GRADUATE MATHEMATICS

1996–97

Department of Mathematics
University of Utah
Salt Lake City, Utah 84112

Chair: James A. Carlson

Associate Chair: Robert M. Brooks

Director of Graduate Studies: Peter Trombi

Graduate Fellowship Chair: C. Herbert Clemens

Graduate Secretary: Frances Hill

Graduate Committee
Peter Trombi, Chair–G.S.
C. Herbert Clemens, Chair–G.F.
Michael Kapovich
James Keener
Hans Othmer
Paul Roberts

The enclosed material was edited by Peter Trombi and Frances Hill.
The cover design is based on a sketch by Jo Hogue Case.
Preface

This bulletin is prepared annually for graduate students, and those considering graduate study, in the Department of Mathematics. It is intended as a supplement to the bulletin of the University of Utah Graduate School, which is available to all graduate students. The editors of this departmental bulletin welcome suggestions for its improvement from graduate students and members of the faculty.
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CALENDAR OF EVENTS FOR 1996–97

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Departmental Written Prelim Exams .......................... M-F, Sept. 9–13
Math Dept. orientation for new graduate students ................ Sept. 7–20

HOLIDAYS, RECESSES, BREAKS
(No classes, day or evening. University closed on holidays)

**Autumn '96**
Veterans' Day Holiday ........................................... M, Nov. 11
Thanksgiving Recess ................................................ Nov. 28 – Dec. 1

**Winter '97**
Martin Luther King/Human Rights Day Holiday .................. M, Jan. 20
Presidents’ Day Holiday ......................................... M, Feb. 17
Spring Break ...................................................... Mar. 21–30

**Spring '97**
Memorial Day Holiday ............................................. M, May 26

**Summer '97**
Independence Day Holiday ........................................ F, July 4
Pioneer Day Holiday ............................................... H, July 24

See any Quarterly Class Schedule book for additional information concerning registration dates and fee payment deadlines.
GENERAL INFORMATION

A Brief History

The University of Utah is a state tax-supported, coeducational institution. Founded in 1850, it is the oldest state university west of the Missouri River. In recent years, the Graduate School has been awarding approximately 205 Ph.D. degrees per year. The University faculty consists of approximately 3700 members.

The Mathematics Department of the University of Utah now awards, on the average, about six Ph.D. degrees per year. A total of 182 people have earned this degree since 1954. Most of them have positions in state and private universities, but several hold nonacademic positions. Several have been participants in national and international conferences in their major areas of interest and others have been visitors at foreign universities. Six have been awarded Sloan Research Fellowships, 12 have been visiting members of the Institute for Advanced Study in Princeton, and 4 have been awarded National Science Foundation Postdoctoral Fellowships.

Our present graduate faculty numbers 49. A number of the current faculty have received national awards including Sloan Fellowships and Presidential Young Investigator Awards. The University has also recognized members of our faculty with Distinguished Professor, University Distinguished Researcher and Teaching Awards. A list of current members of the faculty, with some of their papers, is included on pp. 54ff. The research interests of the faculty are the areas of specialization available for graduate study. They include diverse areas of pure mathematics such as algebraic geometry, differential geometry, geometric topology, symplectic topology, group theory, harmonic analysis, Lie groups, commutative algebra, several complex variables. They also include a wide variety of applied mathematics such as composite materials, mathematical biology, mathematical physics, approximation theory, ordinary, partial and functional differential equations, probability theory and statistics, scientific computing, stochastic processes.

During the present year there are approximately 27 members of the Mathematics faculty associated with government-sponsored research contracts.

Research Facilities

The Mathematics Branch Library collection in theoretical mathematics consists of 195 journal subscriptions, 15,000 bound journals and 9,500 books. In addition, the Marriott Library collection includes numerous books and journals of interest to mathematics researchers and scholars. There are extensive interactive computing and computer graphics facilities available in the Department.
Computing Facilities

The Department provides outstanding computing facilities for use by faculty, students and staff. In mid-1995, the fully-Internetworked workstation and microcomputer configuration included more than 230 systems in a range of models from these architectures:

- DEC Alpha (13)
- DECstation (28)
- Hewlett-Packard 9000/737 (7)
- NeXT (10)
- Silicon Graphics (23)
- Sun SPARC (51)
- IBM PC (1)
- Apple Macintosh (100)

These include at least one file server from each UNIX architecture. Four dual-processor Sun SPARC 20/512 servers manage user home directories.

Four student laboratories provide the public physical access to the systems. Each user has just one home directory, independent of login architecture, and all users have login access to about 50 public UNIX workstations. Most standard programs are available on all architectures.

One large classroom provides a large-screen projection system for Silicon Graphics workstation and videotape output, plus a smaller projection system for personal computer display. There are graphics workstation video recording facilities, two color printers, and about 20 distributed laser printers, including three high-volume duplex laser printers in the student laboratories. A faculty research modem pool and a campus-wide modem pool provide dialup access to the facilities from home computers. These modem pools also support SLIP and PPP network connections, permitting home users to run normal windowing and network programs.

The facility is a hub on the campus air-blown fiber-optic network backbone, which can provide several orders of magnitude in expanded network capacity, as the need arises.

Research projects can apply for additional computer resources at the Utah Supercomputing Institute, with clusters of high-end IBM RS/6000, IBM SP/2, and Silicon Graphics Power Challenge systems capable of delivering more than 3 gigaflips of computing power.

For more information about the Department and its activities and facilities, visit the site [http://www.math.utah.edu](http://www.math.utah.edu) on the World-Wide Web.

Conferences and Symposia

In recent years the Department of Mathematics has sponsored the following mathematical conferences. (Proceedings of most of these conferences have been published and are available in the departmental offices or Mathematics Library.)

1970 - Several Complex Variables (held at Park City, Utah)
1971 - Ring Theory (held at Park City, Utah)
1972 - Delay and Functional Differential Equations and Their Applications
1972 - Vector and Operator Valued Measures and Applications (held at Snowbird Resort, Alta, Utah)
1974 - Geometrical Topology (held at Park City, Utah)
1974 - Computer Aided Geometric Design (held on University of Utah campus)
1975 - Finite Groups (held at Park City, Utah)
1976 - Stochastic Differential Equations (held at Park City, Utah)
1977 - Partial Differential Equations and Geometry (held in Salt Lake City)
1978 - Nonlinear Oscillations in Biology (American Mathematical Society summer seminar held on University of Utah campus)
1979 - Mathematical Aspects of Developmental Biology (held on University of Utah campus)
1980 - Mathematical Aspects of Physiology (American Mathematical Society-SIAM summer seminar held on University of Utah campus)
1981 - Field Workshop in Mathematical Biology (jointly sponsored with the University of Arizona and held at the Upper Salt Creek Canyon, Canyonlands, Utah)
1982 - Representation Theory of Reductive Groups (held at Park City, Utah)
1983 - Second Field Workshop in Mathematical Biology (Hart's Draw just outside boundary of Canyonlands, Utah)
1983 - Far Western Sectional Meeting of American Mathematical Society (held on University of Utah campus)
1984 - Combinatorial Group Theory & Very Low Dimensional Topology (held at Alta Lodge, Alta, Utah)
1985 - Nonlinear Oscillations in Biology and Chemistry (held on University of Utah campus)
1986 - Nonlinear Partial Differential Equations (held on University of Utah campus)
1987 - Joint Summer Meeting, American Mathematical Society and Mathematical Association of America (held on University of Utah campus)
1988 - Workshop on Geometric Methods in Representation Theory (held in Salt Lake City)
1988 - Workshop on Discrete Groups, Hodge Structures and Harmonic Maps (held at University Park Hotel)
1989 - American Mathematical Society Symposium in Pure Mathematics, Topic: Complex Geometry and Lie Theory, attendance approximately 120 people (held at Sundance, Utah)
1990 - Nonlinear Wave Propagation and Phase Transitions, (at University Park Hotel)
1990 - Computational Methods for Fluid Dynamics and the Evolution of Fronts and Interfaces (held on University of Utah campus)
1991 - National Science Foundation Summer Geometry Institute (held in Park City, Utah)
1992 - National Science Foundation Summer Geometry Institute (held in Park City, Utah)
1993 - Minisymposium: Competition for Space and Territoriality (held on University of Utah campus)
1995 - Minisymposium: Conformal Mapping (held on University of Utah campus)
1995 - Utah Nonlinear Analysis Workshop (held on University of Utah campus)
1996 - Minisymposium: Measuring, Representing, Estimating, Interpolating, Modeling and Visualizing Cardiac Electrophysiologic Phenomena (held on University of Utah campus)
1996 - Minisymposium: Biofluid Dynamics (held on University of Utah campus)

Financial Aid
Many of the graduate students in mathematics are supported by teaching assistantships (for students admitted to the master’s degree program) and by teaching fellowships (for students admitted to the Ph.D. degree
program. (For convenience in this bulletin, “teaching fellowship” will usually be used to include both “teaching assistantship” and “teaching fellowship,” except where it is necessary to make a distinction between them.) Stipends and duties are discussed on p. 23. In all cases, tuition is waived for teaching fellows and teaching assistants.

Applications

The following information comes from the Admissions Office of the Graduate School. Each item must be completed before the application can be processed.

1. Completed Application for Admission to Graduate School

   (a) Read the application carefully. Omitted information can delay the processing of your application.
   (b) You should turn in your application and transcripts as soon as possible in order for the information to be sent to your department on time.
   (c) Allow processing time of four to six weeks in the Admissions Office.
   (d) State the name of the department you wish to apply to clearly on the appropriate line of the application.

2. Appropriate Application Fee

   (a) Application fees must be paid in full before your application can be processed. Late processing fees will be assessed on all applications received after published University deadlines. (see application for these dates)

3. Transcripts, Deadlines, Scores and other related material

   (a) Two copies of transcripts from each college or university you have attended, excluding the University of Utah

      Note: Transcripts you have had sent to the University of Utah in the past should be on file if you attended the University. Check with the Admissions Office if you have questions regarding this issue.

   (b) Double check with your department on deadlines. Departmental deadlines must be adhered to when they occur ahead of University deadlines.

   (c) Graduate admissions test scores should be sent directly to the department you are applying for, not to the Admissions Office. (e.g. GRE, GMAT, MAT, etc.)

   (d) Reference letters should be sent directly to your department.

   (e) Personal statements should be sent directly to your department.

Admission to graduate status in either a Master’s or Ph.D. program requires that students hold a Bachelor’s degree, or its equivalent, with a grade point average of at least 3.0 and that they show promise of success in graduate work. Applicants are urged to take the advanced mathematics portion of the Graduate Record Examination. Foreign students are required to take both the TOEFL and TSE tests.

Students are normally admitted at the beginning of the autumn quarter. It is desirable that applications for teaching fellowships and teaching assistantships, as well as other financial grants, be submitted as early as possible. Applications received before March 1 will automatically be considered for fellowships for the following autumn quarter. Highly qualified applicants who are not awarded a fellowship or assistantship because of the limited number of positions available may be invited to have their application included in a pool for awards for subsequent quarters of that academic year.

Tuition

Tuition (12 hours) is currently $766.70 per quarter for Utah residents and $2,356.20 per quarter for non-residents. (Tuition rates may change without notice.) All resident tuition fees are waived for teaching fellows and teaching assistants, and in most cases nonresident tuition will also be waived. All international students are required to pay $15.00 each quarter to help cover additional administration costs that occur. Supported students who withdraw from a course covered by their tuition waiver will be financially responsible for the tuition of that course.
Health Insurance Requirement

The University of Utah has instituted a program requiring students to have and maintain health insurance coverage. For the academic year beginning Autumn 1996, all matriculated graduate students registered for credit hours, and all undergraduate students registered for six or more credit hours must either (1) enroll in the University sponsored student insurance plan, or (2) complete and return the Insurance Action Form to the Student Insurance Office (555 Foothill Blvd., Salt Lake City, UT 84112). On the form, students must provide information verifying that they have other health insurance which will cover them for the entire academic year. One of these two actions must take place by the second Friday of the quarter to avoid a registration hold. Students beginning any quarter other than Autumn must comply by the second Friday of the quarter they begin and each subsequent Autumn quarter of every academic year.

Students are not required to purchase the University sponsored plan. However, if a student chooses not to purchase the University plan and fails to return a completed Insurance Action Form (including signature) by the second Friday of the quarter; a HOLD will be placed on the student’s registration.

Questions regarding the compliance requirements should be directed to the Student Insurance Office Coordinator, (801) 585-6949.

Housing and Cost of Living

The University accepts applications for on-campus residence hall and University student apartment housing without regard to religious affiliation, race, color, sex, national origin or disability.

Residence Halls (on-campus)

Housing for mature graduate students is provided within the residence halls complex on campus. In the residence halls one rents a room only, and shares bathroom and kitchen with a large number of people. One’s neighbors will be mostly undergraduates. Food services are offered as well as special study facilities and programs. The area accommodates approximately 200 persons and is subject to all policies and procedures relating to residence halls living. The area is governed by a 24-hour-a-day, 7-day-a-week quiet policy. Room charges range from $1,523.00 for a double room to $2,235.00 for a single room for the academic year (three quarters). Full linen service (optional) is available for $46.36 for the academic year. Dues in the Residence Halls Student Association are $10.00 per quarter.

For further information contact Office of Residential Living, S11D Van Cott Hall, University of Utah, Salt Lake City, Utah 84112, (801) 581-6293.

Meal service is available on a point plan at any University Food Service location including the Union Terrace, the Panorama Room, Ballif Commons, the Annex and snack bar in University building. To use the point plan, students deposit money in their University Food Service account and receive a bonus ranging from 0% to 9% depending on the amount deposited. Students “pay” with their University ID card for the a la carte dishes they choose, and the cost is deducted from the points in their account. Expenses for food are thus based on the amount and number of meals an individual student eats. Prices for the average-sized breakfasts, lunches and dinners are $3.00, $4.00 and $5.00 respectively. Points can be carried over from one quarter to another. Refunds are made if a student has points left over at graduation or upon withdrawal from school. A Ute Point Refund application will need to be filled out and returned to the Food Service office before a refund is given. For non-resident hall students, refunds can be given at any time. Resident hall students need to obtain a dorm release and return it to the Food Service office. Refunds will be made for the balance of the account less prorated portion of the bonus credited and taxes paid (based on your discount percentage) less a $10.00 processing fee. For further information contact the Food Service office, 30 Olpin Union, University of Utah, (801) 581-7257.

On-Campus Apartments

Housing for single students (only in Medical Plaza Towers), students with families, faculty and staff is available on-campus in University apartment communities.

Medical Plaza Towers, two 14-story apartment buildings, and a town house complex are located adjacent to the University Health Sciences Center. Unfurnished one-, two- and three-bedroom apartments and
three-bedroom town houses are available. Apartments have living room carpeting, Levelor blinds, range, refrigerator and disposal. Central coin-operated laundry facilities are located in each tower. Storage lockers, a children’s playground and convenient parking are additional features. Monthly rents include utilities (except telephone), routine maintenance and trash removal: $383 for one bedroom; $465 to $485 for two bedrooms; $610 for three bedrooms; and $685 for three-bedroom town houses. Currently there is a 8- to 12-month waiting list.

University Village is a community of unfurnished one-, two- and three-bedroom apartments located within walking distance of the campus, bordering an attractive residential area of the city. University Village is available to families only. The apartments are unfurnished except for an electric stove, refrigerator and disposal. Space is provided for washing machines, and each building has coin-operated laundry facilities. North and East Village units are carpeted and air conditioned. Rates include all utilities (except telephone), cable, routine maintenance and trash removal: $298 to $357 per month for one bedroom; $357 to $414 per month for two bedrooms; $513 per month for three bedrooms. Currently there is a 6- to 18-month waiting list at this location.

The Villages feature two community centers, preschool, early childhood education programs, various adult programs, and landscaped grounds, gardens and picnic areas.

For further information contact University Student Apartments, 1945 Sunnyside Avenue, Salt Lake City, Utah 84108, (801) 581-8667.

Off-Campus Housing

House and apartment listings can be found in the classified section of the Salt Lake Tribune, the Deseret News and the student newspaper, The Daily Utah Chronicle. Prices for accommodations vary according to the type rented. The price range for studio apartments is $317 to $390 per month; $414 to $456 for one bedroom apartments and $511 to $630 for two bedroom apartments. One- and two-bedroom apartments are the most commonly available off-campus housing options.

The University’s total enrollment is currently over 27,000. During 1995–96 there were 34 men and 16 women who were teaching fellows and assistants in mathematics. Our graduate students come from different areas of the United States as well as several foreign countries.

The Community

The Salt Lake City metropolitan area has a population of over half a million and is the cultural, economic and educational center of the Intermountain West. The Utah Symphony, Ballet West and Utah Opera are located in Salt Lake City. The Delta Center is the home of professional teams such as the Utah Jazz (basketball).

Climate and geography combine in Salt Lake City environs to provide many opportunities for those interested. Some of the world’s best skiing is available less than an hour’s drive from the University campus.
PROGRAMS OF STUDY

The Mathematics Department offers programs leading to the degrees of Doctor of Philosophy, Master of Philosophy, Master of Arts, Master of Statistics and Master of Science in Mathematics.

MASTER OF ARTS AND MASTER OF SCIENCE DEGREES

A. Graduate School Requirements:

The Master of Arts degree requires standard proficiency in one language — French, German or Russian. The Master of Science degree does not have a language requirement. Otherwise, the degree requirements for the M.S. and M.A. degrees are identical.

Requirements for these degrees are explained in some detail on pp. 32–33 of the 1993–95 Graduate School Bulletin. Note particularly that a number of forms must be filed, and that certain time limitations are to be observed. Some remarks are in order relative to these requirements.

1. A comprehensive oral and/or written qualifying examination in mathematics is given, usually after a student has completed at least a year of graduate study. (See below.) The Master’s Project may require a final oral examination. This exam is called the project defense or thesis defense and is separate from the comprehensive examination.

2. Each Master’s candidate will be assigned an academic advisor upon entering the program. This advisor has the primary responsibility of guiding and evaluating the candidate’s progress through the Master’s program. The advisor chairs the candidate’s Supervisory Committee consisting of three members. Questions concerning the interpretations of degree requirements should be directed to the candidate’s advisor.

B. Departmental Requirements:

Requisites for the Master’s degree in pure mathematics are:

Course Requirements
1. Math 521, 522, 523 (analysis)
2. Math 531, 532, 533 (algebra)
3. One 600-level sequence consisting of three one-quarter courses (e.g., 621, 622, 623)
4. Four additional one-quarter courses at the 500 or 600 level

Graduation Requirements
1. Pass two of the written qualifying exams
   OR
2. Take an oral comprehensive exam (see description below) and complete a Masters Project. The students supervisory committee has the option of specifying these alternatives for the project.
   a. Masters thesis. The student should take his/her oral comprehensive exam prior to scheduling a Defense of Thesis; the Defense of Thesis is not a replacement for the Oral Comprehensive exam.
   b. A curriculum project.
   c. Presenting a series of lectures at the graduate level.
   d. Taking 5 additional one-quarter 600 or 700 courses beyond the “four additional courses” specified in (4) of “Course Requirements.” (This can be accomplished by taking three 600 level courses in the second year).

As specified by requirements of the Graduate School, a description of a nonthesis option and the basis for its selection shall be included with the student’s proposed program. This statement and the proposed program of study must then have the approval of the departmental Director of Graduate Studies and be submitted to the Graduate Dean with the proposed program of study. By arrangement with the Graduate School, those students writing master’s theses may use credit hours in courses, numbered 600 or above and in the general area of specialization of the thesis, to fulfill the 9 hours requirement of 697 (Thesis
Requisites for the Master’s degree in applied mathematics are:

Course Requirements
1. Either two 600-level sequences in mathematics or 521–2–3 and one 600-level sequence
2. Seven additional one-quarter courses at the 500- or 600-level

Graduation Requirements
The Master’s project. (See above)

A Comprehensive Examination
Such an examination is required by the Graduate School and is separate from the final oral examination in which a thesis is defended. The student’s supervisory committee shall specify whether this examination will be an Oral Comprehensive Examination or a Written Comprehensive examination or both.1

The Master’s Oral Comprehensive Examination will be conducted by the student’s committee and should be held at least one quarter prior to the quarter in which the student plans to complete the requirements for a master’s degree. The written examination will consist of passing the Written Ph.D. Qualifying Examinations in two areas.

Remarks and Suggestions
Courses which are offered regularly at the 500-level include:

Pure Mathematics:
- Math 521, 522, 523: Introduction to Real Analysis
- Math 530: Introduction to Number Theory
- Math 531, 532, 533: Linear Algebra, Geometric Groups, Rings and Fields
- Math 541, 542, 543: Introduction to Differential Equations
- Math 551, 552: Introduction to Topology
- Math 553: Curves and Surfaces in Euclidean space

Applied Mathematics:
- Math 507: Introduction to Probability
- Math 504, 505: Introduction to Stochastic Processes
- Math 508, 509: Statistical Inference
- Math 511, 512, 513: Mathematical Biology
- Math 514, 515, 516: Topics in Mathematical Chemistry
- Math 561, 562, 563: Introduction to Numerical Analysis

Students should also be aware of 500-level offerings in other departments (e.g., courses in Computer Science, Mathematical Physics, Economics, etc.) which can be applied to fulfill the course requirements for the Master’s program in mathematics. Permission to include such courses must be obtained from the student’s committee.

All graduate students who have not had an appropriate course in computer programming are strongly encouraged to consult faculty about appropriate classes in programming early in their program.

Persons in the Master’s program are expected to complete their Master’s degree before entering the Ph.D. program. (Only in exceptional cases will permission be given to enter the Ph.D. program without completing the Master’s program.) The normal schedule for Master’s students who wish to continue for the Ph.D. is that they apply to the Ph.D. program during their final year as a Master’s student and that they complete the Master’s degree at the end of that year. Those who plan to take the written qualifying exam to complete their graduation requirements to the Masters Degree, may take

1 Both may be required by the committee. A marginal pass of the written examination is one justification for requiring both exams.
those exams prior to the beginning of the Fall Quarter of their third year. Their admission to the Ph.D. Program is contingent on their successful completion of these exams.

Financial support for the Master’s program will be limited to two years. Teaching loads and stipends are indicated on pp. 23.

Anyone wishing to pursue the study of mathematics toward a Ph.D. degree, but whose preparation does not qualify him/her to enter directly into the Ph.D. degree program, should enter the Master’s program with the assurances that:

1. It will not hinder nor significantly delay his/her progress since it is the appropriate “next step” toward his/her goal.

2. Courses for the Master’s degree will provide the introductory material and motivate the more abstract and theoretical approach to the same subjects in the Ph.D. program. However, successful completion of the Master’s degree does not imply automatic acceptance into the Ph.D. program. Acceptance and financial support for the Ph.D. program is awarded on the basis of a review of the application materials submitted, in a single competition among all applicants, irrespective of whether their previous degrees come from the University of Utah or other institutions.

All candidacy forms for the Master’s degree should be submitted to the Graduate Secretary who will forward them to the Graduate School.

C. Sequence of Procedures for the Master’s Degree

There are time requirements and procedures that must be met in the course of completing a Master’s degree. The following schedule is designed to help the candidate meet the necessary deadlines.

Schedule

1. First quarter of graduate work:
   Discuss your proposed program with your advisor at the beginning of the quarter. Your advisor’s name may be obtained from the Graduate Secretary.

2. Second quarter of graduate work:
   Meet again with your advisor to discuss your progress and any changes in your program. Discuss with him/her your chosen area of study and Master’s degree project. It may be desirable for the Director of Graduate Studies to make some changes in the committee membership after you choose your area of study and your master’s degree project.

3. Three quarters before you plan to graduate:
   Make the final plan for your course work and have it approved by your entire committee. Subsequent changes in the program are to be approved by your committee and reported to the Graduate School. Talk with members of your committee about plans for your comprehensive examination (to be taken early in third quarter of second year) including topics that might be included on it; those of you choosing to take a written qualifying exam should consult with your advisor on the best strategy for taking the exam. Remember, the oral comprehensive exam must be taken before scheduling a thesis or project defense.

4. Two quarters prior to graduation:
   File the “Request for Supervisory Committee” and “Application for Admission to Candidacy for a Master’s Degree” forms with the Director of Graduate School. These cannot be filed until at least one quarter of graduate work is completed and must be filed at least one quarter before you plan to graduate. (These forms can be picked up from the Graduate Secretary.)

5. Early in your final quarter:
   Candidates writing a thesis should schedule the (Defense of Thesis) Final Oral Examination with their supervisory committee. A Handbook for Theses and Dissertations is available in the Graduate School Office for details regarding the preparation and presentation of theses.
   If you are not otherwise enrolled for at least three credit hours during the quarter in which you plan to defend your thesis, you must register for three credit hours of “Faculty Consultation” (mathematics 698) before taking this final oral examination.
6. **Six weeks prior to graduation:**
   Have an acceptable draft of the thesis in the hands of your advisor. No time can be set for starting to write a thesis, since conditions vary. Consult with your advisor about the estimated time for writing a thesis.

   Several drafts of a manuscript are usually required before a final acceptable copy is reached. Consult with members of your committee regarding the stage at which they wish to see a copy.

7. **Five weeks prior to graduation:**
   Deliver a copy of the thesis to each member of your committee at least two weeks prior to the examination date.

   Review the Graduate School’s “Schedule of Procedures” for further information about procedures that should be followed in the final quarter before graduation.

**Time Limit**
A period of four years is allowed to complete degree requirements for a Master’s degree. Extensions beyond this four-year limit must be recommended by the supervisory committee and approved by the Dean of the Graduate School. The same time limit applies to M.S., M.A., M.Phil. degrees. Supported students are entitled to tuition waivers for a total of two years or six quarters for M.S., M.A., and M.Phil. degrees.

**Transfer Credit**
At most nine hours of transfer credit from another university will be allowed in a 45-hour graduate program toward a master’s degree.

**D. Recommended schedule of study toward a master’s degree and for those planning to enter the Ph.D. program.**

1. Master’s degree students **not planning to apply for the Ph.D. degree program** should proceed with the following recommended schedule:

<table>
<thead>
<tr>
<th>YEAR</th>
<th>ACCOMPLISHMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Study three 500-level or 600-level courses throughout the year.</td>
</tr>
<tr>
<td>2</td>
<td>At the beginning of the year, talk with members of your committee about plans for a master’s degree project. Take courses that will enable you to complete the required hours of approved credit. Prepare to take the oral comprehensive examination not later than the sixth week of Spring Quarter. Plan to complete the requirements for a master’s degree by the end of the year.</td>
</tr>
</tbody>
</table>

2. Master’s degree students who subsequently **plan to apply for admission to the Ph.D. degree program** should proceed with the following recommended schedule:

<table>
<thead>
<tr>
<th>YEAR</th>
<th>ACCOMPLISHMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Study three 500-level or 600-level courses throughout the year. Where at least two 600-level courses are studied, take at least two written qualifying examinations at the end of the year, in September.</td>
</tr>
<tr>
<td>2</td>
<td>Study at least two courses at the 600-level or 700-level throughout the year. Apply for admission to the Ph.D. degree program no later than February 15. Complete the requirements for a master’s degree. Complete the written qualifying examinations at the end of the year, in September.</td>
</tr>
</tbody>
</table>

**NOTE:** The following is quoted from the Bulletin of the University of Utah Graduate School 1993–95:

**Time Limit.** All work for the master’s degree must be completed within four consecutive calendar years. On recommendation from the student’s supervisory committee, the Dean of the Graduate School can modify or waive this requirement in meritorious cases.
MASTER OF STATISTICS (MATHEMATICS) PROGRAM

A student is admitted to the program by the University Statistics Committee by making application through the Graduate School. If the University Statistics Committee admits the student, the Mathematics Department will admit him/her to its Master’s program. No form needs to be signed by the Mathematics Department for this. Upon completion of the student’s program, the University Statistics Committee will notify the Graduate School and the Mathematics Department. The degree, Master of Statistics (Mathematics), will be awarded by the Mathematics Department.

Prerequisites
1. Either a Bachelor’s degree in Mathematics, or the equivalent, e.g., two years of Calculus and two senior level mathematics sequences.  
2. Math 307, 308, 309, or equivalent.

Course requirements
1. Math 507, 508, 509
2. Math 607
3. One sequence of Math 601–2–3 or 604–5–6
4. Three sequences of graduate level courses approved by supervisory committee.
5. Math 696 (Master’s project) 3–6 hours.
6. Written Competency examination in applied statistics.
7. Oral examination on project (Math 696), this is, a “project defense.”

MASTER OF SCIENCE DEGREE PROGRAM FOR SECONDARY SCHOOL TEACHERS OF SCIENCE OR MATHEMATICS

The College of Science of the University of Utah, including the Departments of Biology, Chemistry, Mathematics and Physics, offers a Master’s Degree program for certified secondary school teachers of science and mathematics.

The novel aspect of this option is that the program is designed for teachers. It will have them begin their studies with courses which are compatible with their knowledge and background in the science subject they teach at the time they enter the program, even if their background in formal studies is not extensive.

Teachers entering the program may study courses primarily in the science discipline they teach, or they may take courses in allied areas for certification or further enrichment. For example, the program for biology teachers under this option could consist largely of biology courses with or without some supporting work in other science disciplines. Another option is the mathematics teacher who wishes a better understanding of the applications, and enters this program to study highly quantitative courses in the other sciences. Seminar type courses in the science curriculum and in science teaching strategies will relate subject matter learned to classroom use.

Specifically, it is not required that the applicants have an academic major or a teaching major in the science subject matter which they teach. To illustrate, consider a successful chemistry teacher who has completed no more than sophomore and perhaps a few junior level courses in chemistry at the college level. If the teacher were to enter the program under a plan to receive this degree in chemistry, the designed program would start at the candidate’s level of knowledge, beginning studies by enrolling in appropriate sophomore or junior level chemistry courses. The program, though starting from that level, would be designed to increase power over the subject matter of chemistry and its presentation, as far as practicable within the limits of a 45 to 50 quarter credit hour program. The same would hold for a teacher wishing to qualify for the degree under this option in Biology, Mathematics or Physics. In each case the program for the teacher would start at the entering level of knowledge and advance as far as possible, in the direction of the candidate’s expressed goals.

2 A “sequence” refers to a course that continues through an academic year.
3 If Math 507, 508, 509 was taken while the student was an undergraduate, then either one of Math 601–2–3, 604–5–6, 607–8–9 or a mathematics sequence listed below is required.
For each teacher entering the program, a graduate committee will be appointed which will work with the candidate to devise an individual program for the Master’s Degree under this option. The committee will then supervise performance and progress toward that degree.

For admission to the program, an applicant must be accepted by an appropriate committee of the College. At the time of application, a teacher should have a valid teaching certificate and be teaching science or mathematics in a secondary school. The teacher should have had at least three years of teaching experience and be recommended by someone in a position to judge performance as a teacher. The candidate must satisfy the general University requirements for admission to the Graduate School. The program has as its objective the improvement of science and mathematics teaching in secondary schools. Candidates are sought who consider themselves to be professional science or mathematics teachers and who plan to remain in the teaching field.

It is assumed that teachers who undertake this program will be regularly employed secondary school teachers and that most of their work in the program will be done in residency in summers, or in late afternoon or evening classes. In some cases, a teacher may be granted a leave of absence from school duties enabling participation on a full time basis at the University during part of an academic year. Each candidate will be asked to engage in a Master’s project in the area which will grant the Master’s degree. The project may consist in the performance of a laboratory experiment, preparation of innovative pedagogy, some kind of approved field work, or a scholarly exposition of an advanced topic. In any case a written report describing the activity will be required. This project will comprise nine of the 45 to 50 quarter hours required for completion of the degree program.

Refer to (C) and (D) above for information and suggestions on completing requirements for Master of Statistics and Master of Science for Secondary School Teachers degrees.

MASTER OF PHILOSOPHY DEGREE

The Master of Philosophy (M.Phil.) degree requires the same qualifications for admission and scholarly achievement as the Doctor of Philosophy degree except that it does not require a doctoral dissertation. There is not a separate program for this degree. All supervisory committees, requirements in major and allied fields, and qualifying examinations apply to this degree. The Master of Philosophy degree, like the Doctor of Philosophy degree, is a terminal degree, and a student will not be considered a candidate for both degrees in the same department. The M.Phil. degree of a student desiring to pursue a doctorate in the department in which he/she was awarded the M.Phil. may be rescinded only by formal action of the Graduate Council on written request of the student.

DOCTOR OF PHILOSOPHY DEGREE

A. Graduate School Requirements:

The following requirements are listed on pp. 33–34 of the 1993–95 Graduate School Bulletin:

The Doctor of Philosophy degree is awarded for high attainment in an advanced specialized field of study. It requires competence in independent research and an understanding of related subjects. This degree is not awarded simply for the fulfillment of residence requirements and the accumulation of credits.

1. Supervisory Committee: A committee normally composed of five faculty members is appointed to supervise a student’s graduate work. One or more members of the supervisory committee must be appointed from another department. The supervisory committee is responsible for approving the student’s academic program, preparing and judging the qualifying examinations, approving the dissertation subject and final dissertation and administrating and judging the final oral examination. The chairperson of the supervisory committee normally directs the student’s research and writing of the dissertation. The final oral examination may be chaired by any member of the supervisory committee consistent with departmental policy. Decisions concerning program requirements, examinations and the dissertation are made by majority vote of the supervisory committee. Supervisory committee members should be members of the University faculty, including regular, visiting, adjunct, clinical and research faculty. They should hold an academic or professional doctorate and should have demonstrated competence to do research, scholarly or artistic work in the
general field of the student’s studies. Appointments to graduate supervisory committees of persons who do not meet these requirements must be recommended and justified by the director of graduate studies of the department and approved by the dean of The Graduate School.

It is the student’s responsibility to initiate a request for a supervisory committee. The department chairperson or director of graduate studies, depending on departmental policy, appoints the committee members, one of whom is designated as chairperson, subject to approval by the dean of The Graduate School.

2. **Program of Study:** Candidates for the Ph.D. degree ordinarily must complete not fewer than three full years (nine quarters) of approved graduate work, (i.e., courses numbered 500 and above), inclusive of work for the M.A. or M.S. degrees. More time may be required. In truly exceptional cases, a shorter period of time in graduate work may be approved by the dean of The Graduate School.

If a supervisory committee finds a graduate student’s preliminary work deficient, the student may be required to register for and complete supplementary courses that do not carry graduate credit. Ph.D. candidates must file the *Program of Study* form, which lists course work and research hours, in the Graduate Records Office. This form is due by the last day of the quarter preceding the quarter of graduation.

3. **Residency:** At least one year (i.e., three consecutive quarters) of the doctoral program must be spent in full-time academic work at the University of Utah. **Nine credit hours is considered a full load, which all TAs and TFs are required to take every quarter.** Off-campus video conference courses may not be used to satisfy any part of this residence requirement.

4. **Qualifying Examination:** Written and oral qualifying examinations (preliminary examinations) are required of each student. The nature and format of these examinations are established by individual departments subject to approval by the Graduate Council. An examination or parts of an examination may be repeated only once and only at the discretion of the student’s supervisory committee.

Qualifying examinations normally are prepared, administered and evaluated by a student’s supervisory committee. However, a department has the option of appointing an examination committee that administers the qualifying examinations and ensures that examinations are properly prepared and evaluated.

5. **Registration:** The candidate must register for a minimum of 20 credit hours of Thesis Research (course number 797, Thesis Research: Ph.D.) and be regularly enrolled at the University for three or more credit hours during the quarter in which the final oral examination is taken. For details, see Minimum Continuous Registration in the Graduate School bulletin.

6. **Language Requirement:** Whether foreign language proficiency is required of candidates is determined by departmental policy. When such proficiency is required, it must be certified by the Department of Languages and Literature on the basis of special examinations or academic courses completed in the language. In some instances, language proficiency may be certified by individual departments if appropriate procedures have been approved in advance by the Dean of The Graduate School. In most cases, however, fulfillment of the language requirements must be verified by the Department of Languages and Literature. Detailed regulations concerning language requirements are listed elsewhere in this section of the Graduate School bulletin.

7. **Dissertation:** The candidate must submit a dissertation embodying the results of scientific or scholarly research or artistic creativity which gives evidence of originality and ability in independent investigation and must contribute to knowledge or the creative arts. The dissertation must show a mastery of the relevant literature and be presented in acceptable style. The style and format of the dissertation are determined by departmental policy and registered with the thesis and dissertation editor, who approves individual dissertations in accordance with departmental policy. The dissertation is approved by the student’s supervisory committee. At least three weeks before the final oral examination (dissertation defense), the student should submit an acceptable draft of the dissertation to the supervisory committee chair, and at least two weeks before the examination date, the committee members should receive copies.
The doctoral dissertation is expected to be available to other scholars and to the general public. It is the responsibility of all doctoral candidates to arrange for the publication of their dissertations. The University accepts three alternatives for complying with the publication requirements.

a. The entire dissertation may be published and distributed by a publisher of the candidate’s choice, exclusive of vanity publishing;
b. The entire dissertation may consist of an article or articles accepted for publication in approved scholarly journals;
c. The dissertation may be microfilmed by University microfilms and copies made for public sale.

Regardless of the option used for meeting the publication requirement, an abstract of each dissertation is to be published in University Microfilm’s *Dissertation Abstracts International*. Detailed policies and procedures concerning the publication requirements, use of restricted data and other matters pertaining to the preparation and acceptance of the dissertation are contained in *A Handbook for Theses and Dissertations* published by The Graduate School.

8. **Final Examination:** The student must pass a final oral examination before graduation. The examination must follow receipt of the dissertation by the supervisory committee. The committee schedules and announces a public oral examination at which the candidate must defend the dissertation. This final oral examination may be chaired by any member of the supervisory committee consistent with departmental policy.

9. **Survey of Earned Doctorates:** This form will be distributed by the thesis editor to all students completing doctoral dissertation. Students complete and return the form to the Thesis Office along with final copies of the dissertation. The survey, conducted by the National Research Council, provides aggregate data used by the National Science Foundation, National Endowment for the Humanities, National Institutes of Health, and other national and state government agencies.

10. **Time Limit:** The time limit for completing the Ph.D. degree is determined by individual departments with the approval of the Graduate Council (see (8) under Departmental Requirements). Requests to exceed established time limits must be recommended by a candidate’s supervisory committee and approved by the departmental director of graduate studies and the dean of The Graduate School. Students whose studies have been interrupted for long periods of time and who have been granted extended time to complete their degrees may be required to complete additional courses, pass examinations, or otherwise demonstrate that they are current in their field. Supported students are entitled to a tuition waiver for a total of five years; three years if they enter with a master’s degree.

11. **Exceptions:** Exceptions to the general requirements for the Ph.D. stated above must be approved by the dean of The Graduate School upon the recommendation of the student’s supervisory committee and the respective director of graduate studies.

**Suggestions and Remarks**

1. The Master’s degree is not a formal requirement for the Ph.D. degree. However, students in the Master’s program are expected to finish their degree before beginning their Ph.D. work.

2. All graduate students who have not had an appropriate course in computer programming are strongly encouraged to consult faculty concerning appropriate programming courses early in their program.

**B. Departmental Requirements**

1. **Supervisory Committee.** An academic advisor will be appointed for each prospective student prior to their first quarter of graduate study. A Supervisory Committee will be appointed for each graduate student by the end of their first year of study. Any student may, at any time, request a change of advisor and/or committee. This request should be made to the Director of Graduate Studies.

   The committee initially appointed for a student shall consist of three people, at least one of whom is in an area of the student’s major interest. After the written qualifying examinations are passed,
the committee shall be expanded to a committee of five as required by the Graduate School. Since a student’s interests may change, the committee can be changed to reflect these interests.

The functions of the student’s supervisory committee should be advising and evaluating. Specifically:

a. The student should meet with his/her advisor at the beginning of each academic year to plan that year’s work, and at least once a quarter to discuss progress. The responsibility for setting these meetings rests with the student.

b. The “Proposed Ph.D. Program”, required by the Graduate School, should be worked out by the student and his/her committee at an early stage, with revisions later if the committee considers them desirable.

c. Any special requests regarding financial aid or program of study should be submitted to the student’s advisor.

2. Course Requirements

a. Course requirements for the Ph.D. degree will consist of at least seven sequences numbered 600 or above, or their equivalent, approved by the student’s supervisory committee. The seven sequences required must include at least 20 credit hours of courses numbered 771–797 (topics courses, seminars, thesis research). The department has made special arrangements with the Graduate School that credit in any of these courses qualifies as “Thesis Research”. The graduate student’s supervisory committee, if it deems it appropriate, may require additional courses and/or require specific courses.

b. Exceptions to the above regulations must be approved on an individual basis by the Graduate Committee upon recommendation by the student’s supervisory committee.

3. Written Qualifying Examination

a. Time of the written qualifying examination.

The written qualifying examination is given each year in September, usually in the second or third week. Most Ph.D. students will take the exam just before the beginning of the second year. Students planning to take the exam for the first time later than their second year must obtain permission from their supervisory committee. If a student is planning on taking a test from outside the math department, it is possible that the test may be given at a time of the year other than September. It is the student’s responsibility to make appropriate arrangements for that test.

b. Nature of the written qualifying examination.

The written part of the Ph.D. qualifying examination in mathematics will consist of three tests, typically in the following seven areas:

- Algebra
- Applied Mathematics
- Differential Equations
- Numerical Analysis
- Real and Complex Analysis
- Topology and Geometry
- Probability/Statistics

Students should choose their tests in consultation with their advisor. One purpose of this consultation is to ensure sufficient breadth in the choice of tests. The student’s choice of tests must be approved by the student’s supervisory committee. A student’s supervisory committee may require (for breadth) a specific course or test in mathematics or some other discipline. The course can be up to a year in length, and may be related to the student’s research interests. Registration forms for the examination are available from the Graduate Secretary. A completed form must be returned to the Graduate Secretary before the end of the spring quarter preceding the exam.

In order to pass the written qualifying examination, a student must pass three tests. The student is permitted two attempts to pass the three tests, taking place within a period of thirteen
months. A maximum of three tests may be taken in each attempt. On the second attempt a student may again take a maximum of three tests, although previously passed tests may not be taken again.

c. **Syllabus.**
The syllabi for the qualifying examination are included in this bulletin. These syllabi are the product of long discussions among the faculty in the various areas, and will not change from year to year, unless approved in advance by the Graduate Committee.

An important point for students to recognize is that the tests will be based on the material in the syllabus, NOT on the material in the preceding year’s course on the subject. The student is responsible for preparing to be examined in all of the topics listed on the syllabus, whether or not all of the subjects were covered in a particular course on the subject.

d. **Departmental committee on the examination.**
The department chairman will appoint a member of the faculty to make the arrangements for the Written Qualifying Examinations to be given in September of each academic year. This person will select two other members of the faculty, in each of the various areas of the examination, to participate in the preparation and evaluation of the examinations.

e. **Description of the tests.**
The test in each area will be a written test of three hours duration. It is hoped that the inclusion of extra questions will reduce the factor of chance, and the student usually will have the option of omitting some of the questions without penalty. The level of the test should be comparable to that of the first-year graduate course in the field. The faculty members responsible for a given test should check to see that the topics covered on the test are compatible with the syllabus. Copies of past examinations are available from the Graduate Secretary. All examinations are proctored.

f. **Grading of the tests.**
After all the tests in a given area have been graded, the person responsible for the test will decide what is to be a passing score on the examination; in doing so, it is expected that they will confer with and enlist the aid of their colleagues in the area of the examination. (The graders will not know identities of the students whose tests they are grading.) Only after this decision has been reached should the anonymity of the students be breached.

g. **Announcement of results.**
Under normal circumstances the student will be informed within one week of the end of the examination period of the passing score on each test and will be allowed to examine their tests.

h. **Appeals.**
Exceptions may be granted to these rules in some cases. Grading of examinations may also be disputed. A student wishing to make an appeal will do so through their supervisory committee or the Director of Graduate Studies. These faculty members will assist the student in taking the necessary actions. A student may also enlist the aid of the Graduate Student Advisory Committee to help in the process. The names of the members of GSAC are listed in this bulletin.

4. **Oral Qualifying Examination.**
A student’s supervisory committee shall conduct an oral qualifying examination no later than May 31 of the spring quarter which follows the successful completion of the written examination. Students who fail the oral qualifying examination may be given a second examination at the discretion of the student’s supervisory committee. Oral examinations may only be repeated once. Responsibility for scheduling the examination rests jointly with the student and his/her advisor. The oral examination is not a test of specific subject matter retention; rather it is designed to measure the student’s overall mathematics maturity and breadth, and his/her skill at chalkboard exposition and verbal exchange. In general the oral examination is concentrated on the area of specialization of the student and related areas. On the other hand, this oral examination is not a thesis defense. **The candidate initiates scheduling,** with his/her supervisory committee approval. This examination should be scheduled as soon as possible after a thesis supervisor has been identified.
5. **Language Requirements.**
The Department of Mathematics does not have language requirements for a Ph.D. degree.

6. **Final Oral Examination.**
The Final Oral Examination, sometimes called the “Thesis Defense,” is distinct from the Oral Qualifying Examination. This examination consists of a public thesis defense. The committee meets after the defense to vote on final approval.

7. **Teaching Requirements of Ph.D. Candidate.**
The department requires each graduate student who is studying toward a Ph.D. degree to teach a minimum of six courses and a maximum of twelve courses, or equivalent tutorials, or laboratory supervisions to be carried out over a minimum of two years and a maximum of six years.

8. **Time Limit.**
The time limit for completion of degree requirements for the Ph.D. degree is seven years (1979–80 University Senate action). Normal progress is one or two years to pass the preliminary written qualifying examinations, and two or three additional years to complete the thesis work. Supported students are entitled to only five years of tuition waivers; three years if they enter with a master’s degree.

C. **Recommended Schedule of Study Toward a Ph.D. Degree**
The following recommended schedules are considered desirable for teaching fellows in the Ph.D. degree program. The numbered years are presumed to begin in September, when the Autumn Quarter begins and end at the start of the next Autumn Quarter. Some students, especially those who have previously studied in other Ph.D. programs, should be challenged to try to shorten the schedules outlined here. Except where there are extenuating circumstances, teaching fellows who fall more than one year behind these schedules, or who fail to complete the written qualifying examination in two attempts should not expect their teaching fellowships to continue. The following procedure will be followed with a request for a review for extenuating circumstances:

1. The student submits a written request to his/her committee, with a description of the basis of the request.
2. The student’s committee reviews the request and submits a written recommendation to the departmental graduate committee.
3. The departmental graduate committee makes a final decision regarding the request.

**YEAR**  **ACCOMPLISHMENTS**

1. Study three 600-level courses throughout the year. Complete the written qualifying examinations at the end of the summer of the first year, in September.
2. Study two or three advanced graduate courses. Attend some seminars. Try to select an area of specialty and a thesis adviser. Complete the oral qualifying examination. Complete the written qualifying examination if a second attempt is necessary.
4. Devote primary attention to developing a thesis. Continue participating in advanced courses and seminars. Find some research topics to pursue beyond a thesis. Complete the requirements for a Ph.D. degree.

D. **Graduate School Schedule of Procedures for the Ph.D. Degree**
The Graduate School has prepared the following “Schedule of Procedures” for students pursuing a graduate degree. (For details, see the Bulletin of the University of Utah Graduate School and A Handbook for Theses and Dissertations, both of which are available in the Graduate School Office.)

1. **First quarter of graduate work:**
   Determine departmental policies regarding formation of a supervisory committee, qualifying or comprehensive examinations and language requirements. Satisfy such requirements when applicable. Consult and comply with Language Proficiency Requirements in the Bulletin of the Graduate School regarding language requirements if your department requires a language. If transfer
credit for graduate work completed elsewhere is to be used, request that official transcripts be sent to the Admissions Office, 250 So. Student Services Building.

2. **Second quarter of graduate work:**
   After consultation with the chair or director of graduate studies of your department, file the “Request for Supervisory Committee” form. Obtain the form from your department or the Graduate Records Office. If membership of this committee changes during your graduate work, a letter requesting a revision must be sent to the Graduate Records Office for approval. Purchase a copy of *A Handbook for Theses and Dissertations* ($4.00) at the Thesis Office, 208 Bldg. 44.

3. **After your supervisory committees is appointed:**
   Plan your course work and your thesis, nonthesis project or dissertation under the direction of your supervisory committee. Consult the thesis and dissertation editor for style guide selection and specific problems of illustration, duplication, copyright or other aspects of manuscript preparation if you are writing a thesis or dissertation.

4a. **Master’s candidates:**
   (i) After completion of 75% of graduate course work file the “Application for Admission to Candidacy for the Master’s Degree” Program of Study. Deadline for filing is the last day of the quarter preceding the quarter of graduation. File the “Application for Admission to Candidacy for the Master’s Degree” (Program of Study) in the Graduate Records Office. List your program of study chronologically, from the earliest to the most recent or projected course work. If you are writing a thesis, list thesis research hours (course number 697) chronologically each quarter they are taken along with other course work. Subsequent changes in this program must be approved and reported by the supervisory committee to the Graduate Records Office.

   (ii) When scheduled by your department take the Comprehensive Examination. File the “Report on the Comprehensive Examination” in the Graduate Records Office.

4b. **Doctoral candidates:**
   (i) After completion of 75% of graduate course work file your “Program of Study”. Deadline for filing is the last day of the quarter preceding the quarter of graduation. File the “Program of Study for the Ph.D., Ed.D., M. Phil. Degree” in the Graduate Records Office and list your program of study chronologically, from the earliest to the most recent or projected course work. List thesis research hours (course number 797) chronologically each quarter they are taken along with other course work. Subsequent changes in this program must be approved and reported by the supervisory committee to the Graduate Records Office.

   (ii) Three quarters before your planned completion date (or earlier) take the qualifying examination.

   (iii) At least one quarter before completion file the “Report of the Qualifying Examination for the Ph.D., Ed.D., or M. Phil. Degree and Recommendation for Admission to Candidacy” with the Graduate Records Office.

5. **Early in your final quarter of graduate work:**
   Schedule the final examination (thesis or dissertation defense or defense of the final project for nonthesis candidates) with your supervisory committee. You must be registered for three quarter hours in the quarter your defense (or final examination) is held. Submit an acceptable draft of your thesis or dissertation to your committee chair at least three weeks before the scheduled defense.

6. **Following the oral defense:**
   For thesis or dissertation students, have each member of the supervisory committee sign the “Supervisory Committee Approval” forms. If changes in the manuscript are required by the supervisory committee, make them before having the final reader of the manuscript and the chair of the department sign the “Final Reading Approval” forms. These forms and instructions on how to prepare them are available in the Thesis Office. Consult with the thesis editor for any problems related to format or organization of your manuscript. Check your file in the Graduate Records Office and make sure that the “Report of the Final Examination” and other documentation have been filed. After this step is completed, nonthesis students are ready to graduate.
7. **After the final typing of the manuscript that incorporates changes required by the committee:**

When the “Supervisory Committee Approval” and the “Final Reading Approval” forms have been signed, submit one copy of the manuscript to the thesis editor for “Format Approval.” “Format Approval” serves as clearance to duplicate the final copies.

For graduation in a particular quarter, one copy of the defended, committee approved manuscript must be submitted to the Thesis Office for “Format Approval” four weeks prior to the last day of the quarter. For specific dates, consult *A Handbook for Theses and Dissertations*.

8. **At least one week before the registrar’s closing date for the quarter:**

Submit three complete, duplicated copies of the thesis or dissertation to the thesis editor for “Graduation Release” (Thesis Release).

9. **Before the registrar's closing date for the quarter (closing date is the last day of final examinations in any quarter):**

The “Graduation Release” and a copy of the “Supervisory Committee Approval” form are filed in the Graduate Records Office by the thesis editor. The “Graduation Release” will be signed in that office if your file is complete. Candidates from the Graduate School of Architecture, the College of Fine Arts and the College of Law take the “Graduation Release” and a copy of the “Supervisory Committee Approval” form to the office of the dean of their college for signature, and then deliver the pink copy of the release to the Graduation office, 250 No. Student Services Building.

**CONGRATULATIONS!!!**
INSTRUCTIONS FOR THE PREPARATION AND SUBMISSION OF THESES, DISSERTATIONS AND ABSTRACTS

When accepted in partial fulfillment of the degree requirements, a master’s thesis or doctoral dissertation becomes the property of the University. However, publication rights are reserved to the author, subject to the provisions of research contracts, patent rights, or other agreements made by the author with the University.

A Handbook for Theses and Dissertations to be followed by the candidate in preparation of the thesis or dissertation is available from the Graduate School or the Thesis Editor. Information is included on bibliographic form and format approval, acceptable style manuals, registrar clearance, submission of the thesis or dissertation, submission of abstracts, and special fees.

It is important that the candidate procure a copy of these instructions before he/she begins the writing of the thesis. The student is invited to consult with the Graduate School Thesis Editor, in 208 Building 44, regarding the thesis or dissertations format. When the completed thesis is submitted a final release for graduation must be obtained from the Thesis Editor.

The use of restricted data for theses and dissertations:

1. Supervisory committees are responsible for approving topics for theses and dissertations and the approval must have the informed consent of the degree candidate to do the research requested.

2. No thesis subject may be approved that will prevent the completed thesis from being made available for public use by the time the degree is granted.

3. The supervisory committee shall schedule a public Final Oral Examination at which time the candidate must defend the thesis satisfactorily before the committee gives final approval of the thesis. This examination must be advertised on the campus one week before the examination data. Anyone may attend the presentation of the thesis.

4. The required number of copies of the completed thesis or dissertation must be submitted for public use to the University of Utah Library by the time the degree is granted.

Exceptions to items 2 and 4 above must be approved by the Graduate Council and can only be made by the Council in those cases where a delay is required to:

1. protect the rights of patent applicants,

2. prevent unjust economic exploitation, or

3. protect the privacy of research subjects.

Department Preparation of Theses, Dissertations and Abstracts

Student theses, dissertations and abstracts which are used toward degree requirements in the Department of Mathematics will not and cannot be typed, duplicated or printed by the departmental secretarial staff with University equipment. Please do not ask for special consideration. These restrictions apply to undergraduate and graduate student theses, dissertations and abstracts. The policy was set by the University, and is endorsed by the College of Science and the Department of Mathematics. Joint papers with faculty, individual nonthesis publications, mathematical reviews and similar publications will be produced by the Department, within the limitations of its resources.
GUIDELINES FOR THE CONTINUATION OF FINANCIAL SUPPORT

The Department of Mathematics attempts to continue financial support to graduate teaching fellows and teaching assistants as warranted by the individual student’s progress and budgetary limitations. We try to support the very best graduate students available. A grant of support is made to attract excellent students and to maintain them through their residency for a graduate degree in mathematics.

A general description of departmental policy for the continuation of financial support is given below. This policy covers some specific situations, but the Department reserves the option of flexible interpretation and redefinition of policy.

Continued financial support is recommended for graduate teaching fellows and teaching assistants who are making satisfactory progress in an approved program of study, and who are performing satisfactorily in their teaching duties. Responsible and capable teaching performance is essential for continuation. Incompetent teachers will not be supported, and cases of conspicuous irresponsibility or neglect will be cause for immediate termination. Besides teaching competence, progress toward a degree is the principal requirement for continued support. Each teaching assistant or teaching fellow must be enrolled and active as a student, in an approved program of study. Conspicuous neglect of courses, or withdrawal from them, can lead to termination of a teaching assistantship or fellowship.

The following are guidelines and schedules for decisions regarding renewals of financial support:

**Teaching Assistants in the Master’s Degree Program**

1. At the end of the winter quarter, evaluations are made by the graduate committee on the progress of teaching assistants in their first year of study toward a master’s degree. Decisions are based on teaching performances and on performance and progress in graduate courses. Notification of renewals or nonrenewals are distributed by April 15.

2. Teaching assistants are supported for at most two years in the master’s degree program. These appointments automatically terminate, without any special notice, at the end of the second academic year. Teaching assistants who wish to apply for admission to the Ph.D. degree program should talk with their committees and attempt to follow the first schedule outlined on p. 17. Teaching assistants who apply for teaching fellowships and admission to the Ph.D. degree will have their applications compared with those of all applicants, both at the University of Utah and at other institutions.

**Teaching Fellows in the Ph.D. Degree Program**

1. For teaching fellows in their first year in the Ph.D. degree program, evaluations are made by the graduate committee at the end of the winter quarter. Decisions are based on teaching performances and progress in graduate courses. Notifications of renewals and nonrenewals are distributed by April 15.

2. For teaching fellows beyond their first year in the Ph.D. degree program, evaluations are made by the graduate committee late in the fall quarter. Decisions are based on teaching performances and on progress toward a Ph.D. degree, following the schedule outlined on p. 17. Notifications of renewals and nonrenewals are distributed by January 1. In some cases, renewals may be contingent upon the completion of specific requirements, e.g., a satisfactory performance on the qualifying examination, or the identification and pursuit of a suitable program of study and research.

3. Although the official time limit for a Ph.D degree is seven years (see p. 17, #8), the department expects students to finish their Ph.D. requirements in at most five years, six years if there are special circumstances, and seven years only if there exists extraordinary reasons. Support for TAs/TFs then is expected to continue for at most five years (three years if the student enters with a master’s degree), any additional support will be given only if the Graduate Committee determines that there is sufficient grounds for continuation. The Graduate School guarantees tuition waivers to Ph.D. students entering with a bachelor’s degree for five years (three years for those entering with a master’s degree). Exceptions are granted on a case by case basis. It is extremely important then for graduate students to realize that their
degree requirements can be met only if they take the written and oral qualifying examinations in a timely manner as outlined on pp. 15–16.

Special Remarks to Graduate Students:

1. Take your teaching duties seriously and give attention to your obligations to the department and to your students.

2. You will probably find that the pursuit of a Ph.D. degree in mathematics is a challenge and that it is not possible to plan and follow a rigid schedule toward the degree. While good performances on the qualifying examinations and in graduate classes are expected of students in the Ph.D. degree program, completion of these formal requirements does not in itself necessarily indicate satisfactory progress toward the Ph.D. Participation in seminars, informal discussions with other students and members of the faculty, and many hours of independent study and thought will be critical toward your development of a research thesis. In reality, your study of mathematics will need to be the dominant feature of your life and as such, no outside employment will be allowed for TFS.

3. The Department of Mathematics sponsors colloquium lectures that are intended primarily for graduate students and members of the faculty. Many of these lectures are presented by mathematicians who are invited from other institutions, and others are presented by members of the departmental faculty. Such a lecture usually includes some expository remarks in the first part, and then perhaps a more specialized discussion toward the end. The department considers attendance at these lectures to be an important part of its program for graduate students. There are opportunities to hear about some important current mathematical developments, to receive suggestions of topics for further study, and to acquire familiarity with various areas of mathematics. There is much for you to gain from the lectures even where you have not had previous contact with the mathematical topics that are discussed.
STIPENDS AND SALARY INFORMATION FOR 1996–97

The normal teaching load for a teaching assistant (M.S., M.A. candidate) is the equivalent of two four-hour sections during one quarter and one four-hour section during each of two quarters. The normal teaching load for a teaching fellow (Ph.D. candidate) is the equivalent of one four-hour section during each quarter. Stipends for lighter loads will be in proportion to the load.

SALARY SCHEDULE FOR 1996–97 (ACADEMIC YEAR)

<table>
<thead>
<tr>
<th></th>
<th>1st year</th>
<th>2nd year</th>
<th>3rd year</th>
<th>4th year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master’s Program</td>
<td>$11,275</td>
<td>$11,275</td>
<td>$11,275</td>
<td>$11,275</td>
</tr>
<tr>
<td>Ph.D. Program</td>
<td>$11,775</td>
<td>$11,775</td>
<td>$11,850</td>
<td>$12,000</td>
</tr>
</tbody>
</table>

In the summer, an additional stipend is often available — $2000 — for teaching a course or lab.

Salary checks are issued every two weeks and are available from the front desk in the departmental office. You will receive your first check under your 1996–97 salary on September 27, 1996. Because of a lag time in the payroll process, your first check will be only a 1/2 check, even though you are listed as having worked the full pay period. Your last check for the academic year will be received on July 4, 1997. Teaching fellows who do not teach during the summer term are advised to make appropriate financial arrangements in advance for June, July and August.

University Research Fellowships. Each year the faculty are asked to name outstanding students for the University Research Fellowship. In recent years one or two graduate students in mathematics have received a fellowship each year. The amount of the award is $6,000, and there are, of course, no teaching duties for a University Research Fellowship. The Department provides additional support, via a teaching assignment, so that the total salary is equivalent to the salary of teaching fellows. The departmental deadline for nomination for the University Research Fellowship is February 15th of the year preceding the award.

You should find your combined obligations in teaching and studying to be a full-time undertaking. The Department of Mathematics does not permit teaching fellows and teaching assistants to assume any additional form of employment.
SUPERVISORY COMMITTEES

Each graduate student will have an advisor and a supervisory committee, appointed by the Director of Graduate Studies. The student’s advisor will be appointed by the Director of Graduate Studies prior to the student’s entrance into the program. The supervisory committee will be appointed by the end of the student’s first year in the program. Students may request a change of advisor or committee member at any time. This request should be made to the Director of Graduate Studies. Initially, each committee will consist of three members of the faculty; committees for Ph.D. degree candidates will later be expanded to a total of five. After an advisor has been appointed, it is the student’s responsibility to seek out his/her advisor to discuss a program of study, and to meet periodically with that advisor at least once each quarter.

1. The advisor of the committee is usually in the area indicated by the student as his/her potential major interest area. If the student expresses a personal choice, and if the faculty member suggested is not already overworked with advising, this person will usually be appointed.

2. The other two members of the Ph.D. candidate’s committee are appointed, in consultation with the student, after the written part of the qualifying examination is completed.

3. If the student’s interests change, the committee makeup will be modified appropriately (by the Director of Graduate Studies after consulting the student and his/her committee).

4. The functions of the advisor and the supervisory committee should be:
   a. Advising the student regarding a program of study.
   b. Evaluating the student’s progress in his/her program of study.
   c. Reviewing any requests for changes or waivers in the usual requirements.

5. The student should make contact with his/her advisor every quarter to discuss progress and possible changes in the program of study. Advisors are requested by the Director of Graduate Studies to make brief comments on each student’s progress each quarter.

6. A majority of the student’s committee is sufficient to approve (or disapprove) his/her program, or petition for an exemption for some requirement. The student, or a dissenting member, can appeal any decision to the Director of Graduate Studies. Such an appeal will usually be reviewed by the departmental Graduate Committee. Appeals or recommendations which implicitly ask for a deviation from Graduate School policy must be reviewed by the Graduate School.
THE GRADUATE STUDENT ADVISORY COMMITTEE (GSAC)

The Graduate Student Advisory Committee exists for the following reasons:

1. To advise new and continuing graduate students concerning curricula, requirements for degrees and other aspects of the graduate program.

2. To make recommendations to the department concerning promotion, tenure and retention of faculty members.

3. To participate in the allocation of ASUU funds supplied to the College of Science Student Council.

4. To make whatever recommendations it feels appropriate concerning the graduate program to the Department of Mathematics.

5. To assist the department in making its policies and requirements fully understood by the graduate students.

This committee shall consist of a number of members, elected in the spring of each year by the mathematics graduate students. For the school year 1996–97 the members are:

Jon Jacobsen, Co-chair
Eric Marland, Co-chair
Alastair Craw
Kelly MacArthur
Sean Sather-Wagstaff
Peter Spiro
SYLLABI FOR QUALIFYING EXAMINATIONS

ALGEBRA

Topics and References

1. GROUPS:
Subgroups, quotient groups, cosets, permutation groups, symmetric and alternating groups, homomorphism and isomorphism theorems, p-groups, Sylow subgroups, Abelian groups, solvable groups. Lagrange’s Theorem, Cayley’s Theorem, Sylow’s Theorems, structure of finitely generated Abelian groups.
References: Cohn, Algebra I, 3.1–3.5, 9.1–9.2, 9.4–9.8. Herstein, Topics in Algebra, Ch. 2. Hungerford, Algebra, 1.1–1.6, 2.1–2.2, 2.4–2.7. Jacobson, Basic Algebra I, 1.1–1.10, 1.12–1.13. Lang, Algebra, 1.1–1.6, 1.9–1.10.

2. RINGS:
References: Cohn I, 6.1–6.8, 10.1, 10.5. Cohn II, 4.6, 10.1–10.3. Herstein, Ch. 3. Hungerford, 3.1–3.3, 3.5–3.6, 9.1–9.5. Jacobson I, 2.1–2.3, 2.5–2.7, 2.9–2.11, 2.14–2.16. Jacobson II, 4.1–4.4. Lang, 2.1–2.2, 2.4, 5.2–5.4, 5.6, 17.1–17.5.

3. MODULES:
Submodules, quotient modules, semisimple modules, free modules, projective modules, injective modules, tensor products. Structure of finitely generated modules over principal ideal domains.

4. LINEAR ALGEBRA:
Vector spaces, dimension, linear transformations, matrices, characteristic polynomials, trace, determinant, rank, rational canonical form, Jordan canonical form, diagonalization. Cayley-Hamilton Theorem, Gaussian elimination, (symmetric) bilinear forms, orthogonal, unitary, and hermitian forms, tensors and exterior algebras.

5. FIELDS AND GALOIS THEORY:
Extension fields, degrees, roots, geometric constructions, splitting fields, algebraic closure, algebraic and transcendental extensions, separable extensions, Galois groups, fundamental theorem of Galois theory, solvability by radicals, finite fields, primitive elements.

6. HOMOLOGICAL ALGEBRA:
Exact sequences, complexes, homology, categories, functors, Ext, Tor.
APPLIED MATHEMATICS

Topics

1. FINITE-DIMENSIONAL LINEAR OPERATORS:
   Spectral theory, Fredholm alternative, generalized inversion, singular value decomposition, minimax
   principle.

2. INTEGRAL AND DIFFERENTIAL OPERATORS:
   Approximation in Hilbert space, compact operators, Hilbert-Schmidt theory, spectral theory, distribu-
   tions, Green’s functions, resolvent operators, method of images, discrete and integral transforms.

3. CALCULUS OF VARIATIONS:
   Euler-Lagrange equations, Hamilton’s principle, approximation techniques.

4. COMPLEX VARIABLE METHODS:
   Analytic function theory, integral theorems, conformal mappings, hodograph transformation, contour
   integration, special functions, transform pairs, scattering theory.

5. ASYMPTOTIC EXPANSIONS:
   Laplace’s method, Watson’s lemma, methods of steepest descent and stationary phase.

Text


Other Texts

DIFFERENTIAL EQUATIONS

Topics


2. Theory of linear systems, matrix exponential, adjoints, Cauchy function, variation of parameters formula, Floquet theory, finite-dimensional spectral theory.


4. Stable and unstable manifolds for stationary points, invariant sets, limit cycles, periodic attractors, structural stability, Poincaré-Bendixson theory.


6. CLASSICAL EQUATIONS OF MATHEMATICAL PHYSICS:
   Heat, Wave and Laplace equations. Fourier series methods, Fourier’s method (separation of variables).

7. INTRODUCTION TO HILBERT SPACES:
   Fourier series, generalized Fourier series. Bessel and Parseval relations, completeness, Riesz representation.

8. COMPACT OPERATORS:
   Fredholm’s theorem (Riesz-Schauder theory), spectral theorem, Fredholm alternative, Hilbert-Schmidt theory, eigenvalue problems.

9. Green’s functions, boundary value problems, eigenfunction expansion.


11. Maximum principles, potential theory, nonlinear elliptic and parabolic problems.


13. ELLIPTIC BOUNDARY VALUE PROBLEMS:

Texts


Other Texts


The following texts are recommended reading, particularly because the cost of Dover editions is comparable to popular paperback novels, but also because these texts are genuine classics:


NUMERICAL ANALYSIS

Topics
1. NUMERICAL LINEAR ALGEBRA:

2. INTERPOLATION AND APPROXIMATION:
   Polynomial, rational, Fourier Series, spline based methods of interpolation and approximation. Quadrature.

3. SOLUTION OF NONLINEAR EQUATIONS AND OPTIMIZATION:

4. NUMERICAL SOLUTIONS OF DIFFERENTIAL EQUATIONS:
   Runge-Kutta methods, linear multistep methods for initial value problems of ODEs. Shooting, finite differences, finite elements for boundary value problems of ODEs. Finite difference and finite element methods for simple PDEs.

Texts


PROBABILITY AND STATISTICS

Topics
1. PROBABILITY:

Probability spaces, Borel-Cantelli lemmas, Countable-state Markov chains, random variables as measurable functions, Expectation as an integral, independence and product measures, Strong law of large numbers, weak convergence and the central limit theorem, conditional expectation and the Radon-Nikodym theorem.

Texts
1. Billingsley, Probability and Measure.

Topics
2. STATISTICS:


Texts
2. Rice, Mathematical Statistics and Data Analysis.
REAL AND COMPLEX ANALYSIS

Topics
1. MEASURE THEORY:

2. BASIC FUNCTIONAL ANALYSIS:
   Hilbert spaces, Banach spaces, Hahn-Banach theorem, Banach-Steinhaus theorem, open mapping theorem.

Texts

Topics
1. COMPLEX ANALYSIS:

Texts
GEOMETRY AND TOPOLOGY

Topics

1. GENERAL TOPOLOGY:
   Metric spaces, paracompact spaces, Urysohn’s Metrization Theorem, Tychnoff Theorem, Baire Category Theorem, Tietze’s Extension Theorem, function spaces, Stone-Cech compactification. [Dugundji, Singer-Thorpe]

2. HOMOTOPY AND COVERING SPACES:
   Fundamental group, H-spaces, covering spaces, universal cover, Van Kampen’s Theorem, computations of homotopy groups of \( \mathbb{R}^n, S^n, \mathbb{CP}^n, \) etc. [Singer-Thorpe, Massey, Greenberg], higher homotopy groups, homotopy sequence of a pair, Brouwer’s Fixed Point Theorem, exact sequences of pairs and fibrations. [Hu: Homotopy Theory, Gray]

3. SIMPLICIAL AND CELL COMPLEXES:
   Simplicial complexes, barycentric subdivision, simplicial approximation, etc. General position [Singer-Thorpe], Jordan Curve Theorem, Schoenflies Theorem. [Greenberg]

4. HOMOLOGY THEORIES:
   Including simplicial (and/or CW) and singular, axioms of a homology theory. [Greenberg, Vick]

5. MANIFOLDS:
   Differential manifolds, construction of tangent bundle and cotangent bundle, exterior algebras, differential forms, DeRham cohomology, implicit function theorem, Froebenius theorem, Lie derivative, deRham theorem. [Singer-Thorpe, Warner, Sternberg]

6. BASIC RIEMANNIAN GEOMETRY:
   Parallel translation and connections, geodesic curvature, structural equations and curvature tensor, geodesic coordinate systems. [Singer-Thorpe]

7. CURVES AND SURFACES IN \( \mathbb{R}^3 \):
   Intrinsic and extrinsic geometry of surfaces, Gauss-Bonnet Theorem, geometries of constant curvature. [Singer-Thorpe]

8. LIE GROUPS:
   Basic definitions, definition of Lie algebra, maximal compact subgroup. [Warner]

Texts


Supplementary References

8. Rushing, *Topological Embeddings*, Academic Press (1.3, 1.4, 1.6D, 1.8, 2.2, 3.2).
SYLLABI FOR UPPER DIVISION AND GRADUATE COURSES AND SEMINARS

(The editors have attempted to make this listing as complete and accurate as current information will permit. However, additions, changes and deletions may occur because of enrollments, faculty leaves, availability of texts, etc.)

501 Nonparametric Statistics (S Qtr)
Instructor: Y. Xiao
Prerequisite: Math 307–308 or equivalent

In this course several ranks methods are studied, such as the Wilcoxon sum-rank methods, Smirnov test, the sign test, the Wilcoxon signed-rank test, the Kruskal-Wallis method and the Friedman method. These methods are compared with the ones in previous courses such as the t-test. The main property of these new methods is that they are applicable, even if the distribution of the population is not normal.

504, 505 Applied Stochastic Processes (W S Qtr)
Instructor: D. Khoshnevisan
Text: To be announced
Prerequisite: Math 507

Topics to be covered:
This is a two-quarter course in Stochastic processes that does not involve measure theory. The treatment will be mostly rigorous, except that certain technical points may be taken for granted.
Topics will include Markov chains, Poisson processes, Markov processes, renewal processes, and Brownian motion. Applications will also be discussed.

507 Introduction to Probability (A W S Qtr)
Instructors: M. Egger, S. Ethier, Y. Xiao
Text: Ross, A First Course in Probability, 4th ed.
Prerequisite: Math 221 or 252

Topics to be covered:
1. Combinatorial analysis
2. Axioms of probability
3. Conditional probability and independence
4. Discrete and continuous random variables
5. Joint distributions
6. Expectation
7. Central limit theorem

508, 509 Statistical Inference (W S+ Qtr)
Instructors: L. Horvath, A. Roberts, Y. Xiao
Prerequisite: Math 507

Topics to be covered:
1. Functions of Random Variables
2. Limiting Distributions
3. Statistics and Sampling Distributions
4. Point Estimation
5. Sufficiency and Completeness
6. Special Distribution Theory
7. Normal Sampling Theory
8. Parametric Estimation
9. Confidence Regions
10. Hypotheses Testing
11. Introduction to Linear Models

*Note: Math 508 will also be offered Spring Quarter, but rather than covering only the first half of the material of Math 508–9, it will cover all the main topics, albeit somewhat less thoroughly.

510 Stochastic Simulation (S Qtr)
Instructor: S. Ethier
Text: To be announced
Prerequisite: Math 507 and some programming skills (see the instructor)

This is a course on the simulation of deterministic and random models, with the emphasis on random models. It will include the theory behind simulation techniques, and hands-on experience with a simulation package.

511, 512, 513 Mathematical Biology (A W S Qtr)
Instructors: W. Coles, M. Lewis, H. Othmer
Prerequisites: Calculus, Ordinary Differential Equations and Introduction to Partial Differential Equations

No previous knowledge of biology will be assumed. The biological background to each problem will be described in sufficient detail to construct the model. Discussion of each topic will entail (1) a description of the biological problem; (2) the development of the mathematical model and assessment of its realism; (3) mathematical analysis of the model; (4) biological interpretation of the results and implications from a modeling viewpoint.

Topics to be covered:

511 Aspects of Population Dynamics
2. Reaction kinetics; biological oscillators and switches; the Belousov-Zhabotinskii reaction.
3. Oscillator generated wave phenomena; central pattern generators (for example, models of fictive swimming).
4. Epidemic models and the dynamics of infectious diseases (including AIDS).

512 Pattern Formation
1. Spatial Spread of populations; biological wave phenomena associated with interacting populations, traveling chemical waves.
2. Reaction-diffusion theory of biological pattern formation with applications to embryology.
3. Mechanical theory of biological pattern formation with applications to current problems in developmental biology.
4. Neural models of pattern formation.
5. Geographical spread of epidemics.

513 Mathematical Models of Biology (no text)
This will be run in a mixed lecture and student seminar format. Students will be expected to complete and present individual term projects. Topics for the lectures and projects will be chosen from physiology, developmental biology and ecology. Students will have a chance to work on projects that they are particularly interested in. Experience with computers and elementary numerical methods is desirable.
521, 522, 523  Introduction to Real Analysis  (A W S Qtr)
Instructor: R. Brooks
Text: Haaser & Sullivan, Real Analysis, Dover (521, 522)
Notes (probably) (523)
Prerequisites: Math 223 and 326 or consent of instructor
Topics to be covered:

521  Real Analysis I
1. Sets and Relations — relations, functions, axiom of choice, partial orders, cardinality.
2. Real Numbers — algebraic and order properties of the real numbers, completion of the reals.
3. Linear Spaces — real vector spaces, independence, basis, algebras.

522  Real Analysis II
1. Fixed Point Theorems — contraction mapping, fixed points and applications.
2. Lebesgue Integration — Riemann integral, step functions, Measure zero, Lebesgue integrable functions, basic integration theorems, Lebesgue measure.
3. Normed Linear Spaces — concrete examples (mostly).
5. Differentiable Functions — in Euclidean space, product and chain rules, implicit and inverse function theorems.

523  Complex Analysis
2. Cauchy’s Theorem and Formula — proof and applications to properties of holomorphic functions.
3. Applications of Cauchy’s Formula — Laurent series, isolated singularities.
4. Calculus of Residues — residue formula and applications to the evaluation of definite integrals.
5. Conformal Mappings — Schwartz lemma, automorphisms of the disc, upper half plane, other examples.

528, 529, 530  Introduction to Number Theory  (A W S Qtr)
Instructor: J. Johnson
Prerequisite: Math 221–22–23
Topics to be covered:

Divisibility, Congruences, Quadratic Reciprocity and Quadratic Forms, Arithmetic Functions, Diophantine Equations, Farey Fractions and Irrational Numbers, Continued Fractions, Primes and Multiplicative Number Theory, Algebraic Numbers, Partition Functions, Density of Sequences of Integers

531, 532, 533  Introduction to Modern Algebra  (A W S Qtr)
Instructor: S. Gersten, P. Roberts
Prerequisite: Math 324
Topics to be covered:

531  (a) Arithmetic in $\mathbb{Z}$; modular arithmetic
(b) Rings and fields
(c) Rings of polynomials; irreducible polynomials; factorization
(d) Ideals; homomorphisms; isomorphisms
(e) Arithmetic in integral domains

532
(a) Groups; subgroups
(b) Normal subgroups; quotients; homomorphisms; isomorphisms
(c) Group actions; symmetric groups; alternating groups
(d) Nilpotent groups; solvable groups
(e) Finitely generated Abelian groups
(f) Free groups; presentations

533
(a) Field extensions
(b) Ruler and compass constructions
(c) Normality; separability
(d) The Galois correspondence
(e) Solutions of equations by radicals

541, 542, 543
**Introduction to Differential Equations** (A W S Qtr)

Instructor: D. Tucker

Text:
- Instructor’s Notes

Prerequisites: Math 222, 331; or 251, 252; or instructor’s consent.

Topics to be covered:

541
Systems of first order linear ordinary differential equations including existence, uniqueness, dependence upon initial data and parameters, and continuation. Various methods of explicit display of solutions for the linear constant coefficient case.

542
Non-linear systems, existence etc. Dynamical systems, local linear approximations, equilibria, behavior of linear systems about equilibria, stability, asymptotic stability.

543
Sturm-Liouville systems and elementary Hilbert spaces. Existence of eigenvalues and eigenfunctions, completeness of the eigenfunctions, and orthogonal expansions.

544, 545, 546
**Introduction to Partial Differential Equations** (A W S Qtr)

Instructor: G. Gustafson

Text:

Supplemental texts:
- F. Bowman, *Introduction to Bessel Functions*, Dover, 60462-4 ($5.95, 145 pages)

Reference text:

Prerequisites: Linear algebra and ordinary differential equations, Math 222 or 251, 252 or equivalent, plus several variable calculus or equivalent.

Topics to be covered:
Survey of calculus and advanced calculus background, Fourier series, Fourier’s method, diffusion, heat conduction, steady-state problems, static equilibrium, dynamics of strings and membranes, waves, Cauchy problem, special functions, Sturm-Liouville methods, Fourier transform methods, Laplace methods, Sturm-Liouville theory, calculus of variations, numerical solutions by finite differences.

547 Applied Dynamical Systems (W Qtr)
Instructor: Staff
Prerequisite: Math 221, 222 or engineering math. The interested student should be an advanced undergraduate or graduate student with a solid mathematics background, but not necessarily a major in mathematics. Some computer programming will be expected.

This course takes through the development of ‘Chaos Theory’. Much of the history is modern, though we will discover the roots in the work of Poincaré and Birkhoff on the stability of the N-Body Problem and homoclinic orbits. We will look at concrete physical systems which exhibit chaotic behavior such as the Lorenz attractor, and the study of tractable geometrical models of such behavior, such as Smale’s horseshoe and period doubling of iterated maps and topological dynamics. Students will complete and present projects relating the material to their own interests.

We refer to the text, *Chaos and Fractals* (AMS), as well as readings from a variety of other sources. The course is meant to be self-contained and suitable for students with varied backgrounds, though a solid understanding of mathematics through elementary systems of ODEs is assumed.

551, 552, 553 Introduction to Topology and Geometry (A W S Qtr)
Instructors: M. Kapovich, H. Rossi
Prerequisites: Math 551 — Advanced calculus series, Math 324
Math 552 — Math 551
Math 553 — Advanced calculus

Topics to be covered:

551 (a) Topology of Euclidean space $\mathbb{R}^n$
   (b) Metric spaces
   (c) Topological spaces
   (d) Continuity; homeomorphisms
   (e) Compactness
   (f) Connectedness
   (g) Separation axioms
   (h) Metrization

552 (a) Classification of surfaces
   (b) Fundamental group; van Kampen theorem
   (c) Covering spaces; examples/applications in group theory and geometry

553 (a) Curves in $\mathbb{R}^3$, curvature, torsion, rigidity
   (b) Surfaces in $\mathbb{R}^3$, shape operator, mean curvature
   (c) Intrinsic nature of Gauss curvature
   (d) Geodesic coordinates, Gauss Bonnet Theorem
(e) Minimal surfaces, rigidity
(f) Introduction to Riemannian geometry

**560**  Survey of Numerical Analysis (W S Su Qtr)
Instructor: Staff
Text: Burden and Faires, *Numerical Methods*
Prerequisites: Math 113, Math 221 or 252, programming ability

Topics to be covered:

Numerical Linear Algebra, Interpolation and Approximation, Numerical Integration and Differentiation, Nonlinear Equations, Optimization, Ordinary and Partial Differential Equations. This is a survey of topics covered in Mathematics 561–2–3–4–5.

**561**  Basic Numerical Analysis (A Qtr)
Instructor: P. Alfeld
Text: Golub and van Loan, *Matrix Computations*
Prerequisites: Math 113, Math 221 or 252, programming ability

Topics to be covered:

Numerical linear algebra, polynomial interpolation, numerical differentiation and integration.

**562**  Approximation Theory (W Qtr)
Instructor: P. Alfeld
Text: None
Prerequisites: Math 561

Topics to be covered:

Least Squares approximation, splines, wavelets, Fourier series, problems in several variables.

**563**  Nonlinear Systems and Optimization (S Qtr)
Instructor: A. Cherkaev
Text: Gill, Murray, Wright, *Practical Optimization*
Prerequisites: Math 561

Topics to be covered:

Numerical solution of nonlinear systems of equations and optimization problems.

**564**  Initial Value Problems (W Qtr)
Instructor: A. Fogelson
Prerequisites: Math 561

Topics to be covered:

Numerical Solution of initial value problems of ordinary and partial differential equations.

**565**  Boundary Value Problems (S Qtr)
Instructor: A. Fogelson
Prerequisite: Math 561

Topics to be covered:

Numerical solution of boundary value problems of ordinary and partial differential equations.

**566/666**  Parallel Numerical Linear Algebra
Instructor: S. Foresti
Text: None
Prerequisite: Math 560 or 561

Topics to be covered:
This course will provide basic concepts of parallel computing (hardware, software, parallel programming environments, algorithm design, and performance evaluation), and will provide students with hands on experience, by studying and implementing parallel versions of fundamental algorithms in linear algebra and scientific computing. There will be an additional term project for those taking this class as Math 666 as opposed to Math 566.

**567/667 Parallel Numerical Techniques for the Solution of Partial Differential Equations**

Instructor: M. Pernice  
Text: None  
Prerequisites: Math 566 and either Math 564 or Math 565

Topics to be covered:

Parallel methods for hyperbolic, parabolic, and elliptic partial differential equations will be discussed. Topics will include explicit and implicit methods for time-dependent problems, and parallel multigrid and domain decomposition methods for elliptic problems. An additional term project is required to obtain credit for Math 667.

**571, 572, 573 Introduction to Applied Mathematics (A W S Qtr)**

Instructor: J. Zhu  
Prerequisites: Math 354; 222 or 353

Topics to be covered:

1. **Symmetric Linear Systems.** Gaussian elimination, positive definite matrices, minimum principles, eigenvalues and dynamical systems, review of matrix theory.
2. **Equilibrium Equations.** Constraints and Lagrange multipliers, resistive networks, structures in equilibrium, least squares and the Kalman filter.
3. **Equilibrium in the Continuous Case.** One-dimensional problems, differential equations of equilibrium, Laplace’s equation and potential flow, vector calculus in three dimensions, equilibrium of fluids and solids, calculus of variations.
4. **Analytical Methods.** Fourier series and orthogonal expansions, discrete Fourier series and convolution, Fourier integrals, complex variables and conformal mapping, complex integration.
5. **Initial-Value Problems.** Ordinary differential equations, stability and the phase plane and chaos, the Laplace transform and the z-transform, the heat equation vs. the wave equation, difference methods for initial-value problems, nonlinear conservation laws.
6. **Boundary value problems.** Poisson’s equation, Green’s function, Potential theory, free boundary problems.

**574 Mathematical Modelling (S Qtr)**

Instructor: P. Fife  
Text:  
Prerequisite: Math 564 or CP SC 522

**591 Supervised Reading**

**601, 602, 603 Analysis of Variance and Multivariate Analysis (A W S Qtr)**

Instructor: L. Horvath  
Text:  
Prerequisites: Math 509 and Math 373

The Splus programming language with interactive graphics will be used on UNIX.

1. Matrices of random variables
2. Distance measures between random variables and observations
3. Multivariate normal distribution
4. Best Linear Prediction
5. Linear regression: estimation, diagnostics, and distribution theory
6. Linear regression: hypothesis testing and confidence intervals
7. Analysis of Variance and Covariance
8. Analysis of Covariance
9. Sample Covariances and Correlations, Wishart distribution
10. Multivariate Regression and Analysis of Variance
11. Principal Components
12. Factor Analysis
13. Discrimination and Classification
14. Clustering
15. Latent Variable Methods

### Mathematical Probability (A W S Qtr)
Instructor: D. Khoshnevisan
Prerequisite: Math 522 (Math 621 recommended concurrently)

Course Summary:
This is a year-long measure-theoretic course in probability theory. In contrast to Math 507, it is mathematically rigorous. Nevertheless, it is ideal for applied mathematicians who plan to use probability in their research.

Topics to be covered:
1. Probability spaces, random variables, expected value, independence, Borel-Cantelli lemmas, laws of large numbers
2. Weak convergence, characteristic functions, central limit theorem
3. Random walks, renewal theory
4. Conditional expectation, martingales
5. Countable-state Markov chains
6. Ergodic theorems
7. Brownian motion

### Mathematical Statistics (A W S Qtr)
Instructor: S. Ethier
Prerequisites: Math 221, 508

Topics to be covered:
1. Statistical models
2. Methods of estimation
3. Optimality theory
4. Some linear models
5. Analysis of discrete data
6. Nonparametric models

### Real/Complex Analysis (A W S Qtr)
Instructor: P. Trombi
Prerequisite: Math 522–2–3 or consent of instructor

Topics to be covered:
1. Measure and integration theory
2. $L^p$ spaces
3. Banach spaces and Hilbert spaces
4. Fourier series and Fourier transforms
5. Holomorphic functions
6. Zeroes, residues and approximation
7. Conformal mapping and analytic continuation
8. Banach algebras
9. Differential equations in complex domains

631, 632, 633 Modern Algebra (A W S Qtr)
Instructor: F. Gross
Text: Univ. of Utah Lecture Notes
Prerequisite: Math 533 or equivalent

Topics to be covered:
1. Groups
2. Rings
3. Group Representations
4. Homological Algebra
5. Field Theory/Galois Theory

634, 635, 636 Combinatorial Group Theory (A W S Qtr)
Instructor: S. Gersten
Text: No required text, although several books and articles will be put on reserve, including the classic treatise in the subject, Lyndon and Schupp, Combinatorial Group Theory
Prerequisites: The first year graduate course in algebra and the geometry-topology at the 500 level including covering space theory for complexes.

The motivating problem in this course will be the word problem for finitely presented groups. This is to give an algorithm to decide whether or not a word in the generators represents the identity element of the group. This was first stated in 1911 by Max Dehn, who showed how to solve it for the fundamental groups of closed Riemann surfaces. It is known to be unsolvable in general, by work of Novikov and Boone, extended later by work of Higman and Rips.

We will begin by studying finitely generated free groups, where there is an easy solution to the word problem. Classic results of Reidemeister and Schreier and of P. Hall will be presented.

Amalgamated free products and HNN extensions will be introduced and their word problems studied. The classic example of a finitely presented group which is not residually finite will be verified. The embedding theorems of Higman, H. Neumann, and B.H. Neumann will be proved.

Hyperbolic groups and automatic groups will be introduced and related to Dehn’s algorithm. Combinatorial curvature and small cancellation groups will be studied.

Markov properties will be introduced and the theorem of Adian and Rabin will be established, that a Markov property of finitely presented groups is algorithmically undecidable.
641, 642, 643 Theory of Differential Equations (A W S Qtr)
Instructor: A. Treibergs

Supplementary Texts:
- M. Hirsch & S. Smale, *DE, Dynamical Sys & Lin Alg* Academic Pr, 1974

Prerequisite: Math 523 or instructor’s consent. Concurrent registration in 621–22–23.

Topics to be covered:
1. Nonlinear analysis tools
2. Existence/uniqueness/continuity theory for ODEs
3. Linear ODEs
4. Stability theory
5. Spectral theory
6. PDEs from classical physics
7. Hilbert Space theory for PDEs
8. Variational methods for PDEs

644 645, 646 Partial Differential Equations (A W S Qtr)
Instructor: P. Fife

Prerequisite: Math 623 or consent of instructor

Topics to be covered:
1. Derivation of certain PDEs arising in the natural sciences (throughout the course).
2. First order nonlinear PDEs
3. Sobolev spaces
4. Second order elliptic PDEs
5. Linear parabolic PDEs
6. Hyperbolic PDE and systems
7. Nonlinear elliptic and parabolic PDEs

651, 652, 653 Topology-Geometry (A W S Qtr)
Instructor: M. Bestvina, N. Korevaar
Text: Bredon, *Topology & Geometry*, Springer

Prerequisite: Math 553 or equivalent

Topics to be covered:
1. Fundamental group, covering spaces
2. Higher homotopy groups, fibrations
3. Simplicial complexes and cell complexes
4. Homology and cohomology theory
5. Differentiable manifolds, differential forms, de Rham’s theorem
6. Introduction to Riemannian geometry
References:
Massey, *A Basic Course in Algebraic Topology*, Springer
Munkres, *Algebraic Topology*
Greenberg and Harper, *Algebraic Topology: A First Course*, Benjamin
Sternberg, *Differential Geometry*, Chelsea
Rotman, *An Introduction to Algebraic Topology*, Springer
Hu, *Differential Manifolds*, Holt
Guillemin and Pollack, *Differential Topology*, Englewood Cliffs
deRham, *Differentiable Manifolds*, Springer
Sternberg, *Differential Geometry*, Chelsea
Fulton, *Algebraic Topology*, Springer

661, 662, 663: Analysis of Numerical Methods (A W S Qtr)
Instructor: A. Fogelson
Text: See below.

Demmel, *Numerical Linear Algebra*;

Golub and Van Loan, *Matrix Computations*


Various handouts.

Prerequisite: A basic course in numerical analysis — if in doubt contact instructor.

Topics to be covered:

Numerical linear algebra, Numerical optimization, Nonlinear systems, Numerical solutions of ODEs and PDEs.

666/566: Methods of Parallel Numerical Linear Algebra
Instructor: S. Foresti
Text: To be announced
Prerequisites: Math 560 or 561; 118 and 119, or working experience in Fortran or C.

Topics to be covered:

This course will provide basic concepts of parallel computing (hardware, software, parallel programming environments, algorithm design, and performance evaluation), and will provide students with hands-on experience, by studying and implementing parallel versions of fundamental algorithms in linear algebra and scientific computing. There will be an additional term project for those taking this class as Math 666 as opposed to Math 566.

667/567: Parallel Numerical Techniques for the Solution of Partial Differential Equations
Instructor: M. Pernice
Text: None
Prerequisites: Math 566 and either Math 564 or Math 565

Topics to be covered:

Parallel methods for hyperbolic, parabolic, and elliptic partial differential equations will be discussed. Topics will include explicit and implicit methods for time-dependent problems, and parallel multigrid and domain decomposition methods for elliptic problems. An additional term project is required to obtain credit for Math 667.

671, 672, 673: Methods of Applied Mathematics (A W S Qtr)
Instructors: A. Cherkaev, J. Keener, M. Lewis
Text: J. P. Keener, *Principles of Applied Mathematics: Transform and Approximation*
Prerequisites: Math 354; and 521 or 541
Topics to be covered:

1. Finite Dimensional Vector Spaces
2. Function Spaces
3. Integral and Differential Operators on Function Spaces
4. Complex Variable Theory
5. Transform Theory
6. Partial Differential Equations and Green’s Functions
7. Asymptotic Expansions

**Math 677, 678, 679 Mathematical Physiology (A W S Qtr)**

Instructor: J. Keener

Text: Instructor’s notes

Prerequisite: Math 671–2-3 or equivalent

Topics to be covered:

This is a new course, the intent of which is to give an overview of human physiology from the viewpoint of mathematical models. Topics will be selected from the following tentative outline (which is far too ambitious to be covered in depth.)

1. Biochemical Reactions
   - The law of mass action, enzyme reactions — Michaelis Menten kinetics, energy conversion — glycolysis
2. Diffusion
   - Fick’s law, electrodiffusion — Nernst’s law, carrier mediated transport and facilitated diffusion, diffusion and reaction
3. Cellular Homeostasis
   - Control of cell volume and transmembrane potential, transmembrane transport, intracellular transport — axonal transport
4. Membrane Ion Channels
   - Constant field theory, Eyring rate theory, channel selectivity, current-voltage relationships
5. Excitability
   - HH Equations, FHN equations
6. Wave Propagation (will not be covered — see Math 689)
   - Spatial coupling, traveling waves, solitary pulses and dispersion, spiral and scroll waves, the eikonal-curvature equation
7. Calcium Dynamics
   - IP3 receptors and mechanistic models, CICR
8. Electrical Bursting
   - Keizer-Chay model, Rinzel analysis, Importance of coupling, Hindmarsh-Rose modified FHN burster
9. Regulation of Cell Function
   - DNA and RNA, regulation of genes, the lac operon, control of mitosis
10. Intercellular Communication
    - Synapses and neural transmitters, gap junctions, intercellular waves
11. Cardiac Electrophysiology, Part I: Cardiac Cells
    - The electrocardiogram (scalar and vector ECG’s), models of cardiac cells, forced oscillations — one dimensional maps
12. Cardiac Electrophysiology, Part II: Cardiac Propagation
    - Spatial coupling/cardiac fibers/gap junctions, myocardial propagation, pacemakers and ectopic foci, cardiac arrhythmias
13. Blood
   Myoglobin and hemoglobin, blood composition — red blood cell production, blood clotting, leukocyte chemotaxis and inflammation

14. Muscles
   Cross bridge theory, calcium mediation, calmodulin, troponin, excitation-contraction coupling

15. The Circulatory System
   Unregulated circulation, fetal circulation, regulation of circulation

16. The Immune System
   The immune response

17. Respiration
   Diffusion, transport, exchange and regulation of gases

18. Urinary Physiology
   Regulation of fluid volume and composition, nephrons and urinary concentration

19. Hormone Physiology
   Ovulation control, gonadotropin oscillations, insulin oscillations

20. The Digestive System
   Coupled oscillations in the small intestine, gastric protection

21. Vision
   Light adaptation, horizontal cells and photoreceptors, receptive fields

22. Hearing
   Waves on the basilar membrane and the Place principle, resonance in hair cells

684, 685, 686  Bifurcation Theory and Its Applications (A W S Qtr)
Instructor: H. Othmer
Text: Lecture notes will be available
Prerequisite: Math 641–42–43 or consent of instructor

Topics to be covered:
1. Calculus in Banach spaces
2. Linear operator theory; semigroups, spectral theory
3. Local bifurcation theory; Lyapunov-Schmidt reduction, Hopf bifurcation for flows
4. Center and inertial manifolds; reduction of finite- and infinite-dimensional systems
5. Normal forms
6. Maps on 1D manifolds: interval maps and circle maps
7. Chaotic dynamics in interval and circle maps
8. Maps on 2D manifolds: Anosov diffeomorphisms, Smale horseshoe, chaotic dynamics
9. Applications to fluid dynamics, elasticity, chemical reaction dynamics, pattern formation and other areas

Topics will be treated in the above order, except that applications will be distributed throughout the course.

691  Supervised Reading

696  Special Projects

697  Thesis Research (Masters)

698  Research Consultation (Masters)

717  Local Riemannian Geometry (A Qtr)
Instructor: H. Clemens
Prerequisites: Math 651–3

Topics to be covered:
1. The Foucault pendulum
2. Tensor calculus
3. Differential calculus with tensors
4. Conditions for a metric to be Euclidean
5. Locally Euclidean manifolds
6. Curvature
7. Geodesics, the exponential map
8. Two-dimensional geometries of constant curvature

**718 Local Kählerian Geometry** (W Qtr)

Instructor: H. Clemens


Prerequisites: Math 651–3, Math 717

Topics to be covered:
1. Complex projective space, the Fubini-Study metric
2. The star operator
3. The Kähler condition
4. Conditions for a Kähler metric to be Euclidean
5. Locally Euclidean manifolds
6. Curvature
7. Induced metrics, curvature inequality
8. The Poincaré metric, one-dimensional geometries of constant curvature

**719 Geometric Analysis: Global Riemannian Geometry studied using differential equations** (S Qtr)

Instructor: A. Treibergs


P. Li, *Geometric Analysis*, Seoul National University Lecture Notes

Prerequisites: Math 651–52–53

Topics to be covered:
1. Laplacian on manifolds and comparison theorems
2. Splitting theorem
3. Maximum principle techniques on noncompact manifolds
4. Harmonic functions on complete manifolds
5. Eigenvalue estimates
6. Isoperimetric inequalities and Sobolev inequality Harnack inequalities for harmonic functions in conformal metric

**721, 722, 723 Lie Group Representations** (A W S Qtr)

Instructor: D. Miličić

Text: Instructor’s notes

Prerequisites: Lie groups, basic differential and algebraic geometry

Topics to be covered:


3. Equivariant geometry of flag varieties. Classification of orbits of complexifications of maximal compact subgroups of real forms.


**724, 725, 726 Several Complex Variables (A W S Qtr)**

Instructor: J. Taylor  
Text: Instructor’s notes  
Prerequisites: Real and Complex Analysis (621–22–23) and some knowledge of algebra and topology

Topics to be covered:

A sheaf theoretic approach to several complex variables and complex algebraic geometry, stressing the similarities between the two subjects. Topics will include the local structure of algebras of holomorphic functions and algebras of regular functions, algebraic and holomorphic varieties, sheaf theory and sheaf cohomology, coherent sheaves, vanishing theorems for sheaf cohomology in the algebraic and holomorphic settings, projective varieties, Serre’s GAGA paper comparing the categories of coherent sheaves in the algebraic and holomorphic theories, vector bundles, compact manifolds, applications to the representation theory of Lie groups (the Borel-Weil-Bott Theorem).

**731, 732, 733 Algebraic Groups (A W S Qtr)**

Instructor: G. Savin  
Text: R. Steinberg, Lectures on Chevalley groups, Yale notes, 1967  
Prerequisites: Some familiarity with simple Lie algebras, root systems, in particular

Topics to be covered:

Arithmetic aspects of reductive groups: Chevalley groups, simple groups over finite field, Bruhat decomposition, Galois cohomology, central extensions, buildings etc.

**737, 738, 739 Elementary Algebraic Geometry (A W S Qtr)**

Instructor: A. Bertram, J. Kollár  
Text: Shafarevich, Basic Algebraic Geometry, Springer-Verlag  
Prerequisites: Math 631–32–33 or equivalent

Topics to be covered:

Affine and projective varieties, regular and rational functions and maps, products, dimension, Hilbert polynomials and the definition of degree, tangent spaces and singularities, completions, blowing up, normal varieties, divisors and differential forms. Curves, elliptic curves, Noether’s theorem and Bézout’s theorem for plane curves, Hurwitz’s theorem, Riemann-Roch for curves. Surfaces, intersections of divisors on surfaces, blowing down exceptional curves, minimal models, Hodge index theorem, the Weil conjectures for curves. Grassmannians, determinantal varieties, secant varieties, quadrics and scrolls. Introduction to schemes, coherent sheaves and algebraic geometry from the “modern” viewpoint.

**751, 752 Algebraic Topology (A W Qtr)**

Instructor: M. Bestvina  
Text: Depends on the topic. List of references will be handed out in class.  
Prerequisite: Math 651–52–53

Topic to be covered:

The course will focus on an interplay between algebraic and geometric methods in topology. The topics will depend largely on the audience. Possibilities include: spectral sequences, cohomology rings of classifying spaces, Morse theory, Whitehead torsion, cohomology of groups.
Math 753  Manifolds of Nonpositive Curvature and Mostow Rigidity (S Qtr)
Instructor: M. Kapovich
Prerequisites: Basic topology and Riemannian geometry

Topics to be covered:

We shall discuss manifolds of nonpositive curvature. Our main goal is to prove a version of Mostow Rigidity Theorem for higher rank symmetric spaces a la Gromov:

Suppose that $X$ is an irreducible symmetric space of nonpositive curvature of rank $\geq 2$, $\Gamma$ is a torsion-free lattice acting on $X$ and $M = X/\Gamma$ is compact. Then (up to rescaling and isometry) the manifold $M$ admits only one metric of nonpositive curvature. In particular, if $f : X \to X$ is a diffeomorphism such that $\Gamma' = f \Gamma f^{-1}$ lies in the group of isometries of $X$, then $\Gamma'$ is conjugate to $\Gamma$ by an isometry.

780  Seminar in Algebraic Geometry (A W Qtr)
Instructor: J. Kollár
Text: To be announced
Prerequisite: Math 737–38–39

780  Seminar in Algebraic Geometry (S Qtr)
Instructor: R. Morelli
Text: To be announced
Prerequisite:

797  Thesis Research (Ph.D.)
798  Research Consultation (Ph.D.)
799  Continuing Registration (Ph.D.)
### RECENT Ph.D. STUDENTS
#### Department of Mathematics
#### 1987–96

<table>
<thead>
<tr>
<th>Year</th>
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<td>Othmer</td>
<td>Univ. of Calif., Davis</td>
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<td>Sirvent, Maritza</td>
<td>Approximation Theory</td>
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<td>Austin, David M.</td>
<td>Topology</td>
<td>Stern</td>
<td>Inst. for Advanced Study</td>
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<td>Geometry</td>
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<td>Joyce, Paul J.</td>
<td>Stochastic Proc</td>
<td>Tavare</td>
<td>University South California Los Angeles, CA</td>
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<td>Arner, Paul R.</td>
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<td>Barry, Phillip J.</td>
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<td>Hoppensteadt</td>
<td>Michigan State University East Lansing, MI</td>
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</table>
FACULTY 1996–97

Three research papers of each faculty member (other than visiting faculty) are included to indicate activity and areas of interest. If desired, more complete bibliographies are available in the departmental office. A list of visiting faculty is included at the end of this section.

DISTINGUISHED PROFESSOR

Kollár, János, Brandeis University, 1984. Algebraic Geometry

PROFESSORS

Alfeld, Peter W., University of Dundee, 1977. Approximation theory

Bestvina, Mladen, University of Tennessee, 1984. Topology

Brooks, Robert M., Louisiana State University, 1963. Topological Algebras

Burgess, C. Edmund, University of Texas, 1951. Topology (1/3 time)

Carlson, James A., Princeton University, 1971. Algebraic Geometry


**Clemens, C. Herbert**, University of California, Berkeley, 1966. Algebraic Geometry


**Ethier, Stewart N.**, University of Wisconsin, 1975. Probability, Mathematical Genetics


**Fogelson, Aaron L.**, New York Univ., 1982. Computational Fluids, Mathematical Physiology


Gross, Fletcher I., California Institute of Technology, 1964. Group Theory


Gustafson, Grant G., Arizona State University, 1968. Ordinary Differential Equations


Hecht, Henryk, Columbia University, 1974. Lie Groups


Horvath, Lajos, Szeged University, 1982. Probability, Statistics


Keener, James P., California Institute of Technology, 1972. Applied Mathematics


**Mason, J. David.** University of California, Riverside, 1968. Probability


**Miličić, Dragan.** University of Zagreb, 1973. Lie Groups


**Milton, Graeme.** Cornell University, 1985. Applied Mathematics


**Rossi, Hugo.** Massachusetts Institute of Technology, 1960. Complex Analysis

Rushing, T. Benny, University of Georgia, 1968. Topology


Schmitt, Klaus, University of Nebraska, 1967. Nonlinear Analysis, Differential Equations


Taylor, Joseph L., Louisiana State University, 1964. Group Representations


Toledo, Domingo, Cornell University, 1972. Algebraic Geometry, Differential Geometry


Trombi, Peter C., University of Illinois, 1970. Lie Groups


Tucker, Don H., University of Texas, 1958. Differential Equations, Functional Analysis


Willett, Douglas W., California Institute of Technology, 1963. Ordinary Differential Equations


ASSOCIATE PROFESSORS

Bertram, Aaron, UCLA, 1989. Algebraic Geometry


ASSISTANT PROFESSORS


Morelli, Robert, Harvard University, 1989. Combinatorics and Algebraic Geometry
[1] Pick’s Theorem and the Todd Class of a Toric Variety, Advances in Mathematics 100(2) (August 1993), 183-231.

Niziol, Wieslawa, Princeton University, 1991. Algebraic Geometry

Ruan, Yongbin, University of California, Berkeley, 1991 Symplectic Topol./Gauge Theory

Zhu, Jingyi, New York University, 1989. Computational Fluid Dynamics

ADJUNCT PROFESSORS

Egger, Marlene J., Stanford University, 1979. Statistics
Reading, James C., Stanford University, 1970. Statistics


ADJUNCT ASSOCIATE PROFESSORS

Beebe, Nelson H. F., University of Florida (Gainesville), 1972. Quantum Chemistry


Clark, Donald D., Brigham Young University, Ed.D., 1974. Secondary Foundations and Instruction

Johnson, Christopher, University of Utah, 1990. Cardiovascular Research

Lewis, Lawrence G., Indiana University, 1969. Complex Analysis


Roberts, Anne D., McGill University, 1972. Analysis


ADJUNCT ASSISTANT PROFESSORS

Foresti, Stefano, Pavia, Italy, 1987. Scientific Computing

Johnson, Jennifer, Brandeis, 1989. Automorphic Forms

Pernice, Michael, University of Colorado, 1986. Scientific Computing

INSTRUCTORS


Bottino, Dean, Tulane, 1996. Mathematical Biology

Chan, Claire, Stanford, 1994. Geometric Measure Theory


Kley, Holger, University of Chicago, 1996. Algebraic Geometry

Megyesi, Gabor, University of Cambridge, 1993. Algebraic Geometry

Sage, Daniel, University of Chicago, 1995. Representation Theory

Xiao, Yimin, Ohio State, 1996. Probability Theory
RESEARCH FACULTY

Eyre, David, University of Utah, 1992. Applied Mathematics
Horn, Roger, Stanford University, 1967. Matrix Analysis


Veronese, Silvia, University of Pavia, 1988. Computational Science

PROFESSORS EMERITI

Davis, E. Allan, University of California, Berkeley, 1951. Mathematical Economics and Teacher Training Programs

VISITING FACULTY

Professors
Mori, Shigafumi, Kyoto (Japan), 1978. Algebraic Geometry (S 1995)

Assistant Professors
Grunbaum, Daniel, Cornell University, 1992. Mathematical Biology

VISITING SCHOLAR

Kelly, Michael, State University of New York at Binghamton, 1985. Topology and Geometry