Handbook for
Mathematics Majors and Minors

2005 – 2006

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Handbook for Mathematics Majors and Minors

This handbook is directed primarily to mathematics majors and minors; its purpose is to provide useful advice and information so that students can get the most out of their studies in mathematics. This handbook should also be a useful resource for potential majors and minors and for university personnel who advise students. The information and policies set forth here are intended to supplement material contained in the *Bulletin of Duke University 2005–2006: Undergraduate Instruction*. Much information about the Mathematics Department, including this handbook, can be found at the web site, `http://www.math.duke.edu`, especially Information for Undergraduates.

The *Duke University Handbook for Mathematics Majors and Minors* is published annually by the Department of Mathematics, Duke University, Box 90320, Durham, NC 27708-0320, USA.

Copies of this handbook are available from Georgia Barnes (121A Physics Building, (919) 660-2801, `barnes@math.duke.edu`). It is also available at the department web site (`http://www.math.duke.edu`).

Corrections to this handbook, proposed additions or revisions, and questions not addressed herein should be directed to William Allard (024B Physics Building, (919) 660-2800, `dus@math.duke.edu`); electronic mail is preferred.

The information in this handbook applies to the academic year 2005-2006 and is accurate and current, to the best or our knowledge, as of August 2005. Inasmuch as changes may be necessary from time to time, the information contained herein is not binding on Duke University or the Duke University Department of Mathematics, and should not be construed as constituting a contract between Duke University and any individual. The University reserves the right to change programs of study, academic requirements, personnel assignments, the announced University calendar, and other matters described in this handbook without prior notice, in accordance with established procedures.

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William Allard
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September 26, 2005

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Courses and Course Selection

Course Numbering and Scheduling

The numbering scheme of upper level courses in the Department of Mathematics (which differs somewhat from that of other departments) is given below.

Numbers	
<200	Undergraduate courses.
200–206	Primarily undergraduate courses. These courses are recommended for students planning graduate study in mathematics.
211–239	Graduate courses for students in mathematics and related disciplines. These courses are also appropriate for advanced undergraduates, especially those interested in the applications of mathematics.
>239	Primarily graduate courses for students in mathematics. However, sufficiently prepared undergraduates are encouraged to enroll. Standard first-year graduate courses in pure mathematics include 241, 245, and 251.

The department intends to offer all of the courses listed in this handbook regularly, assuming sufficient demand and staff. The courses that are offered every year are usually offered according to the schedule below.

Fall and spring:	104, 107, 108, 111, 114, 121, 131, 135, 139
Fall:	124, 181, 187, 200, 203, 215
Spring:	104X, 126, 133, 136, 188, 201, 204, 206
Fall or spring:	seminars from among 123S, 128S, 132S, 160S, 196S, 197S

Rapid Reference Course List

104. Linear Algebra and Applications
104C. Linear Algebra with Scientific Computation
104X. Honors Linear Algebra
107. Linear Algebra and Differential Equations
108. Ordinary and Partial Differential Equations
111. Applied Mathematical Analysis I
114. Applied Mathematical Analysis II
121. Introduction to Abstract Algebra
123S. Geometry
124. Combinatorics
126. Introduction to Linear Programming and Game Theory
128S. Number Theory
131. Elementary Differential Equations
132S. Nonlinear Ordinary Differential Equations
133. Introduction to Partial Differential Equations
135. Probability (C-L: STA 104)
136. Statistics (C-L: STA 114)
139. Advanced Calculus I
149S. Problem Solving Seminar
160S. Mathematical Numerical Analysis
181. Complex Analysis
187. Introduction to Mathematical Logic
188. Logic and its Applications (C-L: PHIL 150 and CPS 148)
191, 192, 193, 194. Independent Study
196S. Seminar in Mathematical Modeling
197S. Seminar in Mathematics
199S. Honors Seminar
200. Introduction to Algebraic Structures I
201. Introduction to Algebraic Structures II
203. Basic Analysis I
204. Basic Analysis II
205. Topology
206. Differential Geometry
215. Mathematical Finance
216. Applied Stochastic Processes
217. Introduction to Linear Models (C-L: STA 244)
221. Numerical Analysis (C-L: CPS 250)
224. Scientific Computing I
225. Scientific Computing II
228. Mathematical Fluid Dynamics
229. Mathematical Modeling
233. Asymptotic and Perturbation Methods

Requirements for the Mathematics Major

The Department of Mathematics offers both the Bachelor of Arts (A.B.) degree and the Bachelor of Science (B.S.) degree. Students who plan to attend graduate school in mathematics or the sciences should consider working toward the B.S. degree, which requires at least eight courses in mathematics numbered above 104. The A.B. degree requires at least seven courses numbered above 104. The specific requirements for the A.B. and B.S. degrees are listed below.

Bachelor of Arts Degree (A.B.)

Prerequisites: Mathematics 31 or 31L or an equivalent course (Advanced Placement course credit allowed); Mathematics 32 or 32L or 41 or an equivalent course (Advanced Placement course credit allowed); Mathematics 103 and Mathematics 104 or equivalent courses. (Many upper level mathematics courses assume programming experience at the level of Computer Science 4.[†])

Major Requirements: Seven courses in mathematics numbered above 104 including Math 121 or 200, and Math 139 or 203.

Bachelor of Science Degree (B.S.)

Prerequisites: Mathematics 31 or 31L or an equivalent course (Advanced Placement course credit allowed); Mathematics 32 or 32L or 41 or an equivalent course (Advanced Placement course credit allowed); Mathematics 103 and 104 or equivalent courses. (Many upper level mathematics courses assume programming experience at the level of Computer Science 4.[†])

Major Requirements: Eight courses in mathematics numbered above 104 including Mathematics 121 or 200; Mathematics 139 or 203; and one of Mathematics 136, 181, 201, 204, 205, 206, 215, 216. Also, one of Physics 41L, 51L, 53L, 61L and one of Physics 42L, 52L, 54L, 62L.

Requirements for the Mathematics Minor

Prerequisites: Mathematics 103 or the equivalent. (Many upper-level courses assume programming experience at the level of Computer Science 4.[†])

Minor requirements: Five courses in mathematics numbered above 103 to include at least one course (or its equivalent) selected from the following: Mathematics 121, 132S, 135, 139, 160S, 181, 187, or any 200-level course.

[†] Students without computer experience are encouraged to take Computer Science 6; students with considerable programming experience are encouraged to take Computer Science 100E.

Course Descriptions

Given below are catalog descriptions of the mathematics courses numbered 104 and above that are most often taken by undergraduates. Comments are in italics. For a complete listing of courses see the undergraduate *Bulletin*. Also, please note that all courses listed below satisfy the **M**, **QID** and **QS** requirements for curriculum 2000. In addition, MTH 139 (Advanced Calculus), MTH 203 (Basic Analysis I) and MTH 196S (Seminar in Mathematical Modeling) satisfy the **W** (writing) requirement. All seminars satisfy the **R** (research) requirement; these are: 123S, 128S, 132S, 160S, 196S, 197S, 198S, 199S.

104. Linear Algebra and Applications. Systems of linear equations and elementary row operations, Euclidean n-space and subspaces, linear transformations and matrix representations, Gram-Schmidt orthogonalization process, determinants, eigenvectors and eigenvalues; applications. Not open to students who have had Mathematics 107. Prerequisite: Mathematics 32, 32L, or 41.

Note: Math 104 is a prerequisite for the mathematics major. Potential majors should take Math 104 or 104C, rather than Math 107 or 111 (see below), for an introduction to linear algebra.

104C. Linear Algebra with Scientific Computation. Introductory linear algebra developed from the perspective of computational algorithms. Similar to Mathematics 104, but emphasizes matrix factorizations and includes the programming of basic algorithms and the use of software packages. Three lectures and one computer laboratory meeting per week. Not open to students who have had Mathematics 107. Prerequisite: Mathematics 32, 32L, or 41.

107. Linear Algebra and Differential Equations. Systems of linear equations, matrix operations, vector spaces, linear transformations, orthogonality, determinants, eigenvalues and eigenvectors, diagonalization, linear differential equations and systems with constant coefficients and applications, computer simulations. Intended primarily for engineering and science students. Prerequisite: Mathematics 103. Not open to students who have had Mathematics 104 or 111.

Note: Math 107 is not recommended for mathematics majors. Mathematics majors should take Math 104 (Linear Algebra and Applications), and then Math 131 for a first course in differential equations, rather than Math 107.

108. Ordinary and Partial Differential Equations. First and second ordinary differential equations with applications, Laplace transforms, series solutions and qualitative behavior, Fourier series, partial differential equations, boundary value problems, Sturm-Liouville theory. Intended primarily for engineering and science students. Prerequisite: Mathematics 107. Not open to students who have had either Mathematics 111 or 131.

111. Applied Mathematical Analysis I. First and second order differential equations with applications; matrices, eigenvalues, and eigenvectors; linear systems of differential equations; Fourier series and applications to partial differential equations. Intended primarily for engineering and science students with emphasis on problem solving. Students taking Math 104, especially mathematics majors, are urged to take Math 131 instead. Not open to students who have had Math 107, 108 or 131. Prerequisite: Mathematics 103.

Note: Math 111 is not recommended for mathematics majors or students taking Math 104. Mathematics majors should take Math 104 (Linear Algebra and Applications), and then Math 131 for a first course in differential equations, rather than Math 111.

114. Applied Mathematical Analysis II. Boundary value problems, complex variables, Cauchy's theorem, residues, Fourier transform, applications to partial differential equations. Not open to students who have had Mathematics 133 or 181. Prerequisites: Mathematics 111 or 131, or 103 or consent of instructor.

121. Introduction to Abstract Algebra. Groups, rings, and fields. Students intending to take a year of abstract algebra should take Mathematics 200-201. Not open to students who have had Mathematics 200. Prerequisites: Mathematics 104 or 111.

123S. Geometry. Euclidean geometry, inversive and projective geometries, topology (Möbius strips, Klein bottle, projective space), and non-Euclidean geometries in two and three dimensions; contributions of Euclid, Gauss, Lobachevsky, Bolyai, Riemann, and Hilbert. Research project and paper required. Prerequisite: Mathematics 32, 32L, or 41 or consent of instructor.

124. Combinatorics. Permutations and combinations, generating functions, recurrence relations; topics in enumeration theory, including the Principle of Inclusion-Exclusion and Polya Theory; topics in graph theory, including trees, circuits, and matrix representations; applications. Prerequisites: Mathematics 104 or consent of instructor.

126. Introduction to Linear Programming and Game Theory. Fundamental properties of linear programs; linear inequalities and convex sets; primal simplex method, duality; integer programming; two-person and matrix games. Prerequisite: Mathematics 104.

128S. Number Theory. Divisibility properties of integers, prime numbers, congruences, quadratic reciprocity, number-theoretic functions, simple continued fractions, rational approximations; contributions of Fermat, Euler, and Gauss. Prerequisite: Mathematics 32, 32L, or 41, or consent of instructor.

131. Elementary Differential Equations. First and second order differential equations with applications; linear systems of differential equations; Fourier series and applications to partial differential equations. Additional topics may include stability, nonlinear systems, bifurcations, or numerical methods. Not open to students who have had Mathematics 108 or 111. Prerequisite: Mathematics 103; corequisite: Mathematics 104.

132S. Nonlinear Ordinary Differential Equations. Theory and applications of systems of nonlinear ordinary differential equations. Topics may include qualitative behavior, numerical experiments, oscillations, bifurcations, deterministic chaos, fractal dimension of attracting sets, delay differential equations, and applications to the biological and physical sciences. Research project and paper required. Prerequisite: Mathematics 111 or 131 or consent of instructor.

133. Introduction to Partial Differential Equations. Heat, wave, and potential equations: scientific context, derivation, techniques of solution, and qualitative properties. Topics to include Fourier series and transforms, eigenvalue problems, maximum principles, Green's functions, and characteristics. Intended primarily for mathematics majors and those with similar backgrounds. Not open to students who have had Mathematics 114. Prerequisite: Mathematics 111 or 131 or consent of instructor.

135. Probability. Probability models, random variables with discrete and continuous distributions. Independence, joint distributions, conditional distributions. Expectations, functions of random variables, central limit theorem. Prerequisite: Mathematics 103. C-L: Statistics 104.

136. Statistics. An introduction to the concepts, theory, and application of statistical inference, including the structure of statistical problems, probability modeling, data analysis and statistical computing, and linear regression. Inference from the viewpoint of Bayesian statistics, with some discussion of sampling theory methods and comparative inference. Applications to problems in various fields. Prerequisites: Mathematics 104 and 135. C-L: Statistics 114.

139. Advanced Calculus I. Algebraic and topological structure of the real number system; rigorous development of one-variable calculus including continuous, differentiable, and Riemann integrable functions and the Fundamental Theorem of Calculus; uniform convergence of a sequence of functions; contributions of Newton, Leibniz, Cauchy, Riemann, and Weierstrass. Not open to students who have had Mathematics 203. Prerequisite: Mathematics 103.

149S. Problem Solving Seminar. Techniques for attacking and solving challenging mathematical problems and writing mathematical proofs. Course may be repeated. Consent of instructor required. Half course.

150. Topics in Mathematics from a Historical Perspective. Content of course determined by instructor. Prerequisite: Mathematics 139 or 203 or consent of instructor.

160S. Mathematical Numerical Analysis. Development of numerical techniques for accurate, efficient solution of problems in science, engineering and mathematics through the use of computers. Linear systems, nonlinear equations, optimization, numerical integration, differential equations, simulation of dynamical systems, error analysis. Prerequisite: Mathematics 103 and 104 and basic knowledge of a programming language (at the level of COMPSCI 6), or consent of instructor. Not open to students who have had Computer Science 150 or 250.

181. Complex Analysis. Complex numbers, analytic functions, complex integration, Taylor and Laurent series, theory of residues, argument and maximum principles, conformal mapping. Not open to students who have had Mathematics 114. Prerequisite: Mathematics 103, 104.

187. Introduction to Mathematical Logic. Propositional calculus; predicate calculus. Gödel completeness theorem, applications to formal number theory, incompleteness theorem, additional topics in proof theory or computability; contributions of Aristotle, Boole, Frege, Hilbert, and Gödel. Prerequisites: Mathematics 103 and 104 or Philosophy 103.

188. Logic and its Applications. Topics in proof theory, model theory, and recursion theory; applications to computer science, formal linguistics, mathematics, and philosophy. Usually taught jointly by faculty members from the departments of computer science, mathematics, and philosophy. Prerequisite: a course in logic or permission of one of the instructors. C-L: Computer Science 148; Philosophy 150.

191. Independent Study. Directed reading in a field of special interest, under the supervision of a faculty member, resulting in a substantive paper or written report containing significant analysis and interpretation of a previously approved topic. Consent of instructor and director of undergraduate studies. (*See additional information on page 15 of this Handbook.*)

192. Research Independent Study. Individual research in a field of special interest under the supervision of a faculty member, the central goal of which is a substantive paper or written report containing significant analysis and interpretation of a previously approved topic. Consent of instructor and director of undergraduate studies required. (*See additional information on page 15 of this Handbook.*)

193. Independent Study. Same as 191, but for seniors.

194. Research Independent Study. Same as 192, but for seniors.

196S. Seminar in Mathematical Modeling. Introduction to techniques used in the construction, analysis, and evaluation of mathematical models. Individual modeling projects in biology, chemistry, economics, engineering, medicine, or physics. Prerequisite: Mathematics 111 or 131 or consent of instructor.

197S. Seminar in Mathematics. Intended primarily for juniors and seniors majoring in mathematics. Required research project culminating in written report. Prerequisites: Mathematics 103 and 104.

200. Introduction to Algebraic Structures I. Groups: symmetry, normal subgroups, quotient groups, group actions. Rings: homomorphisms, ideals, principal ideal domains, the Euclidean algorithm, unique factorization. Not open to students who have had Mathematics 121. Prerequisite: Mathematics 104 or equivalent.

201. Introduction to Algebraic Structures II. Fields and field extensions, modules over rings, further topics in groups, rings, fields, and their applications. Prerequisite: Mathematics 200, or 121 and consent of instructor.

203. Basic Analysis I. Topology of R^n, continuous functions, uniform convergence, compactness, infinite series, theory of differentiation, and integration. Not open to students who have had Mathematics 139. Prerequisite: Mathematics 104.

204. Basic Analysis II. Differential and integral calculus in R^n. Inverse and implicit function theorems. Further topics in multi-variable analysis. Prerequisite: Mathematics 104; Mathematics 203, or 139 and consent of instructor.

205. Topology. Elementary topology, surfaces, covering spaces, Euler characteristic, fundamental group, homology theory, exact sequences. Prerequisite: Mathematics 104.

206. Differential Geometry. Geometry of curves and surfaces, the Serret-Frenet frame of a space curve, the Gauss Curvature and Codazzi-Mainardi equations, the Gauss-Bonnet formula. Prerequisite: Mathematics 104.

215. Mathematical Finance. An introduction to the basic concepts of mathematical finance. Topics include modeling security price behavior, brownian and geometric brownian motion, mean variance analysis and the efficient frontier, expected utility maximization, Ito's formula and stochastic differential equations, the Black-Scholes equation and option pricing formula. Prerequisite: Mathematics 103, 104, 135 or equivalent, or consent of instructor.

216. Applied Stochastic Processes. An introduction to stochastic processes without measure theory. Topics selected from: Markov chains in discrete and continuous time, queuing theory, branching processes, martingales, Brownian motion, stochastic calculus. Not open to students who have taken Mathematics 240. Prerequisite: Mathematics 135 or equivalent. C-L: Statistics 253.

217. Linear Models. Multiple linear regression and model building. Exploratory data analysis techniques, variable transformations and selection, parameter estimation and interpretation, prediction, Bayesian hierarchical models, Bayes factors and intrinsic Bayes factors for linear models, and Bayesian model averaging. The concepts of linear models from Bayesian and classical viewpoints. Topics in Markov Chain Monte Carlo simulation introduced as required. Prerequisites: Statistics 213 or equivalent. C-L: Statistics 244.

221. Numerical Analysis. Error analysis, interpolation and spline approximation, numerical differentiation and integration, solutions of linear systems, nonlinear equations, and ordinary differential equations. Prerequisites: knowledge of an algorithmic programming language, intermediate calculus including some differential equations, and Mathematics 104. C-L: Computer Science 250.

(Mathematics 160S or 221, but not both, may count toward the requirements for a major or minor in mathematics; see the course description for Mathematics 160S.).

224. Scientific Computing I. Structured scientific programming in C/C++ and FORTRAN. Floating point arithmetic and interactive graphics for data visualization. Numerical linear algebra, direct and iterative methods for solving linear systems, matrix factorizations, least squares problems and eigenvalue problems. Interactive methods for nonlinear equations and nonlinear systems, Newton's method. Prerequisite: Mathematics 103 and 104.

225. Scientific Computing II. Approximation theory: Fourier series, orthogonal polynomials, interpolating polynomials and splines. Numerical differentiation and integration. Numerical methods for ordinary differential equations: finite difference methods for initial and boundary value problems, and stability analysis. Introduction to finite element methods. Prerequisite: Mathematics 224 and familiarity with ODEs at the level of Mathematics 111 or 131.

228. Mathematical Fluid Dynamics. Properties and solutions of the Euler and Navier-Stokes equations, including particle trajectories, vorticity, conserved quantities, shear, deformation and rotation in two and three dimensions, the Biot-Savart law and singular integrals. Additional topics determined by the instructor. Prerequisites: Mathematics 133 or an equivalent course.

229. Mathematical Modeling. Formulation and analysis of mathematical models in science and engineering. Emphasis on case studies; may include individual or team research projects.

233. Asymptotic and Perturbation Methods. Asymptotic solution of linear and nonlinear ordinary and partial differential equations. Asymptotic evaluation of integrals. Singular perturbation. Boundary layer theory. Multiple scale analysis. Prerequisite: Mathematics 114 or equivalent.

Recommended Course Sequences

This section provides recommended course sequences appropriate to areas where a mathematics background is helpful, recommended, or required. For additional information on such areas, see the subsequent section, **After Graduation: Educational and Professional Opportunities** (page 20).

Applications of Mathematics

Many professions and many graduate and professional school programs regard a strong background in mathematics as highly desirable. Therefore, students having a primary interest in some other discipline may also want to pursue a major or minor in mathematics.

Basic Courses	MTH 131, 135, 136, 160S (or 221)
Engineering and Natural Science	MTH 107, 108, 132S, 133, 139, 181, 196S, 203, 216, 224, 238
Business and Economics	MTH 126, 132S, 215, 216
Computer Science	MTH 124, 126, 187, 188, 200, 201

Actuarial Science

Actuaries can earn professional status by passing a series of examinations administered by the Society of Actuaries and Casualty Actuarial Society. The first two exams are:

- $ExamP:\ Probability$;
- $ExamFM: FinancialMathematics$.

Old copies of these exams, together with answer keys and solutions, and information about submitting an application for the exams, can be found on the web at

`www.BeAnActuary.org`

Also see the booklet "Basic Education Catalog" published by the Society of Actuaries; copies are available in Rm 121 Physics. The optimal time to take the first exam is soon after completing a calculus-based probability course such as MTH 135 and a statistics course such as MTH 136. The following is a list of Duke courses that are useful in preparing for a career as an actuary.

Probability and statistics	MTH 135, 136
Mathematical finance	MTH 215
Applied stochastic processes	MTH 216
Intermediate Economics III	ECON 110
Introduction to Econometrics	ECON 139
Financial Markets and Management	ECON 157
Data Analysis for Undergraduate Research	STA 121
Probability and Statistical Methods	STA 214
Linear Models	STA 244

The Society of Actuaries has recently made some changes in the structure of the examinations. In the future certain topics on preliminary subjects will have to be "Validated by Educational Experience" (VEE); in other words, by a college course. These topics are: Economics (macro and micro), Corporate Finance, and Applied Statistics (time series and regression). The following two courses at Duke have been approved by the VEE committee:

Data Analysis for Undergraduate Research	STA 121
Introduction to Econometrics	ECON 139

For further information or additional advice about careers in the actuarial sciences, please contact Professor Jerry Reiter of the Institute of Statistics and Decision Sciences [jerry@stat.duke.edu], Emily Reither [ere3s@allstate.com], or Jon Swope [Jon.Swope@WatsonWyatt.com] (Emily and Jon majored in mathematics at Duke).

The curriculum in Mathematical Decision Sciences at the University of North Carolina at Chapel Hill includes an Actuarial Science option through which students may take specialized courses in Long-Term Models (OR 161, fall semester) and Short-Term Models (OR 162, spring semester). Descriptions of these courses can be found at the curriculum's web site, www.or.unc.edu/MDSweb. Under a reciprocal agreement between the two universities, students at Duke may enroll concurrently in these courses offered by UNC–Chapel Hill (see page 77 of the *Bulletin of Duke University, 2005–2006: Undergraduate Instruction*). Note, however, that prior approval from the Director of Undergraduate Studies must be sought for such courses to count toward mathematics major or minor credit.

Charles W. Dunn (email `cwd0926@aol.com`), a Duke graduate and Fellow of the Society of Actuaries, teaches the UNC courses and will be happy to answer questions about them or about actuarial science in general.

Teaching Mathematics The following courses are recommended for students planning careers as teachers of mathematics in secondary schools:

Geometry (MTH 123S)	Advanced Calculus (MTH 139 or 203)
Abstract Algebra (MTH 121 or 200)	Computer Science (COMPSCI 4 or 6)
Probability/Statistics (MTH 135/136)	

The following courses would also be helpful:

Combinatorics (MTH 124)	Logic (MTH 187)
Number Theory (MTH 128S)	Mathematical Modeling (MTH 196S)
Differential Equations (MTH 131)	Two courses in Physics (*See page 3.*)

A student interested in becoming a secondary mathematics teacher should contact Jack Bookman (027A Physics, 660-2831, `bookman@math.duke.edu`)or Richard Hodel (228C Physics, 660-2846, `hodel@math.duke.edu`). There are several paths that one might pursue to major in mathematics and also to be qualified to teach:

1. To become certified to teach so that one can go directly into secondary school teaching upon completion of an undergraduate degree, a student should complete the requirements for the mathematics major, meet the requirements for certification in North Carolina (which includes a prescribed list of mathematics and education courses), and complete a

teaching internship during the spring semester of the senior year. Contact Susan Wynn in the Program in Education (213 West Duke, East Campus, 660-3075) for a more complete description of these requirements.

2. Alternatively, a student may complete the undergraduate degree in mathematics and proceed directly to graduate school to obtain a master of arts in teaching (MAT) or a master of arts in mathematics education. Either degree prepares one for a secondary school teaching position with an advanced pay scale, and some junior colleges employ teachers who hold these degrees. Duke has one of the most innovative MAT programs in the country. It is virtually unique with its emphasis on extensive classroom experience and on advanced mathematics courses rather than on education courses. For information about this program see the Director, Rosemary Thorne (West Duke, 684-4353, `rrt@acpub.duke.edu`) or the representative for the Mathematics Department, Richard Hodel (228C Physics, 660-2846, `hodel@math.duke.edu`).

3. To teach in a private school, only an undergraduate degree with a major or minor in mathematics may be required. However, a mathematics major is highly recommended.

Graduate Study in Mathematics

A student planning to pursue graduate study in mathematics should develop a program of study that provides both variety of experience and a strong background in fundamental areas. The core courses for either pure or applied mathematics are Mathematics 181, 200–201, and 203–204; one of the sequences 200–201/203–204 should be taken no later than the junior year. Mathematics 131, 205, and 206 are recommended. Students interested in applied mathematics should consider Mathematics 132S, 133, 135, 136, 160S, 196S, 215, 216, 221 and 224. Advanced students are encouraged to take standard graduate–level courses (numbered 231 and above) in their senior (and occasionally in their junior) years: in particular, Mathematics 241, 245, and 251 are recommended.

Graduate programs usually expect that applicants will take the Graduate Record Examination Subject Test in mathematics, which emphasizes linear algebra, abstract algebra, and advanced calculus, but also includes questions about complex analysis, topology, combinatorics, probability, statistics, number theory, and algorithmic processes.

Statistics

Students who plan to pursue graduate work in statistics or operations research should follow a program similar to that given above for graduate study in mathematics and should include some of the following electives: Mathematics 135, 136, 215, 216, and 217, as well as COMPSCI 6 and 100. A strong background in mathematics (especially analysis and linear algebra) and computing is the best basis for graduate work in statistics.

Students who do not intend to pursue graduate work should elect Mathematics 135, 136, 215, 217, COMPSCI 6 or 100 as well as some of the following courses: Mathematics 216, 218, 160 (or 221), STA 242, COMPSCI 108. Statistics students at all levels are encouraged to take computer programming courses.

At present, job prospects are good at all degree levels for those who have a strong background in statistics and some computer programming experience. For further information, see Jerry Reiter, Director of Undergraduate Studies in the Institute of Statistics and Decision Sciences (213 Old Chemistry, 668-5227, `jerry@stat.duke.edu`).

Advising and Advice

Advising. Usually, a student prepares a long-range plan and declares a first major in mathematics through the Premajor Advising Center; the student is then assigned an official faculty advisor by the Director of Undergraduate Studies. First majors are required to meet with their advisors each semester during the registration interval. The student and advisor should work together to ensure that the program of study is consistent with the student's interests and professional goals.

A student who has declared a second major or a minor in mathematics will receive formal advising in the department of his or her first major; however second majors and minors and students considering a degree in mathematics may see the Director of Undergraduate Studies for advice or for referral to an appropriate member of the mathematics faculty. A second major or a minor in mathematics (or a change of major or minor) may be declared in the Office of the Registrar.

Choosing courses. Every mathematics major must take one course in abstract algebra (Mathematics 121 or Mathematics 200) and one course in advanced calculus (Mathematics 139 or Mathematics 203). To avoid conflicts during the final semesters of a major's program, these courses should be taken as early as practicable. An essential part of these courses is proving mathematical theorems. Students with little exposure to proofs should probably take the 100–level version of these courses. Students who are comfortable with abstract ideas, and especially those students who are contemplating graduate work in mathematics, should consider taking the 200–level courses. The remaining courses may be chosen from both pure and applied areas of mathematics.

Probability and statistics courses. The standard sequence in probability and statistics is Mathematics 135–136. Mathematics 135 covers the basics of probability and Mathematics 136 covers statistics, building on the material in Mathematics 135. Those desiring a further course in probability should select either Mathematics 215 or 216 or both; a further course in statistics is Mathematics 217.

The Institute of Statistics and Decision Sciences (ISDS) offers a number of courses in statistics at various levels for students of varied mathematics backgrounds. Usually, such courses cannot be counted for mathematics major or minor credit unless they are cross-listed in the Department of Mathematics. The Director of Undergraduate Studies may approve certain statistics courses numbered above 200 for credit, but usually only courses that have a prerequisite of Mathematics 136 or its equivalent will be considered.

Transfer Credit

Before enrolling at another school in a course for which transfer credit is wanted, a student must

(1) obtain departmental approval for the course, and
(2) obtain approval from the student's academic dean.

To obtain departmental approval a student must contact

- the Director of Undergraduate Studies (DUS) for courses in mathematics to be taken abroad;
- the Associate Director of Undergraduate Studies (ADUS) for courses in mathematics numbered above 103 to be taken in the United States;
- the Supervisor of First-year Instruction (SFI) for courses numbered 103 and below.

The departmental approval of any summer courses should be requested **before the last week of classes** of the spring semester.

Although the decision to approve or disapprove a particular course will be made by the Director, Associate Director of Undergraduate Studies or the Supervisor of First Year Instruction, a student can often make a preliminary determination by following the procedure below.

1. Verify that the number of transfer credits complies with limits set by the university (see *Bulletin of Duke University 2005-2006 Undergraduate Instruction* p. 26-27 under **The Major** and under **The Minor**.) At least half of the major/minor courses should be taken at Duke. In particular, Math 121 and 139 must be taken at Duke except for special circumstances for which students should petition to DUS.
2. Obtain the regular catalog (or at least a copy of the pages containing descriptions of the mathematics courses) from the other school. All undergraduate mathematics courses should be included, so the course in question can be considered in the context of the other school's mathematics program. Summer catalogs seldom contain enough information; and some regular catalogs are not sufficiently detailed; and in such a case, the petitioning student must obtain a syllabus or other official written description of the contents of the course.
3. Determine whether the school is on the semester system or the quarter system. If it is on the quarter system, two courses are needed to obtain one credit at Duke.
4. For summer courses, determine the number of contact hours, which is the product of the length of the class period in hours and the number of days that the class meets. Only courses with 35 or more contact hours are acceptable for transfer credit.
5. After determining that a course qualifies under all the criteria above, see the Director or Associate Director of Undergraduate Studies or the Supervisor of First Year Instruction, as appropriate for the course (see above).

6. If transfer credit is approved by the Department of Mathematics, seek the approval of the appropriate academic dean.

To receive transfer credit, a course grade of C– or higher is required; however, the university does not include a grade earned at another school as part of a student's official transcript.

A student who has obtained transfer credit may still enroll in the corresponding Duke course, but transfer credit will then be lost.

A student considering a course offered during a summer term should bear in mind that such courses are frequently cancelled, owing to low enrollment.

General questions about university policy on transfer credit should be addressed to Deborah Shoffner (`deborah.shoffner@duke.edu`, 684-9029) or Harry Nelson (`harry.nelson@duke.edu`, 684-5655), to whom the required approval forms and transcripts are sent (103 Allen Building, facsimile: 684-4500).

Credit for Courses Taken Abroad

Students frequently study abroad through programs administered by the Office of Foreign Academic Programs. The Department of Mathematics encourages study abroad and expects that increasing number of students will complete course work, including courses in mathematics, at foreign universities. However, students who study abroad must take care to ensure that the mathematics courses taken abroad count toward the mathematics major (or minor) and that the requirements of the mathematics major (or minor) are met. At least half of the major/minor courses must be taken at Duke. In particular, Math 121 and 139 must be taken at Duke except for special circumstances for which students should petition to the Director of Undergraduate Studies.

Courses to be taken abroad must be pre-approved by the Director of Undergraduate Studies, by the dean responsible for study abroad and by the student's academic dean; final credit will not be awarded until the content of the actual courses taken has been reviewed by the Director of Undergraduate Studies. Courses scheduled to be offered abroad may be canceled with little advance notice, or they may differ from a student's expectations. Students are responsible for contacting the the Director of Undergraduate Studies and the deans by electronic mail, facsimile, or telephone to obtain advance approval for alternative courses.

Resources and Opportunities

Independent Study

An independent study course (i.e., Mathematics 191, 192, 193, or 194) offers a student the opportunity to pursue advanced study in a particular area of mathematics; alternatively, independent study may be pursued in an area in which courses are not usually offered by the department. (A student may not obtain credit by independent study for a course that is offered frequently.)

A student wishing to register for an independent study course must first make arrangements with a faculty member having expertise in the desired area. (The supervision of an independent study is a significant commitment by a faculty member, and no faculty member is obligated to agree to supervise an independent study.)

The student must then submit a proposal to the Director of Undergraduate Studies. The proposal should be prepared in consultation with the supervising faculty member, and it should contain a title, a brief plan of study, and a statement of how the work will be evaluated. The proposal must be typewritten, and it must signed by both the student and the supervising faculty member. The proposal will be considered in the context of the student's interests, academic record, and professional goals. If the proposal is approved, the Director of Undergraduate Studies will issue a permission number for course registration.

By faculty regulation, the student and supervising professor must meet at least once every two weeks during the fall or spring semester and at least once each week during a summer term.

Summer Opportunities

Many students participate in summer research programs and internships, mostly at other colleges and universities and in businesses and government agencies. Of particular note are "Research Experiences for Undergraduates," which are sponsored by the National Science Foundation and conducted by mathematics faculty at a number of colleges and universities. Links can be found at the department's web site.

Summer opportunities will be advertised on departmental bulletin boards and through electronic mail, usually in the late fall and early winter months; students should apply as early as practicable.

Employment in the Department

The Department of Mathematics employs undergraduate students as office assistants, graders, help room/session tutors, and laboratory teaching assistants. Working as a laboratory teaching assistant can be valuable preparation for a student planning to become a mathematics teacher.

Applicants for the positions of grader, help room/session tutor, and laboratory teaching assistant should have taken the course involved and received a grade no lower than B. However, a student who received a good grade in a higher level course or who has advanced placement may be eligible to grade for a lower level course not taken.

Students wishing to apply for available positions may obtain an application in the Department of Mathematics Offices, Physics Building, Suite 121A.

Math-Physics Library

The Math-Physics Library recently merged with Vesic Engineering Library, and is now located in Room 210 Teer Building (660-5368, facsimile: 681-7595). The library has a comprehensive collection of textbooks, monographs, journals, and reference works treating mathematics, statistics, physics, and astronomy. In addition, the library maintains materials on reserve for specific courses.

Talks for Undergraduates

From time to time a mathematician is invited to give a talk that is specifically for undergraduates. Recent speakers and their topics are listed below.

Joseph Gallian (U. Minn. Duluth)	*Touring the Torus*
Robert Devaney (Boston)	*The Mathematics behind the Mandelbrot Set*
Donald Knuth (Stanford)	*Leaper Graphs*
Colin Adams (Williams)	*Real Estate in Hyperbolic Space*
Jeffrey Weeks (Minnesota)	*Visualizing Four Dimensions*
Lloyd N. Trefethen (Cornell)	*Computational Mathematics in the 1990's*
Underwood Dudley (DePauw)	*Formulas for Primes*
Lisa Fauci (Tulane)	*Modeling Biofilm Processes in a Moving Fluid*
Barry Cipra (Mathematical writer)	*Solved and Unsolved Problems in Grade School Math*
Frank Morgan (Williams, Princeton)	*Soap Bubble Geometry Contest*
Martin Nowak (IAS)	*Fairness and Cooperation*
Sir Roger Penrose (Oxford University)	*Science and the Mind*
Walter Mientke (U. of Nebraska)	*Approximations of Arithmetic Sums*
Dusa McDuff (SUNY Stony Brook)	*4-Dimensional Polytopes*
Jordan Ellenberg (Princeton)	*The Mathematics of the Card Game Set*

Duke University Mathematics Union

The Duke University Mathematics Union (DUMU) is a club for undergraduates with an interest in mathematics. Recent activities include sponsoring talks for undergraduates (see below) and hosting a mathematics contest for high school students; the contest attracted participants from throughout the southeast. Information about meetings and activities will be distributed by electronic mail and posted in the department. For current information about DUMU, see the Undergraduate Program page at the department's web site, and click on the link for DUMU.

Graduation with Distinction in Mathematics

Mathematics majors who have strong academic records are eligible for graduation with distinction in mathematics. The requirements are:

(1) An overall GPA of at least 3.3 and a mathematics GPA of at least 3.5, maintained until graduation;

(2) A paper demonstrating significant independent work in mathematics, normally written under the supervision of a tenured or tenure-track faculty member of the Department of Mathematics. Usually the paper will be written as part of an independent study taken in the senior year (Mathematics 193, 194);

(3) An oral presentation of the paper, open to the public.

A student must apply for graduation with distinction in the spring of the junior year. The application should be prepared according to the specifications for an independent study course application (see page 15), and the application should state the intention to pursue graduation with distinction in mathematics.

In the spring of the senior year, the Director of Undergraduate Studies will name a committee, normally including the candidate's supervisor, to evaluate the paper and oral presentation. The evaluation committee will determine whether distinction will be awarded, and if so, the level of distinction: Graduation with Distinction in Mathematics, Graduation with High Distinction in Mathematics, or Graduation with Highest Distinction in Mathematics.

Competitions and Awards

Competitions

A half-credit Problem Solving Seminar (Mathematics 149S) is offered each fall to help students develop creative strategies for solving challenging mathematical problems; admission is by consent of the instructor. Each year students are encouraged to participate in the Virginia Tech Mathematics Contest, the William Lowell Putnam Mathematics Competition, and the Mathematical Contest in Modeling. Duke Putnam teams placed *first* in the nation in 1993, 1996 and 2000, *second* in 1990 and 1997 and *third* in 1999 and from 2001 to 2004. The Duke team in the Mathematical Contest in Modeling was ranked Outstanding from 1998 to 2002 and in 2005, 6 years out of the last 8.

Karl Menger Award

The Karl Menger Award, first given in 1989, is a cash prize awarded annually by the Department of Mathematics for outstanding performance in mathematical competitions. The selection committee is appointed by the Director of Undergraduate Studies.

Karl Menger (1902–1985) was a distinguished mathematician who made major contributions to a number of areas of mathematics. The Karl Menger Award was established by a gift to Duke University from George and Eva Menger-Hammond, the daughter of Karl Menger.

The Julia Dale Prize in Mathematics

The Julia Dale Prize is a cash prize awarded annually by the Department of Mathematics to a mathematics major (or majors) on the basis of excellence in mathematics. A selection committee is appointed by the Director of Undergraduate Studies.

Julia Dale, an Assistant Professor of Mathematics at Duke University, died early in her career in 1936. Friends and relatives of Professor Dale established the Julia Dale Memorial Fund; the Julia Dale Prize is supported by the income from this fund, which was the first memorial fund established in honor of a woman member of the Duke faculty.

Computational Resources

All mathematics majors and minors are encouraged to develop computer skills and to make use of E-Mail (every Duke student is assigned a university E-Mail address upon matriculation). Some courses in mathematics may require students to use computers. In some cases, university-maintained computer clusters will suffice; in other cases, students may be required to use a workstation in our Unix Cluster.

General information. The department maintains a cluster of Unix Workstations in Room 250AB, Physics Building. ACPUB logins are not accepted on these machines; a Mathematics Account is required (see below). There are nine RedHat Linux Workstations and a laser printer (designated `lw3`). This cluster is for undergraduate and graduate instruction and other appropriate purposes; it is open 24 hours a day except when in use by classes or for scheduled laboratory instruction. Students doing mathematics work have priority for use of the workstations. These Workstations, which utilize the Linux® operating system, provide access to E-Mail and the World Wide Web; moreover, original or previously written programs in FORTRAN, Pascal, C, and C++ may be run on these machines, and the mathematical software packages Maple® (`xmaple`), Mathematica® (`mathematica`) and Matlab® (`matlab`) are available to all users.

Opening an account. Mathematics first majors may obtain individual accounts to use the department's network of Unix Workstations. Applications can be submitted online from the Computing Resources Web Page at http://www.math.duke.edu/computing. Accounts for mathematics first majors will expire upon graduation, withdrawal from the university, or change of first major.

Other undergraduate students will be granted access to joint class accounts or to individual temporary accounts when they are enrolled in mathematics classes that require access to the department's network. Class accounts and temporary accounts will expire automatically at the end of each academic term.

Students are responsible for copying materials that they wish to preserve before the accounts expire. File should be transferred to another networked computer via Secure Copy (`scp`), available from http://www.math.duke.edu/cgi-bin/sshdownload, or through our web based file transfer system, called the Global Desktop Environment, located at http://www3.math.duke.edu/cgi-bin/gde BEFORE the account expires. A CDROM image of your home directory can be created upon account termination. Please contact the Systems Staff for info regarding CD creation.

Electronic mail. Users can send and receive E-Mail through the department's network; a typical E-Mail address has the form `userid@math.duke.edu`. The easiest way to read mail is through one of our Web Based Email programs. You can read mail through the Global Desktop Environment at http://www3.math.duke.edu/cgi-bin/gde by selecting the MailBox icon at the top of the page or through Twig at

http://www.math.duke.edu/secure/twig/index.php3.

To read or send mail, the user can choose from the programs `gpmail`, the text based mail reader `pine`, or the mail component of `mozilla`; one must be in the X-Windows program (`graphics screen`) to use `gpmail` or `mozilla`. The program `gpmail` is recommended for use within the department and is compatible with `pine` so it can be used interchangeably when connecting over slower links.

World Wide Web (WWW): Department of Mathematics Home Page. A wide variety of current departmental information, including course information, departmental policies, and pointers to other mathematical web servers, can be found on the WWW home page. An internet browser program, such as `mozilla`, can be used to view the home page; the Uniform Resource Locator (URL) is `http://www.math.duke.edu`. Information about Computing Resources and Secure Remote Access to the Mathematics Department is located at http://www.math.duke.edu/computing. Current versions of this handbook and the local UNIX guide ("Using UNIX in the Duke Mathematics Department") can be accessed from the department's home page.

Inquiries and help. Routine questions (e.g., "How do I use this program? Why doesn't this work? How do I set up the defaults?") should be addressed by electronic mail to `req@math.duke.edu`. IMPORTANT : Please include as much specific information as possible, e.g., the workstation name, the exact command syntax used, any error messages encountered, and a log of the session.

Some Frequently Asked Questions about how to use the linux systems in the department are answered at `http://www.math.duke.edu/computing/faq.html`. Please check here for answers before contacting support.

Remote Access. The Mathmatics Department Firewall prevents telnet, ftp, imap, pop, and all other forms of unencrypted access. You will need to use SSH, available from http://www.openssh.com, or a Secure Web Browser (Netscape, Mozilla, Internet Explorer) to access resouces in the department from remote locations. The Global Desktop Environment at http://www3.math.duke.edu/cgi-bin/gde is a good place to start if you need remote access to departmental resources. There are also several links and tips on the Computing Security Page available at http://www.math.duke.edu/computing/secure.html.

Security. The UNIX operating system is only secure if users take responsibility for its protection. Every user is responsible for the security of his or her own account. Departmental policy prohibits the sharing of passwords or accounts and any other activity

that undermines the security of the university's computer systems. Users should be sure to log out when they finish using the machines in university clusters. Any suspicious activities related to the computers or accounts should be reported immediately to the system administrators. More complete information on security can be found in the local UNIX guide.

User policy. The computer system of the Department of Mathematics is provided to support mathematical instruction and research. To ensure that the system is fully available for these purposes, the Department of Mathematics has established a policy on responsible use of its computer system. This policy can be found on the web at `http://www.math.duke.edu/computing/policy.html`. Violations of the user policy may lead to suspension of the user's account or referral to the appropriate authority for disciplinary action. University policies and regulations, including the Duke Undergraduate Honor Code, and state and federal statutes, including the North Carolina Computer Crimes Act, cover many potential abuses of computers and computer networks.

After Graduation: Educational and Professional Opportunities

Career Information

The web is the best and most up-to-date source of information on career opportunities in mathematics. The following organizations have useful web sites:

(1) American Mathematical Society
(2) Association of Women in Mathematics
(3) Mathematical Association of America
(4) American Statistical Association
(5) Institute of Mathematical Statistics
(6) Society of Actuaries

An easy way to access these web sites is to use **Google**; search for *American Mathematical Society,* or *mathematical societies,* and so on.

The **Career Center** (located in Room 110, Page Building) is an excellent source of information on career opportunities in mathematics. Angie Smith (`angie.smith@duke.edu`) is the career specialist in mathematics and related fields; appointments can be made by calling 660-1050.

The Career Center administers electronic mailing lists for information about summer jobs, internships, on-campus employment, temporary positions, long-term employment, and on-campus recruiting by various employers. To subscribe to the mailing list for mathematics and related disciplines, go to the Career Center's extensive website at `http://career.studentaffairs.duke.edu`.

Business, Law, and Health Professions

Business and law schools welcome and even actively recruit applications from students with a major in mathematics. Business schools require a strong quantitative background like that provided by an undergraduate degree in mathematics. Law schools value the analytical reasoning that is a basic part of a mathematical education. Medical schools regard mathematics as a strong major, and a number of mathematics majors at Duke have been successful in their applications to medical school. A mathematics background is also a strong credential for other health professions, e.g., dentistry, veterinary medicine, and optometry. Although the department receives some information about professional programs, more detailed information, including pamphlets, handouts, etc., is available from the offices of the deans listed below.

Business School
Dean Martina Bryant
02 Allen Building
684-2075 (Fax: 668-6393)
martina.bryant@duke.edu

Law School
Dean Gerald Wilson
116 Allen Building
684-2865 (Fax: 684-3414)
gerald.wilson@duke.edu

Health Professions
Dean Kay Singer
011 Allen Building
684-6221 (Fax: 660-0488)
kay.singer@duke.edu

First-year students and sophomores interested in the health professions are encouraged to visit the website at `http://www.aas.duke.edu/trinity/prehealth`. To ask specific questions, freshmen should contact Dr. Donna Kostyu (`donna.kostyu@duke.edu`) and sophomores should contact Dr. Milton Blackmon (`milton.blackmon@duke.edu`).

Teaching Mathematics

Duke graduates who have majored in mathematics and have teaching certification are in strong demand in the field of secondary education. Each year a few students graduate from Duke with teaching certification in secondary school mathematics, and they find that high schools—both public and private—are very interested in hiring them. A mathematics major can receive secondary mathematics certification either as an undergraduate, through the Program in Education, or through the Masters of Arts in Teaching (MAT) Program, a one-year program following graduation. The MAT Program allows qualified students to begin study during their final undergraduate semester and has substantial scholarship support available for qualified students. Duke's MAT program is highly innovative with an emphasis on extensive classroom experience and on advanced mathematics courses rather than on education courses.

For information on the Program in Education, contact Vicki Stocking (213 West Duke, 660-3075). For advice about this program from a member of the Mathematics Department, see Jack Bookman (027A Physics, 660-2831, `bookman@math.duke.edu`). For information on Duke's MAT program, contact the Director, Rosemary Thorne (213 West Duke, 684-4353, `rrt@acpub.duke.edu`). For advice about MAT program from a member of the Mathematics Department, see Richard Hodel (228C Physics Building, 660-2846). Students considering teaching as a profession can get excellent experience working as graders, lab T.A.'s and/or help room assistants in the Department of Mathematics.

Graduate Study in Mathematics

A Doctor of Philosophy (Ph.D.) in pure or applied mathematics requires roughly five years of graduate work beyond the bachelor's degree. The first years are spent in course work, while the later years are spent primarily doing original research culminating in a dissertation. Most graduate students in mathematics can get financial support for their study—both tuition and a stipend for living expenses. In return for this support the student usually performs some service for the department, most commonly teaching introductory undergraduate courses. Highly qualified students may receive fellowships or research assistantships that require little or no teaching.

About one-half of Ph.D.'s in mathematics find long-term employment at academic institutions, either at research universities such as Duke or at colleges devoted primarily to undergraduate teaching. At research universities, the effort of most faculty members is divided between teaching and conducting research in mathematics. The employment situation for Ph.D.'s in mathematics for academic positions is currently very tight. Most nonfaculty mathematicians are employed by government agencies, the private service sector, or the manufacturing industry.

Students considering graduate school in mathematics are urged to consult with the mathematics faculty and with the Director of Graduate Studies. The choice of graduate school and the area of study may make a significant difference in future job prospects. information about graduate programs is available through the World Wide Web; to find out about Duke's graduate program in mathematics, go to `http://www.math.duke.edu`.

Other Opportunities

Graduate school in statistics, operations research, computer science, and mathematics-related scientific fields. Information about graduate programs in fields closely related to mathematics is available on the web. Students can also consult with corresponding graduate programs at Duke.

United States Government. A number of U.S. Government agencies hire graduates with strong preparation in mathematics; for example:

- Air Force and Navy
- Bureau of Census
- National Security Agency
- Peace Corps

All of these organizations have a web page with information about employment opportunities.

Financial Services Industry, Management, etc. There are many occupations that do not use mathematics directly but for which a major in mathematics is excellent preparation. Many employers are looking for individuals who have skills that are obtained by mathematical training: clear, logical thinking; ability to attack a problem and find the best solution; prompt attention to daily work; sureness in handling numerical data; analytical skills. Because many companies provide specific on-the-job training, a broad range of courses may be the best preparation for such occupations.

Recent Graduates. About 35% of graduates with majors or minors in mathematics proceed directly to graduate or professional school. Most other graduates are employed in the private or public sectors. The following is a list of typical positions taken by recent Duke alumni with undergraduate degrees in mathematics:

2001

- Derivatives analyst, Goldman Sachs
- Investment banking analyst, Lehman Brothers
- Computer Programer, ViASIC
- Information technology consultant, Pricewaterhouse Corp.
- Analyst, Accenture (formerly Andersen Consulting)

2002

- Finance analyst, Ford Motor Corp.
- Actuary, CIGNA Corp.
- Associate business analyst, Synygy Inc.
- Research assistant, Project Hope
- Founded, own Renewal Enterprises

2003

- Investment banking analyst, UBS Warburg
- Investment banking analyst, Raymond James
- Actuary, CIGNA
- Actuarial analyst, Watson Wyatt
- Submariner, US Navy

2004

- Actuarial analyst, Allstate
- Actuarial analyst, Segal Company
- Actuarial analyst, Watson Wyatt
- Investment banking analyst, Dresdner Kleinwort Wasserstein
- Research and development, Glaxo-Smith-Kline

2005

- Software engineer, Google Inc.
- Associate consultant, Marakon Associates
- Investment banking analyst, Goldman Sacks
- Consultant, McKinsey & Company
- IBM

Research Interests of the Faculty

Faculty members, their undergraduate/graduate schools, and research areas are listed below; more detailed information can be found via the department's WWW server (`http://www.math.duke.edu`). An asterisk (*) indicates a joint appointment with the department of physics.

Faculty Member	**Research Area**
W. K. Allard (Villanova, Brown)	Scientific computing
D. Anderson (U. Virginia, Duke)	Applied math, analysis
P. S. Aspinwall* (U.C., Oxford)	String theory
J. T. Beale (CalTech, Stanford)	Partial differential equations, fluid mechanics
H. Bray (Rice U., Stanford U.)	Differential geometry
R. L. Bryant (N. C. State, UNC)	Nonlinear partial differential equations, differential geometry
A. Catla (U. Kansas, Northwestern U.)	Applied math to pattern formation
A. Degeratu (U. Bucharest, MIT)	Differential geometry, algebraic geometry, mathematical physics
R. M. Hain (U. Sydney, U. Illinois)	Topology of algebraic varieties, Hodge theory
J. Hanke (Princeton)	Number theory and algebraic geometry
J. L. Harer (Haverford, Berkeley)	Geometric topology, combinatorial group theory
R. E. Hodel (Davidson, Duke)	Set-theoretic topology, set theory, logic
M. Huber (Harvey Mudd C., Cornell U.)	Probability theory and stochastic processes
A. Jafari (Sharif U. Iran, Brown U.)	Arithmetic geometry

E. Katz (Ohio State U., Stanford U.)	Algebraic geometry
D. P. Kraines (Oberlin, Berkeley)	Algebraic topology, game theory
A. Layton (Duke, U. of Toronto)	Mathematical physiology, scientific computing
H. E. Layton (Asbury, Duke)	Mathematical physiology
D. Lee (Harvard, Stanford)	Geometric analysis
R. Levy (Oberlin College, NCSU)	Thin liquid films and surfactants
J. Mattingly (Yale, Princeton)	Probability, stochastic processes
G. Mitchener (Duke, Princeton)	Biology and other natural sciences, dynamical systems and ergodic theory
D. R. Morrison (Princeton, Harvard)	Algebraic geometry, mathematical physics
A. Oron (Israel Inst. of Tech.)	Partial differential equations, fluid instabilities, thin-film flows
W. L. Pardon (Michigan, Princeton)	Algebra, geometry of varieties
G. Pearlstein (U. of Massachusetts, Amherst)	Hodge theory and algebraic geometry
A. O. Petters (Hunter College, MIT)	Gravitational lensing, general relativity, astrophysics, singularity theory
R. Plesser* (Tel Aviv, Harvard)	String theory, quantum field theory
M. C. Reed (Yale, Stanford)	Applications of mathematics to physiology and medicine
L. D. Saper (Yale, Princeton)	Analysis and geometry on singular spaces
D. G. Schaeffer (Illinois, MIT)	Partial differential equations, applied mathematics
C. L. Schoen (Haverford, Chicago)	Algebraic geometry
F. Schwartz (U. of Chile, Cornell)	Geometry

M. A. Stern (Texas A & M, Princeton)	Geometric Analysis
J. A. Trangenstein (U. Chicago, Cornell)	Nonlinear conservation laws, environmental clean-up, shocks in fluids
S. Venakides (Nat'l Tech. U. Athens, NYU)	Partial differential equations, integrable systems
T. P. Witelski (Cooper Union, Cal Tech)	Differential equations, mathematical biology, perturbation methods
J. Wang (U. of Sci. & Tech. of China, Ohio State U.)	Numerical Analysis, scientific computing
R. Yoshida (Berkeley, U. of California, Davis)	Applied mathematics
X. Zhou (Chinese Acad. of Sciences, Rochester)	Partial differential equations, integrable systems

Rapid Reference Course List

104. Linear Algebra and Applications
104C. Linear Algebra with Scientific Computation
104X. Honors Linear Algebra
107. Linear Algebra and Differential Equations
108. Ordinary and Partial Differential Equations
111. Applied Mathematical Analysis I
114. Applied Mathematical Analysis II
121. Introduction to Abstract Algebra
123S. Geometry
124. Combinatorics
126. Introduction to Linear Programming and Game Theory
128S. Number Theory
131. Elementary Differential Equations
132S. Nonlinear Ordinary Differential Equations
133. Introduction to Partial Differential Equations
135. Probability (C-L: STA 104)
136. Statistics (C-L: STA 114)
139. Advanced Calculus I
149S. Problem Solving Seminar
160S. Mathematical Numerical Analysis
181. Complex Analysis
187. Introduction to Mathematical Logic
188. Logic and its Applications (C-L: PHIL 150 and COMPSCI 148)
191, 192, 193, 194. Independent Study
196S. Seminar in Mathematical Modeling
197S. Seminar in Mathematics
199S. Honors Seminar
200. Introduction to Algebraic Structures I
201. Introduction to Algebraic Structures II
203. Basic Analysis I
204. Basic Analysis II
205. Topology
206. Differential Geometry
215. Mathematical Finance
216. Applied Stochastic Processes
217. Introduction to Linear Models (C-L: STA 244)
221. Numerical Analysis (C-L: COMPSCI 250)
224. Scientific Computing I
225. Scientific Computing II
228. Mathematical Fluid Dynamics
229. Mathematical Modeling
233. Asymptotic and Perturbation Methods

Undergraduate Calendar

Fall 2005

August	
24	Wednesday—New undergraduate student orientation
29	Monday, 8:00 A.M.—Fall semester classes begin; Drop/Add continues
September	
9	Friday 5:00 P.M.—Drop/Add ends
October	
2	Sunday—Founders' Day
7	Friday, 7:00 P.M.—Fall break begins
12	Wednesday, 8:00 A.M.—Classes resume
14	Last day for reporting mid semester grades
November	
2	Wednesday—Registration begins for spring semester, 2006
16	Wednesday—Registration ends for spring semester, 2006
17	Thursday—Drop/Add begins
22	Tuesday, 10:30 P.M.—Thanksgiving recess begins at the end of period 3
28	Monday, 8:00 A.M.—Classes resume
December	
9	Friday—Fall semester classes end
10–11	Saturday-Sunday—Reading period
12	Monday—Reading period (9:00am-7:00pm)
12	Monday—Final examinations begin (7:00pm)
15	Thursday—Reading period (9:00am-2:00 pm)
18	Sunday, 10:00 P.M.—Final examinations end

Spring 2006

January	
11	Wednesday, 8:00 A.M.—Spring semester classes begin; Drop/Add continues
16	Monday—M. L. King holiday: no classes
25	Wednesday, 5:00 P.M.—Drop/Add ends
February	
24	Friday—Last day for reporting mid semester grades
27	Monday—Registration begins for summer 2006
March	
10	Friday, 7:00 P.M.—Spring recess begins
20	Monday, 8:00 A.M.—Classes resume
April	
5	Wednesday—Registration begins for fall semester 2006
14	Friday—Registration ends for fall semester 2006; summer 2006 registration continues
15	Saturday—Drop/Add begins
26	Wednesday—Spring semester classes end
27–30	Thursday—Sunday—Reading period
May	
1	Monday—Final examinations begin
3	Wednesday—Reading period(9:00am-2:00pm)
6	Saturday, 10:00 P.M.—Final examinations end
12	Friday—Commencement begins
14	Sunday—Graduation exercises; conferring of degrees