Minor Program Requirements:

Before declaring a minor in Managerial Economics, a student must complete the following courses with a combined grade point average (GPA) of at least 2.800. All of these courses must be taken for a letter grade. In determining admission to minor status, the Department of Agricultural and Resource Economics counts only the first repeat of any pre-minor course.

Economics 1A and 1B ..... 8 units
Mathematics 16A-16B or 21A-21B ..... 6-8 units
Statistics 13 ..... 4 units

The Department of Agricultural and Resource Economics offers four minor emphases open to students majoring in other disciplines who wish to complement their study programs with a minor in Managerial Economics. Each emphasis requires Agricultural and Resource Economics 100A, which has prerequisites of Economics 1A-1B and Mathematics 16A-16B. For some courses, Statistics 13 and 103 may be required. Variable-unit courses and lower division courses are not accepted for any emphasis.

	UNITS
Managerial Economics	**18**
General emphasis	
Agricultural and Resource Economics 100A or the equivalent	4
Additional upper division courses in Agricultural and Resource Economics	14
Agricultural Economics emphasis	
Agricultural and Resource Economics 100A or the equivalent	4
Additional upper division courses in Agricultural and Resource Economics	14
Select 9 or more units from Agricultural and Resource Economics 120, 130, 132, 138, 139, 140, 145, 150.	
Select additional upper division Agricultural and Resource Economics courses to complete the 18-unit total for the minor.	
Environmental and Natural Resource Economics emphasis	
Agricultural and Resource Economics 100A or the equivalent	4
Additional upper division courses in Agricultural and Resource Economics	14
Select 9 or more units from Agricultural and Resource Economics 175 and 176, and either 100B or 120.	
Select additional upper division Agricultural and Resource Economics courses to complete the 18-unit total for the minor.	
Managerial Economics emphasis	
Agricultural and Resource Economics 100A or the equivalent	4
Additional upper division courses in Agricultural and Resource Economics	14
Select 9 or more units from Agricultural and Resource Economics 112, 118, 136, 157, 171A, 171B.	
Select additional upper division Agricultural and Resource Economics courses to complete the 18-unit total for the minor.	

Graduate Study. See Graduate Studies, on page 104.

Master of Education (M.Ed.) (A Graduate Group)

The Master of Education (M.Ed.) program is no longer admitting students; admissions are suspended.

Maternal and Child Nutrition (Department of Nutrition)

Charles E. Hess, Ph.D., Chairperson of the Department

Department Office. 3135 Meyer Hall
(530) 752-4630;
http://extension.ucdavis.edu/unit/agriculture_and_food_science/master/maternal_and_child_nutrition/

Faculty

Faculty members are listed on the Web site.

Graduate Study. The Nutrition Department offers the degree of M.A.S. in Maternal and Child Nutrition. This program consists of three required six-unit core courses (Nutrition During Pregnancy, Lactation and Infant Nutrition, and Child and Adolescent Nutrition), six to eight units of special topics seminars, two units of electives, and a six-unit student project (produced in consultation with a three-member guidance committee) for a total of 36 units. Each of the core courses will comprise 10 weeks of in-class instruction twice per week for two-and-a-half hours per meeting. Classes will also include online discussion of related material and readings.

Each student will be assigned a three-member guidance committee consisting of two members of the teaching faculty and an additional qualified faculty member to advise the student in choosing an elective and identifying a student project.

Preparation. Admission to the program requires a bachelor's degree with prior course work that includes (or is comparable to): one year of general chemistry, two quarters of organic chemistry, a course in statistics, one course in general physiology, and two quarters of the biochemistry of nutrition.

Graduate Advisors. Kathryn G. Dewey, Ph.D., Professor *(Nutrition)*, Jane Heinig, Ph.D., Academic Administrator *(Nutrition)*

Courses in Maternal and Child Nutrition. See courses under Nutrition, on page 427.

Mathematical and Physical Sciences

(College of Letters and Science)

Louise H. Kellogg, Ph.D., Program Director

Program Office. 1201 Social Sciences and Humanities Building

Committee in Charge

Andreas J. Albrecht, Ph.D. *(Physics)*
R. David Britt, Ph.D. *(Chemistry)*
Shirley Chiang, Ph.D. *(Physics)*
Louise H. Kellogg, Ph.D. *(Geology)*
Mark J. Kurth, Ph.D. *(Chemistry)*
Isabel P. Montañez, Ph.D. *(Geology)*
Motohico Mulase, Ph.D. *(Mathematics)*
Bruno L. Nachtergaele, Ph.D. *(Mathematics)*
Wolfgang Polonik, Ph.D. *(Statistics)*
Francisco J. Samaniego, Ph.D. *(Statistics)*
Abigail Thompson, Ph.D. *(Mathematics)*

The Program of Study

The Division of Mathematical and Physical Sciences teaches students to use experimental studies and theoretical analyses to find solutions to real world problems. Students learn to address issues such as cleaning up the environment, preserving natural resources and creating innovative materials for the future. From the study of atoms to the examination of distant galaxies, from abstract number theory to the development of new chemical compounds, the division provides students with the skills to build the world of tomorrow.

The program in Mathematical and Physical Sciences provides an organizational structure within the College of Letters and Science for facilitating the development of innovative curricular initiatives across the mathematical and physical sciences, including offering broadly conceived, integrative undergraduate- and graduate-level courses. The program also may house resident faculty pursuing interdepartmental research and teaching in this area of inquiry.

Courses in Mathematical and Physical Sciences (MPS)

Lower Division Courses

1. General Science: Science in the News (4)
Lecture—3 hours; laboratory/discussion—1 hour. Prerequisite: lower division standing. Basic principles in science including numeracy, scale, energy, and time; the scientific method; good and bad science. Emphasis on science topics recently in the news. GE credit: SciEng.—III.

11A-11B. Mathematical and Physical Sciences Seminar (2–2)
Lecture—2 hours. Prerequisite: mentorship for undergraduate research participants in the physical and mathematical sciences. Research and writing in the mathematical and physical sciences. Presentations by various science faculty members.—I-II. (I-II.)

Mathematics

See Mathematics; and Applied Mathematics (A Graduate Group), on page 153.

Mathematics

(College of Letters and Science)

Bruno Nachtergaele, Ph.D., Chairperson

Department Office. 1130 Mathematical Sciences Bldg.
(530) 752-0827;
studentservices@math.ucdavis.edu;
http://www.math.ucdavis.edu

Faculty

Eric Babson, Ph.D. Professor
Zhaojun Bai, Ph.D., Professor *(Computer Science)*
Craig Benham, Ph.D., Professor
Joseph Biello, Ph.D., Associate Professor
James Bremer, Ph.D., Assistant Professor
Angela Y. Cheer, Ph.D., Professor
Jesus De Loera, Ph.D., Professor
C. Albert Fannjiang, Ph.D., Professor
Roland Freund, Ph.D., Professor
Dmitry B. Fuchs, Ph.D., Professor
Janko Gravner, Ph.D., Professor
Robert Guy, Ph.D., Assistant Professor
Joel Hass, Ph.D., Professor
John K. Hunter, Ph.D., Professor
Michael Kapovich, Ph.D., Professor
Gregory J. Kuperberg, Ph.D., Professor
Timothy Lewis, Ph.D., Associate Professor
Fu Liu, Ph.D., Assistant Professor
E. O. Milton, Ph.D., Professor
Academic Senate Distinguished Teaching Award
Alexander I. Mogilner, Ph.D., Professor
Ben Morris, Ph.D., Associate Professor
Motohico Mulase, Ph.D., Professor
Bruno L. Nachtergaele, Ph.D., Professor
Brian Osserman, Ph.D., Assistant Professor
E. Gerry Puckett, Ph.D., Professor
Naoki Saito, Ph.D., Professor
Anne Schilling, Ph.D., Professor
Jennifer Schultens, Ph.D., Professor

Albert Schwarz, Ph.D., Professor
Steve Shkoller, Ph.D., Professor
Alexander Soshnikov, Ph.D., Professor
Thomas Strohmer, Ph.D., Professor
J. Blake Temple, Ph.D., Professor
Becca Thomases, Ph.D., Assistant Professor
Abigail Thompson, Ph.D., Professor
Craig A. Tracy, Ph.D., Professor
Monica Vazirani, Ph.D., Associate Professor
Roman Vershynin, Ph.D., Professor
Andrew Waldron, Ph.D., Professor
Qinglan Xia, Ph.D., Assistant Professor
Hong Xiao, Ph.D., Assistant Professor

Emeriti Faculty

David Barnette, Ph.D., Professor Emeritus
Donald C. Benson, Ph.D., Professor Emeritus
Carlos R. Borges, Ph.D., Professor Emeritus
Robert J. Buck, Professor Emeritus
Gulbank D. Chakerian, Ph.D., Professor Emeritus, *Academic Senate Distinguished Teaching Award*
Doyle O. Cutler, Ph.D., Professor Emeritus
James R. Diederich, Ph.D., Professor Emeritus
Allan L. Edelson, Ph.D., Professor Emeritus
Robert D. Glauz, Ph.D., Professor Emeritus
Shirley A. Goldman, M.S., Lecturer Emerita
Charles A. Hayes, Jr., Ph.D., Professor Emeritus
Kurt Kreith, Ph.D., Professor Emeritus
Arthur J. Krener, Ph.D., Professor
Melven R. Krom, Ph.D., Professor Emeritus
Gary J. Kurowski, Ph.D., Professor Emeritus
David G. Mead, Ph.D., Professor Emeritus *Academic Senate Distinguished Teaching Award*
Donald A. Norton, Ph.D., Professor Emeritus
Washek F. Pfeffer, Ph.D., Professor Emeritus
G. Thomas Sallee, Ph.D., Professor *Academic Senate Distinguished Teaching Award*
Sherman K. Stein, Litt.D. (hon.), Ph.D., Professor Emeritus, *Academic Senate Distinguished Teaching Award*
Robert W. Stringall, Ph.D., Professor Emeritus
Takayuki Tamura, D.Sc., Professor Emeritus
Howard J. Weiner, Ph.D., Professor Emeritus
Roger Wets, Ph.D. Professor Emeritus

Affiliated Faculty

John Chuchel, Ph.D., Lecturer
Ali Dad-del, Ph.D., Lecturer
Duane Kouba, Ph.D., Lecturer
Lawrence Marx, Ph.D., Lecturer

The Major Programs

Mathematics is the study of abstract structures, space, change, and the interrelations of these concepts. It also is the language of the exact sciences.

The Program. Students majoring in mathematics may follow a program leading to either the Bachelor of Arts or the Bachelor of Science degree. After completing basic introductory courses such as calculus and linear algebra, students plan an upper division program in consultation with a faculty adviser. The upper division course offering is grouped into entry level, core, and enrichment courses. Entry level courses are designed to serve as a bridge between the concrete mathematics of the lower division and the more abstract concepts taught in upper division courses. The core classes are intended to provide basic mathematical techniques, whereas the enrichment choices allow students to further mathematical knowledge and skills that feature their research or career interests. This individualized program can lead to graduate study in pure or applied mathematics, elementary or secondary level teaching, or to other professional goals. It can also reflect a special interest such as computational and applied mathematics, computer science, or statistics, or may be combined with a major in some other field.

Career Alternatives. A degree in mathematics provides entry to many careers in addition to teaching. For instance, operations research, systems analysis, computing, actuarial work, insurance, and financial services are only a few such careers. Mathematics is also a sound basis for graduate work in a variety of fields, such as law, engineering, and economics.

A.B. Major Requirements:

UNITS

Preparatory Subject Matter 43-46
- Mathematics 12 (or high school equivalent) 0-3
- Mathematics 21A, 21B, 21C, 21D, 22B 19
- Mathematics 25, 67 8
- Computer Science Engineering 30 or Engineering 6 4
- Additional non-Mathematics courses chosen from natural sciences 12

Depth Subject Matter 34-38
- *A. Entry Level (Optional)* 0-4
  (Suggested choices: one course from Mathematics 108, 114, 115A, 141, 145)
- *B. Core* 16
  - Mathematics 125AB 8
  - Mathematics 135A 4
  - Mathematics 150A 4
- *C. Choose one Plan from the following two: (up to 4 of these 18 units may be approved upper division courses outside of the Department of Mathematics with extensive use of mathematics)* 18

Plan 1: General Mathematics

Additional upper division mathematics units selected in consultation with and subject to approval of an adviser 18

Plan 2: Secondary Teaching
- Mathematics 111 4
- Mathematics 115A 4
- Mathematics 141 4
- Additional upper division mathematics units selected in consultation with and subject to approval of an adviser 6

Note: Students who wish to satisfy the single subject matter waiver for the teaching credential should see an adviser as early as possible.

Total Units for the Major 77-84

Applied Mathematics

B.S. Major Requirements:

UNITS

Preparatory Subject Matter 42-48
- Mathematics 12 (or high school equivalent) 0-3
- Mathematics 21A, 21B, 21C, 21D, 22B 19
- Mathematics 25, 67 8
- Computer Science Engineering 30, 40 8
- One two-quarter sequence from Physics 9A-9B; Biological Sciences 1A-1B; Chemistry 2A-2B; Economics 1A-1B; Statistics 32, 102; or other applied preparatory courses approved by your adviser 7-10

Depth Subject Matter 48-52
- *A. Entry Level (Optional)* 0-4
  (Suggested choices: one course from Mathematics 108, 114, 115A, 141, 145)
- *B. Core* 32
  - Mathematics 150A 4
  - Mathematics 135A 4
  - Mathematics 125AB 8
  - Mathematics 119A 4
  - Mathematics 128AB 8
  - Mathematics 185A 4
- *C. Enrichment Courses* 16
  1. Choice of two courses from Mathematics 118ABC, 119B, 124, 128C, 129, 133, 167, 168 8
  2. Choice of one course from Mathematics 111, 114, 115A, 116, 135B, 141, 145, 146, 147, 148, 150B, 165, 185B 4
  3. One approved upper division course outside the Department of Mathematics with extensive use of mathematics 4

Total Units for the Major 90-100

Mathematics

B.S. Major Requirements:

UNITS

Preparatory Subject Matter 34-38
- Mathematics 12 (or high school equivalent) 0-3
- Mathematics 21A, 21B, 21C, 21D, 22B 19
- Mathematics 25, 67 8
- Computer Science Engineering 30 or Engineering 6 4
- Physics 9A (Plans 1 and 2) or one course from Physics 7A, Statistics 13, 32, 100 or 102 (Plan 2) 3-4

Depth Subject Matter 48-52

Choose one plan from the following two:

Plan 1: General Mathematics
- *A. Entry Level (Optional)* 0-4
  (Suggested choices: one course from Mathematics 108, 114, 115A, 141, 145)
- *B. Core* 28
  - Mathematics 150ABC 12
  - Mathematics 135A 4
  - Mathematics 125AB 8
  - Mathematics 185A 4
- *C. Enrichment* 20
  1. Choice of four courses from Mathematics 111, 114, 115AB, 116, 135B, 141, 145, 146, 147, 148, 165, 185B 16
  2. Choice of one course from Mathematics 119A, 124, 128A, 128B, 129, 133, 167, 168 or one approved upper division course outside the Department of Mathematics with extensive use of mathematics 4

Plan 2: Mathematics for Secondary Teaching
- *A. Entry Level (Optional)* 0-4
  (Suggested choices: one course from Mathematics 108, 114, 145)
- *B. Core* 28
  - Mathematics 150A 4
  - Mathematics 135A 4
  - Mathematics 125AB 8
  - Mathematics 111 4
  - Mathematics 115A 4
  - Mathematics 141 4
- *C. Enrichment* 20
  1. Choice of four courses from Mathematics 114, 116, 118A, 119AB, 128A, 129, 133, 135B, 145, 147, 148, 165, 167, 168, 185AB. Up to four units can be approved upper division units outside the Department of Mathematics with extensive use of mathematics 16
  2. Choice of one course from Mathematics 115B, 146, 150B 4

Total Units for the Major 82-90

Mathematical and Scientific Computation

B.S. Major Requirements:

UNITS

Preparatory Subject Matter 35-38
- Mathematics 12 (or high school equivalent) 0-3
- Mathematics 21ABC or Mathematics 17ABC, 21D, 22B 19
- Mathematics 25, 67 8
- Computer Science Engineering 30, 40 8

Depth Subject Matter 48-52
- *A. Entry Level (Optional)* 0-4
  (Suggested choices: one course from Mathematics 108, 114, 115A, 141, 145)
- *B. Core* 28
  - Mathematics 150A 4
  - Mathematics 135A 4
  - Mathematics 125AB 8
  - Mathematics 128ABC 12

C. Enrichment 12
1. Choice of two courses from Mathematics 118ABC, 119AB, 129, 133, 167, 185A 8
2. Choice of one course from Mathematics 111, 114, 115A, 116, 135B, 141, 145, 146, 147, 148, 150B, 165 4

D. Choose one Emphasis from the following two 8

Computational and Mathematical Biology Emphasis

Mathematics 124 4
One approved upper division course in Biology 4

Computational and Mathematics Emphasis

Mathematics 168 4
One approved upper division course involving extensive computation or theory of computation 4

Total Units for the Major 83-90

Recommended Language Preparation. Bachelor of Science degree candidates are advised, but not required, to satisfy the same language requirement as that for a Bachelor of Arts degree candidate, and to fulfill it in French, German, or Russian.

Major Advisers. For a current list of faculty advisers, contact the Student Services office at *studentservices@math.ucdavis.edu*, or our see Web site.

Depth Subject Matter Requirements. Certain mathematically oriented courses given by other departments are admissible in partial satisfaction of the depth subject matter requirements with prior departmental approval. Up to three units of Math 194 may be counted toward the depth subject matter requirements. Additionally, up to three units of Math 189, Math 198, and Math 199, can be counted.

Statement of Objectives. As early as possible, but no later than the last quarter of the sophomore year or no later than the beginning of the first quarter of the junior year for transfer students, each prospective mathematics major, in consultation with a faculty adviser, should file a formal program of study in one of the majors offered in mathematics. Forms to be used for this are available on our Web site or from the Department office. Failure to file a formal program could lead to a delay in graduation.

Information for Undergraduates. Assistance in planning an undergraduate major program in mathematics is available on our Web site, as well as by consulting a faculty adviser.

Mathematics Placement Requirement. Students who wish to enroll in Mathematics 12, 16A, 17A, 21A, 21AH, 36 and 67 must satisfy the mathematics placement requirement. See the Department of Mathematics' Web page for details well in advance of enrolling. Students who do not satisfy the requirement will be administratively dropped from these courses. Dates and times for the Precalculus Diagnostic Exam, one of the ways to meet this requirement, are posted on the Learning Skills Center Web page. The Center also provides review materials, review workshops, and other recommended remedial math courses.

The Mathematics Placement Requirement is waived when one of the following conditions is met: *(a)* Advanced Placement Calculus AB exam score of 4 or 5; *(b)* Advanced Placement Calculus BC exam score of 3, 4, or 5; *(c)* a score of 700 or above on the Mathematics section of the SAT Reasoning Test; or (*d*) in either of the SAT Mathematical Subject tests (Level 1 or Level 2) a score of 700 and above.

Honors and Honors Program. Students who have completed at least 135 units with a minimum GPA of 3.500 in courses counted towards their major are automatically admitted to the Honors Program. Students who are eligible will be notified of their standing by the department at the beginning of the Fall quarter of their senior year.

Students in the Honors Program who meet the minimum GPA requirement and who complete a senior project in consultation with their faculty adviser may also be recommended by the department for graduation with High Honors or Highest Honors. Recommendations will be based on evaluations of students' academic achievements in their major and the quality of their senior project. For complete details, see our Web site at *http://www.math.ucdavis.edu*.

Minor Program Requirements:

UNITS

Mathematics 20

Upper division units in mathematics (exclusive of Mathematics 192, 197TC, 198, 199) 20

Teaching Credential Subject Representative. Ali Dad-del

Graduate Study. The Department offers programs of study and research leading to the M.A. and Ph.D. degrees in Mathematics. Information regarding graduate study may be obtained by consulting our Web site, and by sending an e-mail to *studentservices@math.ucdavis.edu*.

Courses in Mathematics (MAT)

Lower Division Courses

B. Elementary Algebra (no credit)
Lecture—3 hours. Basic concepts of algebra, including polynomials, factoring, equations, graphs, and inequalities. Offered only if sufficient number of students enroll. Not open to Concurrent student enrollment. (P/NP grading only.) (There is a fee of $45.)—I. (I.)

C. Trigonometry (no credit)
Lecture—2 hours. Basic concepts of trigonometry, including trigonometric functions, identities, inverse functions, and applications. Offered only if sufficient number of students enroll. Not open to Concurrent student enrollment. (P/NP grading only.) (There is a fee of $30.)—I. (I.)

D. Intermediate Algebra (no credit)
Lecture—3 hours. Basic concepts of algebra, designed to prepare the student for college work in mathematics, such as course 16A or 21A. Functions, equations, graphs, logarithms, and systems of equations. Offered only if sufficient number of students enroll. Not open to Concurrent student enrollment. (P/NP grading only.) (There is a fee of $15.)—I, II. (I, II.)

12. Precalculus (3)
Lecture—3 hours. Prerequisite: two years of high school algebra, plane geometry, plane trigonometry; and obtaining required score on the Precalculus Diagnostic Examination. Topics selected for their use in calculus, including functions and their graphs, slope, zeroes of polynomials, exponential, logarithmic and trigonometric functions, sketching surfaces and solids. Not open for credit to students who have completed any of courses 16A, 16B, 16C, 17A, 17B, 17C, 21A, 21B, or 21C with a *C-* or better.—I, II, III. (I, II, III.)

Note: Mathematics 16A, 16B, and 16C are intended for students who will take no more Mathematics courses. Mathematics 17A, 17B, and 17C have the same level of rigor as 16A, 16B, and 16C, yet are much more broad mathematically (containing algebra, differential equations and probability, besides traditional calculus), and are intended for biology students who do not wish to take more rigorous Mathematics courses.

16A. Short Calculus (3)
Lecture—3 hours. Prerequisite: two years of high school algebra, plane geometry, plane trigonometry, and satisfying the Mathematics Placement Requirement. Limits; differentiation of algebraic functions; analytic geometry; applications, in particular to maxima and minima problems. Not open for credit to students who have received credit for Mathematics 17B, 17C, 21A, 21B, or 21C. Only 2 units of credit to students who have completed course 17A. GE credit: SciEng.—I, II, III. (I, II, III.)

16B. Short Calculus (3)
Lecture—3 hours. Prerequisite: course 16A, 17A, or 21A. Integration; calculus for trigonometric, exponential, and logarithmic functions; applications. Not open for credit to students who have completed courses 17C, 21B, or 21C. Only 2 units of credit to students who have completed course 17B. GE credit: SciEng.—I, II, III. (I, II, III.)

16C. Short Calculus (3)
Lecture—3 hours. Prerequisite: course 16B, 17B, or 21B. Differential equations; partial derivatives; double integrals; applications; series. Not open for credit to students who have completed course 21C. Only two units of credit to students who have completed course 17C. GE credit: SciEng.—I, II, III. (I, II, III.)

Note: Mathematics 16A, 16B, and 16C are intended for students who will take no more Mathematics courses. Mathematics 17A, 17B, and 17C have the same level of rigor as 16A, 16B, and 16C, yet are much more broad mathematically (containing algebra, differential equations and probability, besides traditional calculus), and are intended for biology students who do not wish to take more rigorous Mathematics courses.

17A. Calculus for Biology and Medicine (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: two years of high school algebra, plane geometry, plane trigonometry, and analytical geometry, and satisfying the Mathematics Placement Requirement. Introduction to differential calculus via applications in biology and medicine. Limits, derivatives of polynomials, trigonometric, and exponential functions, graphing, applications of the derivative to biology and medicine. Not open for credit to students who have completed course 16B, 16C, 21A, 21B, or 21C. Only 2 units of credit to students who have completed course 16A. GE credit: SciEng.—I, II, III. (I, II, III.)

17B. Calculus for Biology and Medicine (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: course 16A, 17A, or 21A. Introduction to integral calculus and elementary differential equations via applications to biology and medicine. Fundamental theorem of calculus, techniques of integration including integral tables and numerical methods, improper integrals, elementary first order differential equations, applications in biology and medicine. Not open for credit to students who have completed course 16C, 21B, or 21C. Only 2 units of credit for students who have completed course 16B. GE credit: SciEng.—I, II, III. (I, II, III.)

17C. Calculus for Biology and Medicine (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: course 16B, 17B, or 21B. Matrix algebra, functions of several variables, partial derivatives, systems of differential equations, and applications to biology and medicine. Not open for credit to students who have completed course 21C. Only 2 units of credit to students who have completed course 16C. GE credit: SciEng.—I, II, III. (I, II, III.)

21A. Calculus (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: two years of high school algebra, plane geometry, plane trigonometry, and analytic geometry, and satisfying the Mathematics Placement Requirement. Functions, limits, continuity. Slope and derivative. Differentiation of algebraic and transcendental functions. Applications to motion, natural growth, graphing, extrema of a function. Differentials. L'Hopital's rule. Not open for credit to students who have completed course 16B, 16C, 17B, or 17C. Only 2 units of credit to students who have completed course 16A or 17A. GE credit: SciEng.—I, II, III. (I, II, III.)

21AH. Honors Calculus (4)
Lecture/discussion—4 hours. Prerequisite: a Precalculus Diagnostic Examination score significantly higher than the minimum for course 21A is required. More intensive treatment of material covered in course 21A. Offered irregularly. GE credit: SciEng.

21AL. Emerging Scholars Program Calculus Workshop (2)
Workshop—6 hours. Prerequisite: concurrent enrollment in course 21A. Functions, limits, continuity. Slope and derivative. Same course content as course 21A. Enrollment for students in the Emerging Scholars Program by instructor's invitation only. Offered irregularly. (P/NP grading only.)

21B. Calculus (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: course 21A or 21AH. Continuation of course 21A. Definition of definite integral, fundamental theorem of calculus, techniques of integration. Application to area, volume, arc length, average of a function, improper integral, surface of revolution. Only 2 units of credit to students who have completed course 16B, 16C, 17B, or 17C. GE credit: SciEng.—I, II, III. (I, II, III.)

21BH. Honors Calculus (4)
Lecture/discussion—4 hours. Prerequisite: a grade of B or better in course 21A or 21AH. More intensive treatment of material covered in course 21B. Students completing 21BH can continue with course 21CH or the regular 21C. Offered irregularly. GE credit: SciEng.

21BL. Emerging Scholars Program Calculus Workshop (2)
Workshop—6 hours. Prerequisite: course 21A or 21AH; concurrent enrollment in 21B. Continuation of course 21A. Same course content as 21B. Enrollment for students in the Emerging Scholars Program by instructor's invitation only. Offered irregularly. (P/NP grading only.)

21C. Calculus (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: course 16C, 17C, 21B, or 21BH. Continuation of course 21B. Sequences, series, tests for convergence, Taylor expansions. Vector algebra, vector calculus, scalar and vector fields. Partial derivitives, total differentials. Applications to maximum and minimum problems in two or more variables. Applications to physical systems. GE credit: SciEng.—I, II, III. (I, II, III.)

21CH. Honors Calculus (4)
Lecture/discussion—4 hours. Prerequisite: a grade of B or better in course 21B or 21BH. More intensive treatment of material covered in course 21C. GE credit: SciEng. Offered infrequently.

21CL. Emerging Scholars Program Calculus Workshop (2)
Workshop—6 hours. Prerequisite: course 21B or 21BH; concurrent enrollment in 21C. Continuation of course 21B. Same course content as course 21C. Enrollment for students in the Emerging Scholars Program by instructor's invitation only. (P/NP grading only.) Offered irregularly.

21D. Vector Analysis (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: course 21C or 21CH. Continuation of course 21C. Definite integrals over plane and solid regions in various coordinate systems. Line and surface integrals. Green's theorem, Stoke's theorem, divergence theorem.—I, II, III. (I, II, III.)

21M. Accelerated Calculus (5)
Lecture/discussion—4 hours; discussion/laboratory—1 hour. Prerequisite: grade of B or higher in both semesters of high school calculus or a score of 4 or higher on the Advanced Placement Calculus AB exam, and obtaining the required score on the Precalculus Diagnostic Examination and its trigonometric component. Accelerated treatment of material from courses 21A and 21B, with detailed presentation of theory, definitions, and proofs, and treatment of computational aspects of calculus at a condensed but sophisticated level. Not open for credit to students who have completed course 21A or 21B; only 3 units of credit will be allowed to students who have completed course 16A and only 2 units of credit will be allowed to students who have completed course 16B. Offered irregularly. GE credit: SciEng.

22A. Linear Algebra (3)
Lecture—3 hours. Prerequisite: nine units of college mathematics and Engineering 6 or knowledge of Matlab or course 22AL (to be taken concurrently). Matrices and linear transformations, determinants, eigenvalues, eigenvectors, diagonalization, factorization. Not open for credit to students who have completed course 67.—I, II, III. (I, II, III.)

22AL. Linear Algebra Computer Laboratory (1)
Laboratory—2-3 hours. Prerequisite: nine units of college mathematics. Introduction to Matlab and its use in linear algebra. (P/NP grading only.)—I, II, III. (I, II, III.)

22B. Differential Equations (3)
Lecture—3 hours. Prerequisite: courses 21C; 22A or 67. Solutions of elementary differential equations.—I, II, III. (I, II, III.)

25. Advanced Calculus (4)
Lecture/discussion—4 hours. Prerequisite: course 21B. Introduction to the rigorous treatment of abstract mathematical analysis. Proofs in mathematics, induction, sets, cardinality; real number system, theory of convergence of sequences. Not open for credit to students who have completed former course 127A.—I, III. (I, III.)

36. Fundamentals of Mathematics (3)
Lecture—3 hours. Prerequisite: satisfaction of the Mathematics Placement Requirement. Introduction to fundamental mathematical ideas selected from the principal areas of modern mathematics. Properties of the primes, the fundamental theorems of arithmetic, properties of the rationals and irrationals, binary and other number systems. Not open for credit to students who have completed course 108. GE credit: SciEng.—IV.

67. Modern Linear Algebra (4)
Lecture/discussion—4 hours. Prerequisite: satisfaction of Math Placement Requirement or course 21A. Rigorous treatment of linear algebra; topics include vector spaces, bases and dimensions, orthogonal projections, eigenvalues and eigenvectors, similarity transformations, singular value decomposition and positive definiteness. Only one unit of credit to students who have completed course 22A.—I, II. (I, II.)

71A-71B. Explorations in Elementary Mathematics (3-3)
Lecture—2 hours; laboratory—3 hours. Prerequisite: two years of high school mathematics. Weekly explorations of mathematical ideas related to the elementary school curriculum will be carried out by cooperative learning groups. Lectures will provide background and synthesize the results of group exploration. (Deferred grading only, pending completion of sequence.) Offered irregularly.

89. Elementary Problem Solving (1)
Lecture—1 hour. Prerequisite: high school mathematics through precalculus. Solve and present solutions to challenging and interesting problems in elementary mathematics. May be repeated once for credit. (P/NP grading only.) Offered irregularly.

98. Directed Group Study (1-5)
Prerequisite: consent of instructor. (P/NP grading only.)—I, II, III. (I, II, III.)

99. Special Study for Undergraduates (1-5)
Prerequisite: consent of instructor. (P/NP grading only.)—I, II, III. (I, II, III.)

Upper Division Courses

108. Introduction to Abstract Mathematics (4)
Lecture/discussion—4 hours. Prerequisite: course 21B. A rigorous treatment of mathematical concepts with emphasis on developing the ability to understand abstract mathematical ideas, to read and write mathematical concepts, and to prove theorems. Designed to serve as preparation for the more rigorous upper division courses. GE Credit: Wri.—I, II. (I, II.)

111. History of Mathematics (4)
Lecture—3 hours; term paper. Prerequisite: eight units of upper division Math; one of the following courses: 25, 67, 108, 114, 115A, 141, or 145. The history of mathematics from ancient times through the development of calculus. Mathematics from Arab, Hindu, Chinese, and other cultures. Selected topics from the history of modern mathematics.—II. (II.)

114. Convex Geometry (4)
Lecture/discussion—4 hours. Prerequisite: courses 21C; 22A or 67. Topics selected from the theory of convex bodies, convex functions, geometric inequalities, combinatorial geometry, and integral geometry. Designed to serve as preparation for the more rigorous upper-division courses. Offered in alternate years.—(II.)

115A. Number Theory (4)
Lecture/discussion—4 hours. Prerequisite: course 21B. Divisibility and related topics, diophantine equations, selected topics from the theory of prime numbers. Designed to serve as preparation for the more rigorous upper division courses.—I. (I.)

115B. Number Theory (4)
Lecture—3 hours; extensive problem solving. Prerequisite: courses 67, 115A. Euler function, Moebius function, congruences, primitive roots, quadratic reciprocity law. Offered in alternate years.—II.

116. Differential Geometry (4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 125A. Vector analysis, curves, and surfaces in three dimensions. Offered in alternate years.—(III.)

118A. Partial Differential Equations: Elementary Methods (4)
Lecture—3 hours; extensive problem solving. Prerequisite: courses 21D; 22B; 22A or 67.Derivation of partial differential equations; separation of variables; equilibrium solutions and Laplace's equation; Fourier series; method of characteristics for the one dimensional wave equation. Solution of nonhomogeneous equations.—I. (I.)

118B. Partial Differential Equations: Eigenfunction Expansions (4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 118A. Sturm-Liouville Theory; self-adjoint operators; mixed boundary conditions; partial differential equations in two and three dimensions; Eigenvalue problems in circular domains; nonhomogeneous problems and the method of eigenfunction expansions; Poisson's Equations.—II. (II.)

118C. Partial Differential Equations: Green's Functions and Transforms (4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 118B. Green's functions for one-dimensional problems and Poisson's equation; Fourier transforms; Green's Functions for time dependent problems; Laplace transform and solution of partial differential equations. Offered irregularly.

119A. Ordinary Differential Equations (4)
Lecture—3 hours; extensive problem solving. Prerequisite: courses 21D; 22B; 22A or 67. Scalar and planar autonomous systems; nonlinear systems and linearization; existence and uniqueness of solutions; matrix solution of linear systems; phase plane analysis; stability analysis; bifurcation theory; Liapunov's method; limit cycles; Poincare Bendixon theory.—II. (II.)

119B. Ordinary Differential Equations (4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 119A. Lorentz equations; Poincare maps; center manifolds and normal forms; scalar and planar maps; phase space analysis for iterated maps; period-doubling bifurcation; Lyapunov exponent; chaos and symbolic dynamics; strange attractors; fractals.—III. (III.)

124. Mathematical Biology (4)
Lecture—3 hours; project. Prerequisite: courses 22A or 67; 22B. Methods of mathematical modeling of biological systems including difference equations, ordinary differential equations, stochastic and

dynamic programming models. Computer simulation methods applied to biological systems. Applications to population growth, cell biology, physiology, evolutionary ecology and protein clustering. MATLAB programming required. Offered in alternate years. —(III.)

125A. Real Analysis (4)
Lecture/discusssion—4 hours. Prerequisite: course 25. Functions, limits of functions, continuity and uniform continuity, sequences of functions, series of real numbers, series of functions, power series. Not open for credit to students who have completed former course 127B.—I, II. (I, II.)

125B. Real Analysis (4)
Lecture/discusssion—4 hours. Prerequisite: course 67 and 125A. Theory of the derivative, Taylor series, integration, partial derivatives, Implicit Function Theorem. Not open for credit to students who have completed former course 127C.—II, III. (II, III.)

128A. Numerical Analysis (4)
Lecture—3 hours; project. Prerequisite: Computer Science: Engineering 30 or equivalent; course 21C; Error analysis, approximation, interpolation, numerical differentiation and integration. Programming in language such as Pascal, Fortran, or BASIC required.—I. (I.)

128B. Numerical Analysis in Solution of Equations (4)
Lecture—3 hours; project. Prerequisite: Computer Science: Engineering 30 or equivalent; courses 21C; 22A or 67. Solution of nonlinear equations and nonlinear systems. Minimization of functions of several variables. Simultaneous linear equations. Eigenvalue problems. Linear programming. Programming in language such as Pascal, Fortran, or BASIC required.—II. (II.)

128C. Numerical Analysis in Differential Equations (4)
Lecture—3 hours; project. Prerequisite: Computer Science: Engineering 30 or equivalent; courses 22A or 67; 22B. Difference equations, operators, numerical solutions of ordinary and partial differential equations. Programming in language such as Pascal, Fortran, or BASIC required.—III. (III.)

129. Fourier Analysis (4)
Lecture—3 hours; extensive problem solving. Prerequisite: courses 21D; 22A or 67; 22B; 25 or consent of instructor. Fourier series and integrals, orthogonal sets of functions. Topics selected from trigonometric approximation, orthogonal polynomials, applications to signal and image processing, numerical analysis, and differential equations.—III. (III.)

133. Mathematical Finance (4)
Lecture—3 hours; extensive problem solving. Prerequisite: courses 67; 135A. Analysis and evaluation of deterministic and random cash flow streams, yield and pricing of basic financial instruments, interest rate theory, mean-variance portfolio theory, capital asset pricing models, utility functions and general principles. MATLAB programming required. Offered in alternate years.—III.

135A. Probability (4)
Lecture/discussion—4 hours. Prerequisite: course 125A. Probability space; discrete probability, combinatorial analysis; independence, conditional probability; random variables, discrete and continuous distributions, probability mass function, joint and marginal density functions; expectation, moments, variance, Chebyshev inequality; sums of random variables, random walk, large number law, central limit theorem. Not open for credit to students who have completed former course 131.—I, II. (I, II.)

135B. Stochastic Processes (4)
Lecture—3 hours; extensive problem solving. Prerequisite: courses 135A; 22A or 67. Generating functions, branching processes, characteristic function; Markov chains; convergence of random variables, law of iterated logarithm; random processes, Brownian motion, stationary processes, renewal processes, queueing theory, martingales.Not open for credit to students who have completed former course 132A.—III. (III.)

141. Euclidean Geometry (4)
Lecture/discussion—4 hours. Prerequisite: courses 21B; 22A or 67. An axiomatic and analytic examination of Euclidean geometry from an advanced point of view. In particular, a discussion of its relation to other geometries. Designed to serve as preparation for the more rigorous upper division courses.—III. (III.)

145. Combinatorics (4)
Lecture/discussion—4 hours. Prerequisite: course 21B. Combinatorial methods using basic graph theory, counting methods, generating functions, and recurrence relations. Designed to serve as preparation for the more rigorous upper division courses.—II. (II.)

146. Algebraic Combinatorics (4)
Lecture/discussion—4 hours. Prerequisite: courses 25; 22A or 67; 145. Enumeration, Polya theory, generating functions, current topics in algebraic combinatorics. Not open for credit to students who have completed former course 149A.—III. (III.)

147. Topology (4)
Lecture—3 hours; extensive problem solving. Prerequisite: courses 67, 125A. Basic notions of point-set and combinatorial topology.—III. (III.)

148. Discrete Mathematics (4)
Lecture/discussion—4 hours. Prerequisite: course 67; or courses 22A and 25. Coding theory, error correcting codes, finite fields and the algebraic concepts needed in their development. Not open for credit to students who have completed former course 149B.—II. (II.)

150A. Modern Algebra (4)
Lecture/discussion—4 hours. Prerequisite: course 67. Basic concepts of groups, symmetries of the plane. Emphasis on the techniques used in the proof of the ideas (Lemmas, Theorems, etc.) developing these concepts. Precise thinking, proof writing, and the ability to deal with abstraction.—I. (I.)

150B. Modern Algebra (4)
Lecture/discussion—4 hours. Prerequisite: course 150A. Bilinear forms, rings, factorization, modules.—II. (II.)

150C. Modern Algebra (4)
Lecture/discussion—4 hours. Prerequisite: course 150B. Group representations, fields, Galois theory.—III. (III.)

160. Mathematical Foundations of Database Theory, Design and Performance (4)
Lecture—3 hours; project. Prerequisite: course 22A or 67; one of the following courses: 25, 108, 114, 115A, 141, or 145. Relational model; relational algebra, relational calculus, normal forms, functional and multivalued dependencies. Separability. Cost benefit analysis of physical database design and reorganization. Performance via analytical modeling, simulation, and queueing theory. Block accesses; buffering; operating system contention; CPU intensive operations. Offered irregularly.

165. Mathematics and Computers (4)
Lecture—3 hours; project. Prerequisite: Computer Science Engineering 30 or equivalent; course 22B and one of the following courses: 25, 67, 108, 114, 115A, 141 or 145. Introduction to computational mathematics, symbolic computation, and computer generated/verified proofs in algebra, analysis and geometry. Investigation of rigorous new mathematics developed in conjunction with modern computational questions and the role that computers play in mathematical conjecture and experimentation.—I. (I.)

167. Applied Linear Algebra (4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 22A or 67. Linear algebra; linear equations; orthogonal projections, similarity transformations, quadratic forms, eigenvalues and eigenvectors. Applications to physics, engineering, economics, biology and statistics.—I, II, III. (I, II, III.)

168. Optimization (4)
Lecture—3 hours; extensive problem solving. Prerequisite: Computer Science: Engineering 30 or equivalent; courses 21C or 25; 22A or 67. Linear programming, simplex method. Basic properties of unconstrained nonlinear problems, descent methods, conjugate direction method. Constrained minimization. Programming language required.—III. (III.)

180. Special Topics (3)
Lecture—3 hours. Prerequisite: courses 25 and 67, or consent of instructor. Special topics from various fields of modern, pure, and applied mathematics. Some recent topics include Knot Theory, General Relativity, and Fuzzy Sets. May be repeated for credit when topic differs. Not offered every year.
—I, II, III. (I, II, III.)

185A. Complex Analysis (4)
Lecture—3 hours; extensive problem solving. Prerequisite: courses 67, 125A. Complex number system, analyticity and the Cauchy-Riemann equations, elementary functions, complex integration, power and Laurent series expansions, residue theory.—II. (II.)

185B. Complex Analysis (4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 185A. Analytical functions, elementary functions and their mapping properties, applications of Cauchy's integral theorem, conformal mapping and applications to heat flow and fluid mechanics. Offered in alternate years.—III.

189. Advanced Problem Solving (3)
Lecture—3 hours. Prerequisite: courses 21D; 22A or 67; 25. Solution and presentation of advanced problem solving techniques. Solve and present interesting and challenging problems of all areas of mathematics. Not offered every year. GE Credit: Wri.—II.

192. Internship in Applied Mathematics (1-3)
Internship; final report. Prerequisite: upper division standing; project approval by faculty sponsor prior to enrollment. Supervised work experience in applied mathematics. May be repeated for credit for a total of 10 units. (P/NP grading only.)—I, II, III. (I, II, III.)

194. Undergraduate Thesis (3)
Prerequisite: consent of instructor. Independent research under supervision of a faculty member. Student will submit written report in thesis form. May be repeated with consent of Vice Chairperson. (P/NP grading only.)—I, II, III. (I, II, III.)

197TC. Tutoring Mathematics in the Community (1-5)
Seminar—1-2 hours; laboratory—2-6 hours. Prerequisite: upper division standing and consent of instructor. Special projects in mathematical education developing techniques for mathematics instruction and tutoring on an individual or small group basis. May be repeated once for credit. (P/NP grading only.)—I, II, III. (I, II, III.)

198. Directed Group Study (1-5)
Prerequisite: consent of instructor. (P/NP grading only.)—I, II, III. (I, II, III.)

199. Special Study for Advanced Undergraduates (1-5)
(P/NP grading only.)—I, II, III. (I, II, III.)

Graduate Courses

201A-201B-201C. Analysis (4-4-4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: graduate standing in Mathematics or Applied Mathematics, or consent of instructor. Metric and normed spaces. Continuous functions. Topological, Hilbert, and Banach spaces. Fourier series. Spectrum of bounded and compact linear operators. Linear differential operators and Green's functions. Distributions. Fourier transform. Measure theory. Lp and Sobolev spaces. Differential calculus and variational methods.—I-II-III. (I-II-III.)

202. Functional Analysis (4)
Lecture—3 hours; term paper. Prerequisite: course 201A-201B-201C. The theory of Fredholm operators. Examples of Fredholm operators (singular inte-

gral operators, elliptic operators in Sobolov spaces). Index theory for Fredholm operators. Unbounded self-adjoint operators. Schrodinger operators and other differential operators. The spectral theorem for these and for unitary operators. Offered in alternate years.—II.

204. Applied Asymptotic Analysis (4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: graduate standing or consent of instructor. Scaling and non-dimensionalization. Asymptotic expansions. Regular and singular perturbation methods. Applications to algebraic and ordinary and partial differential equations in the natural sciences and engineering. Offered in alternate years.—(I.)

205. Complex Analysis (4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: course 185 or the equivalent or consent of instructor. Analytic continuation, Riemann mapping theorem, elliptic functions, modular forms, Riemann zeta function, Riemann surfaces.—III. (III.)

206. Measure Theory (4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 125B. Introduction to measure theory. Introduction to measure theory. The study of lengths, surface areas, and volumes in general spaces, as related to integration theory. Offered in alternate years.—III.

210A. Topics in Geometry (3)
Lecture—3 hours. Prerequisite: bachelor's degree in mathematics or consent of instructor. Topics in advanced geometry related to curriculum at all levels. Required for M.A.T. degree program for prospective teachers. May be repeated for credit with prior consent of instructor. Offered irregularly.

210AL. Topics in Geometry: Discussion (1)
Lecture/discussion—1 hour (to be arranged). Prerequisite: course 210A (concurrently); consent of instructor. Special topics related to course 210A which are of special interest to teachers and candidates for M.A.T. degree program. May be repeated for credit. Offered irregularly.

210B. Topics in Algebra (3)
Lecture—3 hours. Prerequisite: bachelor's degree in mathematics or consent of instructor. Topics in advanced algebra related to curriculum at all levels. Required for M.A.T. degree program for prospective teachers. May be repeated for credit with prior consent of instructor. Offered irregularly.

210BL. Topics in Algebra: Discussion (1)
Lecture/discussion—1 hour (to be arranged). Prerequisite: course 210B (concurrently); consent of instructor. Special topics related to course 210B which are of special interest to teachers and candidates for M.A.T. degree program. May be repeated for credit. Offered irregularly.

210C. Topics in Analysis (3)
Lecture—3 hours. Prerequisite: bachelor's degree in mathematics or consent of instructor. Topics in advanced analysis related to curriculum at all levels. Required for M.A.T. degree program for prospective teachers. May be repeated for credit with prior consent of instructor. Offered irregularly.

210CL. Topics in Analysis: Discussion (1)
Lecture/discussion—1 hour (to be arranged). Prerequisite: course 210C (concurrently); consent of instructor. Special topics related to course 210C which are of special interest to teachers and candidates for M.A.T. degree program. May be repeated for credit. Offered irregularly.

215A-215B-215C. Topology (4-4-4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: graduate standing or consent of instructor. Fundamental group and covering space theory. Homology and cohomology. Manifolds and duality. CW complexes. Fixed point theorems. Offered in alternate years.—(I-II-III.)

218A. Partial Differential Equations (4)
Lecture/discussion—3 hours; term paper or discussion. Prerequisite: courses 22A or 67; 125B. Initial and boundary value problems for elliptic, parabolic and hyperbolic partial differential equations; existence, uniqueness and regularity for linear and nonlinear equations; maximum principles; weak solutions, Holder and Sobolev spaces, energy methods; Euler-Lagrange equations. Offered in alternate years.—II. (II.)

218B. Partial Differential Equations (4)
Lecture—3 hours; term paper or discussion. Prerequisite: courses 22A, 127C. Initial and boundary value problems for elliptic, parabolic and hyperbolic partial differential equations; existence, uniqueness and regularity for linear and nonlinear equations; maximum principles; weak solutions, Holder and Sobolev spaces, energy methods; Euler-Lagrange equations. Offered in alternate years.—III. (III.)

219. Ordinary Differential Equations (4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: course 22A or 67, 22B, 125B or consent of instructor. Theory of ordinary differential equations. Dynamical systems. Geometric theory. Normal forms. Bifurcation theory. Chaotic systems. Offered irregularly.

221A. Mathematical Fluid Dynamics (4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: course 118B or consent of instructor. Kinematics and dynamics of fluids. The Euler and Navier-Stokes equations. Vorticity dynamics. Irrotational flow. Low Reynolds number flows and the Stokes equations. High Reynolds number flows and boundary layers. Compressible fluids. Shock waves. Offered in alternate years.—(I.)

221B. Mathematical Fluid Dynamics (4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: course 118B or consent of instructor. Kinematics and dynamics of fluids. The Euler and Navier-Stokes equations. Vorticity dynamics. Irrotational flow. Low Reynolds number flows and the Stokes equations. High Reynolds number flows and boundary layers. Compressible fluids. Shock waves. Offered in alternate years.—(II.)

222. Introduction to Biofluid Dynamics (3)
Lecture—3 hours. Prerequisite: Population Biology 231/Ecology 231 and Neurobiology, Physiology and Behavior 245 or consent of instructor. The basic principles of fluid dynamics are introduced in the first half of the course by describing various phenomena studies from a biofluids perspective. The equations of fluid motion associated with these phenomena are derived and studied in the second half. Offered irregularly.

226A. Numerical Methods: Fundamentals (4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: course 128AB or equivalent, or consent of instructor; familiarity with some programming language. Fundamental principles and methods in numerical analysis, including the concepts of stability of algorithms and conditioning of numerical problems, numerical methods for interpolation and integration, eigenvalue problems, singular value decomposition and its applications. Offered in alternate years.—(I.)

226B. Numerical Methods: Large-Scale Matrix Computations (4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: course 167 or equivalent, or consent of instructor; familiarity with some programming language. Numerical methods for large-scale matrix computations, including direct and iterative methods for the solution of linear systems, the computation of eigenvalues and singular values, the solution of least-squares problems, matrix compression, methods for the solution of linear programs. Offered in alternate years.—(II.)

226C. Numerical Methods: Ordinary Differential Equations (4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: course 22B or equivalent, or consent of instructor; familiarity with some programming language. Numerical methods for the solution of ordinary differential equations, including methods for initial-value problems and two-point boundary-value problems, theory of and methods for differential algebraic equations, dimension reduction of large-scale dynamical systems. Offered in alternate years.—(III.)

227. Mathematical Biology (4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: graduate standing or consent of instructor. Nonlinear ordinary and partial differential equations and stochastic processes of cell and molecular biology. Scaling, qualitative, and numerical analysis of mathematical models. Applications to nerve impulse, chemotaxis, muscle contraction, and morphogenesis. Offered in alternate years.—I.

228A-228B-228C. Numerical Solution of Differential Equations (4-4-4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: course 128C. Numerical solutions of initial-value, eigenvalue and boundary-value problems for ordinary differential equations. Numerical solution of parabolic and hyperbolic partial differential equations. Offered in alternate years.—I-II-III.

235A-235B-235C. Probability Theory (4-4-4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: 235A—courses 125B and 135A or Statistics 131A or consent of instructor; 235B—course 235A/Statistics 235A or consent of instructor; 235C—course 235B/Statistics 235B or consent of instructor. Measure-theoretic foundations, abstract integration, independence, laws of large numbers, characteristic functions, central limit theorems. Weak convergence in metric spaces, Brownian motion, invariance principle. Conditional expectation. Topics selected from martingales, Markov chains, ergodic theory. (Same course as Statistics 235A-235B-235C.)—I-II-III. (I-II-III.)

236A-236B. Stochastic Dynamics and Applications (4-4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: course 201C or course/Statistics 235B; course/Statistics 235A-235B-235C recommended. Stochastic processes, Brownian motion, Stochastic integration, martingales, stochastic differential equations. Diffusions, connections with partial differential equations, mathematical finance. Offered in alternate years.—I-II.

239. Differential Topology (4)
Lecture—3 hours; extensive problem solving. Prerequisite: vector calculus, point-set topology, course 201A, or consent of instructor; course 250AB highly recommended. Topics include: differentiable manifolds, vector fields, transversality, Sard's theorem, examples of differentiable manifolds; orientation, intersection theory, index of vector fields; differential forms, integration, Stokes' theorm, deRham cohomology; Morse functions, Morse lemma, index of critical points.—III. (III.)

240A. Differential Geometry (4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: course 116 or consent of instructor. Manifolds. Differentiable structures. Vector fields and tangent spaces. Bundles, tensors, forms, Grassman algebras. DeRham cohomology. Riemannian geometry. Connections, curvature, geodesics, submanifolds. Curves and surfaces. Positive and negative curvature; Morse Theory; homogeneous spaces; Hodge theory; applications.—I. (I.)

240B. Differential Geometry (4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: course 116 or consent of instructor. Manifolds. Differentiable structures. Vector fields and tangent spaces. Bundles, tensors, forms, Grassman algebras. DeRham cohomology. Riemannian geometry. Connections, curvature, geodesics, submanifolds. Curves and surfaces. Positive and negative curvature; Morse Theory; homogeneous spaces; Hodge theory; applications.—II. (II.)

240C. Differential Geometry (4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: course 116 or consent of instructor. Manifolds. Differentiable structures. Vector fields and tangent spaces. Bundles, tensors, forms, Grassman algebras. DeRham cohomology. Riemannian geometry. Connections, curvature, geodesics, submani-

folds. Curves and surfaces. Positive and negative curvature; Morse Theory; homogeneous spaces; Hodge theory; applications. Offered irregularly.—(III.)

245. Enumerative Combinatorics (4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 145, 150 or the equivalent, or consent of instructor. Introduction to modern combinatorics and its applications. Emphasis on enumerative aspects of combinatorial theory. Offered in alternate years.—I.

246. Algebraic Combinatorics (4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 245 or consent of instructor. Algebraic and geometric aspects of combinatorics. The use of structures such as groups, polytopes, rings, and simplicial complexes to solve combinatorial problems. Offered in alternate years—II.

250A-250B-250C. Algebra (4-4-4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: graduate standing in mathematics or consent of instructor. Group and rings. Sylow theorems, abelian groups, Jordan-Holder theorem. Rings, unique factorization. Algebras, and modules. Fields and vector spaces over fields. Field extensions. Commutative rings. Representation theory and its applications.—I-II-III. (I-II-III.)

258A. Numerical Optimization (4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: courses 25, 167. Numerical methods for infinite dimensional optimization problems. Newton and Quasi-Newton methods, linear and sequential quadratic programming, barrier methods; large-scale optimization; theory of approximations; infinite and semi-infinite programming; applications to optimal control, stochastic optimization and distributed systems. Offered in alternate years.—(I.)

258B. Variational Analysis (4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: courses 25 and 167, or consent of the instructor. Foundations of optimization theory. The design of solution procedures for optimization problems. Modeling issues, and stability analysis. Offered in alternate years.—(II.)

261A-261B. Lie Groups and Their Representations (4-4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: course 215A, 240A, 250A-250B or the equivalent or consent of instructor. Lie groups and Lie algebras. Classification of semi-simple Lie groups. Classical and compact Lie groups. Representations of Lie groups and Lie algebras. Root systems, weights, Weil character formula. Kac-Moody and Virasoro algebras. Applications. Offered in alternate years.—(II-III.)

265. Mathematical Quantum Mechanics (4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: course 201 or consent of instructor. Mathematical foundations of quantum mechanics: the Hilbert space and Operator Algebra formulations; the Schrödinger and Heisenberg equations, symmetry in quantum mechanics, basics of spectral theory and perturbation theory. Applications to atoms and molecules. The Dirac equation. Offered in alternate years.—(I.)

266. Mathematical Statistical Mechanics and Quantum Field Theory (4)
Lecture—3 hours; term paper or discussion—1 hour. Prerequisite: course 265 or consent of instructor. Mathematical principles of statistical mechanics and quantum field theory. Topics include classical and quantum lattice systems, variational principles, spontaneous symmetry breaking and phase transitions, second quantization and Fock space, and fundamentals of quantum field theory. Offered in alternate years.—(II.)

271. Applied and Computational Harmonic Analysis (4)
Lecture—3 hours; extensive problem solving. Prerequisite: courses 125B or 201C; and 128B or 167; and 129 or equivalent, or consent of instructor. Introduction to mathematical basic building blocks (wavelets, local Fourier basis, and their relatives) useful for diverse fields (signal and image processing, numerical analysis, and statistics). Emphasis on the connection between the continuum and the discrete worlds. Offered in alternate years.—(II.)

280. Topics in Pure and Applied Mathematics (3)
Lecture—3 hours. Prerequisite: graduate standing. Special topics in various fields of pure and applied mathematics. Topics selected based on the mutual interests of students and faculty. May be repeated for credit when topic differs.—I, II, III. (I, II, III.)

290. Seminar (1-6)
Seminar—1-6 hours. Advanced study in various fields of mathematics, including analysis, applied mathematics, discrete mathematics, geometry, mathematical biology, mathematical physics, optimization, partial differential equations, probability, and topology. May be repeated for credit. (S/U grading only.)—I, II, III. (I, II, III.)

298. Group Study (1-5)

299. Individual Study (1-12)
(S/U grading only.)—I, II, III. (I, II, III.)

299D. Dissertation Research (1-12)
(S/U grading only.)—I, II, III. (I, II, III.)

Professional Courses

301A-301B-301C. Mathematics Teaching Practicum (3-3-3)
Fieldwork—5 hours; discussion—1 hour. Prerequisite: course 302A-302B-302C and 303A-303B-303C concurrently or consent of instructor. Specialist training in mathematics teaching. Teaching, training, and cross observing classes taught using large group Socratic techniques, small group guided inquiry experiences, and/or other approaches to teaching at various grade levels. Required for advanced degrees in mathematics education. May be repeated once for credit. Offered irregularly.

302A-302B-302C. Curriculum Development in Mathematics (1-1-1)
Lecture/discussion—1 hour. Prerequisite: course 303A-303B-303C concurrently or consent of instructor. Mathematics curriculum development for all grade levels. Required for advanced degrees in mathematics education. May be repeated once for credit. Offered irregularly.

303A-303B-303C. Mathematics Pedagogy (1-1-1)
Lecture/discussion—1 hour. Prerequisite: course 302A-302B-302C or 210L concurrently or consent of instructor. An investigation of the interplay of mathematical pedagogy and mathematical content, including a historical survey of past and present methods in view of some of the influences that shaped their development. May be repeated once for credit. Offered irregularly.

390. Methods of Teaching Mathematics (3)
Lecture—1 hour; discussion—1 hour; laboratory—2 hours. Prerequisite: graduate standing. Practical experience in methods and problems of the teaching of mathematics at the university level. Includes discussion of lecturing techniques, analysis of tests and supporting material, preparation and grading of examinations, and related topics. Required of departmental teaching assistants. May be repeated for credit. (S/U grading only.)—I. (I.)

399. Individual Study (2-4)
Independent study—2-3 hours; discussion—1 hour. Individual study of some aspect of mathematics education or a focused work on a curriculum design project under supervision of a faculty member in mathematics. May be repeated once for credit. (S/U grading only.)—I, II, III. (I, II, III.)

Medical Informatics (A Graduate Group)

See Health Informatics (A Graduate Group), on page 314.

Medical Microbiology

See Medicine, School of, on page 367.

Medical Pharmacology and Toxicology

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Medicine

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Medicine, School of

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