The University of Utah

Department of Mathematics

GRADUATE BULLETIN

2015–2016

GRADUATE MATHEMATICS 2015–2016

Department of Mathematics
University of Utah

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Cover: Brighton ski area

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Preface

This *Graduate 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 *Graduate Catalog* of the University of Utah Graduate School, which is available to all graduate students.

The editors of the Mathematics Department *Graduate Bulletin* welcome suggestions for its improvement from graduate students and members of the faculty.

When this document is read online with any PDF file viewer, document hyperlinks on URLs and faculty names are *active*: select them to jump to their target locations in a Web browser. Colored page numbers are also active; select one to move to that page in the PDF viewer.

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Utah Canyon Country

Calendar of Events for 2015–2016

While most important calendar dates are chosen well in advance of publication of this *Graduate Bulletin*, some are subject to change. For the latest correct data, consult these Web sites (also available as links on the semester/term headings below):

http://registrar.utah.edu/academic-calendars/fall2015.php
http://registrar.utah.edu/academic-calendars/spring2016.php
http://registrar.utah.edu/academic-calendars/summer2016.php

EVENT	Fall Semester 2015	Spring Semester 2016	Summer Term 2016
Class schedule available on the web	M, Mar 2	M, Sep 28, 2015	T, Feb 2
Classes begin	M, Aug 24	M, Jan 11, 2016	M, May 16
Last day to drop (delete) classes	F, Sep 4	F, Jan 22	W, May 25
Last day to add classes	F, Sep 4	F, Jan 22	W, May 25
Last day to elect CR/NC option	F, Sep 4	F, Jan 22	W, May 25
Tuition payment due	F, Sep 4	F, Jan 22	W, May 25
Last day to withdraw from term length classes	F, Oct 23	F, Mar 4	F, Jun 24
Last day to reverse CR/NC option	F, Dec 4	F, Apr 22	F, Jul 29
Classes end	H, Dec 10	T, Apr 26	W, Aug 3
Reading Day	F, Dec 11	W, Apr 27	n/a
Final exam period	M–F, Dec 14–18	H–W, Apr 28–May 4	H–F Aug 4–5
Grades available on the web	T, Dec 29	T, May 17	T, Aug 16
Annual Commencement/Convocation Exercises		H–F, May 5–6	

Departmental Written Qualifying Exams (Prelims) ...... M–W, Aug 17–19, 2015 and W–F, Jan 6–8, 2016
Math Dept. TA training for new graduate students and instructors .... Aug. 12–21, 2015

Holidays, Recesses, Breaks
(No classes, day or evening. University closed on holidays)

Fall Semester 2015

Labor Day Holiday .... M, Sep 7
Fall Break .... M–F, Oct 12–16
Thanksgiving Break .... H–F, Nov 26–27
Holiday Recess .... Sa, Dec 19–Su, Jan 10

Spring Semester 2016

Martin Luther King/Human Rights Day Holiday .... M, Jan 18
Presidents' Day Holiday .... M, Feb 15
Spring Break .... M–F Mar 14–18

Summer Term 2016

Memorial Day Holiday .... M, May 30
Independence Day Holiday .... M, Jul 4
Pioneer Day Holiday (observed in Utah) .... M, Jul 25

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 the listed 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 has more than 50 professors. 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 is included on p. 59. 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, commutative algebra, differential geometry, geometric group theory, geometric topology, 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, 30 members of the Mathematics faculty are associated with government-sponsored research contracts.

The University's total enrollment is currently about 32,000. During 2014–2015, there were 76 men and 21 women who were Teaching Assistants in mathematics. Our graduate students come from different areas of the United States as well as many foreign countries.

Research Facilities

The Marriott Library collection includes numerous books and journals of interest to mathematics researchers and scholars. Many of the journals, and journal databases, are also available electronically when accessed from inside the campus network.

There are extensive computing facilities available in the Department, and nearby on campus. See p. 27.

Applying to Graduate Programs

Applications

Since August 2011, all application to graduate programs in mathematics are done on-line. It is not 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/GradApplicInst1.html. Sample application materials and individualized application checklists may be found on the 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 applications for financial aid to start the following Fall Semester is **January 1st**. Most financial aid is in the form of teaching assistantships during the Fall and Spring Semesters. Alternative support from individual research grants, and additional support from summer teaching, may also be available. Financial aid is typically given only to students in the Ph.D. program.

Instructions for the On-Line Application for Graduate Admissions and Financial Aid

The 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 may be found on the website http://www.math.utah.edu/grad/GradApplicInst1.html. 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 1st**.

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://csme.utah.edu/mssst/mssst-application-requirements.

Instructions for applying to the Professional Master of Science and Technology (PMST) program may be found at http://pmst.utah.edu/prospective-students/admissions.

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**
  Here 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/grad/. You can also find information about satisfying the University of Utah's language requirements for non-native English speaking graduate students, and the TOEFL (Test of English as a Foreign Language) examinations.
- **Basic Information — All Applicants**
  - *Personal Data.* Fill in your name, address, and Social Security Number.
  - *Contact Information.* Fill in addresses and e-mail 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 in the M.S. and Ph.D.

programs take classes and exams together. Students in the M.S. program may apply for admission to the Ph.D. program in their second year. Students making good progress experience a seamless transition to the Ph.D. 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 don't 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 is Fall Semester 2016–2017. Teaching Assistantships are offered beginning in the Fall Semester only, and are typically only given to students in the Ph.D. program.

– *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 subject exam for all applicants for Master of Mathematics and Doctor of Philosophy programs, but does not require the GRE from applicants to the MStat (Mathematics) program, nor to the Master of Mathematics (Teaching) program. The Department *does* consider applications without a GRE subject exam score, but such applications may be at a disadvantage. Please *do* indicate your GRE scores if you have those too, as well as your subject score. Master of Mathematics (Teaching) candidates 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 are also asked 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 post-high-school educational institutions that you have attended, and to upload copies of transcripts. Unofficial transcripts are sufficient until you are made an offer; in such a case, you must then supply *official* 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. We are more interested in hearing about your current interests in mathematics, and why Utah is a good fit for you, than in why you decided to study mathematics. The Statement of Purpose is also where you can discuss any teaching experience that you may have. You may also choose to include a list of the mathematics courses (or related courses) that you have taken, along with a short description of the syllabus and the course text. This is particularly useful if the Recruitment Committee is not familiar with your undergraduate institution. 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. Usually the financial support available to first-year students consists of a teaching assistantship that pays a stipend and a tuition waiver. Teaching Assistants are assigned various duties including teaching classes, running recitation or lab sections, and grading. For “Applicant Survey,” you may tell us where you found out about Graduate Mathematics Programs at Utah. Indicate whether you intend to complete your degree as a full-time/part-time student. For “Comments,” you may supply any additional information here.

- *Full Time Employee Page*. Fill in this page if you are a 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, Mathematics, and Physics & Astronomy. For “GPA,” estimate your grade point average from STEM (science, technology, engineering and mathematics) classes. 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 e-mail contact information. AY sends e-mail to your referees and asks 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).

Additional Information for Applicants

For 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.

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 1st. Applications received before April 1st are considered for financial aid for the following Fall Semester as long as positions remain available.

Financial Aid

Most mathematics graduate students are supported by teaching assistantships. Others may be supported by teaching fellowships or research assistantships depending on the source of funding. (For convenience in this *Graduate Bulletin*, *teaching fellowship* is usually used to include both *teaching assistantship* and *teaching fellowship*, except where it is necessary to make a distinction between them.)

Tuition Fees

Tuition (nine hours) is approximately $3300 per semester for Utah residents and $10,650 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://gradschool.utah.edu/tbp/tuition-benefit-program-guidelines. All international students are required to pay $75 each semester to help cover additional administrative costs. **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/.

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 United Healthcare; see http://gradschool.utah.edu/tbp/insurance-information/.

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 section of **The Salt Lake Tribune** (http://www.sltrib.com/), the **Deseret News** (http://www.desnews.com/), the student newspaper, **The Daily Utah Chronicle** (http://www.dailyutahchronicle.com/), and also on radio and television station **KSL** (http://www.ksl.com/).

Programs of Study

The Mathematics Department offers programs leading to the degrees of Doctor of Philosophy, Master of Arts, Master of Statistics, Master of Science in Mathematics, Master of Science in Computational Engineering and Science (see p. 14), and a Master of Science and Technology Degree. Students in the MS Mathematics (Teaching) program receive the Master of Science in Mathematics degree.

Master of Arts and Master of Science Degrees

- **Graduate School Requirements**:

  The Master of Arts degree requires standard proficiency in one foreign 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. The student is responsible for submitting forms on time. Some remarks are in order relative to these requirements:

  - Comprehensive oral and/or written qualifying examination in mathematics are usually taken 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.
  - Each Master's candidate is assigned an Academic Advisor upon entering the program. This Advisor has the primary responsibility of guiding and evaluating the candidate's progress through the Master's program. The Advisor chairs the candidate's Supervisory Committee consisting of three faculty members who certify that the candidate has fulfilled the requirements of the degree. Questions concerning the interpretations of degree requirements should be directed to the candidate's Advisor.
  - Thesis candidates must register for a minimum of six credit hours of thesis research (Math 6970), and at least one credit hour 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.

- **Departmental Requirements**:

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

Course Requirements

All coursework must be at the Master's level, courses numbered 5000 or above.

- Math 5210 (real analysis)
- Math 5310, 5320 (algebra)
- One 6000-level sequence consisting of two one-semester courses
- 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 (options 2–4) 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 required 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, Master's 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

All coursework must be at the Master's level, courses numbered 5000 or above.

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

Graduation Requirements

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

- **Comprehensive Examination**:

  A Comprehensive Examination is required by the Graduate School. It may consist of written Qualifying Exams (option 1), a Final Defense (options 2 or 4), or the Comprehensive Exam (option 3). The Supervisory Committee shall specify whether this examination is an Oral Comprehensive Examination, or a Written Comprehensive Examination, or both. (An additional oral exam 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 is 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 requires passing the Written Ph.D. qualifying examinations in two areas.

- **Remarks and Suggestions**

Course Offerings

Courses that 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 & Astronomy, etc.) that 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.

Students wishing to continue to the Ph.D. program

All graduate students who have not had an appropriate course in computer programming are strongly encouraged to consult faculty about suitable classes in programming early in their program. Familiarity with one or more computer-algebra systems, and the TEX and LATEX typesetting systems, is expected of *all* graduating mathematicians, and many employers in engineering, mathematics, and science require job candidates to have good programming skills in numerical languages, such as C, C++, C#, Fortran, or Java. Graduates in statistics must have additional expertise in statistical software systems. Departmental computing staff are always happy to offer advice, guidance, and help in developing computer-programming experience.

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 assurance that courses for the Master's degree 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.

Students in the Master's program are expected to complete their Master's degree before entering the Ph.D. program. **(Only in exceptional cases is permission 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 by January 1st of 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 Master's degree, may take those exams prior to the beginning of the Spring 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 is limited to *two* years.

Master's students who wish to apply to the Ph.D. program in Mathematics must fill out an application form available from the Graduate Program Coordinator and do not need to reapply through AY to the Graduate School. Applicants to the Ph.D. Program must arrange *three* letters of recommendation to support their application. 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.

- **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

- **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, find a Graduate Advisor and arrange a three-person Supervisory Committee. **It is the responsibility of the student to suggest a Committee to the Graduate Advisor, who is the Committee Chair.**

  Meet with your Advisor toward 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.

- **One year before you plan to graduate**:
  Make the final plan for your course work, submit your *Program of Study* through the Graduate Program Coordinator 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), and 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.

- **One semester prior to graduation**:
  File the *Request for Supervisory Committee* and *Application for Admission to Candidacy for a Master's Degree* forms for the Graduate School to the Mathematics Graduate Program Coordinator. 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 online. Copies can be picked up from the Graduate Program Coordinator.)

- **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 one credit hour during the semester in which you plan to defend your thesis, you must register for one credit hour 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*.

- **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, because 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.
- **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. and M.A. degrees. Supported students are entitled to tuition waivers for a total of *two* years or *four* semesters for Master's degrees.

Transfer Credit

Upon the approval of the Master's Committee, at most *nine* hours of non-matriculated credit from the University of Utah, or *six* hours of transfer credit from another university, are allowed in the graduate program toward a Master's degree.

- **Recommended schedule of study toward a Master's degree with intent to enter the Ph.D. program**
  - 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 5000-level or 6000-level courses throughout the year, including two qualifying exam preparation sequences. Take at least two written qualifying examinations by Spring Semester of 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 January 1st. 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 Graduate Catalog* under degree requirements.

> **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

An applicant selects Master of Statistics — Mathematics (MST) in the Graduate School application. A student is admitted to the program by the Departmental Statistics Committee and the Departmental Admissions Committee. The degree, Master of Statistics (Mathematics), is awarded by the Mathematics Department.

Prerequisites

- Either a Bachelor's degree in Mathematics, or the equivalent, e.g., two years of Calculus and two senior level mathematics sequences.[1]
- Math 3070, 3080, 3090, or equivalent.

Course requirements

The Master of Statistics (Mathematics) degree requires 36 credits of graduate level coursework, numbered 5000 or higher.

- Math 5010, 5080, 5090[2]
- Math 6010, 6020
- Math 6070
- Electives approved by Supervisory Committee, 15 credits.
- Math 6960 (Master's project), 3–6 hours.
- Oral examination on the Curriculum Project (Math 6960); this is a "Curriculum Project Defense."

Master of Science in Mathematics Teaching

Candidates interested in Master of Science in Mathematics Teaching in the Department of Mathematics should choose one of the following two tracks:

Track 1: For applicants who are not licensed secondary mathematics teachers but wish to pursue alternate route to licensure (ARL).

Track 2: For applicants who are licensed secondary mathematics teachers.

Track 1 Information

A student may be admitted to the program by the Mathematics Education Committee after making application through the Graduate School and satisfying admission requirements of the Graduate School. Upon admission by the Mathematics Education Committee, the student is also admitted to the Mathematics Department Masters program. The teacher candidates conduct research as part of their course work, investigating content knowledge needed to successfully teach secondary-school mathematics, and doing so in a community of professional teachers who work together on improving mathematics instruction for all students.

Track 1 Prerequisites

- A Bachelors degree in Mathematics (preferred), Mathematics Teaching, or related field, with an equivalent of at least 6 of the courses required by the Utah State Office of Education for Level 4 Mathematics. Those courses are:
  - 2210 Multivariate Calculus
  - 2270 Linear Algebra
  - 2280 Differential Equations
  - 4030 Foundations of Algebra
  - 3100 Foundations of Geometry
  - 3070 Probability and Statistics (above introductory level)
  - 4090 Methods of Teaching Secondary Mathematics
  - 3210 Foundations of Analysis

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

[2] If Math 5010, 5080, 5090 were taken while the student was an undergraduate, they must be replaced by three courses approved by the Committee or the Director of Graduate Studies.

plus one of these:

  - 4400 Number Theory
  - 3010 History of Mathematics
  - 5700 Capstone Course

- Praxis 2 (5161): Math Content Knowledge with a score of at least 165
- Satisfy University requirements for Graduate School admission.

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

Track 2 Information

For applicants who are licensed secondary mathematics teachers. The College of Science of the University of Utah, consisting of the Departments of Biology, Chemistry, Mathematics, and Physics & Astronomy, offers admission to this Master's degree to help practicing teachers acquire a deeper and broader science background. Applicants apply through Continuing Education at the University of Utah (AOCE).

Track 2 Prerequisites

- Licensure with at least a level 3 mathematics endorsement or a valid teaching certificate and currently teaching mathematics or science in a secondary school.
- Praxis 2 (5161): Math Content Knowledge with a score of at least 165.
- At least two years teaching experience as of the beginning date of the MS program.
- Recommendation by a professional educator who can judge the applicant's professional performance performance.
- Satisfy University requirements for Graduate School admission.

Track 1 and 2 Course requirements

The Graduate School at the University of Utah has a list of requirements for the M.S. degree; see the University of Utah General Catalog, http://www.ugs.utah.edu/catalog/. The Graduate School requires a total of 39 semester credit hours for this degree including at least 30 core courses, of which at least 6 credit hours are from discipline-specific mathematics courses at 5000 level or above (any exceptions must be approved by the Graduate Program Coordinator). The M.S. Mathematics Teaching program as currently configured requires 40 credit hours.

- First Summer Semester:
  - Session I: Math 5140 Teaching and Learning Middle School Math
  - Session II: Math 5270 Transformational Geometry
  - Session III: Math 5280 Statistics and Probability
- First Academic Year Autumn Semester:
  - Math 5150 Curriculum and Instruction (High School)
  - Math 5155 Curriculum and Instruction Practicum (Middle and High School)
  - ARL students also take education courses required for licensure
- First Academic Year Spring Semester:
  - Math 5160 Curriculum and Instruction (High School)
  - Math 5165 Curriculum and Instruction Practicum (Middle and High School)
  - ARL students also take education courses required for licensure
- Second Summer Semester:

  - Session I: Math 6100 Concepts of Calculus
  - Session II: Math 6090 Topics in the History of Mathematics
  - Session III: Math 6080 Topics in Contemporary Mathematics
- Interim Exam (before, during, or immediately following 2nd Summer Semester):
  - Prepared oral response to questions
  - Presentation of project plan by student. The plan must be approved by the student's Committee before the project research begins. The student's Committee is composed of at least two members of the Mathematics Department.
- Second Academic Year Autumn Semester:
  - Math 5740 Mathematical Modeling
  - Math 6960 MS project preparation course I
  - ARL students also complete a program of mentored student teaching
- Second Academic Year Spring Semester:
  - Math 5700 Program Capstone Course
  - Math 6960 MS project preparation course II
  - ARL students also complete a program of mentored student teaching
- Masters Project (6 credits): Students conduct research and report on their findings in a Masters project.
- Final Examination: Successful performance on a final oral examination that covers work presented for the Masters degree and defense of the project.

For more information, see http://www.math.utah.edu/mathed/master_mt.html or contact Paula Tooman mailto:tooman@math.utah.edu for administrative information, or Emina Alibegović mailto:emina@math.utah.edu for academic program information.

Master of Science Degree Program for Secondary School Teachers of Science or Mathematics

The College of Science of the University of Utah, consisting of the Departments of Biology, Chemistry, Mathematics, and Physics & Astronomy, 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 Master's program works like this:

- once accepted into the program, a Graduate Committee is appointed for the teacher;
- the 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 that 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 to 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 comprises *six* of the 30 to 33 semester hours required for degree completion.

Because 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 requires that applicants:

- must be accepted by the MSSST Committee;
- must have a valid teaching certificate and be teaching science or mathematics in a secondary school;
- do not need an academic or teaching major in the science subject he or she currently teaches to enter the program;
- must have at least three years teaching experience and be recommended by a professional educator who can judge their performance;
- must satisfy University requirements for Graduate School admission.

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 2015–2016, the Mathematics members of the CES Coordinating Committee are Alexander Balk and Peter Alfeld. The CES program has a Web site at http://www.ces.utah.edu/.

- To apply for admission into the CES program, a student must:
  - have a background in the core areas of Computer Science, Mathematics, Physics & Astronomy, Electrical Engineering, Chemistry, Mechanical Engineering, etc.;
  - complete an application for the CES program, available at http://www.ces.utah.edu/admissions.html#application; and
  - submit the application to the CES Steering Committee.
- The requirements for the CES M.S. Degree are posted at http://www.ces.utah.edu/student_resources.html.
  They include tracks with thesis, with courses, and with a project.

Professional Master of Science and Technology

The Professional Master of Science and Technology (PMST) Program is a professional, non-thesis, interdisciplinary degree program that includes graduate science coursework as well as coursework in business, communication, and management. In addition, PMST students are required to complete an internship with a company, organization, or governmental agency. The program offers four science tracks: Biotechnology, Computational Science, Environmental Science, and Science Instrumentation. For more information, please visit the PMST Program website at http://pmst.utah.edu.

PMST Curriculum

36 credit hours

- Advanced Quantitative Skills (9 credits);
- Transferable Skills (9 credits);
- Internship (3 credits);
- Science Track (15 credits).

Doctor of Philosophy Degree

- **Graduate School Requirements**
  Please visit the Web site http://gradschool.utah.edu/graduate-catalog/degree-requirements for information on the Ph.D. degree requirements.

- **Departmental Requirements**

  - **Supervisory Committee**
    An academic mentor is appointed for each prospective student prior to the first semester of graduate study. An Academic Advisor and a Supervisory Committee is 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 faculty members, 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 Ph.D.'s. One Committee member must be from another department. Because a student's interests may change, the Committee can be changed to reflect those interests.

    The function of the student's Supervisory Committee should be to advise, evaluate, and certify. Specifically:

    * 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*.
    * 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.
    * 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 is conducted.
    * Any special requests regarding financial aid or program of study should be submitted to the student's Advisor.

    For more information, see p. 26.

  - **Course Requirements**

    * Course requirements for the Ph.D. degree 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 graduate student's Supervisory Committee, if it deems it appropriate, may require additional courses and/or require specific courses.
    * Exceptions to the above regulations must be approved on an individual basis by the Graduate Committee upon recommendation by the student's Supervisory Committee.

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

    * **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.

∗ **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.

Students should register for the exams with the Graduate Program Coordinator by the end of May for the August exams, and the end of September for the January exams. In order to pass the written qualifying examinations, a student must pass three tests. Ph.D. students are expected to take 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 must 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 should take two exams by August before the second year, and have passed all three exams by August before their third year. Students whose background is not sufficient to complete the exams on this schedule should discuss their plans with their advisor. After consulting their advisor, students can submit a request to the Graduate Committee to take the exams on a delayed schedule. All such requests will be approved, as long there is a clear plan to complete the exams in a reasonable time period, given the student's background.

The Graduate Committee reviews students' progress towards completing their written exams in January of their second year. Students' renewal-of-support letter for that year must include the date that the Graduate Committee expects the student to complete their written exams (if they have not already done so). Failure to pass at this specified date typically results in termination from the graduate program.

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 from taking the exams until they can adequately prepare.

A student who wishes to remain in the program but has either

- failed a written qualifying exam twice, or
- has not passed the written qualifying exams by the date specified in the most recent renewal of support letter,

may petition the graduate committee for an additional and final attempt if it is done promptly after the student becomes academically deficient. These petitions are not always granted.

This petition must include a letter from the student and a letter from the student's advisor or academic mentor but may include other documentation.

The Graduate Committee will then consider the petition on a case by case basis. Criteria that will be considered include: extenuating circumstances, performance on previous qualifying exams, performance in the class associated with the qualifying exam, and overall academic performance. Regardless of the outcome of the petition, the student will be informed of the Graduate Committee's decision in writing.

∗ **Syllabi**
The syllabi for the qualifying examination are included in this *Graduate Bulletin*. These syllabi are the product of long discussions among the faculty in the various areas, and *do 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 are 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.

∗ **Departmental Committee on the examination**
The Department Chair 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. That person selects two members of the faculty, in each of the various areas of the examination, to participate in the preparation and evaluation of the examinations.

∗ **Description of the tests**
The test in each area is a written test of three hours duration. It is hoped that the inclusion of extra questions reduces the factor of chance, and the student usually has 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.

∗ **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.

∗ **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 his/her tests.

∗ **Appeals**
The Graduate Committee handles all 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 does so through the Supervisory Committee or the Director of Graduate Studies. These faculty members assist the student in taking the necessary actions. A student may also enlist the aid of the *Graduate Student Advisory Committee* (GSAC) to help in the process. The names of the members of GSAC are listed in this *Graduate Bulletin*.

– **Oral Qualifying Examination**
Ph.D. students are required to take an oral qualifying 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. 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 is conducted. Most Mathematics Oral Qualifying Exams have followed one of two plans:

- The student answers questions based on his/her graduate courses. Students taking this type of exam should, in consultation with their Supervisory Committee, prepare a written syllabus of the topics that are covered on the exam. Typically students take the exam within one year of completing their written exams.
- The student makes a presentation of a background topic, or on his/her preliminary research. The student proposes the plan for the rest of the Ph.D. research. The student answers questions based on the presentation/ proposal/graduate courses. Typically students take this exam two years after completing their written exams.

Students should fix a tentative date (for example "Spring Semester 2016") for their oral exam before the Graduate Committee meets to review their progress in January of their third year. The Director of Graduate Studies should be informed if there is a change to this date. Students who do not complete their exams in a timely fashion may receive a warning in their annual renewal-of-support letter. If, after receiving this warning, they do not complete the exam in the specified time, they may be terminated from the graduate program.

– **Foreign Language Requirements**
The Department of Mathematics does not have foreign language requirements for a Ph.D. degree.

– **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.

– **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.

– **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.

- **Graduate School Schedule of Procedures for the Ph.D. Degree**

  The Graduate School has prepared the *Graduation Overview for Doctoral Candidates* for students pursuing a graduate degree, available at the Web site http://gradschool.utah.edu/current_students/graduation-overview-for-doctoral-candidates. Thesis information may be found at http://gradschool.utah.edu/thesis/. See http://gradschool.utah.edu/thesis/handbook/ for *A Handbook for Theses and Dissertations*.

- **Recommended Schedule of Study Toward a Ph.D. Degree**

  The following recommended schedules are considered desirable for Teaching Assistants 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 Assistants 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 assistantships to continue. The following procedure is followed with a request for a review for extenuating circumstances:

  - The student submits a written request to his/her Committee, with a description of the basis of the request.
  - The student's Committee reviews the request and submits a written recommendation to the departmental Graduate Committee.
  - The departmental Graduate Committee makes a final decision regarding the request.

YEAR	ACCOMPLISHMENTS
1	Study three 6000-level courses throughout the year. Try to select an area of specialty and a thesis adviser. 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. Complete the written qualifying examination if a second attempt is necessary. Complete the oral qualifying examination.
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.

- **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 earn a Master's degree along the way should follow the procedures outlined for Recommended Schedule of Study toward a Master's degree with intent to enter the Ph.D. program (see p. 10). 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 *cannot* be double-counted. The coursework allotted for the Master's degree is reported in the Program of Study for the Master's Degree Form. Students should list the minimum number of course credits (30), on their M.S. programs of study forms. The course requirements for the Ph.D. must be satisfied by the remaining courses.

Although the fact that a student supported by a Teaching Assistantship has a limited number of tuition benefit semesters computed using the University's formula is usually not a problem, the *student is responsible* to make sure that tuition benefits cover the total semester hours needed for both the required Master's and Ph.D. coursework. That is another reason why the Department requires students to register for the maximal hours allowed by tuition benefits (usually 12 credits) 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*, http://gradschool.utah.edu/thesis/handbook/, 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. You may request that the thesis office make a preliminary format review. When the completed thesis is submitted, a final release for graduation *must* be obtained from the Thesis Editor.

The Mathematics Department has long maintained LaTeX class and style files that help campus student authors of theses and dissertations to conform to University of Utah requirements. See the Web site http://www.math.utah.edu/pub/uuthesis/.

Here are considerations about 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:

- protect the rights of patent applicants, or
- prevent unjust economic exploitation, or
- protect the privacy of research subjects.

Some possibly useful advice

Authoring a good thesis is much like writing a book: you should expect the effort to take *several months* of work. The task is easier if you already have considerable experience with the TeX and LaTeX typesetting system, and particularly with the many extensions for support of specialized mathematical typesetting. Two recommended books are *LaTeX: a Document Preparation System* plus *The LaTeX Companion*, or, alternatively in one volume, the *Guide to LaTeX*. For mathematical typography, we strongly recommend *Math into LaTeX*. If you are just getting started with LaTeX typesetting, *First steps in LaTeX* is a good starter book that is small enough to read in an evening or two. Your desk should have a good manual of style for writing in the English language, a good English dictionary, and a thesaurus or synonym dictionary. The famous *Chicago Manual of Style* is a widely-used resource for American writing and document-style practices, and there are several other style handbooks listed in the bibliography file at http://www.math.utah.edu/pub/tex/bib/texbook3.html.

Students whose native language is not English may find the writing job particularly challenging, and may need extra help and advice from a native speaker who is skilled in exposition, grammar, and typography. Even for native speakers of English, writing is likely to be hard. It is a good idea for graduate students to share dissertation and thesis proofreading jobs with each other, and to critique each other's writing skills. Good writing is a *craft* that requires extensive practice for almost everyone, and it is one of the most important skills, beyond particular technical knowledge, that you can take forward into a professional career. You should proofread your own work carefully, and consider it your professional duty to hand your Supervisory Committee, and the Thesis Office, a document that is largely free of errors.

The University of Utah Writing Center can assist graduate students who are in need of help with English in preparing dissertations and theses: see http://writingcenter.utah.edu/graduate-services/index.php.

Bibliographic data for your dissertation or thesis are best managed by the BibTeX system, for which there is an extensive online tutorial. References tend to be reused, and BibTeX makes it easy to enter them just *once*, and then get them formatted in any of *hundreds* of styles that may be required by particular journals or publishers. Your research group may already have a collection of BibTeX entries that you can build upon for your own reference lists. There are extensive publication databases in BibTeX format in the Mathematics Department, some of which may be useful to you, particularly if you work in applied or numerical mathematics, or in probability and statistics. Consult departmental computing staff for details, and visit http://www.math.utah.edu/pub/tex/bib.

There are numerous software tools installed on our computer systems that can make your document production and typesetting jobs easier, and the final product much better. Feel free to consult the Mathematics Department computing staff for advice, assistance, and guidance in preparing your bibliographies, dissertation, or thesis. You should definitely *not* use word-processor software to prepare a dissertation or thesis in mathematics; the results are very likely to be *completely unacceptable* to the mathematics community, and to mathematics publishers.

Department Preparation of Theses, Dissertations and Abstracts

Student theses, dissertations and abstracts that 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 non-thesis publications, mathematical reviews and similar publications may 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 Assistants as warranted by the individual student's progress and budgetary limitations. Continued financial support during the period stated in your offer letter is contingent on your satisfactory performance toward your degree and satisfactory performance in your teaching duties. This policy covers some specific situations, but the Department reserves the option of flexible interpretation and redefinition of policy.

Responsible and capable teaching performance is essential for continuation. Incompetent teachers are not supported, and cases of conspicuous irresponsibility or neglect cause immediate termination.

Besides teaching competence, progress toward a degree is the principal requirement for continued support. Each Teaching Assistant 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. **There is a withdrawal penalty if a student's registration fall under the minimum requirement of nine credit hours, or if a student withdraws late from a course.**

All graduate 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://gradschool.utah.edu/tbp/tuition-benefit-program-guidelines). **Students adding and/or dropping courses after the published University deadline(s) are 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 is billed for the full tuition for that semester. All international students must pay a fee of $75 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

- 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.
- Teaching Assistants are supported for at most two years in the Master's degree program. The University limit is *four* semesters of tuition benefit support for Master's students. 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 is 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. 19. Supported and unsupported Master's students who apply for teaching assistantships 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 Assistants in the Ph.D. Degree Program

- For Teaching Assistants 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.
- For Teaching Assistants 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 in the table on p. 19. 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.
- Although the official time limit for a Ph.D degree is *seven* years (see p. 18, #8), the Department expects students to finish their Ph.D. requirements in at most *five* years. *Six* years may be allowed if there are special circumstances, and *seven* years only if there exist extraordinary reasons. Support for TAs is expected to continue for at most *five* years (*three* years if the student enters with a Master's degree). Any additional support is 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 petition for an additional year (*two* semesters) of tuition waiver. Please check the Graduate School Web site for current information.
- 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 in the table on p. 19.

Special Remarks to Graduate Students

- Take your teaching duties seriously and give attention to your obligations to the Department and to your students.
- 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 are critical for your development of a research thesis. In reality, your study of mathematics needs to be the dominant feature of your life and as such, **no outside employment is allowed for TAs**.
- In addition to classes, seminars, and GSAC colloquia organized by students, 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/her 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.

- Because mathematics is the foundation of several other fields of study, including economics, engineering, and science, and your career is likely to require interactions with people in other fields of academia, government, and industry, it is a good idea to broaden your exposure beyond the narrow focus of your graduate-research topic. Consider making it a practice to attend seminars and colloquia in other campus departments, and learn about the history, and pioneers, of your field of research. Both will enrich and expand your knowledge, and your future career opportunities. Most employers are unlikely to be interested in your particular research area; what is *much more important* for them is that you are a person who can solve difficult problems using your analytical skills and thought processes, and possibly also, your ability to program computers. If you can clearly present your ideas, and argue for your point of view, verbally, and in writing, you are then a valued asset for your employer.

Termination of Graduate Students

Students have the right to complete their academic program if they are in good academic standing as described in this *Graduate Bulletin*. Students, however, do *not* have the legal right to support as a teaching assistant. If a promise is made for one year of funding, then the Department has *no* obligation for further funding. At the beginning of Spring Semester, all graduate students are evaluated by the Graduate Committee on the progress in their study toward a 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.

- If the graduate student fails to maintain his/her academic standing, such as by failing qualifying exams, then he/she is terminated from the program. Appeals for termination decisions should be made promptly in writing to the Graduate Committee. For example, if a student has failed his/her qualifying exams, the Graduate Committee may hear a petition that a student be allowed to retake a qualifying exam.
- University Policy 6-309 regulates the procedure of hiring and firing of Teaching Assistants, among other academic staff, in cases of neglect of duties. The Course Coordinator and the Associate Chair are supervisors of teaching assistants as employees of the University. They periodically evaluate teaching assistants' job performance, notify them of any deficiencies, and monitor improvement in job fulfillment. The Graduate Committee decides continuation of Teaching Assistantships, or termination from the program, based on reported teaching performances. Notifications of renewals or nonrenewals are distributed by April 15. Appeals of termination decisions must be made first in writing to the Graduate Committee.

Supervisory Committees

Each graduate student *shall* 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 members 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 certify that the work meets degree standards.

The student's mentor is initially appointed by the Director of Graduate Studies prior to the student's entrance into the program. The student will choose an Advisor and 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 consists of *three* members of the faculty; Committees for Ph.D. degree candidates are expanded later 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.

- The Committee Chair (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, the requested person is normally appointed.
- 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. The Ph.D. Committee shall consist of *five* faculty members, at least *three* must be regular faculty in the Department of Mathematics and at least *one* must be from another department.
- If the student's interests change, the Committee makeup is modified appropriately by the Director of Graduate Studies, after consulting the student and Committee.
- The function of the Advisor and the Supervisory Committee should be:
  - Advise the student regarding a program of study.
  - Evaluate the student's progress in his/her program of study.
  - Review any requests for changes or waivers in the usual requirements.
- 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 year.
- 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 that explicitly or implicitly ask for a deviation from Graduate School policy must be reviewed by the Dean of the Graduate School.

The Supervisory Committee *sets its own ground rules* about how it will conduct preliminary and final oral exams for both Master's and Ph.D. students. It is the responsibility of the student to arrange with the Committee the scope of questions and how the exam is conducted.

Computing Facilities

The Department provides outstanding computing facilities for use by faculty, students, staff, research associates, and invited guests. In mid-2015, the fully-Internetworked workstation and microcomputer configuration included about 400 systems in a range of models from these architectures:

- Apple Macintosh (47);
- IBM x3550 (2 CPUs, 6 cores/CPU, 24GB DRAM) (2);
- IBM x3755 (4 CPUs, 8 cores/CPU, 128GB DRAM) (3);
- IBM x3750 M4 (8 CPUs, 8 cores/CPU, 128GB DRAM) (4);
- IBM x3750 M4 (4 CPUs, 8 cores/CPU, 128GB RAM) (2);
- IBM x3950 (8 CPUs, 8 cores/CPU, 1024GB DRAM) (1);
- Intel IA-64 Itanium (1);
- Intel x86 Pentium and AMD Athlon (2);
- Oracle Sun X4470 (four 8-core 16-thread Xeon CPUs, 256GB DRAM) primary fileserver (1);
- Silicon Graphics (1);
- Sun AMD64 Opteron and Intel Xeon (26);
- Sun Ray thin-client stations (289);
- Sun SPARC workstations and servers (12);
- Sun Ultra 24 x86-64 workstations (3);
- Sun X4500 (two dual-core Opteron CPUs, 16GB DRAM) secondary fileserver (1);
- Virtual machine pool (six hosts, 18 CPUs, 108 cores, about 50 flavors of Unix).

Those systems include at least one fileserver from each UNIX architecture.

Operating systems

Operating systems and CPU types include DragonflyBSD (x86-64), FreeBSD (x86 and x86-64), GNU/Hurd (x86), GNU/Linux (IA-64, MIPS, SPARC, x86, and x86-64, with distributions from ArchLinux, CentOS, Debian, Fedora, Gentoo, openSUSE, Scientific Linux, Slackware, and Ubuntu), IRIX (MIPS), kFreeBSD (x86-64), MacOS (PowerPC and x86-64), Minix (x86), MirBSD (x86), NetBSD (x86), OpenBSD (x86 and x86-64), Solaris (SPARC, x86, and x86-64), and Windows 7 (x86-64).

That great variety of computing environments provides an outstanding laboratory test bed for software development and portability testing. Most of our users work in either GNU/Linux x86-64 or Mac OS/X x86-64 desktop environments. Access to any of the others is available on request, but may sometimes require the help of Mathematics Department computing staff to create and enable suitable login access.

Fileservers

The 32-core primary fileserver provides 44TB 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. Storage was increased to 58TB during summer 2013.

The 4-core secondary fileserver provides 24TB of storage that is used for batch-job scratch space (*not* backed up to tape), and for storage of older filesystem snapshots from the primary server.

Network services

E-mail, FTP, and Web services are each provided by separate operating-system zones on the primary fileserver. Print services run on an independent multi-homed virtual machine.

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

Thin-client stations

Sun Ray thin-client services on the Solaris SPARC architecture are provided by two 16-core Sun T5240 systems, and on the GNU/Linux x86-64 architecture by six IBM X3750 M4 32- and 64-core servers.

Since the late 1990s, most users of the Department of Mathematics computing facilities have thin-client desktops, reducing heat and desk space, and eliminating workstation noise. The Department enjoys greater computing security and ease of administration, because thin clients cannot be used to attack the network or servers, and because thin-client stations have no local disks to back up. Users gain access to many more CPU and DRAM resources than would otherwise be affordable with desktop computers, and in the rare cases where their current server fails, they can immediately resume work on another server. Users can choose either a Solaris or a GNU/Linux desktop environment by selecting an appropriate server at login time. Finally, when machine-room servers are upgraded, *all* thin-client users enjoy immediate benefits of enhanced performance.

Instructors may wish to exploit the ability to tie a thin-client session to a smart card, so that they can setup a convenient computing desktop environment in their offices, detach the session by removing the smart card, and reattach to the same session in the classroom by inserting the smart card there. After class, they can move the smart card, and their session, back to their office workstation.

Home directories

Each user normally 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.

Computers in classrooms

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

Laboratory access policies

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

Printing facilities

There are more than 40 distributed laser printers, including ten Xerox 6280 and 6360 color laser printers, an HP LaserJet 3700dn color laser printer, and four high-volume duplex laser printers in the student laboratories. In addition, there are five Xerox WorkCentre 7545 color digital copier/printer/scanner systems (45 pages/minute), a Xerox WorkCentre 7346 color digital copier/printer/scanner system (50 pages/minute), and a Xerox ColorQube 9303 digital copier/printer/scanner (90 pages/minute).

Network hardware summary

The Mathematics Department computing 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 building wired network connections provide 10 Mb/s, 100 Mb/s, and 1 Gb/s secure connections, and all offices have at least four network ports. The University of Utah campus Internet connections was expanded to several independent 10 Gb/s uplinks in 2013–2014.

In summer 2013, the internal Mathematics backbone was upgraded to support 10 Gb/s connections between servers and network switches. In fall 2015, the departmental uplink to the campus backbone was upgraded to 10 Gb/s.

All buildings, and adjacent outdoor areas, have wireless network access, managed externally by *University Information Technology* (UIT) staff; visit http://wireless.utah.edu/ for details.

Reliability, backups, and snapshots

All servers are located in a central machine room with its own cooling system and emergency power system with a battery-based Uninterruptible Power Supply (UPS), plus an outside diesel-fueled electrical generator as a failover system when batteries are exhausted. Network hubs share the same reliable power system.

Daily ZFS filesystem snapshots on the Sun Solaris fileserver provide users with immediate online access to their data from the last several days, as described in the *Files* FAQ at http://www.math.utah.edu/faq/files/. All filesystems are backed up nightly to tapes covering the last few months. The tape server holds up to 500 tapes, each of 800GB (LTO-4) or 3200GB (LTO-6) raw capacity, and is shared with other departments in the College of Science. During summer 2013, the tape server was upgraded with two new LTO-6 drives, *quadrupling* tape backup capacity, and helping to reduce backup times.

Off-campus access

All physical computer systems are reachable from anywhere on the global Internet, including home systems with DSL or cable modem Internet connections. All virtual machines require local access through a gateway machine.

Batch computing

Batch computing services are provided by a dual-processor Itanium-2 server, three 4-CPU AMD64 servers, a Sun Blade 8000 server with eight 2-CPU 8-core AMD64 blades (restricted to Mathematical Biology group members) and two 4-CPU 16-core Xeon blades (accessible to all departmental users), and the terabyte-memory IBM 3950 64-core server.

Campus large-scale computing resources

Research projects can apply for additional computer resources at the *Center for High-Performance Computing* (CHPC) on several clusters (800+ nodes, 7000+ cores, and 48 GPUs) with Infiniband and Gigabit Ethernet interconnects. Visit the CHPC Web site, http://www.chpc.utah.edu/, for further details.

CHPC staff are housed in the INSCC building directly to the east of the Mathematics Department, but most of the CHPC computing resources are in data centers elsewhere in the city.

CHPC staffers frequently offer one-hour tutorials on use of CHPC resources and software; if the presentations are of possible interest to you, visit their news site, and/or subscribe to the chpc-hpc-users e-mail announcement list.

Web resources

For more information about the Department and its activities and facilities, visit its Web site, its personnel directory, and its frequently-asked questions (FAQ) repository that provides much more detail about our computing facilities.

The Graduate Student Advisory Committee (GSAC)

The Graduate Student Advisory Committee exists for the following reasons:

- To advise new and continuing graduate students concerning curricula, requirements for degrees and other aspects of the graduate program.
- To make recommendations to the Department concerning promotion, tenure, and retention of faculty members.
- To participate in the allocation of ASUU funds supplied to the College of Science Student Council.
- To make whatever recommendations it feels appropriate concerning the graduate program to the Department of Mathematics.
- To assist the Department in making its policies and requirements fully understood by graduate students.

The Committee shall consist of a number of members, elected in the spring of each year by the mathematics graduate students. For the school year 2015–2016, the members are:

- *GSAC Co-Chairs*: Sean McAfee, Jenna Noll;
- *GSAC Retention Promotion and Tenure Committee*: Adam Brown, Chris Miles, Todd Reeb, Laura Strube, Shiang Tang;
- *GSAC Colloquium*: Anna Romanova;
- *GSNACS (refreshments)*: Sean McAfee, Huy Dinh, Katie Link, Anna Nelson;
- *GSAC Recruitment Committee*: Heather Brooks, James Farre, Nick Cahill, Erin Lineberger, Shiang Tang;
- *Fun and Friendship (social outreach)*: Katie Link, Huy Dinh;
- *Web page maintenance*: Kyle Steffen;
- *Intramural Sports (social outreach)*: James Gossell, Derrick Wigglesworth.

Student representatives and contact people from various disciplines:

- *Algebraic Geometry*: Thomas Goller;
- *Applied Mathematics/PDE*: Kyle Steffen;
- *Commutative Algebra*: Daniel Smolkin;
- *International Students*: Franco Rota;
- *Mathematical Biology*: Chris Miles;
- *Probability/Statistics*: Tony Lam, Jenny Kenkel;
- *Representation Theory*: Adam Brown;
- *Topology/Geometric Group Theory*: Nick Cahill.

Syllabi for Qualifying Examinations

Algebra

Topics: Math 6310, Modern Algebra I

- **Group theory**: subgroups, normal subgroups, quotient groups, homomorphisms, isomorphism theorems, groups acting on sets, orbits, stabilizers, orbit decomposition formula, Lagrange's Theorem, Cayley's Theorem, Sylow Theorems, permutation groups, symmetric and alternating groups, simple groups, classification of groups of small order, simplicity of the alternating group on at least 5 letters, direct products and semi-direct products of groups, exact and split exact sequences, commutator subgroups, solvable groups, solvability of p-groups, classical matrix groups, automorphism groups, Jordan–Holder theorem, free groups, presentations of groups.
- **Module theory**: free modules, submodules, quotient modules, tensor symmetric and exterior products of modules, projective and injective modules, exact sequences, complexes, homology, connecting homomorphisms, Tor and Ext functors.
- **Rings**: ideals, quotient rings, groups rings, matrix rings, division rings, commutative rings, prime and maximal ideals, group of units, principal ideal domains, unique factorization domains, structure theorem for modules over a principal ideal domain and its applications to abelian groups and to linear algebra, rational and Jordan forms, eigenvectors, eigenvalues, minimal and characteristic polynomials, Cayley–Hamilton Theorem.

Topics: Math 6320, Modern Algebra II

- **Fields**: finite and algebraic extensions, degrees, roots, straight edge and compass constructions, splitting fields, algebraic closure, finite fields, derivatives of polynomials and multiple roots, separable and normal extensions, primitive elements, Galois groups, fundamental theorem of Galois theory, solvability by radicals, cyclotomic polynomials, constructible regular polygons, transcendental extensions.
- **Rings revisited**: polynomial rings, Gauss' Lemma, Eisenstein's criterion, localization and field of fractions, noetherian rings, Hilbert's Basis Theorem, integral extensions, algebraic sets, Hilbert's Nullstellensatz.
- **Optional topics**: There is typically time remaining to cover a number of topics such as the following; however, since this is at the discretion of the Instructor, the qualifying exam should avoid questions based on these.
  - bilinear forms, quadratic forms and signature, symmetric bilinear forms, alternate forms, orthogonal geometry, Witt's Cancellation theorem,
  - semisimple rings, finite-dimensional algebras, Jacobson radical, Jacobson Density Theorem, Artin–Wedderburn Theorem,
  - graded rings, Hilbert functions, Krull dimension,
  - representations of finite groups, complete reducibility, Maschke's theorem, characters, orthogonality relations, character tables, representations of S_n.

Texts

- N. Jacobson, *Basic Algebra II*, Second edition, Dover (2009) [ISBN 0-486-47187-X, 978-0-486-47187-7].
- D. S. Dummit and R. M. Foote, *Abstract Algebra*, Third edition, Wiley (2004) [ISBN 0-471-43334-9, 978-0-471-43334-7].
- S. Lang, *Algebra*, Third edition, Springer (2002) [ISBN 0-387-95385-X, 978-0-387-95385-4].

Applied Mathematics

Topics

- Introduction to function spaces: metric spaces: convergence, completeness; continuity of functions; separability; contraction mapping principle; vector spaces; Banach spaces; compactness; L^p spaces (without measure theory).
- Linear operators: linear operators; bounded linear operators; linear functionals; dual spaces; compact operators; mention Hahn–Banach Theorem and consequences; weak and weak* convergence; reflexive spaces; Fredholm alternative.
- Hilbert spaces: Inner product spaces; orthogonal projections; orthonormal sets; linear functionals and bilinear forms; Riesz representation theorem; Lax–Milgram theorem; adjoint operators; Fredholm alternative in Hilbert spaces.
- Spectral theory: resolvent and spectrum; basic results for bounded linear operators; spectral properties of compact operators; bounded self-adjoint operators; spectral theorem for compact self-adjoint operators; more general spectral representations.
- Distributions: spaces of test functions; definition of distributions; operations on distributions; Fourier transform and tempered distributions.
- 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.

Texts

- E. Kreyszig, *Introductory Functional Analysis with Applications*, Wiley (1989) [ISBN 0-471-50459-9, 978-0-471-50459-7]. [Typically used for Math 6710.]
- F. G. Friedlander and M. S. Joshi, *Introduction to the Theory of Distributions*, Second edition, Cambridge (1998) [ISBN 0-521-64971-4, 978-0-521-64971-1]. [Optional supplement.]
- J. P. Keener, *Principles of Applied Mathematics: Transformation and Approximation*, Addison Wesley (1988) [ISBN 0-201-15674-1, 978-0-201-15674-4]. [Typically used for Math 6720. Parts may also be used as a supplemental reference for Math 6710.]

Ordinary and Partial Differential Equations

ODE Topics

- **Initial value problems**: Fixed-point theorems; Basic existence and uniqueness; Dependence on initial conditions.
- **Linear equations**: The matrix exponential; Linear autonomous systems; General linear systems; Periodic linear systems and Floquet theory.
- **Boundary value problems**: Sturm–Liouville problems; Compact symmetric operators; Green's functions; Integral equations; Rayleigh–Ritz method.
- **Dynamical systems theory**: Flows, orbits and invariant sets; Definitions of stability; Planar dynamics and Poincaré–Bendixson; Hamiltonian mechanics; Stable and unstable manifolds; Hartman–Grobman theorem; Method of averaging.
- **Perturbation methods**: Regular perturbation theory, nonlinear oscillations; Poincaré–Linstedt; Singular perturbation theory, method of multiple scales; Boundary layers; WKB methods.

ODE Texts

- G. Teschl, *Ordinary differential equations and dynamical systems*, AMS (2012) [ISBN 0-8218-8328-3, 978-0-8218-8328-0].
- J. David, *Applied Mathematics*, Fourth edition, Wiley–Interscience (2013) [ISBN 0-471-74662-2, 978-0-471-74662-1].

PDE Topics

- **Scalar conservation laws and first-order equations**: Linear transport equation and conservation laws; Traffic dynamics; Weak solutions and shock waves; Method of characteristics for quasilinear equations; General first-order equations.
- **Waves and vibrations**: General concepts eg. types of waves, group velocity, dispersion relations; One-dimensional wave equation, waves on a string; The D'Alembert formula and characteristics; Classification of second-order linear equations; Multi-dimensional wave equation, the Cauchy problem.
- **Diffusion**: The one-dimensional diffusion equation; Uniqueness: integral methods and maximum principles; Fundamental solution and the global Cauchy problem; Random walks; Global Cauchy problem, maximum principles; Some nonlinear problems: traveling waves.
- **The Laplace equation**: Harmonic functions, mean value theorems, maximum principles; Fundamental solution and the global Cauchy problem; Green's functions; Potential theory.
- **Variational formulation of elliptic problems**: Linear operators and duality; Lax–Milgram theorem and minimization of bilinear forms; Galerkin method; Variational formulation of Poisson's equation in 1D; Variational formulation of Poisson's equation in higher dimensions.

PDE Texts

- S. Salsa, *Partial differential equations in action: from modelling to theory*, Springer (2007) [ISBN 88-470-0751-8, 978-88-470-0751-2].

Geometry and Topology

Geometry and Topology Topics

- Definition of a manifold via charts, submanifolds,
- Inverse function theorem (recalled from real analysis), immersions, submersions, (local) diffeomorphisms, local immersion and submersion theorems, regular values and transversality, preimage theorem, basic examples of manifolds: R^n, S^n, T^n, RP^n, CP^n, Stiefel manifolds, Grassmannians, the notion of Lie groups and basic examples, e.g., $\mathrm{GL}_n(R)$, $\mathrm{SL}_n(R)$, $\mathrm{SO}(n)$, $\mathrm{SL}_n(C)$, $\mathrm{SO}(p,q)$, etc.
- Tangent space, vector bundles, tangent and normal bundle, stability of immersions, submersions, etc.
- Partitions of unity and applications: approximating continuous maps by smooth maps, existence of a Riemannian metric.
- Sard's theorem (proof not required), transversality theorem, Morse functions (existence, stability).
- Manifolds with boundary, classification of 1-manifolds (e.g., using Morse functions), Brouwer's fixed point theorem (also for continuous maps using approximations).
- Normal bundle, tubular neighborhood theorem, Whitney embedding theorem.
- Intersection theory $\mathrm{mod}\,2$, Jordan–Brouwer.

- Orientations, RP^n orientable iff n odd, intersection theory, winding number, degree (e.g., degree and fixed points on spheres), Lefschetz fixed point theorem, vector fields, Poincaré–Hopf, Euler characteristic.
- Differential forms, exterior derivative, pullbacks, closed and exact forms, wedge product, integration, Stokes, Poincaré lemma, de Rham cohomology, degree formula, Gauss–Bonnet.
- Integral curves, flow, Lie bracket, Lie derivative, Lie algebra of a Lie group, exponential map on a Lie algebra (compute basic examples), foliations, examples of nonintegrable plane fields, Frobenius theorem and applications to Lie groups.

Geometry and Topology Texts

- V. Guillemin and A. Pollack, *Differential Topology*, Prentice-Hall (1974) [ISBN 0-13-212605-2, 978-0-13-212605-2].
- M. Spivak, *A Comprehensive Introduction to Differential Geometry*, Third edition, Publish or Perish (1999) [ISBN 0-914098-70-5, 978-0-914098-70-6].
- J. M. Lee, *Introduction to Smooth Manifolds*, Second edition, Springer (2013) [ISBN 1-4419-9981-7, 978-1-4419-9981-8].

Algebraic Topology Topics

Chapters and page numbers refer to Hatcher's book.

- Ch 0: Basic notions of homotopy, deformation retraction, adjunction spaces, cell complexes (see also appendix), cell complex structures on standard spaces: Sn, CP^n, RP^n, T^n, graphs, surfaces. $\mathrm{SL}_n(R)$ deformation retracts to $\mathrm{SO}(n)$.
- Ch 1: free products of groups and amalgams, fundamental group, van Kampen, computing 1 of cell complexes and standard spaces, covering spaces, lifting properties, deck group, Galois correspondence, free properly discontinuous actions, Lie groups have abelian 1, covering space of a Lie group is a Lie group, $\mathrm{SO}(2) = S^1$, $\mathrm{SO}(3) = \mathrm{RP}^3$, $\mathrm{SL}_2(R)$.
- Ch 2: and simplicial complexes, simplicial homology, singular homology, basic properties (homotopy invariance, long exact sequences, Mayer–Vietoris, excision), degree via homology, computation of homology for cell complexes, homology with coefficients, Euler characteristic, Brower's fixed point theorem, invariance of domain, $H-1$ = 1ab.
- Ch 3: Cohomology, universal coefficient theorem, cup and cap products, cohomology ring, computation for standard spaces, use to prove Borsuk–Ulam and e.g., to see that S_2, S_4 and CP are not homotopy equivalent, orientability, fundamental class and Poincaré duality statement. Lefschetz and Alexander duality.
- (p. 218–221) Method for showing two homology theories are equivalent. Illustrate on a subset of the following:
  - equivalence of singular and simplicial homology (p. 128–130);
  - de Rham theorem (this is in Lee's book);
  - Künneth formula (p. 218–221);
  - Poincaré duality in de Rham cohomology, i.e., $H_i(M)Hc_n - i(M)R$ induced by M is nondegenerate, say for M with finite good cover (see Spivak, Ch 11).

Algebraic Topology Texts

- A. Hatcher, *Algebraic Topology*, Cambridge University Press (2002) [ISBN 0-521-79160-X (hardcover), 0-521-79540-0 (paperback), 978-0-521-79160-1 (hardcover), 978-0-521-79540-1 (paperback)].

Numerical Analysis

Topics

- **Numerical linear algebra**: Direct and iterative methods for linear system of equations; Error analysis; Methods for finding eigenvalues and eigenvectors; LU, QR, Cholesky, Singular value decomposition; Least squares.
- **Interpolation and approximation**: Polynomial, rational, Fourier series; Spline based methods for interpolation and approximation; Quadrature; Orthogonal polynomials.
- **Solution of nonlinear equations and optimization**: Contraction mapping principle; Newton's method, Quasi-Newton methods; Conjugate gradient method, Steepest descent method; Linear programming; Constrained optimization.
- **Numerical solutions of differential equations**: Runge–Kutta methods, Linear multi-step methods for initial value problems; Shooting methods for boundary value problems; Finite differences and finite elements for boundary value problems; Finite difference and finite element methods for simple PDEs.

Texts

- E. W. Cheney, *Introduction to Approximation Theory*, Second edition, McGraw-Hill (1998) [ISBN 0-8218-1374-9, 978-0-8218-1374-4].
- 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*, Second edition, Johns Hopkins University Press (1989) [ISBN 0-8018-3772-3 (hardcover), 0-8018-3739-1 (paperback), 978-0-8018-3772-2 (hardcover), 978-0-8018-3739-5 (paperback)].
- 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].
- A. Quarteroni, R. Sacco, and F. Saleri, *Numerical mathematics*, Springer (2000) [ISBN 0-387-98959-5, 978-0-387-98959-4].
- D. R. Kincaid and E. W. Cheney, *Numerical analysis: mathematics of scientific computing*, Third edition, AMS (2009) [ISBN 0-8218-4788-0, 978-0-8218-4788-6].
- L. N. Trefethen and D. Bau, III, *Numerical Linear Algebra*, SIAM (1997) [ISBN 0-89871-361-7, 978-0-89871-361-9].
- L.N. Trefethen, *Approximation Theory and Approximation Practice*, SIAM (2013) [ISBN 1-61197-239-6, 978-161-197-2-39-9].

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*, Third edition, Wiley (1995) [ISBN 0-471-00710-2, 978-0-471-00710-4].
- R. Durrett, *Probability: Theory and Examples*, Second edition, 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**: Measure spaces, measurable functions and positive measures, integration, convergence, construction of Lebesgue measure, properties of Lebesgue measure. Riesz representation theorem. Jensen's Theorem, Hölder's inequality, Minkowski inequality, L^p spaces are complete. Fubini's Theorem. Complex measures, Radon–Nikodym theorem. Vitali covering theorem, Lebesgue density theorem and Lebesgue differentiation theorem. Fourier transform and properties, Inversion theorem, Parseval's theorem, Plancherel's Theorem.
- **Functional analysis**:
  Hilbert space, Cauchy–Schwartz, parallelogram law, continuous linear functionals. Banach–Steinhaus, Open mapping theorem, closed graph theorem, Hahn–Banach theorem. Linear functionals on L^p, $p < \infty$. Weak topology.
- **Complex analysis**: Holomorphic functions, Cauchy–Riemann equations, Cauchy's Theorem, Cauchy's integral formula, Maximum principle, Taylor series for holomorphic functions, Liouville's theorem, Runge's Theorem. Normal families, isolated singularities, Laurent series, residue theorem, applications to compute definite integrals. Rouche's Theorem, Maximum principle. Conformal mappings, examples, Schwartz lemma, isometries of the hyperbolic plane, Montel's theorem, Riemann mapping theorem. Infinite products, Weirstrass factorization theorem. Analytic continuation, monodromy. Elliptic functions. Picard's theorem.

Texts

- W. Rudin, *Real and Complex Analysis*, Third edition, McGraw-Hill (1987) [ISBN 0-07-054234-1, 978-0-07-054234-1].
- F. Jones, *Lebesgue integration on Euclidean spaces*, Revised edition, Jones and Bartlett (2001) [ISBN 0-7637-1708-8, 978-0-7637-1708-7].
- C. C. Pugh, *Real Mathematical Analysis*, Second edition, Springer (2015) [ISBN 3-319-17770-2, 978-3-319-17770-0].
- H. Royden and P. Fitzpatrick, *Real Analysis*, Fourth edition, Prentice Hall (2010) [ISBN 0-13-511355-5, 978-0-13-511355-4].
- J. B. Conway, *A course in functional analysis*, Second edition, Springer (2010) [ISBN 1-4419-3092-2, 978-1-4419-3092-7].
- Y. Katznelson, *An introduction to harmonic analysis*, Third edition, Cambridge University Press (2004) [ISBN 0-521-54359-2, 978-0-521-54359-0].

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*, Second edition, 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*, Second edition, 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 staff or texts, and so on.

5010	**Introduction to Probability** (Fall, Spring, Summer Semesters)
Instructors:	J. Sainath, S. Lawley, F. Rassoul-Agha, A. Krishnan
Text:	S. Ross, *A First Course in Probability*, Ninth edition, Prentice-Hall (2012) [ISBN 0-321-79477-X, 978-0-321-79477-2], plus instructional notes by D. Khoshnevisan and F. Rassoul-Agha
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 Semesters)
Instructor:	F. Rassoul-Agha
Text:	G. F. Lawler, *Introduction to Stochastic Processes*, Chapman and Hall/CRC (2006) [ISBN 1-58488-651-X, 978-1-58488-651-8]
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 Semesters)
Instructors:	T. Alberts, S. Ethier, & R. Reeder,
Text:	L. J. Bain and M. Engelhardt, *Introduction to Probability and Mathematical Statistics*, Second edition, Duxbury (2000) [ISBN 0-534-38020-4, 978-0-534-38020-5]
Meets with:	**6824**, coursenumber6828
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 Semesters)
Instructors:	O. Lewis & staff
Texts:	Recommended: L. Edelstein-Keshet, *Mathematical Models in Biology (SIAM Classics in Applied Mathematics **46**)*, 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, *A Course in Mathematical Biology: Quantitative Modeling with Mathematical and Computational Methods (SIAM Mathematical Modeling and Computation **12**)*, 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 that 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:	H. Hecht
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 Semesters)
Instructor:	S. Patrikis & M. Bestvina
Text:	M. Artin, *Algebra*, Prentice Hall (1991) [ISBN 0-13-004763-5, 978-0-13-004763-2]
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 polynomials 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:	K. Schwede
Text:	W. Trappe and L. Washington, *Introduction to Cryptography with Coding Theory*, Second edition, Pearson (2005) [ISBN 0-13-186239-1, 978-0-13-186239-5]
Prerequisites:	Math 4400 and 5310
Topics:	Classic and modern methods of encryption, applications to public-key ciphers (RSA, ElGamal, etc.), random number generators, attacks on encryption systems, error correcting codes; computational number theory. A project/paper is required.

5410	**Introduction to Ordinary Differential Equations** (Fall Semester)
Instructor:	D. Harutyunyan
Texts:	M. Hirsch, S. Smale, R. Devaney, *Differential Equations, Dynamical Systems and an Introduction to Chaos*, Third edition, Academic Press (2013) [ISBN 0-123-82010-3, 978-0-123-82010-5] S. Ahmad and A. Ambrosetti, *A Textbook on Ordinary Differential Equations*, Springer (2014) [ISBN 3-319-02128-1, 978-3-319-02128-7]
Meets with:	**6840**
Prerequisites:	Math 2220 and 3310; 2250; or instructor's consent.
Topics:	Applications of systems to mechanics, biology, circuits, astrophysics, chemistry, meteorology. Linear systems, matrix exponential, phase plane analysis, existence, uniqueness, continuous dependence, stability and bifurcation of rest points, periodic orbits, chaos.

5440	**Introduction to Partial Differential Equations** (Fall Semester)
Instructor:	M. Cassier
Text:	J. D. Logan, *Applied Partial Differential Equations*, Third edition, Springer (2015) [ISBN 3-319-12492-7, 978-3-319-12492-6]
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. Treibergs
Text:	S. H. Strogatz, *Nonlinear Dynamics and Chaos: with Applications to Physics, Biology, Chemistry, and Engineering*, Second edition, Westview Press (2015) [ISBN 0-8133-4910-9, 978-0-8133-4910-7]
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.

5510	**Introduction to Topology** (Fall Semester)
Instructor:	K. Bromberg
Text:	J. R. Munkres, *Topology*, Second edition, Prentice Hall (2000) [ISBN 0-13-181629-2, 978-0-13-181629-9]
Prerequisites:	Math 3220
Topics:	Introduction to metric spaces, Lipschitz maps, isometries, group of isometries of the Euclidean plane, surfaces as metric spaces, geodesics, topological spaces, continuity, compactness, connectedness, identification spaces.

5520	**Introduction to Algebraic/Geometric Topology** (Spring Semester)
Instructor:	D. Studenmund
Text:	W. S. Massey, *Algebraic Topology: an Introduction*, Springer (1991) [ISBN 3-540-90271-6, 978-3-540-90271-3]
Prerequisites:	Math 4510 and 5310
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 Semesters)
Instructor:	P. Alfeld & V. Shankar
Text:	no textbook
Meets with:	**6610**, **6865**
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.

5710	**Introduction to Applied Mathematics I, II** (Fall Semester)
Instructor:	A. Balk
Text:	G. Strang, *Introduction to Applied Mathematics*, Wellesley-Cambridge Press (1986) [ISBN 0-9614088-0-4, 978-0-9614088-0-0]
Prerequisites:	Math 2250, 3150, 3160, 5710
Topics:	(**57100**) Symmetric linear systems, positive definite matrices, eigenvalue problems, equilibrium equations for discrete and continuous systems, boundary value problems in ODEs and PDEs, boundary integrals.
	(**5720**) Fourier methods, initial value problems in ODEs and PDEs, conservation laws, network flows and combinatorics, optimization.

5740	**Mathematical Modeling** (Spring Semester)
Instructor:	C. Hohenegger
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.

5750-001	**Topics in Applied Mathematics: Mathematics and Climate** (Spring Semester)
Instructor:	K. Golden
Text:	No textbook
Meets with:	**6880-002**
Prerequisites:	Math 2270 or instructor's permission
Topics:	Impartial Combinatorial Games (Take-Away Games, The Game of Nim, Graph Games, Sums of Combinatorial Games), Two-Person Zero-Sum Games (The Strategic Form of a Game, Matrix Games, Domination, The Principle of Indifference, Solving Finite Games, The Extensive Form of a Game), Two-Person General-Sum Games (Bimatrix Games – Safety Levels, Noncooperative Games – Equilibria, Models of Duopoly, Cooperative Games), and Games in Coalitional Form (Many-Person TU Games, Imputations and the Core, The Shapley Value, The Nucleolus).

5760, **5765**	**Introduction to Mathematical Finance I, II** (Fall, Spring Semesters)
Instructor:	J. Zhu
Text:	G. Campolieti and R. N. Makarov, *Financial Mathematics: a Comprehensive Treatment*, CRC Press (2014) [ISBN 1-4398-9242-3, 978-1-4398-9242-8]
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: L. Horváth

Texts: 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 (2002) [ISBN 0-13-044941-5, 978-0-13-044941-2]

Prerequisites: Math 5010, 5080, 5090, 2270

Topics: Introduction to univariate linear modes. 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: Braxton Osting

Text: R. A. Johnson and D. W. Wichern, *Applied Multivariate Statistical Analysis*, Sixth edition, 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: S. Ethier

Text: R. Durrett, *Probability: Theory and Examples*, Fourth edition, Cambridge University Press (2010) [ISBN 0-521-76539-0, 978-0-521-76539-8]

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: S. Ethier

Text: A. DasGupta, *Asymptotic Theory of Statistics and Probability*, Springer (2008) [ISBN 0-387-75970-0, 978-0-387-75970-8]

Prerequisites: Math 2270, 5080, 5090

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

6180 **Topics in Complex Geometry**

Instructor: Staff

Text: To be announced

Prerequisite: Math 5210, 4200

Topics: To be announced.

6210	**Real Analysis** (Fall Semester)
Instructor:	J. Chaika
Text:	W. Rudin, *Real and Complex Analysis*, Third edition, McGraw-Hill (2001) [ISBN 0-07-054234-1, 978-0-07-054234-1]
Prerequisite:	Math 5210, 4200
Topics:	Measures and integrals, L_p-spaces, Hilbert spaces, Banach spaces, Fourier series.

6220	**Complex Analysis** (Spring Semester)
Instructor:	Y.-P. Lee
Text:	L. V. Ahlfors, *Complex analysis*, Third edition, McGraw-Hill (2007) [ISBN 0-07-000657-1, 978-0-07-000657-7]
Prerequisite:	Math 5210, 4200
Topics:	Analytic functions, complex integration, conformal mapping, families of analytic functions, zeros of analytic functions, analytic continuation.

6260	**Representation Theory**
Instructor:	D. Miličić
Text:	To be announced
Prerequisite:	To be announced.
Topics:	To be announced.

6310, 6320	**Modern Algebra I, II** (Fall, Spring Semesters)
Instructor:	S. Iyengar & A. Singh
Texts:	N. Jacobson, *Basic Algebra I*, Second edition, Dover (1985) [ISBN 0-7167-1480-9, 978-0-7167-1480-4] (6310) N. Jacobson, *Basic Algebra II*, Second edition, Dover (2012) [ISBN 0-486-47187-X, 978-0-486-47187-7] (6320) D. Dummit and R. Foote, *Abstract Algebra*, Third edition, Wiley (2003) [ISBN 0-471-43334-9, 978-0-471-43334-7] (supplement) S. Lang, *Algebra*, Springer (2002) [ISBN 0-387-95385-X, 978-0-387-95385-4] (supplement)
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 Semesters)
Instructor:	P. Bressloff & J. Keener
Text:	C. Chicone, *Ordinary Differential Equations with Applications*, Springer (2010) [ISBN 1-4419-2151-6,978-1-4419-2151-2]
Prerequisite:	Math 5210 or instructor's consent.
Topics:	(**6410**) Existence, uniqueness theory; stability theory; invariant manifolds; periodic motions; bifurcation theory; boundary value problems; applications. (**6420**) First-order equations: characteristics, transport equations, shocks, Hamilton-Jacobi theory. Boundary value problems for the Laplace equation: maximum principles, Green's functions, Hilbert space methods. Cauchy and initial-boundary value problems for the heat equation and wave equation: existence and basic properties.

6510	**Differentiable Manifolds** (Fall Semester)
Instructor:	K. Wortman
Texts:	Instructor's notes V. Guillemin and A. Pollack, *Differential topology*, Prentice-Hall (1974) [ISBN 0-13-212605-2, 978-0-13-212605-2] M. Spivak, *A Comprehensive Introduction to Differential Geometry*, Third edition, Publish or Perish (1999) [ISBN 0-914098-70-5, 978-0-914098-70-6] J. M. Lee, *Introduction to Smooth Manifolds*, Second edition, Springer (2013) [ISBN 1-4419-9981-7, 978-1-4419-9981-8]
Prerequisite:	"C" or better in 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, the Frobenius integrability theorem, differential forms, DeRham cohomology.
6520	**Introduction to Algebraic Topology** (Spring Semester)
Instructor:	A. Bertram
Text:	K. Wortman's notes A. Hatcher, *Algebraic topology*, Cambridge University Press (2002) [ISBN 0-521-79160-X, 978-0-521-79160-1]
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 Semesters)
Instructor:	D. Xiu
Text:	L. N. Trefethen and D. Bau, *Numerical Linear Algebra*, SIAM (1997) [ISBN 0-89871-361-7, 978-0-89871-361-9]
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, *Numerical Solution of Partial Differential Equations*, 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 multidimensional 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:	F. Guevara Vasquez
Text:	E. Kreyszig, *Introductory Functional Analysis with Applications*, Wiley (2006) [ISBN 0-471-50459-9, 978-0-471-50459-7]
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 pseudoinverse 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, *Principles of Applied Mathematics: Transformation and Approximation*, 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.
6730	**Perturbation Methods** (Fall Semester)
Instructors:	J. P. Keener
Text:	M. Holmes, *Introduction to Perturbation Methods*, Springer (1995) [ISBN 0-387-94203-3, 978-0-387-94203-2]
Prerequisites:	Math 6710 or equivalent.
Topics:	The course discusses the four basic problems of singular perturbation theory, namely singular boundary value problems, singular initial value problems, multiple time scale problems, and multiple space scale problems. The names of the techniques include matched asymptotic expansions, time scale analysis, multiple-time scale analysis, averaging and homogenization. Applications are made to a variety of problems in the physical and life sciences.
6750	**Continuum Mechanics: Fluid Dynamics** (Fall Semester)
Instructor:	A. Fogelson
Text:	D. J. Acheson, *Elementary Fluid Dynamics*, Clarendon Press (1990) [ISBN 0-19-859679-0, 978-0-19-859679-0]
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 Semesters)
Instructor:	A. Borisyuk & P. Bressloff
Text:	No textbook
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 are 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 Semesters)
Meets with:	**5010**
6810, **6815**	**Stochastic Processes and Simulation I, II** (Fall, Spring Semesters)
Meets with:	**5040**, **5050**
6820	**Introduction to Probability** (Spring Semester)
Meets with:	**5075**
6824	**Statistical Inference I** (Fall, Spring Semesters)
Meets with:	**5080**
6828	**Statistical Inference II** (Fall, Spring Semesters)
Meets with:	**5090**
6830, **6835**	**Mathematical Biology I, II** (Fall, Spring Semesters)
Meets with:	**5110**, **5120**
6840, **6845**	**Introduction to Differential Equations** (Fall, Spring Semesters)
Meets with:	**5410**, **5420**
6850	**Introduction to Partial Differential Equations** (Fall Semester)
Meets with:	**5440**
6860, **6865**	**Introduction to Numerical Analysis I, II** (Fall, Spring Semesters)
Meets with:	**5610**, **5620**
6870	**Mathematical Modeling** (Spring Semester)
Meets with:	**5740**
6880-001	**Topics in Applied Mathematics** (Fall, Spring Semester)
Meets with:	**7875-8**
6880-002	**Topics in Applied Mathematics** (Fall, Spring Semester)
Meets with:	**5750-002**
6890-002	**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
6950	**Topics in Algebraic Topology**
Instructor:	D. Toledo
Text:	J. W. Minor and J. D. Stasheff, *Characteristic classes*, Princeton University Press (1974) [ISBN 0-691-08122-0, 978-0-691-08122-9]
Topics:	To be announced.
6960-001	**GSAC Colloquium** (Fall, Spring Semesters)
Instructor:	K. Bromberg
Topics:	GSAC Colloquium. TA Training workshop.
6960-0XX	**Special Projects**
Instructor:	Staff
6970	**Thesis Research** (Masters)
Instructor:	Staff
7800-001	**Topics in Algebraic Geometry** (Fall, Spring Semesters)
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.
7853	**Topics in Geometric Topology** (Fall, Spring Semesters)
Instructor:	M. Bestvina, J. Chaika, & K. Wortman
Text:	To be announced
Prerequisite:	Consent of Instructor
Topics:	Various topics in geometric group theory, to be offered on the basis of need or interest. May be repeated for credit when the topics vary.
7875	**Various special topics**
Instructor:	Staff
Text:	Selected readings from several texts
Prerequisites:	Math 6610 and Math 6620
Topics:	This course consists of several sections, each devoted to a particular topic. The topics vary from term to term, and instructor to instructor. Please consult with the Graduate Program Coordinator for details about the offerings in coming terms.
7970	**Thesis Research (Ph.D.)**
Instructor:	Staff

Recent Ph.D. Students
Department of Mathematics
1987–2015

Ph.D. Graduate	Research Area	Advisor	Post-graduate position
2015			
Omprokash Das	Algebraic Geometry	Hacon	Tata Institute of Fundamental Research, Mumbai, India
Megan Gorringe Dixon	Mathematical Biology	Keener	
Kenneth (Jack) Jeffries	Commutative Algebra	Singh	University of Michigan, Ann Arbor, MI
Cristian Martinez	Algebraic Geometry	Bertram	University of California/Santa Barbara, CA
Greg Rice	Statistics	Horváth	University of Waterloo, Waterloo, ON, Canada
Jia Wang	Statistics	Horváth	Goldman Sachs
Yohsuke Watanabe	Topology	Bromberg	University of Hawaii at Manoa
2014			
Kei Yuen Chan	Representation Theory	Trapa	University of Amsterdam, The Netherlands
Chih-Chieh Chen		Savin	
Sarah Cobb	Geometric Group Theory	Wortman	Midwestern State University, Wichita Falls, TX
Veronika Ertl	Algebraic Geometry	Nizioł	Universität Regensburg, Germany
Brendan Kelly	Geometric Group Theory	Wortman	Harvard University, Cambridge, MA
Michał Kordy	Applied Mathematics	E. Cherkaev	University of Utah
Sonya Leibman	Geometric Group Theory	Bestvina	
Ross Magi	Mathematical Biology	Keener	Walla Walla University, WA
Brian Mann	Geometric Group Theory	Bestvina	Amazon
James Moore	Mathematical Biology	Adler	Georgia Tech, Atlanta, GA
Feng Qu	Algebraic Geometry	Lee	Max-Planck-Institute für Mathematik, Bonn, Germany

Andrew Thaler	Applied Mathematics	Milton	The Institute for Mathematics and Its Applications (IMA), St. Paul, MN
Yuchen Zhang	Algebraic Geometry	Hacon	University of Michigan, Ann Arbor, MI
Dylan Zwick	Algebraic Geometry	Bertram	Overstock
2013			
Geoffrey Hunter	Mathematical Biology	Keener	Ontario Institute for Cancer Research, Toronto, ON, Canada
Xiaodong Jiang	Algebraic Geometry	Hacon	Myriad Genetics, Salt Lake City, UT
Aaron Wood	Representation Theory	Savin	University of Missouri, Columbia, MO
2012			
Brittany Bannish	Mathematical Biology	Fogelson	University of Central Oklahoma, Edmond, OK
Davide Fusi	Algebraic Geometry	de Fernex	The Ohio State University, Columbus, OH
Erica Graham	Mathematical Biology	Adler	University of North Carolina, Chapel Hill, NC
Adam Gully	Applied Mathematics	Golden	McMaster University, Hamilton, ON, Canada
Brian Knaeble	Statistics Education	Horváth	University of Wisconsin–Stout, Menomonie, WI
Christopher Kocs	Representation Theory	Savin	DOD Hill Air Force Base, Ogden, UT
Ching-Jui (Ray) Lai	Algebraic Geometry	Hacon & Lee	Purdue University, West Lafayette, IN
Erika Meucci	Geometric Group Theory	Bestvina	Paul H. Nitze School of Advanced International Studies, Bologna
Ben Murphy	Applied Mathematics	Golden	University of California/Irvine, CA
Ron Reeder	Statistics	Horváth	Watson Laboratories, Salt Lake City, UT
Christopher Remien	Mathematical Biology	Adler & Cerling	National Institute for Mathematical and Biological Synthesis, University of Tennessee, Knoxville, TN
Anna Schoening	Probability	Rassoul-Agha	University of Utah
Stefano Urbinati	Algebraic Geometry	Hacon	University of Warsaw, Poland

Liang Zhang	Probability	Khoshnevisan	Michigan State University, East Lansing, MI
2011			
Julian Chan	Commutative Algebra	Singh	Weber State University, Ogden, UT
Matthew Housley	Representation Theory	Trapa	Brigham Young University, Provo, UT
Elisha Hughes	Statistics	Horváth	Myriad Genetics Inc., Salt Lake City, UT
Sean Laverty	Mathematical Biology	Adler	Swarthmore College, PA
Loc Nguyen	Differential Equations	Schmitt	École Normale Supérieure, Paris, France
Blerta Shtylla	Mathematical Biology	Keener	Mount Holyoke College, Hadley, MA
Ben Trahan	Representation Theory	Trapa	University of Utah
Yuan Zhang	Applied Mathematics	A. Cherkaev	Universidad de Castilla-La Mancha, Cuidad Real, Spain
2010			
Yael Algom-Kfir	Geometric Group Theory	Bestvina	Yale University, New Haven, CT
Courtney Davis	Mathematical Biology	Adler	University of Maryland, College Park, MD
Trung Dinh	Commutative Algebra	Roberts	FPT University, Hanoi, Vietnam
Lindsay Erickson	Mathematical Biology	Fogelson	Sandia National Labs, Livermore, CA
Giao Huynh	Mathematical Biology	Adler	Oakland University, Oakland, CA
Casey Johnson	Representation Theory	Trapa	National Security Agency
Karim Khader	Probability	Khoshnevisan	Division of Epidemiology, University of Utah
Zachary Kilpatrick	Mathematical Biology	Bressloff	University of Pittsburgh, PA
Sarah Kitchen	Representation Theory	Miličić	Albert-Ludwigs Universität, Freiburg, Germany
Hwan Yong Lee	Applied Mathematics	Dobson	Drexel University, Philadelphia, PA
Karin Leiderman	Mathematical Biology	Fogelson	Duke University, Durham, NC
Frank Lynch	Mathematical Biology	Keener	Occidental College, Los Angeles, CA
William Malone	Geometric Group Theory	Bestvina	C. H. Flowers High School, Springdale, MD

Jay Newby	Mathematical Biology	Bressloff	Oxford University, Oxford, UK
Michael Purcell	Probability	Khoshnevisan	National Security Agency
Russell Richins	Applied Mathematics	Dobson	Michigan State University, East Lansing, MI
Shang-Yuan Shiu	Probability	Khoshnevisan	Academia Sinica, Taipei, Taiwan
Josh Thompson	Geometric Group Theory	Bromberg	Colorado State University, Fort Collins, CO
2009			
Tommaso Centeleghe	Number Theory	Savin	Universität Duisburg-Essen, Essen, Germany
Scott Crofts	Representation Theory	Trapa	University of California, Santa Cruz, CA
Jason Preszler	Number Theory	Savin	University of Puget Sound, Tacoma, WA
Amber Smith	Mathematical Biology	Adler	Los Alamos National Laboratory, NM
Nessy Tania	Mathematical Biology	Keener	University of British Columbia, Vancouver, BC, Canada
2008			
Erin Chamberlain	Commutative Algebra	Roberts	Brigham Young University, Provo, UT
Elizabeth Doman Copene	Mathematical Biology	Keener	Idaho Technology Inc., Salt Lake City, UT
William Nesse	Mathematical Biology	Bressloff	University of Ottawa, Ottawa, ON, Canada
Gueorgui Todorov	Algebraic Geometry	Bertram	Princeton University, Princeton, NJ
2007			
Berton Earnshaw	Mathematical Biology	Bressloff	University of Utah, and Michigan State University, East Lansing, MI
Domagoj Kovacevic	Number Theory	Savin	
Lars Louder	Geometric Group Theory	Bestvina	University of Michigan, Ann Arbor, MI
Meagan McNulty	Mathematical Biology	Adler	William & Mary College, Williamsburg, VA
Elijah Newren	Mathematical Biology	Fogelson	Sandia National Laboratory, Albuquerque, NM
Qiang Song	Commutative Algebra	Singh	MISYS, Beijing, China
Dali Zhang	Inverse Problems	E. Cherkaev	University of Calgary, Calgary, AB, Canada

John Zobitz	Mathematical Biology	Adler	Augsburg College, Minneapolis, MN
	2006		
Nathan Albin	Applied Mathematics	A. Cherkaev	Universität Duisburg-Essen, Essen, Germany and California Institute of Technology, Pasadena, CA
Renate Caspers	Stochastic Processes	Mason	
Kenneth Chu	Complex Algebraic Geometry	Toledo	University of Texas at Austin, TX
Matthew Clay	Geometric Group Theory	Bestvina	University of Oklahoma, Norman, OK
Zrinka (Despotović) Keenan	Geometric Group Theory	Bestvina	Royal Bank of Scotland, Edinburgh
Young-Seon Lee	Math Physiology	Keener	Cornell University, Ithaca, NY
Andrew Oster	Mathematical Biology	Bressloff	The Ohio State University, Columbus, OH
Kazuma Shimomoto	Algebra	Roberts	University of Minnesota, Minneapolis, MN
	2005		
Renzo Cavalieri	Algebraic Geometry	Bertram	University of Michigan, Ann Arbor, MI
Stefanos Folias	Mathematical Biology	Bressloff	Boston University, Boston, MA
An Hai Le	PDE	Schmitt	MSRI, Berkeley, CA
Fumitoshi Sato	Algebraic Geometry	Bertram	Korea Institute for Advanced Study, Seoul, Korea
	2004		
Robert Guy	Mathematical Biology	Fogelson	University of Utah
Brynja Kohler	Mathematical Biology	Keener	Utah State University, Logan, UT
Eiko Koizumi	PDE	Schmitt	Ellis College, New York Institute of Technology online
Denis Lukic	Representation Theory	Miličić	Northwestern University, Evanston, IL
Greg Peipmeyer	Algebra	Roberts	University of Nebraska, Lincoln, NE
Thomas Robbins	Math Ecology	Lewis	University of Utah
	2003		
Emina Alibegović	Geom Group Theory	Bestvina	University of Michigan, Ann Arbor, MI

Anca Mustata	Algebraic Geometry	Clemens	University of British Columbia, Vancouver, BC, Canada
Andrei Mustata	Algebraic Geometry	Bertram	University of British Columbia, Vancouver, BC, Canada
Bradford Peercy	Mathematical Biology	Keener	Rice University, Houston, TX
Matthew Rudd	PDE	Schmitt	University of Texas at Austin, TX
Inbo Sim	PDE	Schmitt	Utah State University, Logan, UT
2002			
Nicholas Cogan	Mathematical Biology	Keener	Tulane University, New Orleans, LA
Martin Deraux	Complex Geometry	Toledo	Purdue University, West Lafayette, IN
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			
Eric Cytrynbaum	Math Physiology	Keener	Institute for Theoretical Dynamics, University of California/Davis, CA
Miguel Dumett	PDE	Keener	Lawrence Livermore National Laboratory, Livermore, CA
Michael Hohn	Numerical Analysis	Folias	Lawrence Berkeley National Laboratory, Berkeley, CA
Jian Kong	Algebraic Geometry	Bertram	The Johns Hopkins University, Baltimore, MD
İsmail Küçük	Applied Mathematics	E. Cherkaev	American University, Sharjah, and Sakarya University, Turkey
Chong Keat Arthur Lim	Rep Theory	Miličić	University of Minnesota, Minneapolis, MN
Xiangdong Xie	Geom Group Theory	Kleiner	Washington University, St. Louis, MO
Chung Seon Yi	Mathematical Biology	Fogelson	Virginia Polytechnic Institute and State University, Blacksburg, VA
2000			
Peter Brinkmann	Geom Group Theory	Gersten	University of Illinois/ Urbana–Champaign, IL
Chin-Yi Chan	Algebra	Roberts	Purdue University, West Lafayette, IN

Irina Grabovsky	Statistics	Horváth	National Board of Medical Examiners, Jacksonville, FL
Sean Sather-Wagstaff	Comm Algebra	Roberts	University of Illinois/ Urbana–Champaign, IL
Haoyu Yu	Mathematical Biology	Fogelson	University of Minnesota, Minneapolis, MN
1999			
Kristina Bogar	Applied Mathematics	Keener	University of Utah
Charles Harris	Analysis	Tucker	University of Utah
Jon Jacobsen	PDE	Schmitt	Pennsylvania State University, State College, PA
Elizabeth Jones	Comm Algebra	Roberts	University of Utah
Nikolaos Tzolias	Algebraic Geometry	Kollár	Oklahoma State University, Stillwater, OK
Toshio Yoshikawa	Applied Mathematics	Balk	Utah State University, Logan, UT
1998			
Hsungrow Chan	Differential Geom	Treibergs	National Tsing Hua University, Hsinchu, Taiwan
Chi Kan Chen	Applied Mathematics	Fife	University of Utah, Post Doctoral
Jeffrey L. Fletcher	Geo Group Theory	Gersten	Louisiana State University, Alexandria, LA
Takayasu Kuwata	Algebraic Geometry	Kollár	Tokyo Denki University, Tokyo, Japan
Andrew L. Kuharsky	Mathematical Biology	Fogelson	Tulane University, New Orleans, LA
Timothy J. Lewis	Mathematical Biology	Keener	New York University, NYC, NY
Natasa Macura	Topology	Bestvina	University of Michigan, Ann Arbor, MI
Eric Marland	Mathematical Biology	Keener	University of California/Davis, CA
Igor Mineyev	Group Theory	Gersten	Max-Planck-Institute für Mathematik, Bonn, Germany
Min Xie	Applied Mathematics	Othmer	Intermountain Health Care, Salt Lake City, UT
1997			
Yongnam Lee	Algebraic Geometry	Clemens	Korea Institute for Advanced Study, Seoul, Korea

Richard Mayer	Algebraic Geometry	Carlson	University of Massachusetts, Amherst, MA
Laura Smithies	Rep Theory	Taylor	Kent State University, Kent, OH
Peter Spiro	Mathematical Biology	Othmer	Incyte Pharmaceuticals, Wilmington, DE
Nien-Tzu Wang	Applied Mathematics	Fogelson	
1996			
José Burillo	Group Theory	Gersten	Tufts University, Medford, MA
Shirnping Chen	Topology	Toledo	Triology Technologies Inc., Taiwan
Ionut Ciocan-Fontanine	Algebraic Geometry	Bertram	Mittag-Leffler Institut, Djursholm, Sweden
John Dallon	Applied Mathematics	Othmer	Warwick University, Warwick, England
Monika Serbinowska	Statistics	Horváth	University of California at San Diego, La Jolla, CA
1995			
Alberto Castro	Geometry	Toledo	Mt. Holyoke College, MA
Adam J. Chmaj	PDE	Fife	Brigham Young University, Provo, UT (Post Doctoral) and Utah State University, Logan, UT (Post Doctoral)
Ha Dang	Applied Mathematics	Fife	University of Utah
Sándor Kovács	Algebraic Geometry	Kollár	MIT, Cambridge, MA
Vy Khoi Le	Nonlinear Analysis	Schmitt	University of Colorado, Boulder, CO
Lingyan Ma	Statistics	Horváth	University of Georgia, Athens, GA
Uwe Mayer	PDE	Korevaar	Brown University, Providence, RI
Pavle Pandžić	Lie Groups	Miličić	MIT, Cambridge, MA
Romuald Sawicz	Applied Mathematics	Golden	University of Minnesota, Minneapolis, MN
Tomasz Serbinowski	Differential Geom	Korevaar	University of California/Irvine, CA
Robert Van Kirk	Mathematical Biology	Lewis	Henry's Ford Foundation, Island Park, ID
1994			
Aldo Bernasconi	Group Theory	Gersten	Chile (not in academia)
John M. O'Reilly	Numerical Analysis	Stenger	

Robert Shalla	Lie Groups	Miličić	Bronx Community College, NYC, NY
1993			
Timothy Bratten	Lie Groups	Hecht	Argentina
Robert Dillon	Applied Mathematics	Othmer	Tulane University, New Orleans, LA
Azniv Kasparian	Algebraic Geometry	Carlson	University of Sofia, Bulgaria
Joo Kim Mok	Statistics	Mason	University of South Korea
Ming He	Probability	Ethier	Weber State University, Ogden, UT
Jeffrey McGough	Differential Equations	Schmitt	University of Nevada, Reno, NV
Endre Szabó	Algebraic Geometry	Kollár	Universität Bayreuth, Germany
Yuanhua Tang	Applied Mathematics	Othmer	Cornell University, Ithaca, NY
Randall Westhoff	Algebraic Geometry	Clemens	Bemidji State University, Bemidji, MN
1992			
Mario R. Candia	Real and Complex Geometry	Hecht	In industry, Chicago, IL
Gregory R. Conner	Algebra and Number Theory	Gersten	Brigham Young University, Provo, UT
Alessio Corti	Algebraic Geometry	Kollár	MSRI, Berkeley, CA
David J. Eyre	Applied Mathematics	Fife	University of Minnesota, Minneapolis, MN
Tina Ma	Statistics	Mason	Pharmaco LSR, Inc., Austin, TX
Denise White	Finite Groups	Gross	Westminster College, Salt Lake City, UT
Guangyan Yin	Applied Mathematics	Stenger	
1991			
Jorge Devoto	Topology	Braam	International Centre for Theoretical Physics (ICTP), Trieste, Italy
Kenneth Ferguson	Topology/ Geometry	Stern	First Quadrant, Pasadena, CA
Christopher Grant	Applied Mathematics	Fife	Georgia Tech, Atlanta, GA
Elham Izadi	Algebraic Geometry	Clemens	Harvard University, Cambridge, MA
Michael Kinyon	Differential Equations	Tucker	Indiana University at Southbend, IN

Yonghao Ma	Algebra	Roberts	Southwest Texas State University, San Marcos, TX
Cameron Wickham	Ring Theory	Roberts	Southwestern Missouri State University, Springfield, MO
James Wiskin	Group Theory	Gross	University of Utah
1990			
Gary DeYoung	Applied Mathematics	Othmer	University of California/Davis, CA
Ya Li	Differential Equations	Keener	Teikyo Westmar University, Le Mars, IA
Ronald Lundstrom	Probability	Tavaré	Cimarron Software, Salt Lake City, UT
Maritza Sirvent	Approximation Theory	Alfeld	Ohio State University, Columbus, OH
1989			
David M. Austin	Topology	Stern	Institute for Advanced Study, Princeton, NJ and Grand Valley State University, Allendale, MI
Luis Hernandez Lamoneda	Geometry	Toledo	University of Chicago, Chicago, IL
Jesus Jimenez Reyes	Complex Geometry	Clemens	University of California/Riverside, CA
Frederick Phelps	Applied Mathematics	Keener	Oxford University, Oxford, UK
1988			
Mladen Božičević	Lie Groups	Miličić	Rutgers University, New Brunswick, NJ
Paul J. Joyce	Stochastic Processes	Tavaré	University of South California, Los Angeles, CA
Thomas Nordhaus	Applied Mathematics	Keener	
Marc Stromberg	Numerical Analysis	Stenger	Texas Tech University, Lubbock, TX
James D. Walker	Applied Mathematics	Folias	Southwest Research Institute, San Antonio, TX
Miljenko Zabčić	Lie Groups	Hecht	MIT, Cambridge, MA
Bertram Zinner	Applied Mathematics	Keener	Auburn University, Auburn, AL
1987			
Paul R. Arner	CAGD	Barnhill	SDRC (Structural Dynamics Research Corporation), Cincinnati, OH
Phillip J. Barry	CAGD	Barnhill	University of Waterloo, Waterloo, ON, Canada

Bernard Bialecki	Numerical Analysis	Stenger	University of Kentucky, Lexington, KY
Roger Chen	Differential Geometry	Li	University of Toledo, Toledo, OH
J. Don Dockery	Applied Mathematics	Keener	Utah State University, Logan, UT
Greg A. Harris	Differential Equations	Schmitt	Auburn University, Auburn, AL
Nela Lakoš	Differential Equations	Schmitt	Ohio State University, Columbus, OH
Dennis Malm	Algebra	Goodearl	Northwest Missouri State University, Maryville, MO
Bruce R. Piper	CAGD	Barnhill	Rensselaer Polytechnic Institute, Troy, NY
Masaji Watanabe	Applied Mathematics	Othmer	Universität Stuttgart, Germany
Diana Woodward	Applied Mathematics	Hoppensteadt	Michigan State University, East Lansing, MI

Faculty 2015–2016

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, Knoxville, 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

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

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

Cherkaev, Elena, Leningrad University, 1988. Applied Mathematics

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

de Fernex, Tommaso, University of Illinois at Chicago, 2002. Algebraic Geometry

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 B., Arizona State University, 1968. Ordinary Differential Equations

Hecht, Henryk, Columbia University, 1974. Lie Groups

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

Iyengar, Srikanth, Purdue University, 1998. Algebraic Geometry

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

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

Rassoul-Agha, Firas, New York University, 2003. Probability Theory

Savin, Gordan, Harvard, 1988. Automorphic Forms

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

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

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

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

Treibergs, Andrejs E., Stanford, 1980. Geometric Analysis

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

Xiu, Dongbin, Brown University, 2005. Numerical Analysis

Associate Professors

Alibegović, Emina, University of Utah, 2003. Mathematics Education, Geometry and Topology

Borisyuk, Alla, New York University, 2002. Mathematical Biology, Applied Mathematics

Chaika, Jonathan, Rice University, 2010. Dynamical Systems and Ergodic Theory

Epshteyn, Yekaterina, University of Pittsburgh, 2007. Numerical Analysis

Schwede, Karl E., University of Washington, 2006. Algebraic Geometry

Wortman, Kevin, University of Chicago, 2003. Geometric Group Theory

Zhu, Jingyi, New York University, 1989. Mathematical Finance

Assistant Professors

Alberts, Tom, New York University, 2008. Probability Theory and Stochastic Processes

Guevara Vasquez, Fernando, Rice University, 2006. Partial Differential Equations

Hohenegger, Christel, Georgia Institute of Technology, 2006. Numerical Analysis, Fluid Mechanics

Narayan, Akil, Brown University, 2009. Applied Mathematics

Osting, Braxton, Columbia University, 2011. Calculus of Variations and Optimal Control

Patrikis, Stefan, Harvard University, 2006. Number Theory and Algebraic Geometry

Assistant Professor (Lecturer)

Cassier, Maxence, École Nationale Supérieure de Techniques Avancées, Paris, France, 2014. Wave propagation, inverse problems and metamaterials

Ghosh Hajra, Sayonita, University of Georgia, 2014 Low dimensional topology, mathematics education and teacher preparation

Huang, Jingyu, University of Kansas, 2015. Probability Theory and Stochastic Processes

Konstantoulas, Ioannis, University of Illinois at Urbana-Champaign, 2014. Dynamical Systems and Ergodic Theory

Krishnan, Arjun, New York University, 2014. Percolation, stochastic homogenization, directed polymers and KPZ universality, concentration inequalities

Lamb, Evelyn, Rice University, 2012. Harmonic Maps and Hyperbolic Geometry

Nandakumar, Vinoth MIT, 2015. Topological Groups

Sainath, Jyothsna, University of Nebraska, Lincoln, 2014. Statistics

Shankar, Varun, University of Utah, 2014. Numerical analysis

Wade, Richard, University of Oxford, 2012. Geometry & Topology

Zhu, Yi, State University of New York at Stony Brook, 2012. Algebraic Geometry

Research Assistant Professor

Boocher, Adam, University of California/Berkeley, 2013. Commutative Algebra and Algebraic Geometry

Harutyunyan, Davit, Hausdorff Center for Mathematics, University of Bonn, 2011. Calculus of Variations and Optimal Control

Honigs, Katrina, University of California/Berkeley, 2015. Algebraic Geometry

Kraitzman, Noa, Michigan State University, 2015. Partial Differential Equations

Lawley, Sean, Duke University, 2014. Mathematical biology, Stochastic switching in evolution equations

Lewis, Owen, University of California/Davis, 2014. Mathematical biology, homogenization, ODEs and PDEs

Ma, Linquan, University of Michigan, 2014. Commutative Rings and Algebra

Mandel, Travis, University of Texas at Austin, 2014. Algebraic Geometry and Geometry

Robertson, Donald, Ohio State University, 2015. Dynamical Systems and Ergodic Theory

Shipman, Ian, University of Chicago, 2011. Algebraic Geometry

Shoemaker, Mark, University of Michigan, 2013. Algebraic Geometry

Studenmund, Daniel, University of Chicago, 2014. Lie groups

Tarasca, Nicola, Humboldt University in Berlin, 2012. Algebraic Geometry

Tu, Yu-Chao, Princeton University, 2014. Algebraic Geometry

Research Professors

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

Horn, Roger, Stanford University, 1967. Matrix Analysis

Palais, Robert, University of California, Berkeley, 1986. Applied Mathematics

Associate Instructors

Cummings, Maggie, University of Utah, 2010. Mathematical Knowledge for Teaching

Housley, Matthew, University of Utah, 2011

Adjunct Professors

Luc, Paul, [Seoul, Korea campus of University of Utah]

Adjunct Associate Professors

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

Adjunct Assistant Professors

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

Clemens, C. Herb, (CSME Associate Director), University of California Berkeley, 1966. Complex Geometry, Algebraic Geometry, Math Education

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

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

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

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

Visiting Scholars

Li, Xiaobin, Sichuan University, 2011. Algebraic Geometry, Symplectic Geometry, Mathematical Physics

Rasmussen, Nils Henry Williams, Universitet i Bergen, Norway 2010. Algebraic Geometry

Zhou, Shengtian, University of Warwick, Coventry, UK 2011. Algebraic Geometry

Visiting Postdoctoral Scholars

Dumont, Thibaut, École polytechnique fédérale de Lausanne, Switzerland, 2015. Ergodic and geometric group theory

Horbez, Camille, Université de Rennes 1, Rennes, France, 2014. Group Theory and Generalizations (Geometric Topology)

Mostafazadehfard, Maral Universidade Federal de Pernambuco, Recife, Brazil, 2014. Commutative Algebra, Algebraic Geometry, Local Cohomology

Hassanzadeh, Seyed Hamid Université de Paris 6, Paris, France, 2009. Commutative Algebra, Homological Algebra, and Algebraic Geometry

Visiting Graduate Students

Tavanfar, Ehsan Shahid Beheshti University, Tehran, Iran

Postdoctoral Fellowship

Liu, Tiankai, MIT, 2014. Algebraic Geometry

Ullery, Brooke University of Michigan, 2015. Algebraic Geometry