NEW YORK UNIVERSITY

THE UNDERGRADUATE PROGRAM
Mathematics Department

ACADEMIC YEAR 2009 – 2010
(Revised March 2010)

New York University
Mathematics Department
Warren Weaver Hall
251 Mercer Street
Room 626
New York, New York 10012
(212) 998-3005
Fax (212) 995-4121

This guide is meant to provide majors with a comprehensive picture of the offerings of the Mathematics Department. It contains information on courses, degree requirements, special programs, activities, prizes and awards. It supplements and repeats the information contained in the New York University Bulletin for the College of Arts and Sciences.

Table of Contents

1. Welcome To The Mathematics Department

The undergraduate division of the Department of Mathematics offers a wide variety of courses in pure and applied mathematics. The faculty are members of the University's Courant Institute of Mathematical Sciences, noted for its advanced training and research programs, which emphasize the applications of mathematics to technology and other branches of science.

In accordance with the Institute's philosophy, emphasizing the applications of mathematics to technology and other branches of science, the department participates in many interdisciplinary programs. Joint programs are available in mathematics and (1) computer sciences, (2) economics, (3) engineering and (4) minor in mathematics secondary school education. They lead to the B.A. in four years, with the exception of the engineering option, which leads to a joint B.S. degree from New York University and a B.E. degree from Stevens Institute of Technology. Additionally, an accelerated B.A. and M.S. degree from New York University in five years is offered. These programs are described in more detail below. Special courses in the mathematical aspects of finance, biology, and medicine are also available.

The department provides an honors program in (1) mathematics and (2) mathematics and computer science for outstanding students. Additionally, independent study courses are available for students with special interests. Qualified undergraduates are granted an opportunity to enroll in courses in the graduate division of the department. All students have access to the Institute's library which houses a large, up-to-date collection of books and technical journals in mathematics and computer science. The library is located on the twelfth floor of the Courant Institute.

2. Advising

Students intending to major in mathematics are urged to declare their major as early as possible as and no later than the beginning of their junior year. Students can declare their major by completing a major declaration form which is found on the undergraduate mathematics website: math.nyu.edu/degree/undergrad/. The department office is located in rooms 626 and 627 of Warren Weaver hall. All matters concerning undergraduate advisement in mathematics are handled there. When necessary, the department administrator will arrange appointments with the Director or Undergraduate Studies for advisement or academic counseling.

Each math major is assigned to a faculty advisor in the math department. All declared mathematics majors must have their proposed course schedules approved each term by his/her faculty advisor. The approved schedule must be signed by their faculty advisor and delivered to the math department administrative staff in room 626 or 627 for final clearance.

Students who believe that they are prepared to start their work in mathematics at an advanced level, or who feel qualified to enter a course without the formal prerequisites, should submit a transcript of prior college level coursework along with course descriptions to the Director of Undergraduate Studies. Students who have not taken college level coursework but feel that they are prepared to enroll in advanced courses should arrange to demonstrate proficiency by taking a

final examination in the prerequisite course for their desired course. Placement exams are offered each semester.

3. Degree Programs

Major in Mathematics. The requirements for a mathematics major are twelve courses numbered V63.0120 or higher. The only exception is Introduction to Abstract Algebra (V63.0246) which counts for the math minor *only*. The courses must include: 1) Calculus I, II, and III (V63.0121, V63.0122, V63.0123), 2) Linear Algebra (V63.0140), (3) Analysis I (V63.0325) and Algebra I (V63.0343). The rest of the 12 required courses must include one of the following: Analysis II, (V63.0326); Algebra II, (V63.0344), or Vector Analysis, (V63.0244). In addition, the student must maintain a 2.0 math GPA.

The sequence Honor Calculus I and II, (V63.0221, V63.0222) is counted as two courses; it covers material from Calculus II and III. Therefore, students enrolling in honors calculus are expected to have a solid background in Calculus I.

Any two computer science courses numbered V22.0101 or higher may be credited toward the 12 course requirement. Students who complete the Pre-medical or Pre-dental Program and who wish to major in mathematics may count any two of the following courses toward their 12 course math requirement: General Physics I and II (V85.0011 and 0012) or Physics I and II (V85.0100 and 0101). However, if these physics courses are used towards the mathematics major, the computer sciences courses will not apply towards the major. Courses taken under the pass/fail option cannot be counted toward the major. A grade of C or better is required in all courses used to fulfill the major requirement.

Joint Major in Mathematics and Computer Science. An interdisciplinary major offered jointly by the Department of Mathematics and Computer Science, provides the opportunity to study both computer science and relevant mathematics courses such as analysis, algebra, probability, and statistics. Eight computer science courses are required for the major. Please refer to the undergraduate computer science website for more information about the computer science courses: http://cs.nyu.edu/web/Academic/Undergrad/ The math requirements are: ten courses numbered V63.0120 or higher from the Mathematics Department, which must include Analysis I (V63.0325) and Algebra I (V63.0343); Intro to Abstract Algebra (V63.0246) cannot be counted if Algebra I (V63.0343) is applied toward the major. The remaining math courses must include one of the following: Analysis II (V63.0326), Algebra II (V63.0344), or Vector Analysis (V63.0244). A grade of C or better is required in all these courses. Please note that it is strongly suggested for students to take Analysis I (V63.0325) before enrolling in Algebra I (V63.0343).

Joint Major in Mathematics and Economics. An interdisciplinary major is offered for studies jointly by the Departments of Mathematics and Economics, providing the opportunity to study economics, computer science, and in mathematics, analysis, statistics, and operations research. The mathematics requirements are nine courses consisting of Calculus I, II, III, (V63.0121 - 123), Linear Algebra (V63.0140), Analysis I, II (V63.0325, 0326) plus three courses chosen

below

Vector Analysis (V63.0224)	Ordinary Differential Equations (V63.0262)
Probability & Statistics (V63.0235)	Partial Differential Equations (V63.0363)
Combinatorics (V63.0240)	Chaos & Dynamical Systems (V63.0264)
Function of Complex Variables (V63.0282)	Honors Linear Algebra (V63.0141)
Theory of Numbers (V63.0248)	Algebra I, II (V63.0343, 0344)
Mathematics of Finance (V63.0250)	Numerical Analysis (V63.0252)
Theory of Probability (V63.0233)	Mathematical Statistics (V63.0234)
Transformations & Geometries (V63.0270)	

The economics requirements are 9 courses in Economics including V31.0005, V31.0006, V31.0011, V31.0013, V31.0020, V31.0266, plus any three economics elective courses, at least two of which must be theory electives numbered V31.0300 to V31.0399. Please refer to the undergraduate economics website for more information about the economics courses: http://econ.as.nyu.edu/page/ugprog. Students in the joint mathematics/economics major may only take the theory sequence. A grade of C or better is required in all of these courses.

Mathematics Minor. The requirement for a mathematics minor is four courses in the department numbered V63.0120 or higher. Only two of these courses may apply simultaneously to the requirements for any other major. At most two mathematics courses in the minor may be transferred from other colleges. Courses taken under the pass/fail option are not counted toward the minor. A grade of C or better is required in all courses applied to the minor.

Joint Mathematics and Computer Science Minor. The requirements are the four courses V63.0121, V63.0122, V22.0101 and V22.0102. A grade of C or better is required. At most one mathematics course in the joint minor may be transferred from other colleges.

Advanced Mathematical Methods Minor. The Advanced Mathematical Methods Minor (for Stern undergraduates) provides students with mathematical tools to handle complex business problems. The requirements are V63.0123, V63.0140, C22.0014, and V63.0252. Students who have a more advanced mathematics background and have the equivalent of V63.0123or V63.0140 can substitute one of the following more advanced courses V63.262, V63.263, or C22.0015.

Mathematics Education Minor for Math Majors. The Mathematics Education Minor (for Mathematics Majors) enables you to complete coursework as an undergraduate in CAS that will reduce the number of credits required of a Steinhardt School of Education M.A. degree in Teachers of Mathematics, Grades 7-12 that will fulfill the requirements for Initial teacher certification. The master's degree will require 30 credits including student teaching internships beyond the bachelor's degree.

Ideally you would want to declare the minor and begin taking these courses during your first semester of junior year. Please be advised that most of these courses require a fieldwork component consisting of classroom observation and participation. For course descriptions, please

see the current Steinhardt School of Education's Undergraduate Bulletin at www.steinhardt.nyu.edu/bulletin.

B.S. /B.E. Program in Engineering. The College of Arts and Science, in cooperation with Stevens Institute of Technology offers a joint B.S./B.E. program in engineering. Students in the program receive the B.S. degree in mathematics from New York University and the B.E. degree from Stevens Institute in either computer, electrical or mechanical engineering. The joint math/engineering students must complete the 12-course math requirement. Students are allowed to take Differential Equation, MA221; and/or Complex Variables, MA234 at Stevens Institute, which are equivalent to V63.0262 and V63.0282, respectively. Students are also allowed to substitute Computer Science I, II, V22.0101, 0102, or Physics I, II, V85.0091, 0093 for a maximum of two math classes. Further information is available from Joseph Hemmes, the coordinator of the B.S./B.E. program, in the College Advising Center, Silver Center, 100 Washington Square East, Room 905, (212) 998-3133.

B.A./M.S. Program in Mathematics. New York University has introduced a program that allows students to obtain a Mathematics Bachelor's and Master's degree in five years. The program is suited to students who have decided not to enter a Ph.D. program at this time but who would like to increase their skills before entering the job market. Qualifying students are accepted into a program toward the end of the sophomore year or during their junior year before they reach 96 credits. Students must earn a minimum of a 3.50 GPA in order to qualify for acceptance into the joint B.A. /M.A. For more information, please contact advisor Dr. Justin Lorts the CAS Advising Center at (212) 998-8521. During the last few undergraduate semesters students should accelerate by taking one quarter of their graduate courses during regular terms and/or during the summer.

4. Honors Program

The honors program is designed for students with a strong commitment to mathematics. It is recommended for students who intend to pursue graduate study in mathematics. The course requirements are: Analysis I, II (V63.0325, 0326) and Algebra I, II (V63.0343, 0344), both usually taken during the junior year; and Honors, I-II, (V63.0393, 0394), usually taken in the senior year. Under special circumstances, with the permission of the department, certain graduate courses may be substituted for Honors I-II. Potential honors students should register for Honors Calculus I, II, (V63.0221-0222). Students must also complete a senior research project. Students should register for two semesters of independent study (V63.0997, 0998) under faculty supervision. Students should seek approval of their research project from the Director of Undergraduate Studies. The research project can also be completed through the mathematics summer research program (S.U.R.E.). Students are required to present their research at the undergraduate research forum in the fall semester of their senior year. The requirements for admission into the honors program are: (1) maintain a grade point average of 3.65 or higher in the major sequence (including Honors requirements); (2) maintain a general grade point average of 3.65 or better, and (3) approval of the director of the honors program. Interested students can consult with the mathematics Honors Advisor, Professor Elie Hameiri at hameiri@cims.nyu.edu. For further general requirements, please see under College of Arts and

Sciences Honors and Awards.

Joint Honors in Mathematics and Computer Sciences This is an interdisciplinary major offered by the Department of Mathematics and the Department of Computer Sciences. The mathematics requirements are V63.0120, V63.0121, V63.0122, V63.0123, V63.0140, V63.0325, V63.0326, V63.0343, V63.344, V63.0393, V63.0394 (V63.0393 and V63.0394 may be substituted for two graduate classes with math faculty approval). The computer science requirements are V22.0101, V22.0102, V22.0201, V22.0202, V22.0310, V22.0421, V22.0453, and three computer science courses listed at the V22.0400 level. Four courses, numbered V22.0101 to V22.0499, must be completed with HONORS credit, one of which must be V22.0300-level or above. Students should complete a guided research, sponsored by either department and be presented at the Dean's Undergraduate Research Conference which takes places in late April. Students are expected to dedicate 10-20 hours per week toward their research.

To be graduated with Latin honors, a student must have completed at least 64 points in courses in the College with passing grades. All graded courses taken while enrolled in the College, or in other divisions of the University, will be used to compute the honors average. Pass grades are not counted, nor are grades received in courses at other institutions. The student must have a good record of conduct and maintain a minimum general average as follows: cum laude, 3.50; magna cum laude, 3.70; summa cum laude, 3.90.

5. Transfer Students

Transfer students who have taken mathematics courses at other colleges should consult the Director of Undergraduate Studies as soon as possible to determine proper placement. They should bring copies of their transcripts along with a catalog descriptions/syllabus of all mathematics courses taken elsewhere. Transfer courses that are to be counted toward major or optional minor requirements must be approved by the department. Official transcripts must also be sent to the University registrar's office.

To graduate with a major in mathematics, transfer students must complete at least 12 eligible mathematics courses, each with grade of C or better. At least half the courses comprising the major must be taken in the College of Arts and Science at New York University during two or more semesters. For the minor in mathematics, at least two of the four required mathematics courses must be taken in residence at the College of Arts and Science at New York University, and can not be applied towards major or minor requirements in other departments.

6. Courses Offered in Academic Year 2009 – 2010

FALL		SPRING	
Discrete Math	V63.0120	Discrete Math	V63.0120
Calculus I	V63.0121	Calculus I	V63.0121
Calculus II	V63.0122	Calculus II	V63.0122
Calculus III	V63.0123	Calculus III	V63.0123
Linear Algebra	V63.0140	Linear Algebra	V63.0140
Intensive Linear Algebra I	V63.0141	Intensive Linear Algebra II	V63.0142
Theory of Probability	V63.0233	Vector Analysis	V63.0224
Theory of Numbers	V63.0248	Mathematical Statistics	V63.0234
Mathematics of Finance	V63.0250	Probability & Statistics	V63.0235
Math in Medicine and Biology	V63.0255	Combinatorics	V63.0240
Ordinary Differential Equations	V63.0262	Intro to Abstract Algebra	V63.0246
Transformations and Geometry	V63.0270	Intro to Math Modeling	V63.0251
Analysis I	V63.0325	Numerical Analysis	V63.0252
Algebra I	V63.0343	Computers in Medicine and Biology	V63.0256
Topology	V63.0375	Ordinary Differential Equations	V63.0262
Special Topics I	V63.0393	Partial Differential Equations	V63.0263
Independent Study	V63.0997	Chaos and Dynamical Systems	V63.0264
		Functions of a Complex Variable	V63.0282
		Analysis I	V63.0325
		Analysis II	V63.0326
		Algebra I	V63.0343
		Algebra II	V63.0344
		Special Topics II	V63.0394
		Special Topics in Fourier Analysis	V63.0395
		Independent Study	V63.0998

NOTES:
• Combinatorics (V63.0240) is offered every spring.
• Transformations and Geometry is offered every fall.
• Special Topics (V63.0395, 96) Topics and prerequisites are announced and posted in advance.
• Honors (V63.0393, 94) Topics are announced and posted in advance.
• The math department rarely offers Logic courses due to low enrollment. However, if students wish to take a Logic course offered by the Philosophy Department, they should consult the Director of Undergraduate Studies to seek approval for the course to count towards the math major.

7. Suggested Course Programs

The programs shown below are suggestions only. Many students will take more mathematics electives than are listed in these programs.

A. Possible program for math majors:

YEAR	FALL	SPRING
First Year	V63.0121 (Calculus I)	V63.0122 (Calculus II)
Second Year	V63.0123 (Calculus III)	V63.0140 (Linear Algebra)
		Math Elective
Third Year	V63.0325 (Analysis I)	V63.0326 (Analysis II) or V63.0343 (Algebra I)
	Math Elective	Math Elective
Fourth Year	V63.0343 (Algebra I)	Math Elective
	Math Elective	V63.0326 (Analysis II) or (V63.0344) Algebra II

NOTE: By the end of the seventh semester students should complete Analysis I, Algebra I, and one or more proofs courses.

B. Possible program for math majors who intend to go into secondary school education:

YEAR	FALL	SPRING
First Year	V63.0121 (Calculus I)	V63.0122 (Calculus II)
Second Year	V63.0123 (Calculus III)	V63.0140 (Linear Algebra)
Third Year	V63.0233 (Probability)	Math Elective
	Math Elective	Math Elective
Fourth Year	V63.0270 (Transform & Geom.)	Math Elective
	V63.0325 (Analysis I)	Math Elective

Recommended electives are V63.0120 (Discrete Mathematics), V63.0255 (Mathematics in Medicine and Biology), V63.0248 (Theory of Numbers), V63.0264 (Chaos & Dynamical Systems), V63.0262 (Ordinary Differential Equations), and V63.0282 (Function of Complex Variables).

C. Possible Honors Program. (Especially recommended for students who intend to go to graduate school for advanced work in mathematics).

YEAR	FALL	SPRING
First Year	V63.0221 (Honor Cal. I)	V63.0222 (Honor Cal. II)
Second Year	V63.0140 (Linear Algebra)	V63.0262 (Ordinary Diff. Equations)
Third Year	V63.0325 (Analysis I)	V63.0326 (Analysis II)
	V63.0343 (Algebra I)	V63.0344 (Algebra II)
Fourth Year	V63.0393 (Honors I)	V63.0394 (Honors II)
	Elective	Elective

Students with advanced standing should begin their freshman year at the appropriate level.

Highly qualified students are encouraged to take graduate mathematics courses provided they satisfy the prerequisites and obtain permission from both undergraduate and graduate departmental advisors.

8. Activities

Mathematics Club. There is an active math club open to all students interested in the study of mathematics. An organizational meeting is held shortly after classes begin in the fall to plan for the coming academic year. Activities include talks by faculty and guest speakers on a variety of topics including mathematics and career opportunities as well as attending conferences. The club is under the supervision of Professor Adi Rangan.

William Lowell Putnam Competition. The mathematics Department participates in the annual William Lowell Putnam Competition, a mathematics competition open to all undergraduate mathematics students in the U.S.A. and Canada. Interested students should contact the department as early as possible in the school year since the contest takes place in early December. A series of preparation sessions is held under the supervision of math faculty.

Peer Mentor Program. The math department has an active peer mentor program for math majors. The program is designed to assist new math majors in making the transition to the math major and life at NYU. If you're interested in becoming a mentor or mentee please send an email to Jillian Kerlin at jillian@math.nyu.edu.

9. Awards

Prizes. Each year the Sidney Goldwater Roth Prize is presented to the graduating senior who has been of greatest service to the department and his or her fellow students, and who shows the greatest promise in mathematics.

Four awards, two senior and two junior, are awarded for excellence in mathematics and/or for service to the department and fellow students.

The Hollis Cooley Memorial Prize is awarded for excellence and exceptional promise in mathematics.

The Perley Lenwood Thorne Medal, endowed by the faculty to honor Professor Thorne at the time of his retirement in 1949, is awarded for outstanding scholarship in mathematics.

Scholarships and Grants. New York University sponsors and administers a wide variety of financial aid programs, including its own scholarship and grant funds and some New York State and Federal funds. For additional information, see the College of Arts and Science Bulletin.

10. Work Opportunities in the Mathematics Department

Tutoring. The department offers paid undergraduate tutoring positions for advanced mathematics majors. Tutors provide free tutoring for undergraduate students taking lower level mathematics courses. Preferred applicants have completed and received at least a B+ in Calculus I, II, III and Linear Algebra, and Analysis I. Interested students should complete an application in room 705 Warren Weaver Hall.

Grading. Paid grader positions are available for advanced mathematics majors. Students grade homework problems for undergraduate mathematics courses. Preferred applicants have completed and received at least a B in Calculus I, II, III, Linear Algebra, and Discrete Mathematics. Interested students should complete an application in room 705 Warren Weaver Hall.

11. Courses Descriptions

Listed below are descriptions of all mathematics courses that satisfy the major and minor requirements. Some of the courses are given only in the fall, others only in the spring, a few are given once every other year, and some only on request. However, any course may be scheduled if there is sufficient demand.

Discrete Mathematics V63.0120 (offered each term)
Prerequisite: Passing V63.0121 with a grade of C or better, or permission of the department. 4 points. A first course in discrete mathematics. Sets, algorithms, induction. Combinatorics. Graphs and trees. Combinatorial circuits. Logic and Boolean algebra.

Calculus Tracks: Two tracks are currently available: The standard track (V63.0121 - 0123) and the honors track (V63.0221 -0222). The honors track assumes that the student knows the material from Calculus I, as the track covers Calculus II and III along with Linear Algebra. The courses V63.0221 – 0222 are worth 5 credits each and count as the equivalent of three mathematics courses, as it will satisfy a student's Calculus and Linear Algebra requirements. The student, however, must still meet the indicated credit requirement associated with his or her major.

For more information about Honors Calculus please visit the Honors Calculus website:
http://math.nyu.edu/degree/undergrad/honors_calculus.html.

While it is possible in some circumstance to switch tracks, it is neither advised nor encouraged. Thus, a student who intends to take the full calculus sequence should be prepared to continue on the same track to complete the sequence. Hand calculators are optional in all sections.

Calculus I V63.0121 (offered each term)
Prerequisite: Passing Departmental placement exam, Advanced Placements scores: AB 4 or better or BC 3 or better, SAT math score of 750 or ACT math score of 34 or Algebra & Calculus (V63.0009) with a grade of C or better, or passing the calculus placement exam. 4 points. Derivatives, antiderivatives, and integrals of functions of one real variable. Trigonometric, inverse trigonometric, logarithmic and exponential functions. Applications, including graphing, maximizing and minimizing functions. Areas and volumes.

Calculus II V63.0122 (offered each term)
Prerequisite: Passing V63.0121 with a grade of C or better, or the equivalent. 4 points. Techniques of integration. Further applications. Plane analytic geometry. Polar coordinates and parametric equations. Infinite series, including power series.

Calculus III V63.0123 (offered each term).
Prerequisite: Passing V63.0122 with a grade of C or better, or the equivalent. 4 points. Functions of several optimization and variables. Vectors in the plane and space. Partial derivatives with applications, especially Lagrange multipliers. Double and triple integrals. Spherical and cylindrical coordinates. Surface and line integrals. Divergence, gradient and curl. Theorem of Gauss and Stokes.

Linear Algebra V63.0140 (offered each term)
Prerequisite: Passing V63.0121 with a grade of C or better, or the equivalent. 4 points. Systems of linear equations, Gaussian elimination, matrices, determinants, Cramer's rule. Vectors, vector spaces, basis and dimension, linear transformations. Eigenvalues, eigenvectors, and quadratic forms.

Honors Linear Algebra I V63.0141. Identical to G63.2110. (offered fall term) NOTE: The graduate course is offered in spring under a different name.
Prerequisite: A grade of B or better in V63.0325 and/or V63.0343 or the equivalent. 4 points. Linear spaces, subspaces, and quotient spaces; linear dependence and independence; basis and dimensions. Linear transformation and matrices; dual spaces and transposition. Solving linear equations. Theory of Determinants. Quadratic forms and their relation to local extrema of multivariable functions.

Honors Linear Algebra II V63.0142 Identical to G63.2120. (offered spring term)
Prerequisite: V63.0141. 4 points. Spectral theory, eigenvalues and eigenvectors; nilpotent operations and Jordan canonical form. Inner products orthogonality, theory of bilinear forms. Self-adjoint mappings, matrix inequalities, polar decomposition. Nomed linear spaces and the exponential map. Implicit function theorem and introduction to Lie groups.

Calculus for Biology and the Life Sciences I V63.0143. Identical to V23.0101 (offered fall term). Prerequisite: V63.0009. 4 points. Equivalent to V63.0121, this course is for calculus students who plan to enter the medical or life sciences. Examples and problems are drawn from a wide selection of topics in biology, including physiology, ecology, genetics, bioinformatics, probability, biostatistics, enzymology and neurophysiology.

Honors Calculus I, II V63.0221-0222 (offered fall and spring terms, respectively)
Honors Calculus I - *Accelerated Calculus with Linear Algebra I* (offered fall term)
Prerequisite: Placement exam or a score of 5 on the Advanced Placement Calculus BC exam. 5 points. This is the first semester to a year long course that will cover the core materials that are usually covered in Calculus II Calculus III and Linear Algebra. Knowledge of the material

covered in Calculus I such as Fundamental theorem of Calculus, Chain Rule and max min are assumed. Topics to be covered are: sequences and series, Taylor's theorem, Power series, vectors and vector valued functions, polar coordinates, complex numbers, functions of several variables, partial derivatives, linear functions, matrices, quadratic surfaces, determinals and inverses.

Honors Calculus II - *Accelerated Calculus with Linear Algebra II* (offered spring term)
Prerequisite: Honors Calculus I with a C or better. 5 points. This is the second semester to a year long course that will cover the core materials that are usually covered in Calculus II Calculus III and Linear Algebra. Knowledge of the material covered in Calculus I such as Fundamental theorem of Calculus, Chain Rule and max min are assumed. Topics to be covered are: sequences and series, Taylor's theorem, Power series, vectors and vector valued functions, polar coordinates, complex numbers, functions of several variables, partial derivatives, linear functions, matrices, quadratic surfaces, determinals and inverses.

Vector Analysis V63.0224 Identical to G63.1002. (offered spring term)
Prerequisite: V63.0325 with a grade of C or better. 4 points. Brief review of multivariate calculus: partial derivatives, chain rule, Riemann inetgral, change of variables, line integrals. Lagrange multipliers. Inverse and implicit function theorems and their applications. Introduction to calculus on manifolds: definition and examples of manifolds, tangent vectors and vector fields, differential forms, exterior derivative, line integrals and integration of forms. Gauss' and Stokes' theorems on manifolds.

Theory of Probability V63.0233 (offered fall term)
Prerequisite: V63.0123 with a grade of C or better and/or the equivalent. 4 points. An introduction to the mathematical treatment of random phenomena occurring in the natural, physical, and social sciences. Axioms of mathematical probability, combinatorial analysis, binomial distribution, Poisson and normal approximation, random variables and probability distributions, generating functions, Markov chains, applications.

Mathematical Statistics V63.0234 (offered spring term)
Prerequisite: V63.0233 with a grade of C or better and/or the equivalent. Not open to students who have taken V63.0235. 4 points. An introduction to the mathematical foundations and techniques of modern statistical analysis for the interpretation of data in the quantitative sciences. Mathematical theory of sampling; normal populations and distributions; chi-square, t, and F distributions; hypothesis testing; estimation; confidence intervals; sequential analysis; correlation, regression; analysis of variance. Applications to the sciences.

Probability and Statistics V63.0235 (offered spring term)
Prerequisite: V63.0122 with a grade of C or better and/or the equivalent. Not open to students who have taken V63.0233. 4 points. A combination of V63.0233 and V63.0234 at a more elementary level, so as to afford the student some acquaintance with both probability and statistics in a single term. In probability: mathematical treatment of chance; combinatorics; binomial, Poisson, and Gaussian distributions; law of large numbers and the normal approximation; application to coin-tossing, radioactive decay, etc. In statistics: sampling;

normal and other useful distributions; testing of hypotheses; confidence intervals; correlation and regression; applications to scientific, industrial, and financial data.

Combinatorics V63.0240 (offered spring of even year)
Prerequisite: V63.0122 with a grade of C or better and/or the equivalent. 4 points. Techniques for counting and enumeration including generating functions, the principle of inclusion and exclusion, and Polyacounting. Graph theory. Modern algorithms and data structures for graph-theoretic problems.

Introduction to Cryptography V63.0243 Identical to V22.0480 (offered spring term)
Prerequisite: V22.0310 with a grade of C or better or permission of the instructor. 4 points. An introduction to both the principles and practice of cryptography and its application to network security. Topics include: symmetric-key encryption (block ciphers, modes of operations, AES); message authentication (pseudorandom functions, CBC-MAC); public-key encryption (RSA, EIGamal); digital signatures (RSA, Fiat-Shamir); authentication applications (identification, zero-knowledge) and others time permitting.

Logic V63.0245 (offered in Philosophy department)
Prerequisite: V63.0122 with a grade of C or better and/or the equivalent. 4 points. Propositional calculus, quantification theory, properties of axiomatic systems, Henkin's theorem. Introduction to set theory, interpretations, models. Computability and its applications to the incompleteness theorem.

Abstract Algebra V63.0246 (offered spring term)
Prerequisite: V63.0122 and V63.0140 with a grade of C or better. 4 points. An introduction to the main concepts, constructs, and applications of modern algebra. Groups, transformation groups, Sylow theorems and structure theory; rings, polynomial rings and unique factorization; introduction to fields and Galois theory.

NOTES: This course does not count toward the math major because of its considerable overlap with the more intensive Algebra I, V63.0243, required as part of the majors program in Mathematics. It is, however, accepted toward the math minor, and is a strongly recommended course in the Steinhardt Math Ed major.

Theory of Numbers V63.0248 (offered fall term)
Prerequisite: V63.0122 with a grade of C or better and/or the equivalent. 4 points. Divisibility theory and prime numbers. Linear and quadratic congruences. The classical number-theoretic functions. Continued fractions. Diophantine equations. RSA cryptography algorithm.

Mathematics of Finance V63.0250 (offered fall term)
Prerequisite: V63.0123 and one of the followings V63.0233/V63.235/V31.0018/V31.0120 (Theory of Probability, Probability & Statistics, Statistics or Analytical Statistics) with a grade of C or better and/or the permission of the instructor. 4 points. Introduction to the mathematics of finance. Topics include: Linear programming with application. Interest rates and present value. Basic probability: random walks, central limit theorem, Brownian motion, lognormal model of

stock prices. Black-Scholes theory of options. Dynamic programming with application to portfolio optimization.

Introduction to Mathematical Modeling V63.0251 (offered spring term)
Prerequisites: V63.0123 with a grade of C or better or permission of the instructor. 4 points. Formulation and analysis of mathematical models. Mathematical tool include dimensional analysis, optimization, simulation, probability, and elementary differential equations. Applications to biology, sports, economics, and other areas of science. The necessary mathematical and scientific background will be developed as needed. Students will participate in formulating models as well as in analyzing them.

Numerical Analysis V63.0252 (offered spring term)
Prerequisites: V63.0123 and V63.0140 with a grade of C or better or permission of the instructor. 4 points. In numerical analysis one explores how mathematical problems can analyzed and solved with a computer. As such, numerical analysis has very broad applications in mathematics, physics, engineering, finance, and the life sciences. This course introduces the subject for mathematics majors. Theory and practical examples using Matlab are combined in the studying of topics ranging from simple root-finding procedures to differential equations and the finite element method.

Mathematics in Medicine and Biology V63.0255 Identical to G23.1501. (offered fall term)
Prerequisite: V63.0121 and V23.0011 or permission of the instructor. 4 points. Intended primarily for premedical students with interest and ability in mathematics. Topics of medical importance using mathematics as a tool: control of the heart, optimal principles in the lung, cell membranes, electrophysiology, countercurrent exchange in the kidney, acid-base balance, muscle, cardiac catheterization, computer diagnosis. Material from the physical sciences and mathematics is introduced as needed and developed within the course.

Computers in Medicine and Biology V63.0256 Identical to G23.1502 (offered spring term)
Prerequisites: V63.0255 or permission of the instructor. Familiarity with a programming language such as Pascal, FORTRAN, or BASIC is recommended. 4 points. Introduces the students of biology or mathematics to the use of the computer as a tool for modeling physiological phenomena. Each student constructs two computer models selected from the following list: circulation, gas exchange in the lung, control of cell volume, and the renal countercurrent mechanism. The student uses the models to conduct simulated physiological experiments.

Ordinary Differential Equations V63.0262 (offered each term)
Prerequisites: V63.0123 and V63.0140 with a grade of C or better or the equivalent. 4 points. First and second order equations. Series solutions. Laplace transforms. Introduction to partial differential equations and Fourier series.

Partial Differential Equations V63.0263 (offered spring term)
Prerequisite: V63.0262 with a grade of C or better or the equivalent. 4 points. Many laws of physics are formulated as partial differential equations. This course discusses the simplest

examples, such as waves, diffusion, gravity, and static electricity. Non-linear conservation laws and the theory of shock waves are discussed. Further applications to physics, chemistry, biology, and population dynamics.

Chaos and Dynamical Systems V63.0264 (offered fall term)
Prerequisite: V63.0122 and V63.0140 with a grade of C or better or the equivalent. 4 points. Topics to include fixed points of one dimensional maps, linear operators and linear approximations; stability and bifurcation; logistic maps, Cantor sets, fractal sets, symbolic dynamics, conjugacy of maps. Introduction to dynamics in two dimensions. Introduction for students with little preparation to the recent discovery that, in certain regimes, fully deterministic mechanics can produce chaotic behavior.

Transformations and Geometries V63.0270 (offered fall term)
Prerequisite: V63.0123 with a grade of C or better or the equivalent. 4 points. An axiomatic and algebraic study of Euclidean, non-Euclidean, affine, and conformal and projective geometries. Special attention to group theoretic methods and the use of complex variables.

Functions of Complex Variable V63.0282 (offered spring term)
Prerequisites: V63.0123 and V63.0140 plus one higher level course with the grade of C or better. 4 points. Complex numbers and complex functions. Differentiation and the Cauchy-Riemann equations. Cauchy's theorem and the Cauchy integral formula. Singularities, residues, and Laurent series. Fractional Linear transformations and conformal mapping. Analytic continuation. Applications to fluid flow etc.

Analysis I V63.0325 (offered each term)
Prerequisite: V63.0122, V63.0123 and V63.0140 or the equivalent. 4 points. The real number system. Convergence of sequences and series. Rigorous study of functions of one real variable: continuity, connectedness, compactness, metric spaces, power series, uniform convergence and continuity.

Analysis II V63.0326 (offered spring term)
Prerequisite: V63.0325 or permission of the department. 4 points. Functions of several variables. Limits and continuity. Partial derivatives. The implicit function theorem. Transformation of multiple integrals. The Riemann integral and its extensions.

Algebra I V63.0343 (offered each term)
Prerequisites: V63.0123 and V63.0140 with a grade of C or better and/or the equivalent. *It is strongly recommended to take V63.0325 before registering for this course.* 4 points. Groups, homomorphisms, automorphisms, permutation groups. Rings, ideals and quotient rings, Euclidean rings, polynomial rings.

Algebra II V63.0344 (offered spring term)
Prerequisite: V63.0343 with a grade of C or better. 4 points. Extension fields, roots of polynomials. Construction with straight-edge and compass. Elements of Galois theory.

Topology V63.0375 (offered fall term)
Prerequisite: V63.0325 or permission of the department. 4 points. Set-theoretic preliminaries. Metric spaces, topological spaces, compactness, connectedness, covering spaces, and homotopy groups.

Differential Geometry V63.0377 (offered spring upon request)
Prerequisite: V63.0326 or permission of the department. 4 points. The differential properties of curves and surfaces. Introduction to differential manifolds and Riemannian geometry.

Honors I-II V63.0393, 0394. Topic varies from year to year. In 2007-8 it is identical to G63.2450/G63.2460 (offered each term)
Prerequisite: Approval of the director of the honors program. 4 points each term. Complex numbers; analytic functions, Cauchy-Riemann equations; linear fractional transformations; construction and geometry of the elementary functions; Green's theorem, Cauchy's theorem; Jordan curve theorem, Cauchy's formula; Taylor's theorem, Laurent expansion; analytic continuation; isolated singularities, Liouville's theorem; Abel's convergence theorem and the Poisson integral formula.

Special Topics I –II V63.0395, 0396 (offered upon request)
Prerequisite: Permission of the department. 4 points each term. Covers topics not offered regularly; experimental courses and courses offered on student demand. Detailed course descriptions are available during preregistration.

Independent Study V63.0997, 0998 (offered each term)
Prerequisite: Permission of the department. 2 or 4 points each term. To register for this course a student must complete an application form for Independent Study and have the approval of a faculty sponsor and the Director of Undergraduate Studies.

12. Graduate Courses Open to Undergraduates

Qualified students may take the courses listed below in the Graduate School of Arts and Science provided they first obtain permission from both undergraduate and graduate departmental advisors. If these courses are offered toward fulfillment of the requirements for the baccalaureate degree, no advanced credit is allowed for them in the graduate school. These courses are all three credit courses.

Numerical Methods G63.2010, 2020
Linear Algebra G63.2111 (for students who have not taken G63.0142)
Scientific Computing G63.2043
Algebra G63.2130, 2140
Number Theory G63.2210, 2220
Topology G63.2310, 2320
Real Variables G63.2430, 2440

Ordinary Differential Equations G63.2470
Introduction to Applied mathematics G63.2701, 2702
Game Theory, Linear Programming G63.2731, 2742
Mathematical Topics in Biology G63.2859, 2851
Basic Probability G63.2911, 2912
Differential Geometry I-II G63.2350-2360

13. Departmental Faculty

Marco M. Avellaneda. Professor. Licenciado en Ciencias 1981, Buenos Aires; Ph.D. 1985, Minnesota. Research interests: applied mathematics, mathematical modeling in finance, probability.

Gerard Ben Arous. Professor. Ph.D. 1981, University of Paris. Research interests: probability theory, stochastic processes, partial differential equations.

Simeon M. Berman. Professor. B.A. 1956, City College; M.A. 1958, Ph.D. 1961, Columbia. Research interests: stochastic processes, probability theory, applications.

Fedor A. Bogomolov. Professor. Diploma 1970, Moscow University; Ph.D. 1974, Steklov Institute of Mathematics. Research interests: algebraic geometry and related problems in algebra, topology, number theory.

Oliver Bühler. Associate Professor. Ph.D. 1996, Cambridge University. Research interests: geophysical fluid dynamics, interactions between waves and vortices, acoustics, statistical mechanics.

David Cai. Professor. B.S. 1984, Peking University; M.S. 1989, Ph.D. 1994, Northwestern. Research interests: nonlinear stochastic behavior in physical and biological systems.

Sylvain E. Cappell. Professor. B.A. 1966, Columbia; Ph.D. 1969, Princeton. Research interests: algebraic and geometric topology, symplectic and algebraic geometry.

Sourav Chatterjee. Associate Professor. Ph.D. 2005, Stanford. Probability theory, stochastic processes, mathematical physics and theoretical statistics. Specific current interests: Stein's method, spin glasses, central limit theorems, random matrix theory.

Jeff Cheeger. Professor. B.A. 1964, Harvard College; M.S. 1966, Ph.D. 1967, Princeton. Research interests: differential geometry and its connections to analysis and topology.

Yu Chen. Associate Professor. B.S. 1982, Tsinghua University; M.S. 1988, Ph.D. 1991, Yale. Research interests: numerical scattering theory, ill-posed problems, scientific computing.

Percy A. Deift. Professor. B.S. 1967, M.S. 1970, Natal, Durban; M.S. 1971, Rhodes South Africa; Ph.D. 1976, Princeton. Research interests: spectral theory and inverse spectral theory,

integrable systems, Riemann-Hilbert problems.

Paul R. Garabedian. Professor. B.A. 1946, Brown; M.A. 1947, Ph.D. 1948, Harvard. Research interests: complex analysis, computational fluid dynamics, plasma physics.

Jonathan B. Goodman. Professor. B.S. 1977, Massachusetts Institute of Technology; Ph.D. 1982, Stanford. Research interests: fluid dynamics, computational physics, computational finance.

Leslie Greengard. Professor. B.A. 1979, Wesleyan; M.D. 1987, Ph.D. 1987, Yale. Research interests: applied and computational math, partial differential equations, computational chemistry, mathematical biology.

Frederick P. Greenleaf. Professor. B.S. 1955 Pennsylvania State; M.A. 1961, Ph.D. 1964, Yale. Research interests: noncommutative harmonic analysis, Lie groups and group representations, invariant partial differential operators.

Mikhael Gromov. Professor. Maitrise 1965, Doctorat 3e Cycle 1969, D.Sc. 1973, University of Leningrad. Research interests: Riemannian manifolds, symplectic manifolds, infinite groups, math models of biomolecular systems.

Sinan Gunturk. Associate Professor. B.S. 1996, Bogazici University; Ph.D. 2000, Princeton. Research interests: harmonic analysis, information theory, signal processing.

Eliezer Hameiri. Professor. B.A. 1970, M.A. 1972, Tel Aviv; Ph.D. 1976, New York. Research interests: applied mathematics, magnetohydrodynamics, plasma physics.

Alexander Hanhart. Clinical Assistant Professor. Topological and Geometric methods in Mathematical Physics, Scientific Computing.

Fengbo Hang. Associate Professor. B.S. 1993, Tsinghua University; M. S. 1996, Peking University; Ph.D. 2001, New York University. Research interests: Geometric analysis and nonlinear partial differential equations.

Helmut Hofer. Professor. Diplom 1979, Ph.D. 1981, University of Zurich. Research interests: symplectic geometry, dynamical systems, partial differential equations.

David Holland. Professor. B.S. 1984, B.A. 1993, M.S. 1986, Memorial University (Newfoundland); Ph.D. 1993, McGill. Research interests: ocean-ice studies, climate theory and modeling.

Richard Kleeman. Professor. B.S. 1980, Australian National University, Ph.D. 1986, Adelaide University. Research interests: climate dynamics, El Nino, predictability of weather and climate dynamical systems.

Bruce Kleiner Professor. Research interests: Geometric analysis, geometric group theory and geometric evolution equations.

Robert V. Kohn. Professor. A.B. 1974, Harvard; M.S. 1975, Warwick (England); Ph.D. 1979, Princeton. Research interests: nonlinear partial differential equations, materials science, mathematical finance.

Denis Kosygin. Clinical Assistant Professor. Research interests: Probability Theory, Dynamical Systems, Mathematical Physics.

Matthew Leingang. Clinical Associate Professor. Ph.D. 2000, Harvard. Research interests: Mathematics Education, Web Pedagogies, differential geometry.

Xue-Mei Li. (Arriving January 2009). Visiting Associate Professor of Mathematics. Research interests: Probability Theory, Stochastic Differential Equations on Geometric Spaces, Analysis on Path Spaces, Infinite Dimensional Geometric Analysis, Geometric Properties of Stochastic Flows.

Fang-Hua Lin. Professor. B.S. 1981, Zhejing; Ph.D. 1985, Minnesota. Research interests: partial differential equations, geometric measure theory.

Andrew Majda. Professor. B.S. 1970, M.S. 1971, Ph.D. 1973, Stanford. Research interests: modern applied mathematics, atmosphere/ocean science, partial differential equations.

Nader Masmoudi. Professor. Ph.D. 1999, University of Paris Dauphine. Research interests: nonlinear parallel differential equations.

Henry P. McKean. Professor. B.A. 1952, Dartmouth; Ph.D. 1955, Princeton. Research interests: probability, partial differential equations, complex function theory.

David W. McLaughlin. Professor. B.S. 1966, Creighton. M. S. 1969, Ph.D. 1971, Indiana University. Research interests: applied mathematics, nonlinear wave equations, visual neural science.

Assaf Naor. Associate Professor. B. S. 1996, M.S. 1998, Ph.D. 2002, Hebrew University. Research interests: analysis, probability; applications to combinatorics, mathematical physics, and theoretical computer science.

Charles M. Newman. Professor. B.S. 1966, Massachusetts Institute of Technology; M.A. 1968, Ph.D. 1971, Princeton. Research interests: probability theory, statistical physics, stochastic models.

Albert B. J. Novikoff. Professor. B.A. 1946, Brown; Ph.D. 1954, Stanford. Research interests: analysis, history of mathematics, pedagogy.

Olivier Pauluis. Assistant Professor. B.S./M.S. 1995, Université Catholique de Louvain; Ph.D. 2000, Princeton. Research interests: climate and the general circulation of the atmosphere, moist convection, tropical meteorology, numerical modeling.

Jerome K. Percus. Professor. B.S. 1947, M.A. 1948, Ph.D. 1954, Columbia. Research interests: chemical physics, mathematical biology.

Charles S. Peskin. Professor. B.A. 1968, Harvard; Ph.D. 1972, Yeshiva. Research interests: applications of mathematics and computing to problems in medicine and biology, cardiac fluid dynamics, molecular machinery within biological cells, mathematical/computational neuroscience.

Aaditya Rangan. Assistant Professor. B.A. 1999, Dartmouth; Ph.D. 2003 California (Berkley) Research interests: Large-scale scientific modeling of physical biological, and neurobiological phenomena.

Weiqing Ren. Associate Professor. B.S., 1994, University of Nanjing; Ph.D. 2002, NYU. Research interests: applied mathematics, scientific computing, multiscale modeling of fluids.

John Rinzel. Professor. B.S. 1967, University of Florida; M.S. 1968, Ph.D. 1973, New York. Research interests: computational neuroscience, nonlinear dynamics of neurons and neural circuits, sensory processing.

Sylvia Serfaty. Professor. M.S. 1995, Ecole Normale Superieure; Ph.D. 1999, University of Paris-Orsay. Research interests: partial differential equations, nonlinear analysis applied to physics.

Jalal M. I. Shatah. Professor. B.S. 1979, Texas (Austin); Ph.D. 1983, Brown. Research interests: partial differential equations, analysis.

Scott Sheffield. Associate Professor. A. B., A. M. 1998 Harvard; Ph.D. 2003 Stanford. Research interests: Probability and mathematical physics.

Michael J. Shelley. Professor. B.A. 1981, Colorado; M.S. 1984, Ph.D. 1985, Arizona. Research interests: applied math and modeling, visual neuroscience, fluid dynamics, computational physics and neuroscience.

K. Shafer Smith. Associate Professor. B.S. 1992, Indiana; Ph.D. 1999, UC Santa Cruz. Research interests: geophysical fluid dynamics, physical oceanography and climate.

Joel H. Spencer. Professor. B.S. 1965, Massachusetts Institute of Technology; Ph.D. 1970, Harvard. Research interests: discrete mathematics, theoretical computer science.

Daniel Stein. Professor. Sc.B. 1975, Brown University; M.A. 1977, Ph.D. 1979, Princeton University. Research interests: theoretical condensed matter physics, statistical mechanics, and

mathematical physics.

Esteban G. Tabak. Professor. Bach. 1988, University of Buenos Aires; Ph.D. 1992, Massachusetts Institute of Technology. Research interests: dynamics of the atmosphere and ocean, energy transfer in systems with many degrees of freedom.

Daniel A. Tranchina. Professor. B.A. 1975, SUNY (Binghamton); Ph.D. 1981, Rockefeller. Research interests: mathematical modeling in neuroscience.

Yuri Tschinkel. Professor. M.A. 1990, Moscow State University; Ph.D. 1992, Massachusetts Institute of Technology. Research interests: algebraic geometry, number theory, automorphic forms.
Kiryl Tsishchanka. Clinical Assistant Professor. Research interests: number theory.

Mark Tygert. Assistant Professor of Mathematics. Computational science and engineering, particularly numerical analysis.

Eric Vanden-Eijnden. Professor. B. S., M. S., 1992, Ph.D. 1997, Universite Libre de Bruxelles. Research interests: stochastic partial differential equations, statistical mechanics, turbulence theory.

S. R. Srinivasa Varadhan. Professor. B.S. 1959, M.A. 1960, Madras; Ph.D. 1963, Indian Statistical Institute. Research interests: probability theory, stochastic processes, partial differential equations.

Harold Weitzner. Professor. B.A. 1954, California; M.A. 1955, Ph.D. 1958, Harvard. Research interests: plasma physics, fluid dynamics, differential equations.

Olof B. Widlund. Professor. M.S. 1960, Ph.D. 1964, Royal Institute of Technology (Stockholm); D. Phil. 1966, Upsala. Research interests: numerical analysis, partial differential equations, parallel computing.

Lai-Sang Young. Professor. B.A. 1973, Wisconsin; M.A. 1976, Ph.D. 1978, California (Berkeley). Research interests: dynamical systems and ergodic theory.

Jun Zhang. Associate Professor. B.S. 1985, Wuhan University (China); Ph.D. 1994, University of Copenhagen. Research interests: fluid dynamics, biophysics, complex systems.