mathematics. (4) Three hours of lecture per week. *Prerequisites: 53, 54, and 113.* History of algebra, geometry, analytic geometry, and calculus from ancient times through the seventeenth century and selected topics from more recent mathematical history. (SP)

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topics as 54: basic linear algebra; matrix arithmetic and determinants. Vector spaces, inner product spaces. Eigenvalues and eigenvectors; linear transformations. Homogenous ordinary differential equations; first-order differential equations with constant coefficients. Fourier series and partial differential equations. No prior computer experience is necessary. (F,SP)

55. Discrete Mathematics. (4) Students will receive no credit for 55 after taking Computer Science 70. Three hours of lecture and two hours of discussion/workshop per week; at the discretion of the instructor, an additional hour of discussion/workshop or computer laboratory per week. *Prerequisites: Mathematical maturity appropriate to a sophomore math class. 1A-1B recommended.* Logic, mathematical induction sets, relations, and functions. Introduction to graphs, elementary number theory, combinatorics, algebraic structures, discrete probability, theory, and statistics. Emphasis on topics of interest to students in computer science. (F,SP)

74. Transition to Upper Division Mathematics. (3) Three hours of lecture per week. *Prerequisites: 53 and 54.* The course will focus on reading and understanding mathematical proofs. It will emphasize precise thinking and the presentation of mathematical results, both orally and in written form. The course is intended for students who are considering majoring in mathematics but wish additional training. (F,SP)

84. Sophomore Seminar. (1) One hour of seminar per week. Sections 1-2 to be graded on a *passed/not passed* basis. Sections 3-4 to be graded on a letter-grade basis. Sophomore seminars are designed for students considering a major in the sponsoring department. They are small, interactive courses in which students will encounter a topic typical of the discipline and become acquainted with the approaches and methods of scholars in that field. Sophomore seminar instructors will become faculty mentors for the students from the time they declare the major until the time they graduate. (F,SP)

H90. Honors Undergraduate Seminar in Mathematical Problem Solving. (1) Course may be repeated for credit. Two hours of seminar per week. *Prerequisites: Consent of instructor; undergraduate standing.* This seminar is designed especially, but not exclusively, to prepare students for the annual national Putnam Mathematical Competition in December. Students will develop problem solving skills and experience by attempting the solution of challenging mathematical problems that require insight more than knowledge. (F)

98. Supervised Group Study. (1-4) Must be taken on a *passed/not passed* basis. Directed Group Study, topics vary with instructor. (F,SP)

Upper Division Courses

C103. Introduction to Mathematical Economics. (3) Three hours of lecture per week. *Prerequisites: 53 and 54. Formerly 103.* Selected topics illustrating the application of mathematics to economic theory. This course is intended for upper-division students in Mathematics, Statistics, the Physical Sciences, and Engineering, and for economics majors with adequate mathematical preparation. No economic background is required. Also listed as Economics C103.

104. Introduction to Analysis. (4) Three hours of lecture per week. *Prerequisites: 53 and 54.* The real number system. Sequences, limits, and continuous functions in **R** and $\mathbf{R}^n$. The concept of a metric space. Uniform convergence, interchange of limit operations. Infinite series. Mean value theorem and applications. The Riemann integral. (F,SP)

H104. Introduction to Analysis. (4) Three hours of lecture per week. *Prerequisites: 53 and 54.* Honors section corresponding to 104. Recommended for students who enjoy mathematics and are good at it. Greater emphasis on theory and challenging problems.

105. Second Course in Analysis. (4) Three hours of lecture per week. *Prerequisites: 104.* Differential calculus in $\mathbf{R}^n$: the derivative as a linear map; the chain rule; inverse and implicit function theorems. Lebesgue integration on the line; comparison of Lebesgue and Riemann integrals. Convergence theorems. Fourier series, L^2 theory. Fubini's theorem, change of variable. (SP)

110. Linear Algebra. (4) No credit allowed after completion of Math 112 or 113B. Three hours of lecture per week and an additional two hours of discussion at the discretion of the instructor. *Prerequisites: 54 or a course with equivalent linear algebra content.* Matrices, vector spaces, linear transformations, inner products, determinants. Eigenvectors. QR factorization. Quadratic forms and Rayleigh's principle. Jordan canonical form, applications. Linear functionals. (F,SP) *Staff*

H110. Linear Algebra. (4) No credit allowed after completion of Math 112 or 113B. Three hours of lecture per week. *Prerequisites: 54 or a course with equivalent linear algebra content.* Honors section corresponding to course 110 for exceptional students with strong mathematical inclination and motivation. Emphasis is on rigor, depth, and hard problems. (SP)

113. Introduction to Abstract Algebra. (4) Three hours of lecture per week. *Prerequisites: 54 or a course with equivalent linear algebra content.* Sets and relations. The integers, congruences and the Fundamental Theorem of Arithmetic. Groups and their factor groups. Commutative rings, ideals and quotient fields. The theory of polynomials: Euclidean algorithm and unique factorizations. The Fundamental Theorem of Algebra. Fields and field extensions. (F,SP)

H113. Introduction to Abstract Algebra. (4) Three hours of lecture per week. *Prerequisites: 54 or a course with equivalent linear algebra content.* Honors section corresponding to 113. Recommended for students who enjoy mathematics and are good at it. Greater emphasis on theory and challenging problems. (F)

114. Second Course in Abstract Algebra. (4) Three hours of lecture per week. *Prerequisites: 113.* Further topics on groups, rings and fields not covered in Math 113. Possible topics include: the Sylow Theorems and their applications to group theory; classical groups; abelian groups and modules over a principal ideal domain; algebraic field extensions; splitting fields and Galois theory; construction and classification of finite fields. (SP)

115. Introduction to Number Theory. (4) Three hours of lecture per week. *Prerequisites: 53 and 54.* Divisibility, congruences, numerical functions, theory of primes. Topics selected: Diophantine analysis, continued fractions, partitions, quadratic fields, asymptotic distributions, additive problems. (F,SP)

118. Wavelets and Signal Processing. (4) Three hours of lecture per week. *Prerequisites: 53 and 54.* Introduction to signal processing including Fourier analysis and wavelets. Theory, algorithms, and applications to one-dimensional signals and multidimensional images. (F,SP)

119. Introduction to Applied Mathematics. (4) Three hours of lecture per week. *Prerequisites: 53 and 54.* A sample of ideas important in the mathematical sciences. Topics: duality in constrained optimization, structure of equilibrium equations (both discrete and continuous), initial value problems, conservation laws, uses of (fast) Fourier transform, calculus of variations, use of complex analysis, chaos. (F)

121A-121B. Mathematical Tools for the Physical Sciences. (4;4) Three hours of lecture per week. *Prerequisites: 53 and 54.* Functions of a complex variable, Fourier series, finite-dimensional linear systems. Infinite-dimensional linear systems, orthogonal expansions, special functions, partial differential equations arising in mathematical physics. Intended for students in the physical sciences who are not planning to take more advanced mathematics courses. (F,SP)

123. Ordinary Differential Equations. (4) Three hours of lecture per week. *Prerequisites: 104.* Existence and uniqueness of solutions, linear systems, regular singular points. Other topics selected from analytic systems, autonomous systems, Sturm-Liouville Theory. (F)

125A. Mathematical Logic. (4) Three hours of lecture per week. *Prerequisites: 113 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. (F,SP)

126. Introduction to Partial Differential Equations. (4) Three hours of lecture per week. *Prerequisites: 104.* 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, *a priori* bounds, the Fourier transform. (SP)

127. Mathematical and Computational Methods in Molecular Biology. (4) Three hours of lecture per week. *Prerequisites: 53, 54, and 55; Statistics 20 recommended.* Introduction to mathematical and computational problems arising in the context of molecular biology. Theory and applications of combinatorics, probability, statistics, geometry, and topology to problems ranging from sequence determination to structure analysis. (F,SP)

128A. Numerical Analysis. (4) Three hours of lecture and one hour of discussion per week. At the discretion of instructor, an additional hour of discussion/computer laboratory per week. *Prerequisites: 53 and 54.* Programming for numerical calculations, round-off error, approximation and interpolation, numerical quadrature, and solution of ordinary differential equations. Practice on the computer. (F,SP)

128B. Numerical Analysis. (4) Three hours of lecture and one hour of discussion per week. At the discretion of the instructor, an additional hour of discussion/computer laboratory per week. *Prerequisites: 110 and 128A.* Iterative solution of systems of nonlinear equations, evaluation of eigenvalues and eigenvectors of matrices, applications to simple partial differential equations. Practice on the computer. (F,SP)

130. The Classical Geometries. (4) Three hours of lecture per week. *Prerequisites: 110 and 113.* A critical examination of Euclid's Elements; ruler and compass constructions; connections with Galois theory; Hilbert's axioms for geometry, theory of areas, introduction of coordinates, non-Euclidean geometry, regular solids, projective geometry. (F,SP)

135. Introduction to the Theory of Sets. (4) Three hours of lecture per week. *Prerequisites: 113 and 104.* Set-theoretical paradoxes and means of avoiding them. Sets, relations, functions, order and well-order. Proof by transfinite induction and definitions by transfinite recursion. Cardinal and ordinal numbers and their arithmetic. Construction of the real numbers. Axiom of choice and its consequences. (F,SP)

140. Metric Differential Geometry. (4) Three hours of lecture per week. *Prerequisites: 104 or 121B.* 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. (SP)

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142. Elementary Algebraic Topology. (4) Three hours of lecture per week. *Prerequisites: 104 and 113.* 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. (F)

160. History of Mathematics. (4) Three hours of lecture per week. *Prerequisites: 53, 54, and 113.* History of algebra, geometry, analytic geometry, and calculus from ancient times through the seventeenth century and selected topics from more recent mathematical history. (SP)

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170. Linear Programming, Games, Models of Exchange. (4) Three hours of lecture per week. *Prerequisites: 53 and 54.* Topics include linear programming, matrix games, models of production and exchange. Treats properties of the models and methods for calculating their behavior.

172. Combinatorics. (4) Three hours of lecture per week. *Prerequisites: 55.* Basic combinatorial principles, graphs, partially ordered sets, generating functions, asymptotic methods, combinatorics of permutations and partitions, designs and codes. Additional topics at the discretion of the instructor. (F,SP) *Staff*

185. Introduction to Complex Analysis. (4) Three hours of lecture per week. *Prerequisites: 104.* 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. (F,SP)

H185. Introduction to Complex Analysis. (4) Three hours of lecture per week. *Prerequisites: 104.* Honors section corresponding to Math 185 for exceptional students with strong mathematical inclination and motivation. Emphasis is on rigor, depth, and hard problems. (SP)

187. Senior Level Analysis. (4) Three hours of lecture per week. *Prerequisites: 104, 113, and 185.* Course gives a comprehensive view of analysis. Emphasis is on the interrelations among topics taken from differential equations, harmonic analysis and group representation, elementary functional analysis and special functions.

189. Mathematical Methods in Classical and Quantum Mechanics. (4) Course may be repeated for credit. Three hours of lecture per week. *Prerequisites: 104, 110, 2 semesters lower division Physics.* Topics in mechanics presented from a mathematical viewpoint: e.g., hamiltonian mechanics and symplectic geometry, differential equations for fluids, spectral theory in quantum mechanics, probability theory and statistical mechanics. See department bulletins for specific topics each semester course is offered. (SP)

191. Experimental Courses in Mathematics. (1-4) Course may be repeated for credit. Hours to be arranged. *Prerequisites: Consent of instructor.* The topics to be covered and the method of instruction to be used will be announced at the beginning of each semester that such courses are offered. See departmental bulletins.

195. Special Topics in Mathematics. (4) Course may be repeated for credit. Hours to be arranged. *Prerequisites: Consent of instructor.* Lectures on special topics, which will be announced at the beginning of each semester that the course is offered.

196. Honors Thesis. (4) Course may be repeated for credit. Hours to be arranged. *Prerequisites: Admission to the Honors Program; an overall GPA of 3.3 and a GPA of 3.5 in the major.* Independent study of an advanced topic leading to an honors thesis. (F,SP)

198. Directed Group Study. (1-4) Group study. *Prerequisites: Must have completed 60 units and be in good standing.* Topics will vary with instructor. (F,SP) *Staff*

199. Supervised Independent Study and Research. (1-4) Hours to be arranged. Must be taken on a *passed/not passed* basis. *Prerequisites: The standard college regulations for all 199 courses.* (F,SP)

Graduate Courses

202A. Introduction to Topology and Analysis. (4) Three hours of lecture per week. *Prerequisites: 104.* Metric spaces and general topological spaces. Compactness and connectedness. Characterization of compact metric spaces. Theorems of Tychonoff, Urysohn, Tietze. Complete spaces and the Baire category theorem. Function spaces; Arzela-Ascoli and Stone-Weierstrass theorems. Partitions of unity. Locally compact spaces; one-point compactification. Introduction to measure and integration. Sigma algebras of sets. Measures and outer measures. Lebesgue measure on the line and Rn. Construction of the integral. Dominated convergence theorem. (F,SP)

202B. Introduction to Topology and Analysis. (4) Three hours of lecture per week. *Prerequisites: 202A and 110.* Measure and integration. Product measures and Fubini-type theorems. Signed measures; Hahn and Jordan decompositions. Radon-Nikodym theorem. Integration on the line and in R^n. Differentiation of the integral. Hausdorff measures. Fourier transform. Introduction to linear topological spaces, Banach spaces and Hilbert spaces. Banach-Steinhaus theorem; closed graph theorem. Hahn-Banach theorem. Duality; the dual of L^p. Measures on locally compact spaces; the dual of $C(X)$. Weak and weak-* topologies; Banach-Alaoglu theorem. Convexity and the Krein-Milman theorem. Additional topics chosen may include compact operators, spectral theory of compact operators, and applications to integral equations. (F,SP)

204A-204B. Ordinary and Partial Differential Equations. (4;4) Three hours of lecture per week. *Prerequisites: Graduate status or consent of instructor.* Fundamental existence theorem for ordinary differential 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. Sequence begins Fall.

205. Theory of Functions of a Complex Variable. (4) Three hours of lecture per week. *Prerequisites: 185.* Normal families. Riemann Mapping Theorem. Picard's theorem and related theorems. Multiple-valued analytic functions and Riemann surfaces. Further topics selected by the instructor may include: harmonic functions, elliptic and algebraic functions, boundary behavior of analytic functions and HP spaces, the Riemann zeta functions, prime number theorem.

206. Banach Algebras and Spectral Theory. (4) Three hours of lecture per week. *Prerequisites: 202A-202B.* Banach algebras. Spectrum of a Banach algebra element. Gelfand theory of commutative Banach algebras. Analytic functional calculus. Hilbert space operators. C^*-algebras of operators. Commutative C^*-algebras. Spectral theorem for bounded self-adjoint and normal operators (both forms: the spectral integral and the "multiplication operator" formulation). Riesz theory of compact operators. Hilbert-Schmidt operators. Fredholm operators. The Fredholm index. Selected additional topics. (F)

207. Unbounded Operators. (4) Three hours of lecture per week. *Prerequisites: 206.* Unbounded self-adjoint operators. Stone's Theorem, Friedrichs extensions. Examples and applications, including differential operators. Perturbation theory. Further topics may include: unbounded operators in quantum mechanics, Stone-Von Neumann Theorem. Operator semigroups and evolution equations, some non-linear operators. Weyl theory of defect indices for ordinary differential operators.

208. C^*-algebras. (4) Three hours of lecture per week. *Prerequisites: 206.* Basic theory of C^*-algebras. Positivity, spectrum, GNS construction. Group C^*-algebras and connection with group representations. Additional topics, for example, C^*-dynamical systems, K-theory.

209. Von Neumann Algebras. (4) Three hours of lecture per week. *Prerequisites: 206.* Basic theory of von Neumann algebras. Density theorems, topologies and normal maps, traces, comparison of projections, type classification, examples of factors. Additional topics, for example, Tomita Takasaki theory, subfactors, group actions, and noncommutative probability.

211. Mathematical Theory of Fluid Mechanics. (4) Three hours of lecture per week. Development of the fundamental equations describing the behavior of fluid continuum followed by the treatment of special topics selected to exhibit different physical situations, analytical techniques, and approximate methods of solutions.

212. Several Complex Variables. (4) Three hours of lecture per week. *Prerequisites: 185 and 202A-202B or their equivalents.* Power series developments, domains of holomorphy, Hartogs' phenomenon, pseudo convexity and plurisubharmonicity. The remainder of the course may treat either sheaf cohomology and Stein manifolds, or the theory of analytic subvarieties and spaces.

214. Differentiable Manifolds. (4) Three hours of lecture per week. *Prerequisites: 202A.* Smooth manifolds and maps, tangent and normal bundles. Sard's theorem and transversality, Whitney embedding theorem. Morse functions, differential forms, Stokes' theorem, Frobenius theorem. Basic degree theory. Flows, Lie derivative, Lie groups and algebras. Additional topics selected by instructor. (F,SP)

215A-215B. Algebraic Topology. (4;4) Three hours of lecture per week. *Prerequisites: 113 and point-set topology (e.g. 202A).* Fundamental group and covering spaces, simplicial and singular homology theory with applications, cohomology theory, duality theorem. Homotopy theory, fibrations, relations between homotopy and homology, obstruction theory, and topics from spectral sequences, cohomology operations, and characteristic classes. Sequence begins fall.

219. Ordinary Differential Equations and Flows. (4) Three hours of lecture per week. *Prerequisites: 214.* Ordinary differential equations. Diffeomorphisms and flows on manifolds. Stable manifolds, generic properties, structural stability. Special topics selected by the instructor. (F)

220. Methods of Applied Mathematics. (4) Three hours of lecture per week. Variational principles; optimization; control; dynamical systems; stochastic ordinary differential equations; estimation; data analysis. (F,SP)

221. Advanced Matrix Computations. (4) Three hours of lecture per week. *Prerequisites: Consent of instructor.* Direct solution of linear systems, including large sparse systems: error bounds, iteration methods, least square approximation, eigenvalues and eigenvectors of matrices, nonlinear equations, and minimization of functions. (F,SP)

222A-222B. Partial Differential Equations. (4;4) Three hours of lecture per week. *Prerequisites: 105 or 202B; 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. Sequence begins fall.

224A-224B. Mathematical Methods for the Physical Sciences. (4;4) Three hours of lecture per week. *Prerequisites: Graduate status or consent of instructor.* Introduction to the theory of distributions. Fourier and Laplace transforms. Partial differential equations. Green's function. Operator theory, with applications to eigenfunction expansions, perturbation theory and linear and non-linear waves. Sequence begins fall. (F,SP)

225A-225B. Metamathematics. (4;4) Three hours of lecture per week. *Prerequisites: 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. Sequence begins fall.

226A. Abstract Machines and Languages. (4) Three hours of lecture per week. *Prerequisites: 135; 114 or 113 and 110.* Finite state automata, regular sets, Turing machines, recursive functions, decision problems. Context-free languages, pushdown automata, ambiguity, special families of languages, power series in non-commuting variables.

227A-227B. Theory of Recursive Functions. (4;4) Three hours of lecture per week. *Prerequisites: 225B.* 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 begins fall.

228A-228B. Numerical Solution of Differential Equations. (4;4) Three hours of lecture per week. *Prerequisites: 128A.* Ordinary differential equations: Runge-Kutta and predictor-corrector methods; stability theory, Richardson extrapolation, stiff equations, boundary value problems. Partial differential equations: stability, accuracy and convergence, Von Neumann and CFL conditions, finite difference solutions of hyperbolic and parabolic equations. Finite differences and finite element solution of elliptic equations.

229. Theory of Models. (4) Three hours of lecture per week. *Prerequisites: 225B.* 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.

235A-235B. Theory of Sets. (4;4) Three hours of lecture per week. *Prerequisites: 125A and 135.* 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. Sequence begins fall.

236. Metamathematics of Set Theory. (4) Three hours of lecture per week. *Prerequisites: 225B 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.

240. Riemannian Geometry. (4) Three hours of lecture per week. *Prerequisites: 214.* Riemannian metric and Levi-Civita connection, geodesics and completeness, curvature, first and second variations of arc length. Additional topics such as the theorems of Myers, Synge, and Cartan-Hadamard, the second fundamental form, convexity and rigidity of hypersurfaces in Euclidean space, homogeneous manifolds, the Gauss-Bonnet theorem, and characteristic classes. (SP)

241. Complex Manifolds. (4) Three hours of lecture per week. *Prerequisites: 214 and 215A.* Riemann surfaces, divisors and line bundles on Riemann surfaces, sheaves and the Dolbeault theorem on Riemann surfaces, the classical Riemann-Roch theorem, theorem of Abel-Jacobi. Complex manifolds, Kahler metrics. Summary of Hodge theory, groups of line bundles, additional topics such as Kodaira's vanishing theorem, Lefschetz hyperplane theorem. (SP)

242. Symplectic Geometry. (4) Three hours of lecture per week. *Prerequisites: 214.* Basic topics: symplectic linear algebra, symplectic manifolds, Darboux theorem, cotangent bundles, variational problems and Lengendre transform, hamiltonian systems, lagrangian submanifolds, Poisson brackets, symmetry groups and momentum mappings, coadjoint orbits, Kahler manifolds. (F,SP)

245A-245B. General Theory of Algebraic Structures. (4;4) Three hours of lecture per week. *Prerequisites: 113 and 135.* Structures defined by operations and/or relations, and their homomorphisms. Classes of structures determined by identities. Constructions such as free objects, objects presented by generators and relations, ultraproducts, direct limits. Applications of general results to groups, rings, lattices, etc. Course may emphasize study of congruence-and subalgebra-lattices, or category-theory and adjoint functors, or other aspects.

249. Algebraic Combinatorics. (4) Three hours of lecture per week. *Prerequisites: 250A or consent of instructor.* (I) Enumeration, generating functions and exponential structures, (II) Posets and lattices, (III) Geometric combinatorics, (IV) Symmetric functions, Young tableaux, and connections with representation theory. Further study of applications of the core material and/or additional topics, chosen by instructor. (F,SP) *Staff*

250A. Groups, Rings, and Fields. (4) Three hours of lecture per week. *Prerequisites: 114 or consent of instructor.* Group theory, including the Jordan-Holder theorem and the Sylow theorems. Basic theory of rings and their ideals. Unique factorization domains and principal ideal domains. Modules. Chain conditions. Fields, including fundamental theorem of Galois theory, theory of finite fields, and transcendence degree. (F)

250B. Multilinear Algebra and Further Topics. (4) Three hours of lecture per week. *Prerequisites: 250A.* Tensor algebras and exterior algebras, with application to linear transformations. Commutative ideal theory, localization. Elementary specialization and valuation theory. Related topics in algebra. (SP)

251. Ring Theory. (4) Three hours of lecture per week. *Prerequisites: 250A.* Topics such as: Noetherian rings, rings with descending chain condition, theory of the radical, homological methods.

252. Representation Theory. (4) Three hours of lecture per week. *Prerequisites: 250A.* Structure of finite dimensional algebras, applications to representations of finite groups, the classical linear groups. (F)

253. Homological Algebra. (4) Three hours of lecture per week. *Prerequisites: 250A.* Modules over a ring, homomorphisms and tensor products of modules, functors and derived functors, homological dimension of rings and modules.

254A-254B. Number Theory. (4;4) Three hours of lecture per week. *Prerequisites: 250A.* Valuations, units, and ideals in number fields, ramification theory, quadratic and cyclotomic fields, topics from class field theory, zeta-functions and L-series, distribution of primes, modular forms, quadratic forms, diophantine equations, P-adic analysis, and transcendental numbers. Sequence begins fall.

255. Algebraic Curves. (4) Three hours of lecture per week. *Prerequisites: 250A-250B or consent of instructor.* Elliptic curves. Algebraic curves, Riemann surfaces, and function fields. Singularities. Riemann-Roch theorem, Hurwitz's theorem, projective embeddings and the canonical curve. Zeta functions of curves over finite fields. Additional topics such as Jacobians or the Riemann hypothesis. (F,SP)

256A-256B. Algebraic Geometry. (4;4) Three hours of lecture per week. *Prerequisites: 250A.* Affine and projective algebraic varieties. Theory of schemes and morphisms of schemes. Smoothness and differentials in algebraic geometry. Coherent sheaves and their cohomology. Riemann-Roch theorem and selected applications. Sequence begins fall.

257. Group Theory. (4) Three hours of lecture per week. *Prerequisites: 250A.* Topics such as: generators and relations, infinite discrete groups, groups of Lie type, permutation groups, character theory, solvable groups, simple groups, transfer and cohomological methods.

258. Classical Harmonic Analysis. (4) Three hours of lecture per week. *Prerequisites: 206 or a basic knowledge of real, complex, and linear analysis.* Basic properties of Fourier series, convergence and summability, conjugate functions, Hardy spaces, boundary behavior of analytic and harmonic functions. Additional topics at the discretion of the instructor.

260. Abstract Harmonic Analysis. (4) Three hours of lecture per week. *Prerequisites: 206.* Topological groups, Haar measure, Pontryagin duality, and structure theory of locally compact abelian groups, Peter-Weyl theorem for compact groups. Further topics may include finer study of harmonic analysis on commutative groups, or else head in the direction of group representations for noncommutative locally compact groups.

261A-261B. Lie Groups. (4;4) Three hours of lecture per week. *Prerequisites: 214.* Lie groups and Lie algebras, fundamental theorems of Lie, general structure theory; compact, nilpotent, solvable, semi-simple Lie groups; classification theory and representation theory of semi-simple Lie algebras and Lie groups, further topics such as symmetric spaces, Lie transformation groups, etc., if time permits. In view of its simplicity and its wide range of applications, it is preferable to cover compact Lie groups and their representations in 261A. Sequence begins Fall.

265. Differential Topology. (4) Three hours of lecture per week. *Prerequisites: 214 plus 215A or some familiarity with algebraic topology.* Approximations, degrees of maps, vector bundles, tubular neighborhoods. Introduction to Morse theory, handlebodies, cobordism, surgery. Additional topics selected by instructor from: characteristic classes, classification of manifolds, immersions, embeddings, singularities of maps.

271. Topics in Foundations. (4) Course may be repeated for credit. Three hours of lecture per week. *Prerequisites: Consent of instructor.* Advanced topics chosen by the instructor. The content of this course changes, as in the case of seminars.

273. Topics in Numerical Analysis. Three hours of lecture per week. *Prerequisites: Consent of instructor.* Advanced topics chosen by the instructor. The content of this course changes, as in the case of seminars. (F,SP)

274. Topics in Algebra. (4) Course may be repeated for credit. Three hours of lecture per week. *Prerequisites: Consent of instructor.* Advanced topics chosen by the instructor. The content of this course changes, as in the case of seminars.

275. Topics in Applied Mathematics. (4) Course may be repeated for credit. Three hours of lecture per week. *Prerequisites: Consent of instructor.* Advanced topics chosen by the instructor. The content of this course changes, as in the case of seminars.

276. Topics in Topology. (4) Course may be repeated for credit. Three hours of lecture per week. *Prerequisites: Consent of instructor.* Advanced topics chosen by the instructor. The content of this course changes, as in the case of seminars.

277. Topics in Differential Geometry. (4) Course may be repeated for credit. Three hours of lecture per week. *Prerequisites: Consent of instructor.* Advanced topics chosen by the instructor. The content of this course changes, as in the case of seminars.

278. Topics in Analysis. (4) Course may be repeated for credit. Three hours of lecture per week. *Prerequisites: Consent of instructor.* Advanced topics chosen by the instructor. The content of this course changes, as in the case of seminars.

279. Topics in Partial Differential Equations. (4) Course may be repeated for credit. Three hours of lecture per week. *Prerequisites: Consent of instructor.* Advanced topics chosen by the instructor. The content of this course changes, as in the case of seminars.

290. Seminars. (1-6) Course may be repeated for credit. Hours to be arranged. 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. (F,SP)

295. Individual Research. (1-12) Course may be repeated for credit. Hours to be arranged. Sections 1-30 to be graded on a letter-grade basis. Sections 31-60 to be graded on a *satisfactory/unsatisfactory* basis. Intended for candidates for the Ph.D. degree. (F,SP)

299. Reading Course for Graduate Students. (1-6) Course may be repeated for credit. Hours to be arranged. Sections 1-30 to be graded on a letter-grade basis. Sections 31-60 to be graded on a *satisfactory/unsatisfactory* basis. Investigation of special problems under the direction of members of the department. (F,SP)

600. Individual Study for Master's Students. (1-6) Course may be repeated for credit. Course does not satisfy unit or residence requirements for master's degree. Hours to be arranged. Must be taken on a *satisfactory/unsatisfactory* basis. *Prerequisites: For candidates for master's degree.* Individual study for the comprehensive or language requirements in consultation with the field adviser. (F,SP)

B prefix=language course for business majors
C prefix=cross-listed course
H prefix=honors course

R prefix=course satisfies R&C requirement
AC suffix=course satisfies American cultures requirement

*Professor of the Graduate School
†Recipient of Distinguished Teaching Award

Berkeley 2003–2005

Professional Courses

300. Teaching Workshop. (3) Two hours of lecture per week, plus class visits. Must be taken on a *satisfactory/unsatisfactory* basis. Mandatory for all graduate student instructors teaching for the first time in the department. The course consists of practice teaching, alternatives to standard classroom methods, guided group and self-analysis of videotapes, reciprocal classroom visitations, and an individual project. (F,SP)

301. Undergraduate Mathematics Instruction. (1-2) Course may be repeated once for credit. Three hours of seminar and four hours of tutorial per week. Must be taken on a *passed/not passed* basis. *Prerequisites: Permission of SLC instructor, as well as sophomore standing and at least a B average in two semesters of calculus. Apply at Student Learning Center.* May be taken for one unit by special permission of instructor. Tutoring at the Student Learning Center or for the Professional Development Program. (F,SP)

Mechanical Engineering

(College of Engineering)

Department Office: 6195 Etcheverry Hall, (510) 642-1338
www.me.berkeley.edu/
Chair: J. Karl Hedrick, Ph.D.

Professors

Alice M. Agogino *(Roscoe and Elizabeth Hughes Chair in Mechanical Engineering)*, Ph.D. Stanford University. Decision and expert systems
David M. Auslander *(Associate Dean, Research and Student Affairs)*, Sc.D. Massachusetts Institute of Technology. Dynamic systems, automatic controls
†Stanley A. Berger, Ph.D. Brown University. Fluid mechanics
David B. Bogy *(William S. Floyd, Jr., Distinguished Professor in Engineering)*, Ph.D. Brown University. Elasticity, plasticity, computer mechanics
Van P. Carey, Ph.D. State University of New York-Buffalo. Transport in multiphase systems, thermophysics of phase-change processes
James Casey, Ph.D. University of California, Berkeley. Continuum mechanics
Jun-Yuan Chen, Ph.D. Cornell University. Turbine combustion, chemical kinetics, numerical simulation
Hari Dharan, Ph.D. University of California, Berkeley. Composite materials
Robert W. Dibble, Ph.D. University of Wisconsin. Combustion, gas dynamics
David A. Dornfeld *(Associate Dean, Interdisciplinary Studies)*, Ph.D. University of Wisconsin. Manufacturing processes, robotics
Carlos Fernandez-Pello, Ph.D. University of California at San Diego. Combustion, heavy and condensed fuels
Michael Y. Frenklach, Ph.D. Hebrew University. Chemical kinetics, combustion chemistry, chemical vapor deposition
*Werner Goldsmith, Ph.D.
Ralph Greif, Ph.D. Harvard University. Thermal radiation, phase change
Costas Grigoropoulos, Ph.D. Columbia University. Heat transfer, laser materials processing
J. Karl Hedrick *(Chair and James Marshall Wells Chair in Mechanical Engineering)*, Ph.D. Stanford University. Control systems, transportation systems
Roberto Horowitz *(Vice Chair, Graduate Study)*, Ph.D. University of California, Berkeley. Automatic control systems design, robotics
Roger T. Howe, Ph.D. University of California, Berkeley. Microsensors and microactuators
George C. Johnson, Ph.D. Stanford University. Ultrasonic stress evaluation
Homayoon Kazerooni, D.Sc. Massachusetts Institute of Technology. Mechatronics, robotics
Tony Keaveny, Ph.D. Cornell University. Tissue engineering and biomechanics
Kyriakos Komvopoulos, Ph.D. Massachusetts Institute of Technology. Tribology, contact mechanics, mechanical behavior of materials
*George Leitmann, Ph.D.
†Dennis K. Lieu, D. Eng. University of California, Berkeley. High-speed electromechanic devices
Fai Ma, Ph.D. California Institute of Technology. Vibration and control
Arun Majumdar, Ph.D. University of California, Berkeley. Nanoscale thermal and biomolecular engineering, micromechanical systems
Alaa Mansour, Ph.D. University of California, Berkeley. Structural reliability and safety, probabilistic dynamics of marine structures, strength of ship and offshore structures, development of design criteria
Philip Marcus, Ph.D. Princeton University. Computational fluid dynamics
*Antoni K. Oppenheim, Ph.D, D.Sc.
Andrew Packard, Ph.D. University of California, Berkeley. Automatic control systems, mechanical systems
Patrick J. Pagni, Ph.D. Massachusetts Institute of Technology. Combustion phenomena, fire research
Albert P. Pisano *(Director, Electronics Research Laboratory)*, Ph.D. Columbia University. Computer-aided design, design optimization
†Kameshwar Poolla, Ph.D. University of Florida at Gainesville. Dynamic systems, automatic controls
Lisa A. Pruitt, Ph.D. Brown University. Tissue biomechanics, biomaterial science
Boris Rubinsky *(Arnold and Barbara Silverman Distinguished Professor in Bioengineering)*, Ph.D. Massachusetts Institute of Technology. Heat, mass transfer, cryopreservation
Omer Savas, Ph.D. California Institute of Technology. Aerodynamics, boundary layers, combustion, rotating flows, turbulence
*Robert F. Sawyer *(Class of '35 Professor of Energy)*, Ph.D. Princeton University. Combustion, fossil and synthetic fuels
Masayoshi Tomizuka *(Director, Engineering Systems Research Center and Cheryl and John Neerhout, Jr., Distinguished Professor)*, Ph.D. Massachusetts Institute of Technology. Automatic control systems, robotics and manufacturing systems
Benson Tongue, Ph.D. Princeton University. Chaotic oscillations in dynamic systems
Kent S. Udell *(Vice Chair, Undergraduate Program)*, Ph.D. University of Utah. Heat transfer, environmental remediation, engineering ethics
Paul K. Wright *(Associate Dean, Distance Learning and Instructional Technology, Co-Director, Management of Technology Program and A. Martin Berlin Professor of Mechanical Engineering)*, Ph.D. University of Birmingham. Manufacturing processes, automation
Ronald W. Yeung, Ph.D. University of California, Berkeley. Hydromechanics, numerical modeling, surface waves, ocean space systems
Cyril P. Atkinson, M.S.M.E. *(Emeritus)*
Gilles M. Corcos, Ph.D. *(Emeritus)*
Don M. Cunningham, M.S. *(Emeritus)*
Iain Finnie, D.Sc., Sc.D. *(The Fife Professor Emeritus)*
Joseph Frisch, M.S. *(Emeritus)*
Frank E. Hauser, Ph.D. *(Emeritus)*
Maurice Holt, Ph.D. *(Emeritus)*
Chieh S. Hsu, Ph.D. *(Emeritus)*
Franklin C. Hurlbut, Ph.D. *(Emeritus)*
George J. Maslach, B.S. *(Emeritus)*
†Clayton D. Mote, Jr., Ph.D. *(FANUC Professor of Mechanical Systems Emeritus)*
Charles W. Radcliffe, M.S., M.E. *(Emeritus)*
Samuel A. Schaaf, Ph.D. *(Emeritus)*
Frederick S. Sherman, Ph.D. *(Emeritus)*
Lawrence Talbot, Ph.D. *(Emeritus)*
Erich G. Thomsen, Ph.D. *(Emeritus)*
George J. Trezek, Ph.D. *(Emeritus)*

Associate Professors

Dorian Liepmann, Ph.D. University of California, San Diego. Classical fluid dynamics, bio-fluid mechanics
Liwei Lin, Ph.D. University of California, Berkeley. NSF-Career MEMS *(microelectromechanical systems)*
Stephen Morris, Ph.D. Johns Hopkins University. Geophysical fluid dynamics
†Oliver M. O'Reilly, Ph.D. Cornell University. Nonlinear dynamics with applications to continuum mechanics
Panayiotis Papadopoulos, Ph.D. University of California, Berkeley. Computational mechanics, solid mechanics
David J. Steigmann, Ph.D. Brown University. Continuum mechanics, solid mechanics, shell theory, electrodynamics
Andrew J. Szeri, Ph.D. Cornell University. Fluid dynamics and nonlinear dynamics

Assistant Professors

Sara McMains, Ph.D. University of California, Berkeley. Computer graphics and geometric modeling
Tarek I. Zohdi, Habilitation Degree, University of Hanover, Germany. Ph.D. University of Texas, Austin. Computational solid mechanics

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Professor

Michael Ries, M.D. *(in residence)*
Kurt S. Spiegler, Ph.D. *(In Residence) (Emeritus)*
Lawrence Stark, M.D. *(Emeritus)*

Associate Professor

David M. Rempel, M.D., M.P.H. *(In Residence)*

Adjunct Professor

Klaus Weinmann, Ph.D.

Overview

Mechanical Engineering includes the science and art of the formulation, design, development, and control of systems and components involving thermodynamics, mechanics, fluid mechanics, mechanisms, and the conversion of energy into useful work. The mechanical engineer needs a thorough preparation in mathematics, physics, chemistry, manufacturing processes, properties of materials, mechanics, fluid mechanics, thermodynamics, as well as intensive design and laboratory experience. The program of study includes basic subjects common to all engineering fields, fundamental subjects important to all mechanical engineers and specialization in one or more phases of mechanical engineering.

The undergraduate program begins at the freshman level with study in the humanities, mathematics, basic sciences, and the foundation design course, Engineering 28. In subsequent years students learn to use engineering science concepts as tools for systems analysis and design. The design and laboratory experience is a major component of the senior year. Students have the opportunity to develop a broad hands-on understanding of the design process involved in significant engineering systems. Undergraduate specialization is provided in the choice of technical electives which may be selected from the subject areas of applied mechanics, automatic controls, electro-mechanical systems analysis, energy conversion, fluid mechanics, heat and mass transfer, materials processing, mechanical design, naval architecture, nuclear engineering, cryogenics, thermodynamics, and biomedical, environmental, and petroleum engineering.

Because of the widening range of technical problems and the limited amount of specialization available in the undergraduate curriculum, qualified students should consider graduate study to enlarge their scientific and technological capability. Further details on undergraduate and graduate fields of emphasis in mechanical engineering are available in the *Announcement of the College of Engineering*. The department also makes available a brochure detailing the undergraduate and graduate programs in mechanical engineering.

The B.S. program is accredited in mechanical engineering by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012. Telephone: (410) 347-7700.

Curriculum for the Bachelor's Degree

A total of 120 units is required, including:

Lower Division. Mathematics 1A-1B, 53 and 54; Chemistry 1A; Physics 7A-7B-7C (Chemistry 1B or Biology 1A may be taken for Physics 7C); Engineering 77, 28, 36, 45.

Upper Division. Mechanical Engineering 102B, 104, 105 or 105B, 106, 107A-107B, 109, C124; Engineering 190; Electrical Engineering and Computer Sciences 100; Civil Engineering 130.

Note: All students must complete (a) six courses (five for double major students) of at least 3 units each in humanities and social studies selected from an approved list of courses (please see the "Humanities and Social Studies" section of the *Announcement of the College of Engineering*); (b) 12 units technical electives, at least 9 in upper division elective mechanical engineering courses. Of these, 3 units must be in an elective course selected from the following list: ME 101, 110, 119, 128, 130, 135, 142, 145, 161, 165. The other technical elective units can be chosen from courses in engineering, physical sciences, mathematics, or statistics. No more than one lower division course can be used to satisfy part of the technical elective requirement. Lower division courses acceptable for technical elective credit in mechanical engineering: Astronomy 7; Biology 1A-1B; Chemistry 1B, 5; Engineering 50, 66; Civil Engineering 70; Molecular and Cell Biology 11, 32; Statistics 20, 25, or any lower division course required by another engineering major.

Mechanical Engineering Options. The following groups of electives are presented to help undergraduates focus their choices on specific professional goals. Each group contains more courses than can be taken within the standard allowance. The electives need not be from any single group.