J. Hopkins U. 1995-96 Math sciences: 1995 Semesters

379.203-204 Intermediate Portuguese
Bensabat-Ott 3 credits

379.205-206 (H) Advanced Portuguese
Bensabat-Ott 3 credits

nterdepartmental

60.374 Latin American Politics
mith

30.445-446 (W) Latin American Studies Seminar
aff

30.669-670 General Seminar of the Institute for lobal Studies in Culture, Power, and History
aff

ourses (School of Hygiene nd Public Health)

1.626 Management of Health Systems in veloping Countries
nke, Thorne

.631 Health Economics in Developing Countries
geldin, Wouters

.643 Infant and Young Child Feeding in eloping Countries
wn

644 International Public Health Communications
dall

645 Nutrition Intervention Programs in eloping Countries
ley, Esrey

646 Ecology of Food and Nutrition
ley

667 Integrated Community-Based *Aedes aegypti* rol
all

682 Clinical Aspects of Tropical Diseases
Clyde, Staff

759 National, Regional, and Urban Health and Planning
ro

Mathematics

The undergraduate program in the Department of Mathematics is intended for students interested in using mathematics to define and solve problems in the sciences, engineering, and other areas, as well as for those who wish to understand further the logical content, geometric meaning, and abstract reasoning of mathematics itself. A flexible program involving a broad selection of courses is a department tradition. The program begins by introducing students to the basics of algebra and mathematical analysis and then gives them the choice of exploring topics in theoretical mathematics or studying applications to physics, economics, engineering, computer science, probability, statistics, or mechanics.

The graduate program is designed primarily to prepare students for research and teaching in mathematics. It is naturally centered around the research areas of the faculty, which include algebraic geometry, algebraic number theory, differential geometry, partial differential equations, topology, several complex variables, algebraic groups, and representation theory. The program can be supplemented in applied directions by courses in theoretical physics, computer science, mechanics, probability and statistics offered in other departments of the Schools of Arts and Sciences and in the Department of Mathematical Sciences of the School of Engineering.

The Faculty

W. Stephen Wilson, Professor (Chair): algebraic topology.

John M. Boardman, Professor: algebraic and differential topology.

Wei-Liang Chow, Professor Emeritus: algebra, algebraic geometry, complex varieties.

Jun-ichi Igusa, Professor Emeritus: algebra, algebraic geometry, modular functions, number theory.

George Kempf, Professor: algebraic geometry.

Victor A. Kolyvagin, Professor, J. J. Sylvester Chair of Mathematics: algebraic number theory.

Jean-Pierre Meyer, Professor: algebraic topology, category theory.

Jack Morava, Professor: algebraic topology, mathematical physics.

Takashi Ono, Professor: algebra, number theory, algebraic groups.

Joseph H. Sampson, Professor Emeritus: differential geometry, global analysis, algebraic geometry.

Joseph A. Shalika, Professor: algebraic groups and representations, number theory.

Bernard Shiffman, Professor: several complex variables, differential geometry.

Vyacheslav V. Shokurov, Professor: algebraic geometry.

Joel Spruck, Professor: partial differential equations, geometric analysis.

Steven Zelditch, Professor: spectral theory, differential geometry.

Steven Zucker, Professor: Hodge theory, algebraic geometry.

Maciej Zworski, Professor: partial differential equations, scattering theory.

William Minicozzi, Assistant Professor: differential geometry, partial differential equations, Cauchy-Riemann geometry.

Geng Xu, Assistant Professor: algebraic geometry.

Dong Zhang, Assistant Professor: partial differential equations, differential geometry.

James Martino, Lecturer (Director of Undergraduate Studies in Mathematics).

Joint Appointment

Jonathan A. Bagger, Professor (Physics and Astronomy): theoretical high-energy physics.

Associated Faculty

David C. Butler, Visiting Assistant Professor: algebraic geometry.

Masaaki Furusawa, Visiting Assistant Professor: automorphic forms, representation theory.

Lianmin Zhou, Visiting Assistant Professor: geometric analysis, partial differential equations.

Facilities

The University's Milton S. Eisenhower Library has an unusually extensive collection of mathematics literature, including all the major research journals. The stacks are open to students. The

J. Hopkins U. 1995-96

department also has a useful reference library, the Philip Hartman Library. Graduate students share departmental offices, and study space can also be reserved in the University library. Students may access the department's Unix workstations and the University's three mainframes from terminals in the department.

The Department of Mathematics is also home to the Japan-U.S. Mathematics Institute (JAMI), which each year invites four or more outstanding mathematicians from Japan. These visitors organize weekly seminars attended by graduate students and faculty.

Undergraduate Programs

Course Scheduling

Students usually begin by taking Calculus I-II, which is offered in two versions to meet the needs of students with different goals and interests. Students in mathematics, the physical sciences, and engineering are encouraged to begin with the 110.108-109 sequence; students majoring in other subjects may wish to take the 110.106-107 sequence which aims at showing how to use the methods of calculus in the biological and social sciences. A one-term pre-calculus course 110.105 is offered for students who could benefit from additional preparation in the basic tools (algebra and trigonometry) used in calculus.

Entering students may receive course credit for Calculus I or Calculus I-II on the basis of the College Board AP exams (see page 17). Students without AP credit who have taken calculus in high school should take the department's placement exam (given during the orientation period before the start of the fall term) and begin their studies with Calculus II if they qualify.

Linear Algebra (110.201), Calculus III (110.202), and Differential Equations (110.302) may be taken in any order after completing Calculus II (110.107 or 110.109). These courses are especially designed to acquaint students with mathematical methods of importance in engineering and the physical, biological, and social sciences. Additional courses oriented toward applications include 110.251, 110.411, 110.417, 110.421 and 110.443. Students interested in the theoretical foundations of mathematics may select 110.403-404, 110.405-406, 110.412, 110.413, and 110.439. Students planning to pursue further study in mathematics should work toward taking these theoretical courses as early as possible in their undergraduate years and are encouraged to take graduate-level courses as soon as they are qualified.

Requirements for the B.A. Degree

In addition to the General Requirements for Departmental Majors (*see page 45*), a candidate for the bachelor's degree in Mathematics is required to have credit for the courses listed below. The same course or substantially overlapping courses may not be used to fulfill more than one departmental requirement. All courses used to meet these requirements must be completed with a grade of C- or better.

- Calculus I, II, and III.
- 110.403 and one other term of algebra, either 110.204 or 110.404. (110.201 Linear Algebra does not satisfy this requirement.)
- Two terms of analysis chosen from 110.405-406, 110.411-412, 110.416, 110.417, 110.421, 110.439 and 110.443.
- Two term courses chosen from 110.201, 110.204, mathematics courses at the 300-level or above, and other courses as noted below.
- Two terms in any one of the following areas of applications of mathematics, or other appropriate advanced courses as approved by the undergraduate advising coordinator:

Physics and Chemistry: 171.204, 171.301-302, 171.303-304, 171.312, 030.453-454
Probability and Statistics: 550.311, 550.312, 550.313, 550.411, 550.412, 550.414
Applied Mathematics: 550.361-362, 550.471, 550.472, 550.481
Economics: 180.301, 180.302, 180.311
Mechanics: 530.301, 530.305, 530.313, 530.321-322
Computer Science: 600.226, 600.337, and 3-credit courses numbered 600.425 or higher.

Honors Program in Mathematics

As a general guideline, departmental honors are awarded to recipients of the B.A. degree who have completed five or more courses within the department at the 400 level or above with at least a 3.4 average.

J. Hopkins 1995-96 U.

0.413, and 110.439. Students plan-
rsue further study in mathematics
k toward taking these theoretical
arly as possible in their undergrad-
ıd are encouraged to take graduate
s as soon as they are qualified.

nts for the B.A. Degree

to the General Requirements for
al Majors (*see page 45*), a candidate
ıelor's degree in Mathematics is
have credit for the courses listed
ıame course or substantially over-
ses may not be used to fulfill more
epartmental requirement. All
to meet these requirements must
l with a grade of C- or better.
II, and III.
l one other term of algebra, either
110.404. (110.201 Linear Algebra
tisfy this requirement.)
of analysis chosen from 110.405-
1-412, 110.416, 110.417, 110.421,
l 110.443.
courses chosen from 110.201,
thematics courses at the 300-level
ıd other courses as noted below.
n any one of the following areas
ions of mathematics, or other
advanced courses as approved
rgraduate advising coordinator:
hemistry: 171.204, 171.301-302,
)4, 171.312, 030.453-454
d Statistics: 550.311, 550.312,
50.411, 550.412, 550.414
ematics: 550.361-362, 550.471,
50.481
0.301, 180.302, 180.311
0.301, 530.305, 530.313,
2
ıce: 600.226, 600.337, and
ırses numbered 600.425

m in Mathematics

ideline, departmental honors
recipients of the B.A. degree
ɛted five or more courses within
at the 400 level or above with at
ge.

J.J. Sylvester Prize

The J. J. Sylvester Prize in Mathematics, which carries a cash award, is given each year to an outstanding graduating senior majoring in mathematics.

The B.A./M.A. Program

By applying the same courses simultaneously toward the requirements for the B.A. and M.A. degrees, an advanced student can qualify for both degrees in four years. Admission to the program is by the standard graduate application form, which should be filed in junior year. Contact the department graduate secretary for further information.

Graduate Programs

Admission

Admission to the Ph.D. program is based on academic records, letters of recommendation, and Graduate Record Examination scores. International applicants must also submit a TOEFL score or other evidence of fluency in English. Applicants who intend to obtain only the M.A. degree may be accepted in special circumstances, but financial support is available only for Ph.D. candidates.

Basic Program

Graduate study in mathematics is centered around *nine basic courses*: 110.601-602, 110.605-606, 110.611-612, 110.615-616, 110.617-618, 110.619-620, 110.631-632, 110.643-644, and 110.645-646. These courses are intended to prepare students for research. The 700-level courses are designed to bring students abreast of recent developments and to prepare them for research in the area of their choice.

The basic graduate courses are built upon the foundations constituted by the 400-level courses 110.403-404, 110.405-406, 110.411-412, and 110.413. Graduate students will be given a written examination upon matriculation to determine whether they should take one or more of these 400-level courses as preparation.

Requirements for the M.A. Degree

See also the general University Requirements for Advanced Degrees, page 51.

The departmental requirements for the M.A. degree are

- Completion of course work (at the University or elsewhere) in algebra, analysis, and topology at least equivalent to what is provided by 110.403-404, 110.405-406, 110.411, and 110.413.
- Completion, while resident at the University, of one of nine basic graduate courses; demonstration of a deeper understanding of the area of mathematics covered by that course by passing a qualifying examination given by members of the department.
- At least two other terms of mathematics courses at the 400-level or above.
- A reading knowledge of French, German, or Russian, to be demonstrated by passing an examination given in the Department of Mathematics.
- For candidates for the B.A./M.A. degree, at least a 3.0 average in the 400-level mathematics courses taken while resident at the University.

Requirements for the Ph.D. Degree

See also the general University Requirements for Advanced Degrees, page 51.

The departmental requirements for the Ph.D. degree are

- Passing a written examination on the fundamentals of algebra and real analysis, as covered in 110.403-404 and 110.405-406.
- A reading knowledge of French, German, or Russian, to be demonstrated by passing an examination given in the Department of Mathematics.
- Passing special qualifying examinations in three of the nine basic graduate courses selected in accordance with departmental rules.
- Some teaching of mathematics, usually at the undergraduate level, under the supervision of a faculty member.
- A written dissertation based upon independent research.
- The final Graduate Board oral examination, which is the dissertation defense.

J. Hopkins U. 1995-96

Financial Aid

Most students admitted to the Ph.D. program receive teaching assistantships and full tuition fellowships. Exceptional applicants are considered for one of the University's George E. Owen Fellowships, which carry no required duties the first year.

William Kelso Morrill Award

The William Kelso Morrill Award for excellence in the teaching of mathematics is awarded every spring to the graduate student who best exemplifies the traits of Kelso Morrill: a love of mathematics, a love of teaching, and a concern for students.

Undergraduate Courses

C

Any course presented as a prerequisite must have been completed with a grade of C- or better.

110.105 (Q) Introduction to Calculus
This course starts from scratch and provides students with all the background necessary for the study of calculus. It includes a review of algebra, trigonometry, exponential and logarithmic functions, coordinates and graphs. Each of these tools will be introduced in its cultural and historical context. The concept of the rate of change of a function will be introduced. Not open to students who have studied calculus in high school.
4 credits fall

110.106-107 (Q) Calculus I, II (Biological and Social Sciences)
Differential and integral calculus. Includes analytic geometry, functions, limits, integrals and derivatives, Taylor's theorem and applications, infinite series, complex numbers, introduction to differential equations. Some applications to the biological and social sciences will be discussed. Each half of the course is offered both terms.
4 credits fall, spring

110.108-109 (Q) Calculus I, II (Physical Sciences and Engineering)
Differential and integral calculus. Includes analytic geometry, functions, limits, integrals and derivatives, Taylor's theorem and applications, infinite series, complex numbers, introduction to differential equations. Some applications to the physical sciences and engineering will be discussed, and the courses are designed to meet the needs of students in these disciplines. The first half is offered fall term; the second half, both terms.
4 credits fall, spring

110.116-117 Honors Supplement to Calculus I, II
All the work is done in class. Students work in groups on problems which are more difficult than the standard homework and exam problems. The course is aimed at high-ability students who come from intellectually isolated backgrounds such as rural communities or weak high schools. Corequisites: 110.106-107 or 110.108-109.

110.120 (Q) From Ancient Accounting to Modern Mathematics
Primarily designed for non-science majors. Basic concepts of mathematics and their cultural, historical context. Prerequisites: high school algebra and geometry.
3 credits

110.201 (Q) Linear Algebra
Vector spaces, matrices, and linear transformations. Solutions of systems of linear equations. Eigenvalues, eigenvectors, and diagonalization of matrices. Applications to differential equations. Prerequisite: Calculus I. Offered both terms.
4 credits fall, spring

= semesters T

110.202 (Q) Calculus III (Calculus of Several Variables)
Calculus of functions of more than one variable: partial derivatives, Taylor's theorem, power series; multiple integrals, line and surface integrals; an introduction to vector analysis. Prerequisite: Calculus II. Offered both terms.
4 credits fall, spring

110.204 (Q) Elementary Number Theory
The student is provided with many historical examples of topics each of which serves as an illustration of and provides a background for many years of current research in number theory. This course also provides the student with concrete examples of general abstract concepts studied in 110.403-404. Primes and prime factorization, congruences, Euler's function, quadratic reciprocity, primitive roots, solutions to polynomial congruences (Chevalley's theorem), Diophantine equations including the Pythagorean and Pell equations, Gaussian integers, Dirichlet's theorem on primes. Prerequisite: a good high school background including one year of calculus.
4 credits spring

J. Hopkins 1995-96 U.

Morrill Award
lso Morrill Award for excellence of mathematics is awarded every raduate student who best exemof Kelso Morrill: a love of mathof teaching, and a concern for

ackgrounds such as rural commuh schools. Corequisites: 110.106.

Ancient Accounting to Modern

for non-science majors. Basic con-s and their cultural, historical con-nigh school algebra and geometry.

Algebra
ices, and linear transformations. of linear equations. Eigenvalues, agonalization of matrices. Appliial equations. Prerequisite: Calh terms.
ng

s III (Calculus of Several

s of more than one variable: par-r's theorem, power series; mul-e and surface integrals; an or analysis. Prerequisite: Calcuerms.
ıg

ary Number Theory
led with many historical exam-which serves as an illustration kground for many years of cur-er theory. This course also pro-concrete examples of general ied in 110.403-404. Primes and ongruences, Euler's function, primitive roots, solutions to es (Chevalley's theorem), Diocluding the Pythagorean and an integers, Dirichlet's theoequisite: a good high school one year of calculus.

110.211-212 (Q) Honors Multivariable Calculus and Linear Algebra
This course includes the material in Calculus III and Linear Algebra with some additional applications and theory. Recommended for mathematically able students majoring in physical science, engineering, or mathematics. Prerequisite: B+ or better in Calculus II, or 5 on the Calculus BC AP Exam.
4 credits

110.251 (Q) Introduction to Modern Mathematics
This seminar course introduces the student to contemporary topics in applicable mathematics. The subject matter, which varies each year, includes topics such as chaos, fractals, and calculus of variations. Prerequisite: Calculus II.
3 credits

110.302 (Q,E) Differential Equations with Applications
This is an applied course in ordinary differential equations, which is primarily for students in the biological, physical and social sciences, and engineering. The purpose of the course is to familiarize the student with the techniques of solving ordinary differential equations. The specific subjects to be covered include first order differential equations, second order linear differential equations, applications to electric circuits, oscillation of solutions, power series solutions, systems of linear differential equations, autonomous systems, Laplace transforms and linear differential equations, mathematical models (e.g., in the sciences or economics). Prerequisite: Calculus II. Offered both terms.
4 credits spring, fall

110.403-404 (Q) Introduction to Advanced Algebra
The basic notions of modern algebra; fundamental theorems on groups, rings, fields, vector spaces, and modules; Galois theory; commutative rings; selected topics. Prerequisite: Linear Algebra.
4½ credits

110.405 (Q) Analysis I
This course is designed to give a firm grounding in the basic tools of analysis. It is recommended as preparation (but may not be a prerequisite) for other advanced analysis courses. Real and complex number systems, topology of metric spaces, limits, continuity, infinite sequences and series, differentiation, Riemann-Stieltjes integration. Prerequisites: Calculus III, Linear Algebra.
4½ credits fall

110.406 (Q) Analysis II
This course continues 110.405, with an emphasis on the fundamental notions of modern analysis. Sequences and series of functions, Fourier series, equicontinuity and the Arzela-Ascoli theorem, the Stone-Weierstrass theorem. Functions of several variables, the inverse and implicit function theorems, introduction to the Lebesgue integral. Prerequisite: 110.405.
4½ credits spring

110.407-408 (Q,N) Geometry and Relativity
Special relativity: Lorentz transformation, Minkowski spacetime, mass, energy-momentum, stress-energy tensor, electrodynamics. Introduction to differential geometry: theory of surfaces, first and second fundamental forms, curvature, Gauss's *theorema egregium*, differentiable manifolds, connections and covariant differentiation, geodesics, differential forms, Stokes theorem. Gravitation as a geometric theory: Lorentz metrics, Riemann curvature tensor, tidal forces and geodesic deviation, gravitational redshift, Einstein field equation, the Schwarzschild solution, perihelion precession, the deflection of light, black holes, cosmology. Prerequisites: Calculus II, Linear Algebra, General Physics II.
4½ credits

110.411 (Q) Methods of Complex Analysis
This course is an introduction to the theory of functions of one complex variable. Its emphasis is on techniques and applications, and it serves as a basis for more advanced courses. Functions of a complex variable and their derivatives; power series and Laurent expansions; Cauchy integral theorem and formula; calculus of residues and contour integrals; harmonic functions. Prerequisite: Calculus III.
4½ credits fall

110.412 (Q) Complex Function Theory
This is a continuation of 110.411. Dirichlet problem; normal families; conformal mapping, Riemann mapping theorem; Weierstrass products; elliptic functions and integrals; algebraic functions, Riemann surfaces. Prerequisite: 110.411 or permission of instructor. Recommended: 110.405. Offered alternate years.
4½ credits

110.413 (Q) Introduction to Topology
The basic concepts of point-set topology: topological spaces, connectedness, compactness, quotient spaces, metric spaces, function spaces. An introduction to algebraic topology: covering spaces, the fundamental group, and other topics as time permits. Prerequisite: Calculus III.
4½ credits fall

110.416 (Q) Ordinary Differential Equations
This course is more theoretical than 110.302. Solutions of standard types of ordinary differential equations,

J. Hopkins 1995-96

existence and uniqueness of solutions, differential inequalities, linear systems and linear equations, adjoint equations, linear equations in the complex plane (and regular singular points), classical equations, oscillations and second order equations, Sturm-Liouville boundary value problems, stability and asymptotic integration of linear and perturbed linear systems. Prerequisites: Calculus III, Linear Algebra. Recommended: 110.405.
4½ credits

110.417 (Q,E) Partial Differential Equations for Applications
Characteristics, classification of second order equations, well-posed problems, separation of variables and expansions of solutions. The wave equation: Cauchy problem, Poisson's solution, energy inequalities, domains of influence and dependence. Laplace's equation: Poisson's formula, maximum principles, Green's functions, potential theory, Dirichlet and Neumann problems, eigenvalue problems. The heat equation: fundamental solutions, maximum principles. Prerequisites: Calculus III, Linear Algebra. Recommended: 110.405.
4½ credits spring

110.420 (Q) Topology of Surfaces
An introduction to the basic concepts of topology as used in the study of surfaces. The fundamental group, singular homology, classification of compact surfaces. Morse theory on surfaces. Prerequisites: Linear Algebra, Calculus III. Recommended: 110.405.
4½ credits

110.421 (Q) Dynamical Systems and Chaos
An introduction to discrete and continuous dynamical systems. The course begins with a thorough study of linear systems with constant coefficients, and then goes on to non-linear systems. Topics include flows, equilibrium points, periodic orbits, Poincaré maps, stability. Conservative and dissipative systems, Hamiltonian systems, ergodic systems, chaos, and entropy. Discussion of examples such as Kroneker flow on a torus, Bernoulli shift, geodesic flow on a surface of revolution, and billiards. Prerequisites: Calculus III, Linear Algebra.
4½ credits

110.425 (Q) Algebraic Geometry
An introduction to the classical geometry of the solution sets of systems of algebraic equations. Ideals, modules, Noetherian rings, function fields, rational functions, local rings. The correspondence between algebra and geometry, Hilbert's Nullstellensatz. Projective space, Bézout's theorem on the intersection of curves, the Zariski topology, abstract algebraic varieties. Prerequisite: 110.403. Recommended: 110.404.
4½ credits

110.439 (Q) Introduction to Differential Geometry
Theory of curves and surfaces in Euclidean space: Frenet equations, fundamental forms, curvatures of a surface, theorems of Gauss and Mainardi-Codazzi, curves on a surface; introduction to tensor analysis and Riemannian geometry; theorema egregium; elementary global theorems. Prerequisites: Calculus III, Linear Algebra.
4½ credits

110.443 (Q,E) Fourier Analysis and Generalized Functions
An introduction to the Fourier transform and the construction of fundamental solutions of linear partial differential equations. Homogeneous distributions on the real line: the Dirac delta function, the Heaviside step function. Operations with distributions: convolution, differentiation, Fourier transform. Construction of fundamental solutions of the wave, heat, Laplace and Schrödinger equations. Singularities of fundamental solutions and their physical interpretations (e.g., wave fronts). Fourier analysis of singularities, oscillatory integrals, method of stationary phase. Prerequisites: Calculus III, Linear Algebra. Recommended: 110.405.
4½ credits

110.463 (Q) Elementary Algebraic Topology
An undergraduate introduction to 110.615-616. The basic geometric ideas will be emphasized, rather than the development of the abstract formalism. Simplicial complexes and mappings; an introduction to singular homology theory; combinatorial manifolds and Poincaré duality (the classical approach); elementary applications. Prerequisites: 110.413, 110.403.
4½ credits

110.502 (Q) Undergraduate Mathematics Seminar
Topics in modern mathematics. For juniors and seniors majoring in mathematics, physics, mathematical sciences (or by permission). Students will contribute by lecturing on topics of their choice. This course does not count toward the requirements for the major.
3 credits

110.599 Independent Study, Undergraduate

Cross-Listed

171.204 Theoretical Mechanics
4 credits spring