
The University of Utah
Department of Mathematics
GRADUATE BULLETIN
2011–2012



GRADUATE MATHEMATICS

2011–2012

Department of Mathematics
University of Utah

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Cover: University of Utah and Wasatch Mountains (Photo: P. Alfeld)

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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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The T. Benny Rushing Mathematics Student Center



CALENDAR OF EVENTS FOR 2011–2012

EVENT	Fall Semester 2011	Spring Semester 2012	Summer Term 2012
Class schedule available on the web	M, Mar 7	M, Sep 19, 2011	M, Feb 6
Classes begin	M, Aug 22	M, Jan 9, 2012	M, May 14
Last day to drop (delete) classes	W, Aug 31	W, Jan 18	W, May 23
Last day to add classes	T, Sep 6	M, Jan 23	T, May 29
Last day to elect CR/NC option	T, Sep 6	M, Jan 23	T, May 29
Tuition payment due	T, Sep 6	M, Jan 23	T, May 29
Last day to withdraw from term length classes	F, Oct 21	F, Mar 2	F, Jun 22
Last day to reverse CR/NC option	F, Dec 2	F, Apr 20	F, Jul 27
Classes end	F, Dec 9	W, Apr 25	W, Aug 1
Reading Day	n/a	H, Apr 26	n/a
Final exam period	M–F, Dec 12–16	F–H, Apr 27–May 3	H–F Aug 2–3
Grades available on the web	T, Dec 28	T, May 15	T, Aug 14
Annual University Commencement/Convocation Exercises		F, May 4	

Departmental Written Qualifying Exams (Prelims) M–W, Aug 15–17, 2011 and W–F, Jan 4–6, 2012

Math Dept. TA training for new graduate students and instructors Aug. 10–19, 2011

HOLIDAYS, RECESSES, BREAKS**(No classes, day or evening. University closed on holidays)*****Fall Semester 2011***

Labor Day Holiday M, Sep 5

Fall Break M–F, Oct 10–15

Thanksgiving Break H–F, Nov 24–25

Holiday Recess Sa, Dec 17–Su, Jan 8

Spring Semester 2012

Martin Luther King/Human Rights Day Holiday M, Jan 16

Presidents' Day Holiday M, Feb 20

Spring Break M–Sa Mar 12–17

Summer Term 2012

Memorial Day Holiday M, May 28

Independence Day Holiday W, Jul 4

Pioneer Day Holiday T, Jul 24

For additional information concerning registration dates and fee payment deadlines see the university schedule(s) at <http://www.sa.utah.edu/regist/registration/registration.htm>.

Please note that these dates may change after printing.

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 600 Ph.D. degrees per year. The University faculty consists of approximately 3100 members.

The Mathematics Department of the University of Utah now awards, on the average, about eight Ph.D. degrees per year. Over 250 people have earned this degree since 1954. Most of them have positions in state and private universities, but some hold nonacademic positions. Six have been awarded Sloan Research Fellowships, 12 have been visiting members of the Institute for Advanced Study in Princeton, and five have been awarded National Science Foundation Postdoctoral Fellowships.

Our present graduate faculty numbers 45. 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. 57. The research interests of the faculty are the areas of specialization available for graduate studies. They include diverse areas in pure and applied mathematics such as algebraic geometry, arithmetic geometry, commutative algebra, differential geometry, geometric topology, group theory, materials and fluids, mathematical biology, mathematical cardiology, mathematical finance, mathematical physiology, numerical analysis, partial differential equations, probability and statistics, representation theory, and stochastic processes.

During the present year, 24 members of the Mathematics faculty are associated with government-sponsored research contracts.

The University's total enrollment is currently about 31,000. During 2010–2011, there were 44 men and 18 women who were Teaching Fellows and Assistants in mathematics. Our graduate students come from different areas of the United States as well as many foreign countries.

Research Facilities

The newly-remodeled and expanded Mathematics Branch Library collection in theoretical mathematics consists of 190 journal subscriptions, 15,000 bound journals and 12,000 books. In addition, the Marriott Library collection includes numerous books and journals of interest to mathematics researchers and scholars. There are extensive interactive computing facilities available in the Department.

COMPUTING FACILITIES

The Department provides outstanding computing facilities for use by faculty, students and staff. In mid-2011, the fully-Internetworked workstation and microcomputer configuration included more than 325 systems in a range of models from these architectures:

- Apple Macintosh (32);
- DEC Alpha (1);
- IBM x3550 (4 CPUs, 6 cores/CPU, 24GB DRAM) (2);
- IBM x3755 (4 CPUs, 8 cores/CPU, 128GB DRAM) (3);
- IBM x3850 (8 CPUs, 8 cores/CPU, 1024GB DRAM) (1);
- Intel IA-64 Itanium (1);
- Intel x86 Pentium and AMD Athlon (3);
- Oracle X4470 (four 8-core 16-thread Xeon CPUs, 256GB DRAM) primary fileserver (1);
- PowerPC GNU/Linux (2)
- Silicon Graphics (3);
- Sun x86-64 Opteron and Xeon (20);
- Sun Ray stations (182);
- Sun SPARC workstations and servers (15);
- Sun Ultra 24 x86-64 workstations (3);
- Sun X4500 (two dual-core Opteron CPUs, 16GB DRAM) secondary fileserver (1);
- Verari cluster (2 AMD64 Opteron CPUs/node) (61);

These include at least one file server from each UNIX architecture. Operating systems and CPU types include Solaris (SPARC, x86, and x86-64), GNU/Linux (Alpha, IA-64, MIPS, PowerPC, SPARC, x86, and x86-64), FreeBSD (x86), IRIX (MIPS), MacOS (PowerPC and x86-64), NetBSD (x86), OpenBSD (x86), and Windows 5 [XP], 6 [Vista], and 7 (x86 and x86-64).

Most of our users work in either Solaris SPARC or GNU/Linux x86-64 environments. However, access to many other types of systems is important to allow software development and testing in diverse environments.

The new quad-processor file server provides 20TB of storage, with a real-time mirror in another building to supply automatic switch-over should any storage or network component, or electrical power, fail.

Web and FTP services are each provided by separate operating-system domains on the central file server.

WeBWorK course services are handled by the two IBM x3550 24-core servers.

Sun Ray services on the Solaris SPARC architecture are handled by six quad-processor Sun Fire V440 systems and two 16-core Sun T5240 systems, and on the GNU/Linux x86-64 architecture by an eight-processor Sun Fire X4600 system, and by three IBM 32-core servers.

Batch computing services are provided by a dual-processor Itanium-2 server, three quad-core AMD64 servers, a Sun Blade 8000 server with four 8-core AMD64 blades (restricted to mathematical biology users) and two 16-core Xeon blades, and the large-memory IBM x3850 64-core server.

All servers are located in a central machine room with its own cooling system and emergency power system (batteries with fail-over to outside electrical generator) and network hubs share the same reliable power system.

Daily ZFS filesystem snapshots on the primary file server provide users with immediate online access to their files from the last several weeks, as documented in the frequently-asked questions Web pages at <http://www.math.utah.edu/faq/files/files.html>. All filesystems are backed up nightly to tapes covering the last few months, The tape server holds up to 500 LTO-4 tapes, each of 800GB raw capacity, and is shared with other departments in the College of Science.

The Mathematics and Physics Department student laboratories are open to members of either department, increasing the access possibilities; computer accounts are, however, managed within each department.

Each user has just one home directory, independent of login architecture, and all users have login access on all of the public workstations. Most standard programs are available on all architectures.

Eight large classrooms provide large-screen projection systems for workstation and videotape output, and there are two portable projection systems for conference-room display.

There are three Xerox 6360 color laser printers, an HP LaserJet 3700dn color laser printer, and about 50 distributed laser printers, including three high-volume duplex laser printers in the student laboratories. In addition, there are two Xerox WorkCentre Pro 65 black-and-white digital copier/printer/scanner systems (65 pages/minute), a Xerox WorkCentre 7346 color digital copier/printer/scanner system (50 pages/minute), and a Canon imageRunner 8070 copier/printer (80 pages/minute).

All computer systems are reachable from anywhere on the global Internet, including home systems with DSL or cable modem Internet connections.

The facility is connected to the campus air-blown fiber-optic network backbone, which can provide several orders of magnitude in expanded network capacity, as the need arises. All network connections provide 10 Mbs, 100 Mbs, and 1 Gbs secure connections, and all offices have at least four network ports.

All buildings, and adjacent outdoor areas, have wireless network access, managed externally by University Information Technology staff (see <http://www.it.utah.edu/services/networking/wireless/>).

University researchers can apply for additional computer resources at the Center for High-Performance Computing on a 1024-node AMD64 Opteron cluster. Visit the CHPC Web site <http://www.chpc.utah.edu/> for further details.

For more information about the Department and its activities and facilities, visit its Web site at <http://www.math.utah.edu/>. That site contains a link to an extensive frequently-asked questions (FAQ) repository that provides much more detail about our computing facilities.

APPLYING TO GRADUATE PROGRAMS

Applications

Starting August 2011, application to graduate programs in mathematics for Fall 2012 and later are done online. It is no longer necessary to send a separate application to the graduate school and to the Department. Detailed instructions are available on the website <http://www.math.utah.edu/grad/>.

Application materials and individualized application checklists may be found on our website. The University application deadlines are **November 1st** for Spring admission, **March 15th** for Summer admission, and **April 1st** for Fall admission. The Mathematics Department deadline for teaching-assistantships applications is **January 15th**.

The online application forms request that you upload the same information as for the mailed application.

Department of Mathematics Instructions for the Online Application for Graduate Admissions and Financial Aid

Here are line-by-line instructions for students interested in applying to admission and financial aid to the following graduate programs: Master of Arts in Mathematics, Master of Science in Mathematics, Master of Statistics (Mathematics) and Doctor of Philosophy in Mathematics. After reading these instructions you may proceed to the Apply Yourself (AY) link. The application need not be completed in one session. Applications for financial aid for the following fall semester are due January 15.

Instructions for applying to the Master of Mathematics (Teaching) program may be found at http://www.math.utah.edu/mathed/master_mt.html.

Instructions for applying to the Master of Science Degree for Secondary School Teachers of Science or Mathematics (MSSST) program may be found at <http://www.science.utah.edu/students/mssst.html>.

Instructions for applying to the Professional Master of Science and Technology (PMST) program may be found at <http://web.utah.edu/pmst/>.

Instructions for applying to the Master of Science in Computational Engineering and Science (CES) program may be found at <http://www.ces.utah.edu/>.

AY Application Instructions You can find advice about the University of Utah's prerequisites for applying to the Graduate School including deadlines. Additional specific requirements of the mathematics department are spelled out in the Mathematics Graduate Bulletin (<http://www.math.utah.edu/dept/gradbull.pdf>). The Department of Mathematics deadline for applications for Teaching Assistantships of the next fall semester is January 15. The deadlines for admission are March 15 for the next fall semester and November 1 for the next spring semester. You can find information about satisfying the University of Utah's language requirements for nonnative English speaking graduate students and the TOEFL tests.

AY Home AY access history.

Basic Information—All Applicants

Personal Data Fill in your name, address, and social security number.

Contact Information Fill in addresses and email address.

Emergency Contact Name someone to contact in case of emergency.

Ethnic Origin You may fill in ethnic origin, veteran and language information.

Program Information For "Program of Interest," select one of "Mathematics MA" (Master of Arts in Mathematics), "Mathematics MS" (Master of Science in Mathematics), "Mathematics MST" (Master of Statistics—Mathematics) or "Mathematics PhD" (Doctor of Philosophy in Mathematics). Students interested in Master of Mathematics (Teaching) should select "Mathematics MS" and follow different instructions on the Master of Mathematics (Teaching) page. For other

programs, please go to the specific program page and follow their instructions, e.g., MSSST applicants should choose “Science Program for Secondary School Teachers (MS).” For “Emphasis Area,” select your most likely area of study in the Department of Mathematics. For example, if you are interested in geometric group theory, then please indicate “geometry/topology.” If you are not sure about what your area will be, or if you do not see your interest listed, please check “undecided,” and describe your emphasis in your Statement of Purpose. For “Undergraduate Major,” indicate major of your undergraduate degree. For “Application Term and Year,” indicate the term for which you are applying. For most applicants to the mathematics programs this will be Fall Semester 2012. Year-long Teaching Assistantships are only offered for the fall semester.

Education History List your previous graduate study experiences including any study at the University of Utah. You are asked to list all universities attended including all graduate programs with dates. For “Test Scores,” the Department of Mathematics requires the GRE exam including the subject exam for all applicants for Masters of Mathematics and Doctor of Philosophy programs, but does not require the GRE from applicants to the MStat (Mathematics) program, nor from the Masters of Mathematics (Teaching) program. Masters of Mathematics (Teaching) submit Praxis scores instead of GRE scores—see specific Master of Mathematics (Teaching) instructions. You may enter your subject score and percentile in the “Other” section. You also have to enter your GRE scores in the College of Science Section of the AY application. For “Colleges and Universities,” you are asked to enter the Colleges and Universities you have attended and upload copies of transcripts.

Residency For “Residency for Tuition Purposes,” supply your residency information and describe your employment history. You may supply information about your parents and your American Indian affiliation.

Academic Interests and Background Please upload your CV. The Mathematics Department now requires that you also upload a Statement of Purpose where you may describe your educational and career objectives. The Mathematics Department does not require a writing sample, but if you wish to upload a mathematical paper or a link to a publication, you may do so here. For “Faculty,” in this optional field you may specify a professor in the Department of Mathematics with whom you would like to work. For “Financial Support,” please indicate whether you are applying for financial support from the Department of Mathematics. The only financial support available from the Department of Mathematics is the Teaching Assistantship with its corresponding Tuition Benefits. Teaching Assistants are assigned various duties including teaching classes, running recitation or lab sections and grading. For “Applicant Survey,” you may tell us where found out about Graduate Mathematics Programs at Utah. Indicate whether you intend to complete your degree as a full-time or part-time student. For “Comments,” you may supply any additional information here.

Full Time Employee Page Fill in this page if you are full-time employee of the University of Utah.

College of Science Page This information is required from applicants to departments in the college: Biology, Chemistry, Physics and Astronomy and Mathematics. For “GPA,” estimate your grade point average from STEM (science, technology, engineering and mathematics) classes. For “Test Scores,” enter your GRE scores and percentages including your subject score, if required. The Department of Mathematics requires the GRE exam including the mathematics subject exam for all applicants for Masters of Mathematics and Doctor of Philosophy programs but not for the MStat (Mathematics) or the Masters of Mathematics (Teaching) programs. Masters of Mathematics (Teaching) submit Praxis scores instead of GRE scores—see specific Master of Mathematics (Teaching) instructions. Enter your GRE scores and percentages including your subject score. In the “Additional Information” section, if you have received any scholastic honors or awards, you may mention them here. If you have any publications that you have authored or co-authored, you may list them here. If you have had teaching positions, you may list them here. If you wish to tell us about any unusual circumstances, you may do so here.

Recommendations For each person providing you a letter of recommendation, please enter their names and email contact information. AY will email your referees and ask them to upload a recommendation. The Department of Mathematics requires at least three letters of recommendation. The most valuable letters are from professors of your advanced mathematics classes and mentors of research projects.

Download Forms If you wish to give your referee a paper recommendation form to send to the Department of Mathematics, please use “Recommendation Form 6” which you can download (there are several letter styles).

Paper Applications for Spring 2012

Applications for Spring 2012 admission may follow the old procedures. To expedite your applications for Spring 2012 admission, please follow these procedures:

1. University of Utah Admissions Office

- (a) Apply online, or download the application at <http://www.sa.utah.edu/admiss/appdownload/> and submit it by postal mail.
- (b) Supply these required documents:
 - i. One copy of transcripts from each college or university you have attended, excluding the University of Utah. 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.
 - ii. For international applicants:
 - Official transcripts in their original language accompanied by an English translated version.
 - Official TOEFL scores, unless the applicant has attended a college or university in the U.S. in the last two years.
 - A copy of a national ID card or the photo-ID page of a current passport.
- (c) Pay the required application fees.
- (d) Track your admission status online regularly to verify that all required documents are received and processed.

Note to international applicants: The I-20 form cannot be processed until *all* documents and fees are submitted to the Admissions Office *and* the student has been admitted by the program.

2. Mathematics Department

- (a) Download and complete the following forms from <http://www.math.utah.edu/grad/>:
 - i. *Application for Admission*;
 - ii. *Letter of Reference Form* (print three copies and follow instructions on the form);
 - iii. *Financial Assistance Application* (optional).
- (b) Supply these required documents:
 - i. One copy of transcripts from each college or university you have attended. International applicants must provide official transcripts in their original language accompanied by an English translated version.
 - ii. Your GRE mathematics subject score. Starting with 2011 applications, we require that you have your GRE scores sent to us.
 - iii. For international applicants, a copy of the official TOEFL and TSE scores, unless the student has attended a college or university in the U.S. in the last two years.
- (c) There are no fees to apply to the Mathematics Department Graduate Program.

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.

Students are normally admitted at the beginning of the Fall Semester, and financial aid to new students is only offered at that time. It is desirable that applications for teaching assistantships be submitted as early as possible. The deadline for applications for financial aid is January 15. Applications received before March 15 are considered for financial aid for the following Fall Semester as long as positions remain available.

Financial Aid

Most graduate students in mathematics are supported by teaching assistantships. Others may be supported by teaching fellowships or research assistantships depending on the source of funding.

Tuition

Tuition (nine hours) is approximately \$2780 per semester for Utah residents and \$8749 per semester for nonresidents. See <http://fbs.admin.utah.edu/income/tuition/general-graduate/>. (Tuition rates may change without notice.) The Graduate Tuition Benefit Program administered by the Graduate School waives tuition fees for Teaching Fellows, Teaching Assistants, and Research Assistants. Graduate students who are supported by teaching assistantships are required to register for 12 credits per semester. The policy is described at <http://www.gradschool.utah.edu/tbp/guidelines.php>. All international students are required to pay \$75 each semester to help cover additional administration costs that occur. **Supported students who withdraw after the drop deadline from a course covered by their tuition waiver are financially responsible for the tuition of that course.**

Health Insurance

The University of Utah sponsors a health insurance plan at excellent rates for students, their spouses and their dependent children under age 26. For details, see <http://www.studenthealth.utah.edu/services/SHI.htm>.

The Graduate School and the Department provide each funded graduate student with a premium subsidy that covers the full cost of group health insurance offered through GM Southwest; see <http://www.gradschool.utah.edu/tbp/insurance.php>.

Housing

The University accepts applications for on-campus residence hall and University student apartment housing. Student residence halls provide a single room and a shared bathroom and kitchen. Visit the Web site <http://www.housing.utah.edu/> for current information, or contact Office of Housing and Residential Living, 5 Heritage Center, University of Utah, Salt Lake City, Utah 84112-2036, (801) 587-2002. Apartment housing for both married and single undergraduate and graduate students is available on campus. Visit the Web site <http://www.apartments.utah.edu/> for current information, or contact University Student Apartments, 1945 Sunnyside Avenue, Salt Lake City, Utah 84108, (801) 581-8667.

Off-campus house and apartment listings can be found in the classified sections of **The Salt Lake Tribune** (<http://www.sltrib.com/>), the **Deseret News** (<http://www.desnews.com/>), and the student newspaper, **The Daily Utah Chronicle** (<http://www.dailyutahchronicle.com/>).

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, Master of Science in Mathematics, Master of Science in Computational Engineering and Science (see p. 18), and a Professional Master of Science and Technology Degree (PMST). Pending approval, it will soon offer a Masters of Mathematics Teaching.

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.

A number of forms must be filed, and certain time limitations are to be observed. Some remarks are in order relative to these requirements.

1. Comprehensive oral and/or written qualifying examination in mathematics are taken usually after a student has completed at least a year of graduate study. (See below.) The Master's Project requires a comprehensive final oral examination. This exam is called the project defense or thesis defense or the final oral 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. Questions concerning the interpretations of degree requirements should be directed to the candidate's advisor.
3. Thesis candidates must register for a minimum of six credit hours of thesis research Math 6970 and at least three credit hours per semester from the time of formal admission to the Graduate Program until all requirements for the degree including the final oral examination (thesis defense) are completed.

B. Departmental Requirements:

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

Course Requirements

1. Math 5210 (real analysis)
2. Math 5310, 5320 (algebra)
3. One 6000-level sequence consisting of two one-semester courses
4. Four additional one-semester courses at the 5000- or 6000-level

Graduation Requirements

There are several options to satisfy the graduation requirements for the Master's Degree. The candidate may pass two qualifying exams and take 30 semester hours of coursework or do nine additional semester hours of Master's Project for a total of 39 hours of coursework. There are four specific options.

1. *Qualifying Exam Option.* Pass two of the written qualifying exams **and** take at least 30 semester hours of approved courses. The exams are comprehensive and serve as the final exam.

OR

2. *Curriculum Project Option.* Write a Curriculum Project and take at least 39 semester hours of approved courses. Students choosing this Non-Thesis Curriculum Project Option may take up to 10 semester hours of Math 6960 Special Projects. The Curriculum Project is in every other way a Thesis but does not need approval from the Thesis Office. The required final examination for this option is the public oral Final Defense of the Project.

OR

3. *Courses Project Option.* Take additional courses at the 6000- or 7000-level for a total of at least 39 semester hours of approved courses. The required final examination for this option is the oral Final Comprehensive Examination.

OR

4. *Thesis Project Option.* Write a Master's Thesis and take at least 39 semester hours of approved courses. Students choosing this Thesis Option may take up to 10 semester hours of Math 6970, Masters Thesis Preparation. The required final examination for this option is the public oral Final Defense of the Thesis. The University Graduate School's Thesis Office must approve the thesis and a copy of the thesis is archived by the University Library. By arrangement with the Graduate School, those students writing Master's theses may use credit hours in courses, numbered 6000 or above and in the general area of specialization of the thesis, to fulfill the 6–10 hours requirement of 6970 (Thesis Research).

The total number of semester hours required for the Master's degree in mathematics should fall in the range 30–39.

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.

Requisites for the Master's degree in applied mathematics are:**Course Requirements**

1. Either two 6000-level sequences, or 5210 and three 6000-level one-semester courses, two of which must form a year-long sequence.
2. Five additional one-semester courses at the 5000- or 6000-level.

Graduation Requirements

Same as those for the M.S. in pure mathematics.

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. (Both may be required by the committee. A marginal pass of the written examination is one justification for requiring both exams.)

The Master's Oral Comprehensive Examination will be conducted by the student's committee and should be held at least one semester prior to the semester 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 5000-level include:

Pure Mathematics:

Math 5210	Real Analysis
Math 5310, 5320	Introduction to Modern Algebra
Math 5410, 5420	Ordinary Differential Equations, Dynamical Systems
Math 5520	Introduction to Algebraic/Geometric Topology

Applied Mathematics:

Math 5010	Introduction to Probability
Math 5040, 5050	Stochastic Processes and Simulation
Math 5080, 5090	Statistical Inference
Math 5110, 5120	Mathematical Biology
Math 5610, 5620	Introduction to Numerical Analysis
Math 5710, 5720	Introduction to Applied Mathematics
Math 5740	Mathematical Modeling
Math 5760, 5765	Introduction to Mathematical Finance

Students should also be aware of 5000-level offerings in other departments (e.g., courses in Biology, Chemistry, Computer Science, Economics, Physics, 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.

Students 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 those exams prior to the beginning of the Fall Semester of their second 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.

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. Applicants to the Ph.D. Program should make sure that their files are as strong as possible by supplying current letters of support.

All candidacy forms for the Master's degree should be submitted to the Graduate Coordinator 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 semester of graduate work:

Discuss your proposed program with the Director of Graduate Studies at the beginning of the semester. By the end of the first year, choose a three-person supervisory committee. **It is the responsibility of the student to suggest a committee to the Graduate Advisor, who will be the committee chair.**

Meet with your advisor towards the end of the Spring Semester 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.

2. One year 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 the second semester of the second year) including topics that might be included on it; those of you choosing to take written qualifying exams 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.

3. One semester 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 the Graduate School. These cannot be filed until at least one semester of graduate work is completed and must be filed at least one semester before you plan to graduate. (These forms may be filed on line. Copies can be picked up from the Graduate Coordinator.)

4. Early in your final semester:

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 semester in which you plan to defend your thesis, you must register for three credit hours of "Faculty Consultation" (mathematics 6980) before taking this final oral examination.

For graduation in a particular semester, 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 semester. For specific dates, consult *A Handbook for Theses and Dissertations*.

5. Six weeks prior to graduation:

Have an acceptable draft of the thesis/project 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.

6. 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 *Graduate Program Calendar* for further information about procedures that should be followed in the final semester 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 four semesters for Master’s degrees.

Transfer Credit

At most six hours of non-matriculated credit from the University of Utah or transfer credit from another university will be allowed in the graduate program toward a Master’s degree.

D. Recommended schedule of study toward a Master’s degree with intent to enter the Ph.D. program.

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

YEAR ACCOMPLISHMENTS

- | | |
|---|---|
| 1 | Study three 5000-level or 6000-level courses throughout the year. Where at least two 6000-level courses are studied, take at least two written qualifying examinations in the summer before the second academic year. |
| 2 | Study at least three courses at the 6000-level or 7000-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 by the summer before the next academic year. |

Note: The following is quoted from *The University of Utah General Catalog 2012–2013*, *Graduate Information* chapter, p. 39:

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.¹
2. Math 3070, 3080, 3090, or equivalent.

Course requirements

1. Math 5010, 5080, 5090²
2. Stat 6070
3. One sequence of Math 6010, 6020
4. Electives approved by supervisory committee, 15 credits.
5. Math 6960 (Master's project) 3–6 hours.
6. Oral examination on the Curriculum Project (Math 6960), this is, a "Curriculum Project Defense."

MASTER OF MATHEMATICS WITH AN EMPHASIS IN TEACHING PROGRAM

The newest degree offered by the department is the Master of Science in Mathematics with emphasis in teaching. The teacher candidates will conduct research as part of their course work that will investigate content knowledge needed to successfully teach secondary school mathematics, and do so in a community of professional teachers who work together on improving mathematics instruction for all students. A student is admitted to the program by the Mathematics Education Committee by making application through the Graduate School. Upon admission by the Mathematics Education Committee, the student is also admitted to the Mathematics Department Master's program. The degree of Master of Mathematics with an Emphasis in Teaching is awarded by the Mathematics Department.

Prerequisites

1. either a Bachelor's Degree in Mathematics, Mathematics Teaching or related field with an equivalent of at least 6 of the courses required being level 4 mathematics endorsement courses
2. Praxis 2 (0061): Math Content Knowledge with a score of at least 143
3. Praxis (0063) Math Content Knowledge, and Mathematics: Proofs, Models and Problems, Part 1

The Mathematics Education Committee may advise candidates to take courses that would ensure their readiness for the required course work in the program.

Course requirements

The Graduate School at the University of Utah has a list of requirements for M.S.; see the University of Utah General Catalog <http://www.ugs.utah.edu/catalog/>. A total of 36–39 credits are required of a candidate: 30 are core courses, and will be taken by the cohort. The remaining 9 credits are to be electives with at least 6 from the discipline specific mathematics courses at 5000 level or above (any exceptions must be approved by the program coordinator). The candidates must take at least four 6000 level courses, of which at least two must be in the Mathematics department. Master's Project (93–96 credits): Students will conduct research and report on their findings in a thesis. The research topic must be approved by the student's committee before the research begins. The committee will be composed of at least two members of Mathematics Department and one member of College of Education.

Final Examination: Successful performance on a final oral examination which covers work presented for the masters degree and defense of the project. The following is a list of departmental requirements for candidates seeking a M.S. in Mathematics Teaching.

1. Math 5150 and 5160,
2. Math 6080 and 6090,
3. SPED 6141

¹A "sequence" refers to a course that continues through an academic year.

²If Math 5010, 5080, 5090 was taken while the student was an undergraduate, then either one of Math 6010, 6020, 6040, 6070, or a mathematics sequence listed below is required.

4. 4 courses associated with licensure (if already held will be replaced by electives approved by the supervisory committee)
5. electives approved by the supervisory committee, 9-12 credits
6. Math 6960 (Master's project), EDU6960 Action Research
7. oral examination on project (Math 6960)

For more information, see http://www.math.utah.edu/mathed/master_mt.html or contact Gwen Allen, Program Assistant, The Center for Science and Mathematics Education, University of Utah, 155 S. 1400 E., Rm. 233, Salt Lake City, UT 84112-0090, (801)585-1985.

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. Started in 1972 by Acting Dean Allan Davis, the M.S. Degree Program for Secondary School Teachers of Science or Mathematics aims to help practicing teachers acquire a deeper and broader science background. The final goal is improvement in the quality of science and mathematics teaching in secondary schools.

The masters program works like this: Once accepted into the program, a graduate committee is appointed for the teacher. This committee works with the teacher to determine goals, and design an individualized program. The committee then supervises performance and progress.

Teachers begin their course work at a level compatible with their current knowledge and background. Teachers may take university courses in the subject they currently teach or may choose to focus on an allied area for certification or further enrichment. For example, a teacher who wants a better understanding of mathematical applications might choose to study highly quantitative courses in other sciences. On the other hand, a biology teacher may choose to concentrate on biology only or strengthen a chemistry background. In addition to regular university courses, those seeking the M.S. Degree for Secondary School Teachers may opt to attend seminar-type courses that teach science curriculum and teaching strategies.

Keeping the demands of a teacher's schedule in mind, enrollees are allowed to take fewer credit hours per semester. To complete the degree, each candidate must perform a Master's project, which may consist of lab work, field work, innovative pedagogy or a scholarly study of an advanced topic. A written report of this activity is required. This report will comprise six of the 30 to 33 semester hours required for degree completion.

Since the objective of the M.S. Degree program for secondary teachers of science or mathematics is to improve the quality of science teaching in schools, the desired applicant is a professional science or mathematics teacher who plans to stay in the field.

Admission requirements include:

1. Applicant must be accepted by an appropriate committee of the college.
2. Applicant must have a valid teaching certificate and be teaching science or mathematics in a secondary school.
3. Applicant does not need an academic or teaching major in the science subject he or she currently teaches to enter the program.
4. Applicant must have at least three years teaching experience and be recommended by a professional educator who can judge their performance.
5. Applicant must satisfy university requirements for graduate school admission.

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.

MASTER OF SCIENCE IN COMPUTATIONAL ENGINEERING AND SCIENCE

The University of Utah Department of Mathematics and the School of Computing have established a joint degree program in *Computational Engineering and Science* (CES). In 2011–2012, the Mathematics members of the CES Coordinating Committee are Aaron Fogelson and Peter Alfeld. The CES program has a Web site at <http://www.ces.utah.edu/>.

1. To apply for admission into the CES program, a student must:
 - Have a background in the core areas of Computer Science, Mathematics, Physics, Electrical Engineering, Chemistry, Mechanical Engineering, etc.
 - Complete an application for the CES program, available at <http://www.ces.utah.edu/future.html>
 - Submit the application to the CES Steering Committee.
2. The requirements for the CES MS Degree are posted at http://www.ces.utah.edu/images/CES_Student_Handbook.pdf
They include tracks with thesis, with courses, and with a project.

PROFESSIONAL MASTER OF SCIENCE AND TECHNOLOGY

The University of Utah Departments of Mathematics, Chemistry, Geology and Geophysics, and Physics have established a different kind of graduate degree *Professional Master of Science and Technology* (PMST). The PMST is a professional nonthesis, inter-departmental, and inter-disciplinary degree program that fuses multiple science fields with computational, management, and business skills. In this program, students will learn practical skills that will better prepare them for future employment and career changes. Telephone (801) 585-5630 for more program information.

The PMST program has a Web site at <http://www.utah.edu/pmst/>.

1. To gain admittance into the PMST program, a student must:
 - Be a graduating senior who is majoring in science.
 - Be a working professional looking to pursue a graduate degree.

PMST Curriculum

36 credit hours

1. Advanced Quantitative Skills (9 credits) data analysis, productive computing, reasoning.
2. Transferable Skills (9 credits) communication, project management, budgeting, decision making, negotiation skills, business and environmental law, basic interpretation of federal and state regulatory and policy issues.
3. Internship (3 credits) an internship or cooperative education experience in business, industry, commerce, or government agency.
4. Science Track (15 credits) Choose one of three science tracks: Computational Science, Science Instrumentation, or Environmental Science.

DOCTOR OF PHILOSOPHY DEGREE**A. Graduate School Requirements:**

Please visit the Web site <http://www.gradschool.utah.edu/catalog/degree.php> for information on the Ph.D. degree requirements.

B. Departmental Requirements

1. **Supervisory Committee.** An academic advisor will be appointed for each prospective student prior to their first semester 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 in writing 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. Three members of the committee must be regular faculty members of the Mathematics Department and all must hold PhD's. One committee member must be from another department. Since a student's interests may change, the committee can be changed to reflect these interests.

The function of the student's supervisory committee should be to advise, evaluate and certify. 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 semester 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, and revised later if the committee considers it desirable.
- c. The committee sets its own ground rules on how it conducts the preliminary and final oral examinations. The student should arrange with the committee the scope of questions and how the exam will be conducted.
- d. Any special requests regarding financial aid or program of study should be submitted to the student's advisor.

(For more information, see p. 29.)

2. Course Requirements

- a. Course requirements for the Ph.D. degree will consist of at least seven sequences numbered 6000 or above, or their equivalent, approved by the student's supervisory committee. The seven sequences required must include at least 14 credit hours of courses numbered 7800–7970 (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 Preliminary Examinations

The Written Ph.D. Preliminary Examinations are the same as the Master's Qualifying Examinations.

- a. **Time of the Written Qualifying Examinations.**
The written qualifying examinations are given in January and August, usually in the week before the beginning of classes.
- b. **Written Qualifying Examination restrictions.**
The written part of the Ph.D. preliminary examination in mathematics consists of three tests, in the following eight areas:

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

Students should choose their tests in consultation with their advisor(s). 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.

Registration forms for the examination are available from the Graduate Coordinator. A completed form must be returned to the Graduate Coordinator before the end of the semester preceding the exam.

In order to pass the written qualifying examinations, a student must pass three tests. Students entering with a strong background in undergraduate mathematics usually attempt all three qualifying exams in August before the beginning of their second year. Those who need to take 5000-level classes upon entrance will need an additional year to prepare for some exams, but all students should attempt at least one exam in August before the beginning of their second year, and must attempt three exams by August preceding their third year. Students have a two year time limit to pass all three tests. Students have a final opportunity to complete the exams in January of their third year (after completing five semesters of course work). Failure to pass at this time will result in termination in the graduate program at the end of the third academic year. A student is permitted to take a maximum of three exams each exam period, and may repeat a failed exam *only once*, and *only* at the discretion of the student's supervisory committee. Students who have taken graduate courses equivalent to our graduate qualifier preparation sequences may take the qualifying exams early. However, students are discouraged to take the exams until they can adequately prepare. The two year time clock begins when the student takes his/her first qualifying exam.

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. It usually takes a summer of study to acquire the global perspective on a subject needed to do well on the tests.

d. **Departmental committee on the examination.**

The Department Chairman appoints a member of the faculty (usually the Director of Graduate Studies) to make the arrangements for the written qualifying examinations of each academic year. This person will select two 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 on the Web at <http://math.utah.edu/grad/qualexams.html>. All examinations are proctored.

f. **Grading of the tests.**

After all the tests in a given area have been graded, the persons responsible for the test decide what is to be a passing score on the examination; in doing so, it is expected that they confer with and enlist the aid of their colleagues in the area of the examination. Student identities are not revealed to the graders.

g. **Announcement of results.**

Under normal circumstances the student is informed within one week after the end of the examinations of the passing score on each test and is 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 a date in the second semester (April 15 for Spring Semester and November 30 for Fall Semester) 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, and should be conducted before much thesis research has been done.

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.

The supervisory committee sets its own ground rules for Ph.D. Oral Qualifying exams. The student should arrange with the committee the scope of questions and how the exam will be conducted. Most mathematics Oral Qualifying Exams have followed one of two plans:

A. The student answers questions based on his/her graduate courses.

B. The student makes a presentation of a background topic or on his/her preliminary research. The student proposes the plan for rest of the Ph.D. research. The student answers questions based on the presentation / proposal / graduate courses.

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 two courses, or equivalent tutorials, or laboratory supervisions to be carried out over a minimum of one year and a maximum of six years, whenever appropriate.

8. **Time Limit.**

The time limit for completion of degree requirements for the Ph.D. degree, as set by the Department, is seven years. Normal progress is one or two years to pass the preliminary written qualifying examinations and advance to candidacy, and two or three additional years to complete the thesis work. The Graduate School limits the maximum number of years for which tuition waivers are granted to supported students. Currently, this is five years with a Bachelor's degree,

or four years with a Master's degree. Entrants with a Bachelor's degree who have taught in our graduate program for four semesters (two years) can request another year of waiver.

C. Graduate School Schedule of Procedures for the Ph.D. Degree

The Graduate School has prepared the *Graduate PhD Program Calendar* for students pursuing a graduate degree, available at the Web site <http://www.gradschool.utah.edu/thesis/>. See also <http://www.gradschool.utah.edu/thesis/handbook.pdf> for *A Handbook for Theses and Dissertations*.

D. 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 when the Fall Semester begins and end at the start of the next Fall Semester. Some students, especially those who have previously studied in other Ph.D. programs, should 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 years 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 6000-level courses throughout the year. Complete the written qualifying examinations at the end of the summer of the first year.
- 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.
- 3 Continue studying some advanced graduate courses. Participate in seminars. Begin work toward a thesis. Complete the oral qualifying examination if not done previously.
- 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.

CONGRATULATIONS!!!

E. Recommended Procedure for Ph.D. Degree Candidates also Wishing a Master's Degree

Students who have entered directly to the Ph.D. Program who wish to pick up a Master's Degree along the way should basically follow the procedures outlined for Recommended schedule of study toward a Master's degree with intent to enter the Ph.D. program (see p. 15). See the Graduate Program Coordinator to arrange that required paperwork be sent to the Graduate School from the Department.

Course credits for the Master's degree and the Ph.D. degree may not be double counted. The coursework allotted for the Masters Degree is reported in the program of Study for the Master's Degree Form. The course requirements for the Ph.D. must be satisfied by the remaining courses. Although it is not usually a problem, since the student supported by a Teaching Assistantship has a limited number of tuition benefit semesters computed using the Universities formula, the student is responsible so make sure that tuition benefits cover the total semester hours needed for both the required Masters and Ph.D. coursework. This is another reason to register for the maximal hours allowed by tuition benefits each semester.

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 302 Park Building, 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 date. 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.

The student should consult the thesis office program calendar frequently to ensure that they are submitting required forms in a timely manner to meet graduation deadlines. Forms are accepted throughout the semester, however, those students wishing a guaranteed graduation in a specific semester must meet the deadline dates listed on their program calendar. The program calendar can be picked up from the graduate program coordinator's office.

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. **There is a withdrawal penalty if a student's registration fall under the minimum requirement of nine credit hours or a student withdraws late from a course.**

All graduate TF's and TA's are eligible for the Graduate Tuition Benefit Program support, which is separately administered by the Graduate School. Students receiving the tuition benefit from the University of Utah Graduate School must be full-time matriculated graduate students in good standing. Full-time status for this purpose is registration of at least nine semester credit hours during the regular academic year. The tuition benefit is valid for a minimum of nine graduate credit hours and a maximum of twelve graduate credit hours for each semester. The department, however, requires that students receiving support should register for the maximum allowed by tuition benefits each semester, which for teaching assistants is 12 credits. There are limits on the number of years of eligibility (see <http://www.gradschool.utah.edu/tbp/guidelines.php>). **Students adding and/or dropping courses after the published university deadline(s) will be responsible for paying any fees and tuition incurred for that semester.** If current registration falls below nine semester credit hours at any time during the semester, the student becomes ineligible for the tuition benefit and will be billed for the full tuition for that semester. All international students must pay a fee of \$75.00 each semester that the tuition waiver does not cover.

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

Teaching Assistants in the Master's Degree Program

1. At the beginning of Spring Semester, evaluations are made by the Graduate Committee on the progress of all graduate students in their first year of study toward a their degree. Decisions to continue or award Teaching Assistantships 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 in the Master's degree program. Students who have been Teaching Assistants for less than a year, but cannot finish the degree program by the end of the second academic year, may request an extension of support and a decision whether to grant the request will be made by the Graduate Committee. 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. 22. Supported and unsupported Masters students 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. It is the responsibility of the applicant to keep their file up to date with current letters of support.

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 beginning of Spring Semester. 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 at the beginning of Spring Semester. Decisions are based on teaching performances and on progress toward a Ph.D. degree, following the schedule outlined on p. 22. Notifications of renewals and nonrenewals are distributed by April 15. 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. 21, #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). The Graduate Tuition Benefit Program has been modified to extend the benefit for certain graduate students who serve as Teaching Assistants, and who entered with a Bachelor's degree. Such students who have served a minimum of four semesters as a full-time TA may earn an additional year (two semesters) of tuition waiver. Please check the Graduate School Web site for current information.
4. It is *extremely important* 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 p. 22.

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 TAs and TFs.**
3. In addition to classes, seminars, GSAC colloquia organized by students, and the Early Research Directions lectures, 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 and a sign that the student is serious about his profession. 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.

SUPERVISORY COMMITTEES

Each graduate student will have an advisor and a supervisory committee. The supervisory committee can approve whatever program of study the student may choose, as long as it satisfies departmental and university guidelines. The committee will advise the student on selection of courses, and guide the student through the research and coursework. They will approve the student's course of study, conduct oral examinations and sign off on the student's work.

The student's advisor (mentor) will be initially appointed by the Director of Graduate Studies prior to the student's entrance into the program. The student will form a supervisory committee 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, the 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 semester.

1. The committee chairman (advisor) is usually chosen to be a faculty member whose research area is the potential research area indicated by the student. 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 fourth and fifth 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 committee).
4. The function of the advisor and the supervisory committee should be:
 - a. Advise the student regarding a program of study.
 - b. Evaluate the student's progress in his/her program of study.
 - c. Review any requests for changes or waivers in the usual requirements.
5. The student should make contact with his/her advisor every semester 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 semester.
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 supervisory committee sets its own ground rules about how it will conduct preliminary and final oral exams for both Masters and Ph.D. students. It is the responsibility of the student to arrange with the committee the scope of questions and how the exam will be conducted.

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 2011–2012 the members are:

- GSAC Co-Chairs
 - Tony Lam and James Moore
- GSAC Retention Promotion and Tenure Committee
 - Morgan Cesa, Brian Knaeble, Chris Kocs (chair), Tony Lam, James Moore, Dylan Zwick
- GSAC Colloquium Committee
 - Brendan Kelly (chair), James Moore
- GSAC Snack and Picnic Committee
 - Andrew Basinski, Sarah Cobb (chair), Laura Czarnecki, Jason Underdown
- GSAC Recruitment Committee
 - Brendan Kelly, Chris Remein, Stefano Urbinati, Aaron Wood (Chair)
- Teaching Guidance
 - Brendan Kelly (chair), Aaron Wood
- Friendship Committee
 - Brendan Kelly
- Web Page Maintenance
 - Chris Kocs

Student representatives and contact people from various disciplines

- *Mathematical Biology*: Erica Graham
- *Algebraic Geometry*: Stefano Urbinati
- *Commutative Algebra*: Jack Jeffries
- *Topology/Geometric Group Theory*: Brendan Kelly
- *Representation Theory*: Aaron Wood
- *Probability/Statistics*: Tony Lam
- *International Students*: Stefano Urbinati

SYLLABI FOR QUALIFYING EXAMINATIONS

ALGEBRA

Topics and References

- 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.

- RINGS:

Ideals, quotient rings, polynomial rings, Euclidean rings, principal ideal domains, unique factorization domains, matrix rings, artinian rings, semisimple rings, finite-dimensional algebras. Jacobson radical, Jacobson Density Theorem, Artin–Wedderburn Theorem.

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.

- MODULES:

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

References: Cohn I, 10.2–10.6. Cohn II, 3.1–3.2, 4.6, 4.10. Herstein, 4.5. Hungerford, 4.1–4.3, 4.5–4.6. Jacobson I, 3.1–3.8. Jacobson II, 3.5, 3.7, 3.10–3.11, 3.13. Lang, 3.1–3.5, 3.8, 15.2, 16.1.

- 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.

References: Cohn I, 4.1–4.7, 7.1–7.3, 11.1–11.5. Herstein, 4.1–4.2, 6.1–6.9.

- 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.

References: Cohn II, Ch. 5, 6.1, 6.3–6.4. Herstein, Ch. 5, 7.1. Hungerford, 5.1–5.7, 5.9. Jacobson I, 4.1–4.13. Jacobson II, 8.1–8.3, 8.7–8.8, 8.14. Lang, 7.1–7.6, 8.1–8.2, 10.6.

- HOMOLOGICAL ALGEBRA:

Exact sequences, complexes, homology, categories, functors, Ext, Tor.

References: Cohn II, 4.1–4.3, 4.8–4.9. Hungerford, 10.1. Jacobson II, 1.1–1.3, 6.1–6.3, 6.5–6.8. Lang, 4.1–4.2.

APPLIED MATHEMATICS

Topics

- FINITE-DIMENSIONAL LINEAR OPERATORS:

Spectral theory, Fredholm alternative, generalized inversion, singular value decomposition, minimax principle.

- INTEGRAL AND DIFFERENTIAL OPERATORS:
Contraction Mapping Theorem, compact operators, Hilbert–Schmidt theory, spectral theory, distributions, Green’s functions, resolvent operators, method of images, discrete and integral transforms.
- CALCULUS OF VARIATIONS:
Euler–Lagrange equations, Hamilton’s principle, approximation techniques.
- COMPLEX VARIABLE METHODS:
Analytic function theory, integral theorems, conformal mappings, contour integration, special functions, transform pairs, scattering theory.
- ASYMPTOTIC EXPANSIONS:
Laplace’s method, Watson’s lemma, methods of steepest descent and stationary phase.

Text

- J. P. Keener, *Principles of Applied Mathematics: Transformation and Approximation*, Addison Wesley (1988) [ISBN 0-201-15674-1, 978-0-201-15674-4].

Other Texts

- G. Strang, *Linear Algebra and its Applications*, Harcourt, Brace, Jovanovich (1988) [ISBN 0-15-551005-3, 978-0-15-551005-0].
- B. Friedman, *Principles and Techniques of Applied Mathematics*, Wiley (1956).
- I. Stakgold, *Boundary Value Problems of Mathematical Physics, Vol. 1*, Macmillan (1967–1968).
- G. F. Carrier, M. Krook and C. E. Pearson, *Functions of a Complex Variable*, Hod Books (1983) [ISBN 0-07-010089-6, 978-0-07-010089-3].
- E. T. Copson, *Asymptotic Expansions*, Cambridge University Press (1967).
- R. Courant and D. Hilbert, *Methods of Mathematical Physics*, Interscience Publishers (1953–1962).

DIFFERENTIAL EQUATIONS

Topics

- Existence-uniqueness theorems for initial value problems: 1. Picard–Lindelöf theorem, Cauchy Peano theorem 2. Dependence upon initial conditions and parameters 3. Differential inequalities 4. Theory of linear systems, variation of constants formula. Floquet theory.
- Stability theory: 1. Stability of perturbed linear systems 2. Lyapunov stability.
- Dynamical Systems 1. Poincaré–Bendixson Theorem 2. Floquet Theory 3. Persistence and Bifurcation of Solutions of Parameter Dependent Equations
- Sturm–Liouville problems and spectral theory.
- Linear PDE: 1. Formulas for Solving Laplace’s, Heat and Wave Equations 2. Distributions 3. Sobolev spaces, trace, Rellich embedding theorem 4. Applications of Lax–Milgram to the study of weak solutions of elliptic PDE’s 5. Regularity theory 6. Spectral theorem for elliptic operators. 7. Energy Methods for Hyperbolic and Parabolic Equations
- Nonlinear PDE: 1. First Order PDE’s 2. Conservation Laws 3. Calculus of variations 4. Maximum principles.
- Hille–Yosida–Phillips semigroup theory: 1. Strongly continuous semigroups of contractions and their generators 2. Hille–Yosida theorem 3. Phillips theorem 4. Parabolic PDE’s 5. Unitary groups and the wave equation.

Text

- Lawrence C. Evans, *Partial Differential Equations*, American Mathematical Society, Providence, RI (1998) [ISBN 0-8218-0772-2].
- Robert C. McOwen, *Partial Differential Equations: methods and applications*, Second Edition ed., Prentice Hall, NJ (2003) [ISBN 0-13-009335-1].

- L. Perko, *Differential Equations and Dynamical Systems*, 3rd ed., Springer, New York (2000) [ISBN 0-387-95116-4]
- D. W. Jordan and P. Smith, *Nonlinear Ordinary Differential Equations—An Introduction for Scientists and Engineers*, 4th ed., Oxford (2007) [ISBN 978-0-199-21203-3]
- K. Schmitt and R. Thompson, *Nonlinear Analysis and Differential Equations: An Introduction*, University of Utah Lecture Notes (2000). <http://www.scribd.com/doc/7847166/Nonlinear-Analysis-Differential-Equations-An-Introduction-Schmitt-Thompson>

GEOMETRY AND TOPOLOGY

Topics

- GENERAL TOPOLOGY:
Metric spaces, paracompact spaces, Urysohn's Metrization Theorem, Tychonoff Theorem, Baire Category Theorem, Tietze's Extension Theorem, function spaces, [Dugundji, Singer–Thorpe]
- HOMOTOPY AND COVERING SPACES:
Fundamental group, covering spaces, universal cover, Van Kampen's Theorem, computations of homotopy groups of \mathbf{R}^n , \mathbf{S}^n , \mathbf{CP}^n , etc., higher homotopy groups, homotopy sequence of a pair, Brouwer's Fixed Point Theorem, exact sequences of pairs and fibrations. [Hatcher]
- SIMPLICIAL AND CELL COMPLEXES:
Simplicial complexes, barycentric subdivision, simplicial approximation, etc. [Hatcher]
- HOMOLOGY THEORIES:
Including simplicial (and/or CW) and singular, axioms of a homology theory, universal coefficient theorem. Cohomology, cup products, Poincaré duality. [Hatcher]
- MANIFOLDS:
Differential manifolds, construction of tangent bundle and cotangent bundle, exterior algebras, differential forms, DeRham cohomology, Froebenius theorem, Lie derivative, deRham theorem. Sard's theorem, transversality, degree theory, Gauss–Bonnet Theorem, vector fields, Poincaré–Hopf index theorem. [Guillemin and Pollack, Spivak]
- LIE GROUPS:
Basic definitions, definition of Lie algebra. [Spivak]

Texts

- V. Guillemin and A. Pollack, *Differential Topology*, Prentice-Hall (1974) [ISBN 0-13-212605-2, 978-0-13-212605-2].
- M. D. Spivak, *A Comprehensive Introduction to Differential Geometry*, Publish or Perish (1979) [ISBN 0-914098-83-7 (hard), 0-914098-79-9 (soft), 978-0-914098-83-6 (hard), 978-0-914098-79-9 (soft)] (leisurely treatment of many topics in differential geometry).
- G. E. Bredon, *Topology and Geometry, Graduate Texts in Mathematics 139*, Springer (1993) [ISBN 0-387-97926-3 (New York), 3-540-97926-3 (Berlin), 978-0-387-97926-7 (New York), 978-3-540-97926-5 (Berlin)].
- A. Hatcher, *Algebraic Topology*, Cambridge University Press (2002) [ISBN 0-521-79160-X (hard), 0-521-79540-0 (soft), 978-0-521-79160-1 (hard), 978-0-521-79540-1 (soft)] <http://www.math.cornell.edu/~hatcher/>.

Supplementary References

- M. P. do Carmo, *Differential Geometry of Curves and Surfaces*, Prentice-Hall (1976) [ISBN 0-13-212589-7, 978-0-13-212589-5].
- M. J. Greenberg and J. R. Harper, *Algebraic Topology: An Introduction*, Addison-Wesley (1981) [ISBN 0-8053-3558-7 (hard), 0-8053-3557-9 (soft), 978-0-8053-3558-3 (hard), 978-0-8053-3557-6 (soft)].
- J. R. Munkres, *Topology—A First Course*, Prentice-Hall (1975) [ISBN 0-13-925495-1, 978-0-13-925495-6].

- W. S. Massey, *A Basic Course in Algebraic Topology*, Springer (1991) [ISBN 0-387-97430-X, 978-0-387-97430-9].
- J. J. Rotman, *Algebraic Topology, Graduate texts in mathematics 119*, Springer (1988) [ISBN 0-387-96678-1, 978-0-387-96678-6].
- I. M. Singer and J. A. Thorpe, *Lecture Notes on Elementary Topology and Geometry*, Springer (1967) [ISBN 0-387-90202-3, 978-0-387-90202-9].
- J. Dugundji, *Topology*, Wm. C. Brown (1989) [ISBN 0-697-06889-7, 978-0-697-06889-7].
- F. W. Warner, *Foundations of Differentiable Manifolds and Lie Groups*, Springer (1983) [ISBN 0-387-90894-3, 978-0-387-90894-6].
- S. Eilenberg and N. E. Steenrod, *Foundations of Algebraic Topology*, Princeton (1952) (Chapters 9 and 10, Čech homology).
- B. Gray, *Homotopy Theory: An Introduction to Algebraic Topology*, Academic Press (1975) [ISBN 0-12-296050-5, 978-0-12-296050-5].
- J. G. Hocking and G. S. Young, *Topology*, Addison-Wesley (1961).
- W. J. Pervin, *Foundations of General Topology*, Academic Press (1964).
- T. Benny Rushing, *Topological Embeddings*, Academic Press (1973) [ISBN 0-12-603550-4, 978-0-12-603550-6] (1.3, 1.4, 1.6D, 1.8, 2.2, 3.2).
- E. H. Spanier, *Algebraic Topology*, Corrected ed., Springer (1981) [ISBN 0-387-90646-0, 978-0-387-90646-1] (Chapter 2: Fibrations).
- N. E. Steenrod, *The Topology of Fibre Bundles*, Princeton (1951) (Ch. 1: Coordinate bundles and fibre bundles).
- S. Sternberg, *Lectures on Differential Geometry*, Prentice-Hall (1964).
- J. W. Vick, *Homology Theory: An Introduction to Algebraic Topology*, Academic Press (1973) [ISBN 0-12-721250-7, 978-0-12-721250-0], J. W. Vick, *Homology Theory: An Introduction to Algebraic Topology*, 2nd ed., Springer (1994) [ISBN 0-387-94126-6 (New York), 3-540-94126-6 (Berlin), 978-0-387-94126-4 (New York), 978-3-540-94126-2 (Berlin)].

NUMERICAL ANALYSIS

Topics

- **NUMERICAL LINEAR ALGEBRA:**
Direct and iterative methods for solving linear algebraic equations. Error analysis. Methods for finding eigenvalues and eigenvectors. Singular value decomposition. Least squares.
- **INTERPOLATION AND APPROXIMATION:**
Polynomial, rational, Fourier Series, spline based methods of interpolation and approximation. Quadrature.
- **SOLUTION OF NONLINEAR EQUATIONS AND OPTIMIZATION:**
Contraction mapping principle, Newton's method, conjugate gradient method, steepest descent method, quasi-Newton methods, linear programming, constrained optimization.
- **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

- E. W. Cheney, *Introduction to Approximation Theory*, 2nd ed., McGraw-Hill (1998) [ISBN 0-8218-1374-9, 978-0-8218-1374-4].
- P. J. Davis, *Interpolation and Approximation*, Dover (1975).

- J. E. Dennis, Jr. and R. B. Schnabel, *Numerical Methods for Unconstrained Optimization and Nonlinear Equations*, Prentice-Hall (1983) [ISBN 0-13-627216-9, 978-0-13-627216-8].
- R. Fletcher, *Practical Methods of Optimization*, Wiley (1987) [ISBN 0-471-27711-8 (vol. 1), 0-471-27828-9 (vol. 2), 978-0-471-27711-8 (vol. 1), 978-0-471-27828-3 (vol. 2)].
- G. H. Golub and C. F. van Loan, *Matrix Computations*, 2nd ed., Johns Hopkins University Press (1989) [ISBN 0-8018-3772-3 (hard), 0-8018-3739-1 (soft), 978-0-8018-3772-2 (hard), 978-0-8018-3739-5 (soft)].
- J. D. Lambert, *Computational Methods in Ordinary Differential Equations*, Wiley (1973) [ISBN 0-471-51194-3, 978-0-471-51194-6].
- A. R. Mitchell and D. F. Griffiths, *The Finite Difference Method in Partial Differential Equations*, Wiley (1980) [ISBN 0-471-27641-3, 978-0-471-27641-8].
- G. Strang and G. F. Fix, *An Analysis of the Finite Element Method*, Prentice-Hall (1973).
- R. Wait and A. R. Mitchell, *Finite Element Analysis and Applications*, Wiley (1985) [ISBN 0-471-90677-8 (hard), 0-471-90678-6 (soft), 978-0-471-90677-3 (hard), 978-0-471-90678-0 (soft)].

PROBABILITY

Topics

- Probability spaces, expectation, independence, Borel–Cantelli lemmas, Strong Law of Large Numbers.
- Weak convergence, characteristic functions, Central Limit Theorem.
- Conditional expectation, martingale convergence theorem, uniform integrability, optional stopping theorem.
- Countable Markov chains, recurrence, transience, stationarity, ergodicity.
- Brownian motion, sample path properties, Donsker’s theorem.

Texts

- P. Billingsley, *Probability and Measure*, 3rd ed., Wiley (1995) [ISBN 0-471-00710-2, 978-0-471-00710-4].
- R. Durrett, *Probability: Theory and Examples*, 2nd ed., Duxbury Press (1996) [ISBN 0-534-24318-5, 978-0-534-24318-0].
- B. Fristedt and L. Gray, *A Modern Approach to Probability Theory*, Birkhäuser (1997) [ISBN 0-8176-3807-5 (Boston), 3-7643-3807-5 (Basel), 978-0-8176-3807-8 (Boston), 978-3-7643-3807-7 (Basel)].
- D. Khoshnevisan, *Probability, Graduate Studies in Mathematics 80*, American Mathematical Society (2007) [ISBN 0-8218-4215-3, 978-0-8218-4215-7]

REAL AND COMPLEX ANALYSIS

Topics

- MEASURE THEORY:
Measurable spaces, measurable functions and positive measures. Integrable functions, integrals. Integration on locally compact spaces, Riesz representation theorem, regular Borel measures, Lusin’s theorem. Integration on product spaces, Fubini’s theorem. Complex measures, Radon–Nikodym theorem. L_p — spaces, duality.
- BASIC FUNCTIONAL ANALYSIS:
Hilbert spaces, Banach spaces, Hahn–Banach theorem, Banach–Steinhaus theorem, open mapping theorem.
- COMPLEX ANALYSIS:
Holomorphic functions, Cauchy–Riemann equations, Cauchy’s theorem, Cauchy’s integral formula, Power series, Taylor series of holomorphic functions, isolated singularities, Laurent series, Residue theorem, applications to calculation of definite integrals. Rouché’s theorem, Conformal mappings, examples, maximum principle, Schwartz lemma, infinite products, Weierstrass factorization theorem. Analytic continuation, monodromy. Elliptic functions, modular functions and Picard’s theorem.

Texts

- W. Rudin, *Real and Complex Analysis*, 3rd ed., McGraw-Hill (1987) [ISBN 0-07-054234-1, 978-0-07-054234-1].
- P. R. Halmos, *Measure Theory, Graduate texts in mathematics 18*, Springer (1975) [ISBN 0-387-90088-8, 978-0-387-90088-9].
- L. V. Ahlfors, *Complex Analysis*, 3rd ed., McGraw-Hill (1979) [ISBN 0-07-000657-1, 978-0-07-000657-7].
- W. Rudin, *Real and Complex Analysis*, 3rd ed., McGraw-Hill (1987) [ISBN 0-07-054234-1, 978-0-07-054234-1].
- J. Ogden and E. G. Milewski, *Schaum's Outline: The Complex Variables Problem Solver*, Research & Education Association (1987) [ISBN 0-87891-604-0, 978-0-87891-604-7].
- T. M. Apostol, *Modular Functions and Dirichlet series in Number Theory*, 2nd ed., Springer (1990) [ISBN 0-387-97127-0, 978-0-387-97127-8].

STATISTICS

- Maximum likelihood estimation and the method of moments. Unbiased estimation and the Cramer–Rao lower bound. Sufficiency, confidence intervals, hypothesis testing, likelihood ratio tests. Chi-squared tests of simple and composite hypotheses. Nonparametric methods. Linear and multivariate statistics.

Texts

- L. J. Bain and M. Engelhardt, *Introduction to Probability and Mathematical Statistics*, 2nd ed., PWS-KENT (1992) [ISBN 0-534-92930-3, 978-0-534-92930-5].
- P. J. Bickel and K. A. Doksum, *Mathematical Statistics: Basic Ideas and Selected Topics*, 2nd ed., Holden Day (Prentice-Hall) [ISBN 0-13-850363-X, 978-0-13-850363-5].

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, and so on.

5010	Introduction to Probability (Fall, Spring, Summer Semester)
Instructors:	K. Bromberg & F. Rassoul-Agha
Text:	S. Ross, <i>A First Course in Probability</i> , 6th ed., Prentice-Hall (2002) [ISBN 0-13-033851-6, 978-0-13-033851-8]
Meets with:	6805
Prerequisites:	Math 2210
Topics:	This is a one-semester course in probability theory that requires calculus. Topics include combinational analysis, axioms of probability, conditional probability and independence, discrete and continuous random variables, expectation, joint distributions, and the central limit theorem.
5040, 5050	Stochastic Processes and Simulation I, II (Fall, Spring Semester)
Instructor:	N. Giorgiu
Text:	R. Durrett, <i>Essentials of Stochastic Processes</i> , Springer (2001) [ISBN 0-387-98836-X, 978-0-387-98836-8]
Meets with:	6810, 6815
Prerequisite:	Math 5010 or equivalent
Topics:	This is a two-semester course in stochastic processes and computer simulation that does not involve measure theory. The treatment is mostly rigorous, except that certain technical points may be taken for granted and computer simulation is used to enhance understanding. Topics may include Markov chains, Poisson processes, Markov processes, renewal processes, queueing theory, reliability theory, and Brownian motion. Applications will also be discussed.
5080, 5090	Statistical Inference I, II (Fall, Spring Semester)
Instructors:	Firas Rassoul-Agha and M. Joseph
Text:	L. J. Bain and M. Engelhardt, <i>Introduction to Probability and Mathematical Statistics</i> , 2nd ed., Duxbury (2000) [ISBN 0-534-38020-4, 978-0-534-38020-5]
Prerequisite:	Math 5010
Topics:	Functions of random variables, limiting distributions, statistics and sampling distributions, point estimation, sufficiency and completeness, special distribution theory, normal sampling theory, parametric estimation, confidence regions, hypotheses testing, introduction to linear models.
5110, 5120	Mathematical Biology I, II (Fall, Spring Semester)
Instructors:	A. Borisyuk, A. Fogelson
Texts:	Recommended: L. Edelstein-Keshet, <i>Mathematical Models in Biology (SIAM Classics in Applied Mathematics 46)</i> , SIAM (2005) [ISBN 0-89871-554-7, 978-0-89871-554-5] and G. de Vries, T. Hillen, M. Lewis, J. Muller, and B. Schonfisch, <i>A Course in Mathematical Biology: Quantitative Modeling with Mathematical and Computational Methods (SIAM Mathematical Modeling and Computation 12)</i> , SIAM (2006) [ISBN 0-89871-612-8, 978-0-89871-612-2]
Meets with:	6830, 6835
Prerequisites:	Math 2280, 3150, or equivalent

Topics: Introduction to mathematical models which are used in ecology, cell biology, physiology and genetics. Techniques covered include ordinary, delay and partial differential equations, discrete time dynamical systems, and stochastic processes. Emphasis on modeling a biological system with appropriate tools, and using geometric and approximation techniques to derive answers to scientific questions.

5210 Introduction to Real Analysis (Spring Semester)

Instructor: T. de Fernex
 Text: G. F. Simmons, *Introduction to Topology and Modern Analysis*, Krieger Publishing Company (2003) [ISBN 1-57524-238-9, 978-1-57524-238-5]
 Prerequisites: Math 3210, 3220, or consent of instructor
 Topics: Construction of the real numbers, metric spaces, fixed-point theorems and applications, Lebesgue integral, normed linear spaces, approximation, Fourier series.

5310, 5320 Introduction to Modern Algebra I, II (Fall, Spring Semester)

Instructor: G. Savin
 Text: L. N. Herstein, *Abstract Algebra*, 3rd ed., Wiley (2001) [ISBN 0-471-36879-2, 978-0-471-36879-3]
 Prerequisite: Math 2250 or 2270, and Math 2900 or 3210
 Topics: (5310) This course begins with a review of the basic properties of sets and integers and continues with an introduction to group theory. It covers the definitions and basic properties of groups, abelian groups, symmetric groups, normal subgroups, and conjugacy. It also includes basic theorems on the structure of groups, Lagrange's theorem, and Sylow's theorem.
 (5320) This course is an introduction to the theory of rings and fields. During the first part of the course, we will study general concepts and the relationship between them: ring, field, ideal, maximal and prime ideal, homomorphism, quotient rings, integral domains and unique factorization domains. We then proceed with an in-depth study of various polynomial rings, applying as many of the concepts as possible. The course continues with the study of field extensions, and concludes with nonconstructibility proofs from geometry. Time permitting, we will study finite fields and/or the Galois correspondence.

5405 Cryptography, Codes, and Computational Number Theory (Spring Semester)

Instructor: A. Singh
 Text: To be announced
 Prerequisites: Math 4400 and 5310
 Topics: Classic and modern methods of encryption, applications to public-key ciphers (RSA, El-Gamal, etc.), random number generators, attacks on encryption systems, error correcting codes; computational number theory. A project/paper is required.

5410, 5420 Introduction to Differential Equations (Fall, Spring Semester)

Instructor: Joyce Lin
 Text: R. Borrelli and C. Coleman, *Differential Equations*, 2nd ed., Wiley (2004) [ISBN 0-471-43332-2, 978-0-471-43332-3] (Fall, Spring)
 Meets with: 6840, 6845
 Prerequisites: Math 2220 and 3310; 2250; or instructor's consent.
 Topics: (5410) Systems, existence, uniqueness, dependence on parameters, continuation, solution basis for constant coefficients, modeling, nonlinear systems, Laplace transforms
 (5420) Series solutions of differential equations, linearization, rest points and stability, asymptotic stability, functions of mathematical physics, partial differential equations of classical physics (heat, wave, Laplace), Sturm–Liouville systems, orthogonal expansions, applications.

5440	Introduction to Partial Differential Equations (Fall Semester)
Instructor:	A. Balk
Text:	H. F. Weinberger, <i>First Course in Partial Differential Equations</i> , Dover (1995) [ISBN 0-486-68640-X, 978-0-486-68640-0]
Meets with:	6850
Prerequisites:	Math 2250 or 2270, 2280
Topics:	Classical wave, Laplace, and heat equations; Fourier analysis; Green's functions; Methods of characteristics.
5470	Chaos (Spring Semester)
Instructor:	A. Borisjuk
Text:	S. H. Strogatz, <i>Nonlinear Dynamics and Chaos</i> , Addison-Wesley (1994) [ISBN 0-201-54344-3, 978-0-201-54344-5]
Meets with:	6440
Prerequisites:	Instructor's permission
Topics:	Nonlinear dynamical systems. Bifurcations. Chaos, strange attractors, fractals. Models from biological and chemical systems, and mechanical and electrical oscillators.
5520	Introduction to Algebraic/Geometric Topology (Spring Semester)
Instructor:	J. Tao
Text:	W. S. Massey, <i>Algebraic Topology: an Introduction</i> , Springer (1991) [ISBN 3-540-90271-6, 978-3-540-90271-3]
Prerequisites:	Math 4510
Topics:	Topology of surfaces. Classification of surfaces. Euler characteristic. Homotopy of maps between topological spaces. Fundamental group of a space. Covering spaces. Applications to group theory and knot theory (as time permits). Degree of mappings of surfaces (if time permits).
5610, 5620	Introduction to Numerical Analysis I, II (Fall, Spring Semester)
Instructor:	F. Guevara Vasquez
Text:	R. Burden and J. D. Faires, <i>Numerical Analysis</i> , 8th ed., Brooks Cole (2004) [ISBN 0-534-39200-8, 978-0-534-39200-0]
Meets with:	6610, 6620
Prerequisites:	Multivariable calculus, linear algebra, programming ability
Topics:	(5610) Numerical linear algebra, polynomial interpolation, numerical differentiation and integration, nonlinear equations, approximation, optimization. (5620) Continuation of Math 5610. Numerical solution of initial and boundary value problems of ordinary and partial differential equations.
5700	Capstone Course in Mathematics (Fall Semester)
Instructor:	K. MacArthur
Text:	Usiskin, Peressini, Marchisotto, and Stanley, <i>Mathematics for High School Teachers: An Advanced Perspective</i> , Prentice Hall (2002) [ISBN 0-130-44941-5, 978-0-130-44941-2]
Prerequisites:	Completion of two of the following: Math 3100, 3210, 3320, 4030, 4090
Topics:	This capstone course examines topics in secondary school mathematics from an advanced perspective. Topics are drawn from Abstract Algebra, Geometry, Analysis, and Number Theory, each rooted in the core secondary school curriculum of number and operations, algebra, geometry, and functions. Students learn to formulate and generalize definitions and theorems that help to unite and explain mathematics. They draw connections between ideas taught separately in different courses. Through their work in this course, they improve their ability to promote their pupils' understanding of mathematics and to make better decisions regarding the direction of their lessons and curriculum.

5710	Introduction to Applied Mathematics I, II (Fall Semester)
Instructor:	G. Milton
Text:	G. Strang, <i>Introduction to Applied Mathematics</i> , Wellesley-Cambridge Press (1986) [ISBN 0-961-4088-0-4, 978-0-9614088-0-0]
Prerequisites:	Math 2250, 3150, 3160, 5710
Topics:	Symmetric linear systems, positive definite matrices, eigenvalue problems, equilibrium equations for discrete and continuous systems, boundary value problems in ODEs and PDEs, boundary integrals.
5740	Mathematical Modeling (Spring Semester)
Instructor:	G. Milton
Text:	To be announced
Meets with:	6870
Prerequisites:	Math 5600 or CP SC 5220
Topics:	Development of mathematical models for physical, biological, engineering, and industrial phenomena and problems, using mainly ordinary and partial differential equations. Involvement of analytical and numerical tools suitable for analysis and visualization of the solutions of these problems.
5750-002	Topics in Applied Mathematics: Optimization (Fall Semester)
Instructor:	A. Cherkhaev
Text:	Jorge Nocedal and Stephen J. Wright, <i>Numerical Optimization</i> , 2nd ed., Springer (2006) [ISBN 0-387-3030-3-0, 978-0-387-3030-3-1]
Meets with:	6880-002
Prerequisites:	Math 5410/5420 or instructor's permission
Topics:	This course discusses various direct methods, such as Gradient Method, Conjugate Gradients, Modified Newton Method, methods for constrained optimization, including Linear and Quadratic Programming, and others. We will also briefly review genetic algorithms that mimic evolution and stochastic algorithms that account for uncertainties of mathematical models. The course work includes several homework assignments that ask to implement the studied methods and a final project, that will be orally presented in the class.
5750-002	Topics in Applied Mathematics: Calculus of Variations (Spring Semester)
Instructor:	E. Cherkhaev
Text:	Robert Weinstock, <i>Calculus of Variations with Applications to Physics and Engineering.</i> , Dover (1974) [ISBN 0-486-6306-9-2, 978-0-486-6306-9-4]
Meets with:	6880-002
Prerequisites:	Math 5410/5420 or instructor's permission
Topics:	The course covers classical techniques of Calculus of Variations, discusses natural variational principles in classical and continuum mechanics, and introduces modern applications: control theory, numerical methods, etc. Clear and elegant methods of Calculus of Variations allow us to solve a lot of problems in Physics and Engineering which will be in the focus of the course.
5760, 5765	Introduction to Mathematical Finance I, II (Fall, Spring Semester)
Instructor:	J. Zhu
Text:	S. E. Shreve, <i>Stochastic Calculus for Finance I: The Binomial Asset Pricing Model</i> , Springer (2004) [ISBN 0-387-24968-0, 978-0-387-24968-1] S. E. Shreve, <i>Stochastic Calculus for Finance II: Continuous-Time Models</i> , Springer (2004) [ISBN 0-387-40101-6, 978-0-387-40101-0]
Prerequisites:	Math 2280 and 5010, 5040
Meets with:	6890, 6895

- Topics: (5760) No arbitrage principle, risk-neutral measure and martingale, Black–Scholes–Merton model, stopping times and American options, random walks and exotic options.
- (5765) Brownian motion, Ito’s calculus, Markov processes and Kolmogorov equations, Girsanov’s theorem, derivation of Black–Scholes formula, some other exotic options, bonds and term-structure models, and an introduction to credit models.

5910-0XX Supervised Reading

Instructor: Staff

6010 Linear Models (Fall Semester)

Instructor: D. Khoshnevisan

Text: Bent Jørgensen, *Time Series: The Theory of Linear Models*, Chapman & Hall (1993) [ISBN 0-412-04261-4, 978-0-412-04261-4] G. Seber and A. Lee *Linear Regression Analysis* Prentice Hall 20020-13-044941-5, 978-0-13-044941-2

Prerequisites: Math 5010, 5080, 5090, 2270

Topics: Introduction to univariate linear models. Simple linear regression. The general linear model. One-sample and one-factor analysis of variance. Multiple regression models. Analysis of residuals. Analysis of variance with two or three factors.

6020 Multilinear Models (Spring Semester)

Instructor: D. Khoshnevisan

Texts: R. A. Johnson and D. W. Wichern, *Applied Multivariate Statistical Analysis*, 6th ed., Prentice-Hall (2007) [ISBN 0-13-187715-1, 978-0-13-187715-3]

Prerequisites: Math 6010

Topics: Introduction to multivariate statistical analysis. The multivariate normal distribution. Mean and covariance estimation. Principal component analysis. Factor analysis. Regression and classification techniques.

6040 Mathematical Probability (Fall Semester)

Instructor: D. Khoshnevisan

Text: D. Khoshnevisan, *Probability*, AMS (2007) [ISBN 0-8218-4215-3, 978-0-8218-4215-7]

Prerequisites: Math 6210

Topics: This is a one-semester graduate course on the foundations of modern probability theory. Topics include the measure-theoretic construction of probability spaces and random variables, classical convergence theorems, martingale theory, and Brownian motion.

6070 Mathematical Statistics (Spring Semester)

Instructor: L. Horváth

Text: No Textbook

Prerequisites: Math 2270, 5080, 5090

Topics: Review of hypothesis testing and point estimation, introduction to simulations, bootstrap methods, and time series analysis.

6130, 6140 Introduction to Algebraic Geometry I, II

Instructor: Y. P. Lee

Text: Robin Hartshorne, *Algebraic Geometry*, ()

Prerequisite: Math 6310, 6320, 6130

Topics: (6130) Varieties, schemes, sheaves, and their morphisms.

(6140) Further properties of schemes and their morphisms, sheaf cohomology.

6170 Riemannian Geometry (Spring Semester)

Instructor: A. Treibergs

Text: I. Chavel, *Riemannian Geometry: A Modern Introduction*, 2nd ed., Cambridge University Press (2006) [ISBN 0-521-85368-0, 0-521-61954-8, 978-0-521-61954-7]

Prerequisite: Math 6510 or consent of instructor

Topics: Riemannian Metrics, Connections, Geodesics and their properties; Completeness. Hopf–Rinow Theorem; Hadamard Theorem. Curvature tensor; Sectional curvature; Ricci and scalar curvature. Space Forms. Cartan’s Theorem on recovering the metric from curvature; hyperbolic space and its properties. Theorems of Bonnet–Meyers–Synge. Comparison Theorems. Closed Geodesics. Preissman’s Theorem. Cut locus. Conjugate locus. Injectivity radius. Isometric Immersions. Second fundamental form. Isoperimetric inequalities. Toponogov Theorem. Alexandrov’s Theorem. Soul Theorem. Sphere Theorem. Gromov–Hausdorff convergence. Collapsing. Ricci Flow and Hamilton’s Sphere Theorem.

6210 Real /Complex Analysis (Fall, Spring Semester)

Instructor: H. Hecht, D. Miličić

Text: W. Rudin, *Real and Complex Analysis*, 3rd ed., McGraw-Hill (2001) [ISBN 0-07-054234-1, 978-0-07-054234-1]

Prerequisite: Math 5210, 4200

Topics: (6210) Measures and integrals, L_p -spaces, Hilbert spaces, Banach spaces, Fourier series.
 (6220) Analytic functions, complex integration, conformal mapping, families of analytic functions, zeros of analytic functions, analytic continuation.

6310, 6320 Modern Algebra I, II (Fall, Spring Semesters)

Instructor: D. Ciobotaru, P. Trapa

Texts: S. Lang, *Algebra*, Springer (2002) [ISBN 0-387-95385-X, 978-0-387-95385-4]

Prerequisite: Math 5320 or equivalent

Topics: Group actions, Sylow theorems, permutation groups, solvable and nilpotent groups, free groups and presentations. Rings and modules: Euclidean rings, PIDs, modules over a PID, canonical forms, applications to linear algebra. Fields: field extensions, finite fields, cyclotomic fields, Galois theory, transcendence degree.

6410, 6420 Ordinary/Partial Differential Equations (Fall, Spring Semester)

Instructor: P. Bressloff

Text: D. Jordan and P. Smith, *Nonlinear Ordinary Differential Equations: An Introduction for Scientists and Engineers*, 4th ed., Oxford University Press (2007) [ISBN 9780199208258, 978-0199208258] (6410) and F. Verhulst, *Nonlinear Differential Equations and Dynamical Systems*, 2nd ed., Oxford University Press (1996) [ISBN 9783540609346, 978-3540609346] (6410) and L. Evans, *Partial Differential Equations*, 2nd ed., AMS (2010) [ISBN 9780821849743, 978-0821849743] (6420)

Prerequisite: Math 5210 or instructor’s consent.

Topics: Existence/uniqueness/continuity theory for ODEs, linear ODEs, stability theory, invariant manifolds, bifurcation theory, perturbation theory, Sturm–Liouville theory, spectral theory, PDEs of classical physics, Hilbert space methods, variational methods, distributions, regularity.

6510 Differentiable Manifolds (Fall Semester)

Instructor: K. Wortman

Texts: M. D. Spivak, *A Comprehensive Introduction to Differential Geometry, vol. 1*, 3rd ed., Publish or Perish (1999) [ISBN 0-914098-70-5, 0-914098-71-3978-0-914098-70-6, 978-0-914098-71-3] and
 V. Guillemin and A. Pollack, *Differential Topology*, Prentice Hall (1974) [ISBN 0-13-212605-2, 978-0-13-212605-2]

Prerequisite: Math 4510 and 5520

Topics: Manifolds, tangent spaces, orientation, Whitney’s embedding theorem, transversality, Sard’s theorem, partitions of unity, tubular neighborhoods, fiber bundles, degree theory, vector fields, flows, Lie derivatives, Frobenius’ integrability theorem, differential forms, DeRham cohomology.

6520	Introduction to Algebraic Topology (Spring Semester)
Instructor:	M. Bestvina
Text:	A. Hatcher, <i>Algebraic Topology</i> , Cambridge University Press (2002) [ISBN 0-521-79160-X (hard), 0-521-79540-0 (soft), 978-0-521-79160-1 (hard), 978-0-521-79540-1 (soft)]
Prerequisite:	Math 5520, 6510
Topics:	Simplicial and cell complexes, homology and cohomology with coefficients, excision, Mayer–Vietoris sequence, cup and cap products, DeRham theorem, Euler characteristic, Poincaré–Hopf theorem, higher homotopy groups, long exact sequence of a fiber bundle, elementary homotopy theory.
6610, 6620	Analysis of Numerical Methods I, II (Fall, Spring Semester)
Instructor:	Y. Epshteyn
Text:	G. H. Golub and C. F. Van Loan, <i>Matrix Computations</i> , 3rd ed., Johns Hopkins University Press (1996) [ISBN 0-8018-5414-8, 978-0-8018-5414-9]
Prerequisite:	Math 5600 or 5620
Topics:	Mathematical and computational analysis of numerical methods in linear algebra, optimization, and ordinary and partial differential equations.
6630	Numerical Solutions of Partial Differential Equations (Spring Semester)
Instructor:	A. Fogelson
Text:	K. W. Morton and D. F. Mayers, <i>Numerical Solution of Partial Differential Equations</i> , Cambridge University Press (1994) [ISBN 0-521-41855-0, 978-0-521-41855-3]
Prerequisite:	Math 6610, 6620, Graduate course in PDE's.
Topics:	Review of analysis of numerical methods for linear one-dimensional partial differential equations (accuracy and stability). Solution of multi-dimensional linear and nonlinear PDE problems using multigrid approaches. Introduction to methods for nonlinear hyperbolic problems including level set methods.
6710	Applied Linear Operator and Spectral Methods (Fall Semester)
Instructors:	J. Keener
Text:	J. P. Keener, <i>Principles of Applied Mathematics: Transformation and Approximation</i> , Addison-Wesley (1988) [ISBN 0-201-15674-1, 978-0-201-15674-4]
Prerequisites:	Math 5210, 5410 or equivalent
Topics:	The theory of linear operators applied to matrix, differential and integral equations, the Fredholm alternative, spectral theory, inverse and pseudo-inverse operators, Hilbert–Schmidt theory and eigenfunction expansions, wavelets, and Fast Fourier Transforms. Applications to a variety of problems of physics, biology, and engineering. This course along with Math 6720 forms the basis of the Applied Mathematics qualifying examination.
6720	Applied Complex Variables, Asymptotic Methods (Spring Semester)
Instructors:	A. Balk
Text:	J. P. Keener, <i>Principles of Applied Mathematics: Transformation and Approximation</i> , Addison-Wesley (1988) [ISBN 0-201-15674-1, 978-0-201-15674-4]
Prerequisites:	Math 3160, 6710
Topics:	The course will develop complex variable techniques used for studying ordinary and partial differential equations coming from physics. The emphasis is on applications rather than pure theory. Complex variable theory; contour integration, conformal methods and applications to solving differential equations, asymptotic methods for evaluating complicated integrals, transforms (including Fourier and Laplace transforms) and their application to solving partial differential equations, wavelets.

6750	Continuum Mechanics: Fluid Dynamics (Fall Semester)
Instructor:	C. Hohenegger
Text:	P. K. Kundu, I. M. Cohen, and H. H. Hu, <i>Fluid Mechanics</i> , 3rd ed., Elsevier Academic Press (2004) [ISBN 0-12-178253-0, 978-0-12-178253-5]
Prerequisites:	Undergraduate ODE and PDE, or Consent of Instructor
Topics:	Derivation of equations of fluid dynamics, Euler and Navier–Stokes equations, Bernoulli’s theorem, Kelvin’s circulation theorem, potential flow, airplane lift, boundary layers, waves in fluids, fluid instabilities, turbulence, dynamics of the atmosphere and ocean.

6770, 6780	Mathematical Biology I, II (Fall, Spring Semester)
Instructor:	J. Keener, A. Borisyuk
Text:	J. P. Keener & J. Sneyd, <i>Mathematical Physiology</i> , Springer (1998) [ISBN 0-387-98381-3, 978-0-387-98381-3]
Prerequisite:	5410, 5420, or consent of instructor
Topics:	(6770) This course will provide an introduction to modeling of all physiology, and will cover approximately the first half of the text. (6780) In this course we will look at models of aspects of the cardiovascular system including blood flow control and characteristics, flow through branching structures, biochemistry and biomechanics of blood clotting, and signal transduction by vascular cells. Analytical and computational approaches to studying the models will be discussed and implemented.

Note: All courses in the 6800 series meet with a 5000-series course, and are for Ph.D. students only. Extra work is required; this should be arranged with the instructor before the end of the second week of classes. See the 5000-series entries for descriptions.

6805	Introduction to Probability (Fall, Spring, and Summer Semester)
Meets with:	5010
6810, 6815	Stochastic Processes and Simulation I, II (Fall, Spring Semester)
Meets with:	5040, 5050
6830, 6835	Mathematical Biology I, II (Fall, Spring Semester)
Meets with:	5110, 5120
6840, 6845	Introduction to Differential Equations (Fall, Spring Semester)
Meets with:	5410, 5420
6850	Introduction to Partial Differential Equations (Fall Semester)
Meets with:	5440
6855	Survey of Numerical Analysis (Spring Semester)
Meets with:	5600
6870	Mathematical Modeling (Spring Semester)
Meets with:	5740
6880-001	Topics in Applied Mathematics (Fall, Spring Semester)
Meets with:	5750-001
6880-002	Topics in Applied Mathematics (Fall, Spring Semester)
Meets with:	5750-002
6890	Introduction to Mathematical Finance I (Fall Semester)
Meets with:	5760
6895	Introduction to Mathematical Finance II (Spring Semester)
Meets with:	5765
6910-0XX	Supervised Reading
Instructor:	Staff

6960-001	GSAC Colloquium (Fall, Spring Semesters)
Instructor:	A. Treibergs, P. Alfeld
Topics:	GSAC Colloquium. TA Training workshop.
6960-0XX	Special Projects
Instructor:	Staff
6970	Thesis Research (Masters)
Instructor:	Staff
7800	Topics in Algebraic Geometry (Spring Semester)
Instructor:	C. Hacon
Text:	To be announced
Prerequisite:	Consent of Instructor
Topics:	Various topics in the area of algebraic geometry, to be offered on the basis of need or interest.
7835	Seminar in Number Theory (Fall Semester)
Instructor:	W. Nizioł
Text:	No Textbook
Prerequisite:	Consent of Instructor
Topics:	Various topics in the area of algebraic number theory, to be offered on the basis of need or interest.
7853	Topics in Geometric Topology (Spring Semester)
Instructor:	K. Bromberg
Text:	To be announced
Prerequisite:	Consent of Instructor
Topics:	This course will cover some recent results in Teichmüller theory. We'll begin with some introductory material about Teichmüller space: quasiconformal maps, quadratic differentials, the Teichmüller metric, and the Weil–Petersson metric. The geometric and topological aspects are emphasized.
7890-001	Topics in Representation Theory (Fall Semester)
Instructor:	D. Miličić
Text:	No Textbook
Prerequisite:	Consent of Instructor
Topics:	Various topics in representation theory, to be offered on the basis of need or interest. May be repeated for credit when the topics vary.
7970	Thesis Research (Ph.D.)
Instructor:	Staff

RECENT Ph.D. STUDENTS
Department of Mathematics
1987–2011

Year	Name	Major Field	Advisor	Subsequent Institution Affiliation
2011	Julian Chan	Commutative Algebra	Singh	Weber State University, Ogden, UT
	Matthew Housley	Representation Theory	Trapa	
	Elisha Hughes	Statistics	Horváth	Myriad Genetics, Salt Lake City, UT
	Sean Lavery	Mathematical Biology	Adler	Swarthmore College, PA
	Loc Nguyen	Differential Equations	Schmitt	École Normale Supérieure, Paris
	Blerta Shtylla	Math Biology	Keener	Mount Holyoke College, Hadley, MA
	Ben Trahan	Representation Theory	Trapa	University of Utah
	Yuan Zhang	Applied Math	A. Cherkhev	Universidad de Castilla-La Mancha, Spain
2010	Yael Algom-Kfir	Geometric Group Theory	M. Bestvina	Yale University
	Courtney Davis	Math Biology	Adler	University of Maryland
	Trung Dinh	Commutative Algebra	Roberts	
	Lindsay Erickson	Math Biology	Fogelson	Sandia National Labs, Livermore, CA
	Giao Huynh	Math Biology	Adler	Oakland University
	Casey Johnson	Representation Theory	Trapa	National Security Agency
	Karim Khader	Probability	Khoshnevisan	Div. Epidemiology, University of Utah
	Zachary Kilpatrick	Math Biology	Bressloff	University of Pittsburgh
	Sarah Kitchen	Representation Theory	Miličić	Albert-Ludwigs University, Freiburg, DE
	Hwan Yong Lee	Applied Math	Dobson	Drexel University
	Karin Leiderman	Math Biology	Fogelson	Duke University
	Frank Lynch	Math Biology	Keener	Occidental College, Los Angeles, CA
	William Malone	Geometric Group Theory	M. Bestvina	
	Jay Newby	Math Biology	Bressloff	Oxford University

Year	Name	Major Field	Advisor	Subsequent Institution Affiliation
2010	Michael Purcell	Probability	Khoshnevisan	National Security Agency
	Russell Richins	Applied Math	Dobson	Michigan State University
	Shang-Yuan Shiu	Probability	Khoshnevisan	Academia Sinica, Taipei
	Josh Thompson	Geometric Group Theory	Bromberg	Colorado State University
2009	Tommaso Centeleghe	Number Theory	Savin	University Duisburg-Essen
	Scott Crofts	Representation Theory	Trapa	University of California, Santa Cruz
	Jason Preszler	Number Theory	Savin	University of Puget Sound, Tacoma, WA
	Amber Smith	Math Biology	Adler	Los Alamos National Laboratory
	Nessy Tania	Math Biology	Keener	University of British Columbia
2008	Erin Chamberlain	Commutative Algebra	Roberts	Brigham Young University
	Elizabeth Doman Copene	Math Biology	Keener	Idaho Technology Inc., Salt Lake City, UT
	Yoshihiro Iwao	Algebraic Geometry	Yuan-Pin Lee	
	William Nesse	Math Biology	Bressloff	University of Ottawa
	Gueorgui Todorov	Algebraic Geometry	Bertram	Princeton University
2007	Berton Earnshaw	Math Biology	Bressloff	University of Utah, Michigan State University
	Domagoj Kovacevic	Number Theory	Savin	
	Lars Louder	Geometric Group Theory	M. Bestvina	University of Michigan
	Meagan McNulty	Math Biology	Adler	William & Mary College, Williamsburg, VA
	Elijah Newren	Math Biology	Fogelson	Sandia National Laboratory
	Qiang Song	Commutative Algebra	Singh	School of Automation, Southeast University, Nanjing, China
	Dali Zhang	Inverse Problems	E. Cherkhev	University of Calgary
	John Zobitz	Math Biology	Adler	Augsburg College, Minneapolis, MN

Year	Name	Major Field	Advisor	Subsequent Institution Affiliation
2006	Nathan Albin	Applied Math	A. Cherkhev	University of Duisburg-Essen, California Institute of Technology
	Renate Caspers	Stochastic Processes	Mason	
	Kenneth Chu	Complex Algb'c Geom	Toledo	University of Texas at Austin
	Matthew Clay	Geometric Group Theory	M. Bestvina	University of Oklahoma
	Zrinka Despotovic	Geometric Group Theory	M. Bestvina	
	Young-Seon Lee	Math Physiology	Keener	Cornell University
	Andrew Oster	Math Biology	Bressloff	The Ohio State University
	Kazuma Shimomoto	Algebra	Roberts	University of Minnesota
2005	Renzo Cavalieri	Algebraic Geometry	Bertram	University of Michigan
	Stefanos Folias	Math Biology	Bressloff	Boston University
	An Hai Le	PDE	Schmitt	MSRI
	Fumitoshi Sato	Algebraic Geometry	Bertram	Korea Institute for Advanced Study
2004	Robert Guy	Math Biology	Fogelson	University of Utah
	Brynja Kohler	Math Biology	Keener	Utah State University
	Eiko Koizumi	PDE	Schmitt	Ellis College, New York Institute of Technology online
	Denis Lukic	Rep Theory	Miličić	Northwestern University
	Greg Peipmeyer	Algebra	Roberts	University Nebraska
	Thomas Robbins	Math Ecology	Lewis	University of Utah
2003	Emina Alibegovic	Geom Group Theory	Bestvina	University of Michigan
	Anca Mustata	Algebraic Geometry	Clemens	University British Columbia
	Andrei Mustata	Algebraic Geometry	Bertram	University British Columbia
	Bradford Percy	Math Biology	Keener	Rice University

Year	Name	Major Field	Advisor	Subsequent Institution Affiliation
2003	Matthew Rudd	PDE	Schmitt	University Texas at Austin
	Inbo Sim	PDE	Schmitt	Utah State University
2002	Nicholas Cogan	Math Biology	Keener	Tulane University
	Martin Deraux	Complex Geometry	Toledo	Purdue University
	Sonjong Hwang	Topology	Kapovich	
	Blake Thornton	Geometric Topology	Kleiner	Westminster College, Salt Lake City, UT
	Sung Yil Yoon	Topology	Bestvina	Rensselaer Polytechnic Institute, Troy, NY
2001	Cytrynbaum, Eric	Math Physiology	Keener	Institute for Theoretical Dynamics
	Dumett, Miguel	PDE	Keener	Lawrence Livermore National Laboratory
	Hohn, Michael	Numerical Analysis	Folias	Lawrence Berkeley National Laboratory
	Kong, Jian	Algebraic Geometry	Bertram	The Johns Hopkins University
	Küçük, İsmail	Applied Math	Cherkaev	American University, Sharjah , Sakarya University, Turkey
	Lim, Chong Keat Arthur	Rep Theory	Miličić	University of Minnesota
	Xie, Xiangdong	Geom Group Theory	Kleiner	Washington University
	Yi, Chung Seon	Math Biology	Fogelson	Virginia Polytechnic Institute and State University
2000	Brinkmann, Peter	Geom Group Theory	Gersten	University of Illinois/ Urbana–Champaign
	Chan, Chin-Yi	Algebra	Roberts	Purdue University
	Grabovsky, Irina	Statistics	Horváth	National Board of Medical Examiners
	Sather-Wagstaff, Sean	Comm Algebra	Roberts	University of Illinois/ Urbana–Champaign
	Yu, Haoyu	Math Biology	Fogelson	University of Minnesota

Year	Name	Major Field	Advisor	Subsequent Institution Affiliation
1999	Bogar, Kristina	Applied Math	Keener	University of Utah
	Harris, Charles	Analysis	Tucker	University of Utah
	Jacobsen, Jon	PDE	Schmitt	Pennsylvania State University
	Jones, Elizabeth	Comm Algebra	Roberts	University of Utah
	Tzoliias, Nikolaos	Algebraic Geometry	Kollár	Oklahoma State University
	Yoshikawa, Toshio	Applied Math	Balk	Utah State University
1998	Chan, Hsungrow	Differential Geom	Treibergs	Tsing Hua University, Taiwan
	Chen, Chi Kan	Applied Math	Fife	University of Utah, Post Doctoral
	Fletcher, Jeffrey L.	Geo Group Theory	Gersten	Louisiana State University, Alexandria, LA
	Kuwata, Takayasu	Algebraic Geometry	Kollár	Tokyo Denki University
	Kuharsky, Andrew L.	Math Biology	Fogelson	Tulane University
	Lewis, Timothy J.	Math Biology	Keener	New York University
	Macura, Natasa	Topology	Bestvina	University of Michigan
	Marland, Eric	Math Biology	Keener	University of California, Davis, CA
	Mineyev, Igor	Group Theory	Gersten	Max Planck Institute, Bonn, Germany
	Xie, Min	Applied Math	Othmer	Intermountain Health Care, Salt Lake City, Utah
1997	Lee, Yongnam	Algebraic Geometry	Clemens	Korean Institute Advanced Study
	Mayer, Richard	Algebraic Geometry	Carlson	University of Massachusetts, Amherst, MA
	Smithies, Laura	Rep Theory	Taylor	Kent State University, Kent, OH
	Spiro, Peter	Math Biology	Othmer	Incyte Pharmaceuticals
	Wang, Nien-Tzu	Applied Math	Fogelson	

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1996	Burillo, José	Group Theory	Gersten	Tufts University, Medford, MA
	Chen, Shirnping	Topology	Toledo	Triology Technologies Inc., Taiwan
	Ciocan-Fontanine, Ionut	Algebraic Geometry	Bertram	Mittag-Leffler Institut, Djursholm, Sweden
	Dallon, John	Applied Math	Othmer	Warwick University, England
	Serbinowska, Monika	Statistics	Horváth	University of California at San Diego, La Jolla, CA
1995	Castro, Alberto	Geometry	Toledo	Mt. Holyoke College, MA
	Chmaj, Adam J.	PDE	Fife	Brigham Young University, Post Doctoral Utah State University, Post Doctoral
	Dang, Ha	Applied Math	Fife	University of Utah
	Kovács, Sándor	Algebraic Geometry	Kollár	MIT, Cambridge, MA
	Le, Vy Khoi	Nonlinear Analysis	Schmitt	University of Colorado
	Ma, Lingyan	Statistics	Horváth	University of Georgia
	Mayer, Uwe	PDE	Korevaar	Brown University
	Pandžić, Pavle	Lie Groups	Miličić	MIT, Cambridge, MA
	Sawicz, Romuald	Applied Math	Golden	University of Minnesota
	Serbinowski, Tomasz	Differential Geom	Korevaar	University of California, Irvine, CA
Van Kirk, Robert	Math Biology	Lewis	Henry's Ford Foundation, Island Park, ID	
1994	Bernasconi, Aldo	Group Theory	Gersten	Chile (not in academia)
	O'Reilly, John M.	Numerical Analysis	Stenger	
	Shalla, Robert	Lie Groups	Miličić	Bronx College

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1993	Bratten, Timothy	Lie Groups	Hecht	Argentina
	Dillon, Robert	Applied Math	Othmer	Tulane University
	Kasparian, Azniv	Algebraic Geometry	Carlson	University of Sofia
	Kim, Joo Mok	Statistics	Mason	University of South Korea
	He, Ming	Probability	Ethier	Weber State University
	McGough, Jeffrey	Differential Equations	Schmitt	University of Nevada
	Szabó, Endre	Algebraic Geometry	Kollár	Universität Bayreuth, Germany
	Tang, Yuanhua	Applied Math	Othmer	Cornell University
	Westhoff, Randall	Algebraic Geometry	Clemens	Bemidji State University, MN
1992	Candia, Mario R.	Real/Comp Geometry	Hecht	
	Conner, Gregory R.	Alg/Number Theory	Gersten	Brigham Young University, Provo, UT
	Corti, Alessio	Algebraic Geometry	Kollár	MSRI
	Eyre, David J.	Applied Math	Fife	University of Minnesota
	Ma, Tina	Statistics	Mason	Pharmaco LSR, Inc., Austin, TX
	White, Denise	Finite Groups	Gross	Westminster College, Salt Lake City, UT
	Yin, Guangyan	Applied Math	Stenger	
1991	Devoto, Jorge	Topology	Braam	ICTP, Trieste, Italy
	Ferguson, Kenneth	Topology/Geometry	Stern	First Quadrant, Pasadena, CA
	Grant, Christopher	Applied Math	Fife	Georgia Tech
	Izadi, Elham	Algebraic Geometry	Clemens	Harvard University
	Kinyon, Michael	Differential Equations	Tucker	Indiana University at Southbend
	Ma, Yonghao	Algebra	Roberts	Southwest Texas State University
	Wickham, Cameron	Ring Theory	Roberts	Southwestern Missouri State
	Wisikin, James	Group Theory	Gross	University of Utah

Year	Name	Major Field	Advisor	Subsequent Institution Affiliation
1990	DeYoung, Gary	Applied Math	Othmer	University of California, Davis
	Li, Ya	Differential Equations	Keener	Taikyo Westmar University
	Lundstrom, Ronald	Probability	Tavaré	Cimarron Software, Salt Lake City, UT
	Sirvent, Maritza	Approximation Theory	Alfeld	Ohio State University
1989	Austin, David M.	Topology	Stern	Institute for Advanced Study. Grand Valley State Univ., Allendale, MI
	Lamoneda, Luis Hernandez	Geometry	Toledo	University of Chicago, Chicago, IL
	Reyes, Jesus Jimenez	Complex Geometry	Clemens	University of California, Riverside, CA
	Phelps, Frederick	Applied Math	Keener	University of Oxford, England
1988	Božičević, Mladen	Lie Groups	Miličić	Rutgers University, New Brunswick, NJ
	Joyce, Paul J.	Stochastic Processes	Tavaré	University of South California, Los Angeles, CA
	Nordhaus, Thomas	Applied Math	Keener	
	Stromberg, Marc	Numerical Analysis	Stenger	Texas Tech University Lubbock, TX
	Walker, James D.	Applied Math	Folias	Southwest Research Inst. San Antonio, TX
	Zabčić, Miljenko	Lie Groups	Hecht	MIT, Cambridge, MA
	Zinner, Bertram	Applied Math	Keener	Auburn University, Auburn, AL
1987	Arner, Paul R.	CAGD	Barnhill	SDRC, OH
	Barry, Phillip J.	CAGD	Barnhill	University of Waterloo, Ontario, Canada
	Bialecki, Bernard	Numerical Analysis	Stenger	University of Kentucky, Lexington, KY
	Chen, Roger	Differential Geo	Li	University of Toledo, Toledo, OH
	Dockery, J. Don	Applied Math	Keener	Utah State University, Logan, UT
	Harris, Greg A.	Differential Equations	Schmitt	Auburn University, Auburn, AL

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1987	Lakoš, Nela	Differential Equations	Schmitt	Ohio State University, Columbus, OH
	Malm, Dennis	Algebra	Goodearl	Northwest Missouri State University, Maryville, MO
	Piper, Bruce R.	CAGD	Barnhill	Rensselaer Polytechnic Institute, Troy, NY
	Watanabe, Masaji	Applied Math	Othmer	Stuttgart University, Germany
	Woodward, Diana	Applied Math	Hoppensteadt	Michigan State University, East Lansing, MI

FACULTY 2011–2012

More complete bibliographies are available in the departmental office, and on faculty Web pages accessible via <http://www.math.utah.edu/people/faculty.html>.

DISTINGUISHED PROFESSORS

Bestvina, Mladen, University of Tennessee, 1984. Topology

Hacon, Christopher D., UCLA, 1998. Algebraic Geometry

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

Milton, Graeme, Cornell University, 1985. Applied Mathematics

PROFESSORS

Adler, Frederick R., Cornell University, 1991. Mathematical Ecology

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

Balk, Alexander M., Moscow Institute of Physics and Technology, 1988. Nonlinear Phenomena

Bertram, Aaron, UCLA, 1989. Algebraic Geometry

Bressloff, Paul C., Kings College, University of London, 1988. Mathematical Biology

Cherkaev, Andrej V. Leningrad Polytechnical Institute, 1979. Optimal Design and Applications

Cherkaev, Elena, Leningrad University, 1988. Applied Mathematics

Dobson, David C. Rice University, 1990. Applied Mathematics

Ethier, Stewart N., University of Wisconsin, 1975. Applied Probability

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

Golden, Kenneth, New York University, 1984. Applied Mathematics

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

Hecht, Henryk, Columbia University, 1974. Lie Groups

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

Khoshnevisan, Davar, University of California, Berkeley, 1989. Probability Theory and Mathematical Statistics

Korevaar, Nicholas J., Stanford University, 1981. Differential Geometry and Partial Differential Equations

Lee, Yuan-Pin, University of California, Berkeley, 1999. Algebraic Geometry, Symplectic Topology, Mathematical Physics

Nizioł, Wiesława, Princeton University, 1991. Arithmetic Geometry

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

Savin, Gordan, Harvard, 1988. Automorphic Forms

Singh, Anurag, Univ. of Michigan, 1998. Commutative Algebra

Smale, Nathan, University of California, Berkeley, 1987. Differential Geometry

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

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

Trapa, Peter, Massachusetts Institute of Technology, 1998. Representation Theory

Treibergs, Andrejs E., Stanford, 1980. Differential Geometry

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

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

ASSOCIATE PROFESSORS

Bromberg, Kenneth W., University of California at Berkeley, 1998. Topology

Ciubotaru, Dan, Cornell University, 2003. Topological and Lie Groups
de Fernex, Tommaso, University of Illinois at Chicago, 2002. Algebraic Geometry
Rassoul-Agha, Firas, New York University, 2003. Probability Theory
Zhu, Jingyi, New York University, 1989. Mathematical Finance

ASSISTANT PROFESSORS

Borisyuk, Alla, New York University, 2002. Mathematical Biology, Applied Mathematics
Epshteyn, Yekaterina, University of Pittsburgh, 2007. Numerical Analysis
Guevara Vasquez, Fernando, Rice University, 2006. Partial Differential Equations
Hohenegger, Chrystal, Georgia Institute of Technology 2006. Numerical Analysis, Fluid Mechanics
Wortman, Kevin, University of Chicago, 2003. Geometric Group Theory
Xu, Chenyang, Princeton University, 2008. Algebraic Geometry

ASSISTANT PROFESSOR (LECTURER)

Alali, Bacim, Louisiana State University, 2008. Partial Differential Equations
Conus, Daniel, Swiss Federal Institute of Technology, 2008. Probability
Docampo Alvarez, Roi, University of Illinois at Chicago, 2009. Algebraic Geometry
Georgiou, Nicos, University of Wisconsin, 2011, Probability Theory
Joseph, Matthew, University of Wisconsin, 2009. Probability Theory
Marcus, Steffen, Brown University, 2011. Algebraic Geometry
Reynolds, Patrick, University of Illinois at Urbana-Champaign, 2011. Geometric Group Theory
Sherwood, Erik, Cornell University, 2008. Mathematical Biology

RESEARCH ASSISTANT PROFESSOR

Adrian, Moshe, University of Maryland 2010. Number Theory, Algebraic Geometry
Du, Jian, Stony Brook University, 2007. Numerical Analysis, Mathematical Biology
Lin, Joyce, University of North Carolina, 2009. Applied Mathematics
Miller, Lance, University of Connecticut 2010. Number Theory
Orum, J. Christopher, Oregon State University, 2004. Stochastic Analysis
Sircar, Sarthok, University of South Carolina, 2009. Computational Fluids, Mathematical Biology
Skorczewski, Tyler, University of California, Davis, 2010. Fluid Mechanics, Mathematical Biology
Tao, Jing, University of Illinois at Chicago, 2009. Geometric Group Theory

RESEARCH PROFESSORS

Beebe, Nelson H. F., University of Florida, 1972. Quantum Chemistry
Horn, Roger, Stanford University, 1967. Matrix Analysis
Palais, Robert, University of California, Berkeley, 1986. Applied Mathematics

RESEARCH ASSOCIATE PROFESSOR

Alibegovic, Emina, University of Utah, 2003. Mathematics Education, Geometry and Topology
Huang, Hsiang-Ping, University of California, Berkeley, 2000. Functional Analysis

ASSOCIATE INSTRUCTORS

Bestvina, Cyndi, University of Tennessee, Mathematics Education
Cangelosi, Amanda, Utah State University, 2008 (M.S.) Statistics, Mathematics Education
Jovanovic-Hacon, Aleksandra, University of California, Los Angeles, 1997 (M.A.). Applied Mathematics

Keir, Marilyn, Stanford University, 1968 (M.A.) Mathematics Education

MacArthur, Kelly, University of Utah, 1995 (M.S.) Mathematics Education

Noonan-Heale, Rebecca, Heriot Watt University 2010. Semigroups, Mathematics Education

van Opstall, Michael, University of Washington, 2004. Commutative Algebra, Mathematics Education

ADJUNCT PROFESSORS

Berzins, Martin, University of Leeds, 1981. Computational algorithms, PDE

Stenger, Frank, University of Alberta, 1966. Numerical Analysis

ADJUNCT ASSOCIATE PROFESSORS

Eyre, David, University of Utah, 1992. Applied Mathematics

Kirby, Michael, Brown University, 2003. Scientific Computation

ADJUNCT ASSOCIATE PROFESSORS

Leelavanichkul, Seubpong, University of Utah, 2007. Computational Mechanics

Toth, Damon, University of Washington, 2006. Mathematical Biology

EMERITUS PROFESSORS

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

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

Coles, William J., Duke University, 1954. Ordinary Differential Equations

Fife, Paul C., New York University, 1959. Applied Mathematics, Partial Differential Equations

Folias, Efthymios S., California Institute of Technology, 1963. Applied Mathematics

Gersten, Stephen M., Cambridge University, 1965. Group Theory

Glaser, Leslie C., University of Wisconsin, Madison, 1964. Geometric Topology

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

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

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

Roberts, Paul C., McGill University, 1974. Commutative Algebra, Algebraic Geometry

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

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

Wolfe, James H., Harvard University, 1948. Geometric Integration Theory