The University of Utah
Department of Mathematics
GRADUATE BULLETIN
2020–2021
About the cover

The late artist Nancy Holt created the Sun Tunnels in the western Utah desert, just south of Lucin, now a ghost town. Lucin was the western terminus of the *Lucin cutoff*, a railroad route built westward from Ogden, Utah in 1902–1904 on a long causeway and bridge across the Great Salt Lake. It shortened by about 70km the previous route that was the first North American transcontinental railroad line, when crews working from the East and the West connected the routes at Promontory, Utah, on 10 May 1869.
GRADUATE MATHEMATICS
2020–2021

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Cover: Golden Spike 150th Anniversary Celebration

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1 General information

This chapter briefly describes the Mathematics Department at the University of Utah, and the research facilities available to its members, within the department, elsewhere on campus, and at national computer laboratories.

1.1 A brief history

The University of Utah is a state tax-supported, coeducational institution. It was founded in 1850, and 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 twelve Ph.D. degrees per year. Over 300 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 graduate faculty has more than 50 professors. Several members 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 available at

http://www.math.utah.edu/people/faculty.html

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, number theory, numerical analysis, partial differential equations, probability and statistics, representation theory, scientific computing and imaging, and stochastic processes.
During the current year, approximately 30 members of the Mathematics faculty are associated with government-sponsored research contracts. The University’s total student enrollment is currently about 33,000. During 2019–2020, there were 74 men and 33 women Ph.D. students in Mathematics. Our graduate students come from many different areas of the United States, as well as from several foreign countries.

1.2 Departmental 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.

The University of Utah was node four of the five founding members of the Arpanet in 1968, the precursor of the worldwide Internet today that drives world communications, commerce, entertainment, and much else. The University of Utah continues to play an important role in advanced networking research, and is a member of consortia that run the world’s fastest long-distance networks. From 2017, the University has a 40Gb/s network backbone, with multiple 10Gb/s links to the Internet through a large firewall that guards against many of the hostile attacks that negatively impact computing and networking worldwide. Almost all campus buildings have 10Gb/s uplinks to the network backbone. In addition, there is wide support throughout campus for both public, and access-controlled private, wireless networking.

There are extensive computing facilities available in the Department, including numerous multiprocessor multicore servers with 128GB of memory, and one with 1024GB of memory, all with a common filesystem for user login directories. Most users access those facilities from desktop thin-client workstations, or from remote computers via the secure-shell protocol that guarantees strong encryption of communications.

There is a huge installation of software, with almost 22,000 available programs, including numerous compilers for all major programming languages, and specialized mathematical, statistical, and scientific libraries and systems. There is also a large collection of virtual machines that provides an outstanding testbed for software portability to many different operating systems.

The main filesystem had a major upgrade in capacity and speed in Spring 2018. It uses ZFS (Zettabyte File System) to provide highly-reliable storage, flexible management and expansion, and user-accessible read-only filesystem snapshots, taken at least daily, and hourly in the active electronic-mail system and also in user home directories. There are generally three to four weeks of user-accessible online snapshots.

For reliability, the main filesystem has a live mirror in another campus building. There are nightly backups of all filesystems to holding disks that are copied to LTO-8 tapes in a 500-tape robot. Nightly ZFS snapshots are copied to a large-storage server in an off-campus datacenter for years-long retention.
1.3. Additional research facilities

A large battery backup power-conditioning system, and outside diesel generator, ensure uninterrupted computer operations, and immunity to electrical power bumps and outages.

Printing, copying, and scanning facilities are available on all building floors, and student computer labs have at least two printers each to reduce waiting times.

Online documentation about our computing environment is available at

http://www.math.utah.edu/faq/

Further details of machine particulars are available from systems staffers in offices LCB 103, 105, and 110. Computer-facility tours for departmental members are available on request, and systems staff are always happy to offer guidance in computer purchases, and to provide short tutorials on numerous aspects of computing.

1.3 Additional research facilities

The University of Utah’s Center for High-Performance Computing (CHPC)

http://www.chpc.utah.edu/

is housed in the INSCC building adjacent to the Mathematics Department buildings.

The Center provides access to thousands of compute nodes in multiple distributed clusters with large parallel filesystem storage, as well as to advanced scientific software, through a quarterly application process that requires a brief description of the research to be performed, but, for modest computing needs, does not require payment.

Campus researchers with large computing needs, and sufficient financial resources from research grants, can also buy portions of the CHPC facilities to leverage economies of scale, and guarantee exclusive access when needed. Nodes that have been idle for some time normally move to a shared pool so that others can use them, avoiding resource waste.

CHPC is a gateway to several national computing facilities for extreme-scale computing, and hosted the National Supercomputer Conferences in Salt Lake City in 2012 and 2016. The University of Utah is a member of the Rocky Mountain Advanced Computing Consortium (RMACC) that encourages communication and collaboration among high-performance computing sites in the West.

1.4 Safety and wellness

Your safety is our top priority. In an emergency, dial 911 or seek a nearby emergency phone (throughout campus). Report any crimes or suspicious people to
1. General information

801-585-COPS; that number will get you to a dispatch officer at the University of Utah Department of Public Safety (DPS; https://dps.utah.edu). If at any time, you would like to be escorted by a security officer to or from areas on campus, DPS will help — just give a call.

The University of Utah seeks to provide a safe and healthy experience for students, employees, and others who make use of campus facilities. In support of this goal, the University has established confidential resources and support services to assist students who may have been affected by harassment, abusive relationships, or sexual misconduct. A detailed listing of University resources for campus safety can be found at https://registrar.utah.edu/handbook/campussafety.php.

Your well-being is key to your personal safety. If you are in crisis, call 801-587-3000; help is close.

The university has additional excellent resources to promote emotional and physical wellness, including the Counseling Center (https://counselingcenter.utah.edu), the Wellness Center (https://wellness.utah.edu), and the Women's Resource Center (https://womenscenter.utah.edu). Counselors and advocates in these centers can help guide you to other resources to address a range of issues, including substance abuse and addiction.
Important dates

This chapter records links to documents recording critical dates for academic terms, thesis deadlines, training sessions, and the critical qualifying examinations.

2.1 University dates

For the most current list of dates, see:

Fall 2020
https://registrar.utah.edu/academic-calendars/fall2020.php

Spring 2021
https://registrar.utah.edu/academic-calendars/spring2021.php

Summer 2021
https://registrar.utah.edu/academic-calendars/summer2021.php

It is particularly important to pay attention to when classes begin and end, and the final days to add or remove classes.

2.2 Thesis related dates

Beyond the University dates listed above, there are also critical dates that one must not miss if writing a dissertation or thesis. See

http://gradschool.utah.edu/thesis/

for the specific dates.

2.3 Departmental dates

• Summer Written Qualifying Exams, TBD.
• Winter Written Qualifying Exams, TBD.
3 Graduate study

This chapter describes the mechanical aspects of graduate work: advisors, committees, exams, and tuition.

3.1 Relevant groups and people in the Department

Before we discuss those, we list the individuals and organizations in the Department who can assist you.

3.1.1 Director of Graduate Studies

The Director of Graduate Studies, currently Elena Cherkaev, oversees the graduate program with the Graduate Committee. She also is a resource for questions about the program. Appeals or questions about any policy or departmental decision can generally be taken to her. You can also appeal any item further to the Department Chair or as specified in the Student Code.

3.1.2 Graduate Program Coordinator

The Graduate Program Coordinator, currently Paula Tooman, runs the graduate program on a day to day basis and helps with the necessary paperwork that must be done at various points in your degree. She is also a resource for questions about the program.

3.1.3 Graduate Committee

The Graduate Committee oversees the progress of all graduate students in the Department, and its decisions are carried out by the Director of Graduate Studies. The Graduate Committee reviews student progress annually and makes decisions about continuation of funding/continuation in the program: see Section 3.5. The current composition of the Graduate Committee can be found at http://www.math.utah.edu/people/committees.html

Subcommittees of this committee are also in charge of various other aspects of the program, such as Funded Graduate Student Travel.
3. Graduate study

3.1.4 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 about promotion, tenure, and retention of faculty members;
- to participate in the allocation of funds from the Associated Students of the University of Utah (ASUU) 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.

More information about GSAC, and its current membership, is at http://www.math.utah.edu/gsac/

3.2 Benefits and opportunities

This section highlights benefits and opportunities available to graduate students in the Mathematics Department at the University of Utah.

3.2.1 Tuition and tuition benefit

For the current tuition costs, see http://fbs.admin.utah.edu/income/tuition/general-graduate/

However, most graduate students who work as a Teaching Assistant (TA), as a Research Assistant (RA), or are supported by a fellowship, are eligible for the University of Utah’s tuition benefit program. For those students, there is no charge for tuition related to their program of study as long as it conforms to certain rules. Here are some key points about the program:

- You must register for between 9–12 credits (9–11 for most students who are not TAs). Students who are supported by RTG grants should register for different amounts that depend on regulations of the grant and the Graduate School.
- Ph.D. students who entered with a Bachelor’s degree have 10 semesters of tuition benefit. The benefit can be automatically extended for 2 additional semesters, if you have served as a TA for at least 4 semesters.

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3.2. Benefits and opportunities

- Ph.D. students who entered with a Master’s degree have at most 8 semesters of tuition benefit. The benefit cannot be automatically extended.

- Master’s degree students receive at most 4 semesters of tuition benefit. The benefit cannot be automatically extended.

- Students who are out of tuition benefit can work with their advisor and the Director of Graduate Students to appeal for more from the Graduate School. These appeals depend on the individual case and frequently are not successful. Such graduate students can also request funding from the Graduate Committee or their advisor, or a combination thereof, to cover the cost of tuition if this appeal to the Graduate School is not successful.

For more details on the Tuition Benefit program, see

http://gradschool.utah.edu/tbp/

3.2.1 Differential tuition

Course fees and differential tuition are typically not covered by the tuition benefit program. However, if the course is part of your program of study and approved by your advisor, you can request that the Department contribute towards covering these additional costs (depending on availability of funds). Your advisor then usually also contributes. The request, and supporting documentation from your advisor, must be made to the Director of Graduate Studies before the start of the semester. All requests are reviewed by the Department Chair and the Director of Graduate Studies.

For details, see

https://fbs.admin.utah.edu/income/ tuition

3.2.2 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/

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3.2.3 Parental leave

If a supported graduate student or a supported student’s spouse or eligible partner1

- gives birth to a child and becomes the child’s legal guardian, or
- adopts a child under six years of age,

then the graduate student (female or male) may request a parental leave of absence with modified duties for one semester for care-giving leave during a semester within 12 months of the child’s arrival.

Care-giving leave means that the student provides the majority of child contact hours during the student’s regular academic working hours for a period of at least 15 weeks. Typically, only one semester of leave is granted per child even if there are two graduate students in the Department who could claim parental leave for the child. In most cases, this benefit is granted at most twice for any supported graduate student.

During the leave of absence, the student has modified assigned duties. Typically, there is no teaching requirement during the period of absence. Students may still conduct research and take classes, including reading classes, but are not necessarily expected to work at the same pace for research projects. It is important that students take at least 3 credits during this semester to maintain their full-time status. During this semester, the student still receives the normal TA stipend and insurance, and, if the student does not use the tuition benefit, tuition costs for 3 credits are covered by the Department.

If a student desires, the deadlines to meet various departmental requirements (such as passing qualifying exams) can be extended by one semester upon request.

Requests for parental leave should be submitted to the Graduate Program Coordinator and are reviewed by the Chair, Associate Chair, and Director of Graduate Studies. A request for a parental leave of absence with modified duties should normally be made no fewer than three months prior to the expected arrival of the child. It is necessary to make this request in advance so that the particular arrangements of the leave can be planned. The request should specify what duties and/or research the student is planning on performing.

Students who experience a medical condition associated with pregnancy, and need accommodations recommended by their medical provider, should contact the University’s Title IX Coordinator, who then works with the student, cognizant faculty, and administration to determine what accommodations are reasonable and effective.

For more complicated situations, the Department tries to proceed in a way similar to the rules for parental leave with modified duties for faculty, as described at

http://regulations.utah.edu/academics/6-315.php

1as defined as an eligible partner through Human Resources

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3.3. Advisors and committees

3.2.4 Funded travel for graduate students

A subcommittee of the Graduate Committee reviews requests by graduate students for funded travel. See

http://www.math.utah.edu/grad/TravelFunding.pdf

Additionally, such students should apply to the Graduate School Graduate Student Travel Assistance Program. For other ideas for sources of funding, see the following Graduate School website:

https://gradschool.utah.edu/diversity/conference-travel/

3.2.5 Other resources for students

The University of Utah offers many other resources for graduate students. We particularly draw attention to the Student Health Center,

http://studenthealth.utah.edu/

the University Counseling Center,

http://counselingcenter.utah.edu/

and the University Writing Center

https://writingcenter.utah.edu/

The Graduate School also maintains a list of resources that students can pursue:

http://gradschool.utah.edu/graduate-student-support-services/

3.3 Advisors and committees

In this section, we discuss advisors, Initial Academic Mentors, and Supervisory Committees.

3.3.1 Initial academic mentors

All Ph.D. students are assigned an Initial Academic Mentor before arrival at the University of Utah. This mentor should meet with the student at least once each semester to plan initial courses. A student may request a change of Initial Academic Mentor at any time by notifying the Director of Graduate Studies and Graduate Program Coordinator. The student works with this mentor in this way until a student selects an academic advisor.
3. Graduate study

3.3.2 Advisors

Master’s degree students are assigned an Initial Academic Mentor upon entering the program and are expected to select an advisor before their second year. Once a Ph.D. student has chosen a research area, he or she should select an academic advisor. Typically, a student might do a reading course with a prospective advisor before deciding. To remain in good academic standing with the program, the Ph.D. student must select an advisor by January of the third year. It is strongly recommended, however, that the student choose an advisor much earlier, during the second year of study.

Once a student has an advisor, it is the student’s responsibility to meet with the advisor and design a program of study. The student should meet with the chosen advisor at the beginning of each academic year to plan that year’s work, and at least once a semester to discuss progress. Typically, this is done much more frequently. The responsibility for setting these meetings rests with the student. Advisors are requested by the Director of Graduate Studies to make brief comments on each student’s progress each year.

A student may request a change of advisor at any time by notifying the Director of Graduate Studies and Graduate Program Coordinator. See also Section 3.5 on termination of the student–advisor relationship.

3.3.3 Committee composition

The following describes the members of a Master’s degree or Ph.D. committee.

- 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 Master’s degree committee shall consist of three faculty members, the majority of whom must be regular faculty in the Department of Mathematics.

- 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. In some cases, faculty at other institutions can also fill the role of an outside committee member. To arrange this, a curriculum vitae of the outside member must be sent to the Graduate Program Coordinator who then requests approval from the Graduate School for this outside member.

- If the student’s interests change, the committee makeup is modified appropriately by the Director of Graduate Studies, after consulting the student and committee.

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3.4. Exams

3.3.4 When to form your committee

For Master’s degree students, the Supervisory Committee should be formed during the first year of study. For Ph.D. students, the Supervisory Committee is typically formed after passing written qualifying exams but it can be done sooner. This committee must be formed prior to taking the oral exam. It is important that this committee is formed as soon as feasible and must be done by January of the third year in the program.

3.3.5 Role of the supervisory committee

The function of the advisor and the Supervisory Committee is to:

- Advise the student regarding a program of study.
- Evaluate the student’s progress in the chosen program of study that is worked out with the committee shortly after the committee is formed.
- Set the ground rules and evaluate the preliminary and final oral examinations. This should be done in consultation with the student.
- Review any requests for changes or waivers in the usual requirements.

3.3.6 What is a program of study?

A program of study is the collection of courses and thesis work that makes up your academic record and that forms the basis of your graduation. You officially add courses to your program of study at certain points in your academic career.

3.3.7 Deviation from requirements

A majority of the student’s committee is sufficient to approve (or disapprove) the program of study, or a 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 is usually 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.

3.4 Exams

Graduate students are required to take both written and oral exams, but some Master’s degree programs require only written or oral exams.

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3. Graduate study

3.4.1 Written preliminary and qualifying examinations

All Ph.D. students are required to pass at least four of the following written qualifying exams at a high-pass level. Additionally, they are required to pass at least two of the following exams. Thus Ph.D. students must pass six (4+2) exams in total.

Students in the Master’s degree program may be required to pass up to 4 written exams, depending on the exact program that they are a part of.

For courses taken in Fall 2020 or later, the following applies. Earning an A in the corresponding course counts as a high pass. Earning a B+ (or A-) in the corresponding course counts as a pass. It is possible for a student to pass out of all required exams via course performance.

Qualifying exams passed before August 2020 normally each count as two high passes for the purpose of these exams. See Subsection 3.4.4 for additional details.

The written Ph.D. preliminary examinations are the same as the Master’s qualifying examinations.

All exams are offered in August, typically in the two weeks before the Fall semester. Additionally, each exam is offered approximately 4 weeks after the end of the corresponding course during the regular academic year. For courses offered in Fall semester, the corresponding exam will normally be held in early January. For courses offered in Spring semester, the corresponding exam will normally be held in May.

3.4.1.1 Exam topics

The written part of the Ph.D. preliminary examination in mathematics consists of tests in the following areas. The associated course number is listed before each area.

6040 Probability
6210 Real Analysis
6220 Complex Analysis
6310 Algebra I
6320 Algebra II
6410 Ordinary Differential Equations
6420 Partial Differential Equations
6510 Differentiable Manifolds
6520 Algebraic Topology
6610 Analysis of Numerical Methods I
6620 Analysis of Numerical Methods II

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6710  Applied Linear Operator and Spectral Methods
6720  Applied Complex Variables and Asymptotic Methods
6824  Statistical Inference I
6828  Statistical Inference II

Syllabi for these qualifying exams are available later in this document: see Chapter 5. Students must recognize that the tests are based on the material in the syllabus, not on the material in the preceding 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.

Students should choose their tests in consultation with their advisor(s) or Initial Academic Mentor. One purpose of this consultation is to ensure sufficient breadth in the choice of tests.

3.4.1.2 When to take exams

In order to pass the written qualifying examinations, a Ph.D. student must pass four tests at a high level (or earn As in the corresponding courses if taken after August 2020) and must pass two additional tests (or earn B+s, A-‘s, or higher in the corresponding courses if taken after August 2020). See Subsection 3.4.4 for details for students starting before 2020.

A Master’s student whose committee has selected the written qualifying exam option must pass four tests (or earn B+s or above in the corresponding courses if taken after August 2020). Master’s degree students who have selected the written qualifying exam option should take the qualifying exams as soon as they have the necessary background.

Ph.D. students, without pre-arranged exceptions (which may, for example, be due to health or life emergencies), are expected to:

• Take 2–3 preliminary exam courses each semester in their first year if they did not pass out of those courses via exams they took when entering the program in August.

• Obtain 4 high passes by the end of January in their second year. Students who do not meet this target should expect to leave the program at the conclusion of year 2.

• Finish all written exams before their third year in the program.

Students who transfer to the Ph.D. program from the Master’s program will normally have these deadlines set 1 year later with respect to when they started the graduate program, see Subsection 3.6.1.

Ph.D. students whose background is not sufficient to take courses and exams on this schedule may, in their first year in the program, request to be transferred
to a Master’s program with a goal of eventually completing the Ph.D. program. In that case, students can take the courses prerequisite to those written exam related courses described above. These students should be given a letter by the Director of Graduate Studies specifying exactly what they need to pass and by when in order to automatically be transferred to the Ph.D. program. Typically, students in this situation will be one year behind other students in terms of requirements for written preliminary and oral qualifying exams.

The Graduate Committee reviews students’ progress towards completing their written exams in January of their second year. Each student’s renewal-of-support letter for that year must include the date that the Graduate Committee expects the student to complete written exams if there is a pre-approved deviation from the schedule listed above. **Failure to pass by this specified date typically results in termination from the graduate program.**

### 3.4.1.3 Normal progress towards passing written exams

In order to make progress towards passing these exams, it is important for students to do well in their courses and to take exams promptly.

Ph.D. students meeting any of the following criteria:

- By the end of January of their first year, have not passed at least 1 exam at the high level and passed one additional exam.
- By May of their first year, have not passed at least three exams at the high level.
- By the start of their second year, have not passed at least four exams at the high level.

should work with their advisor or initial academic mentor and the director of graduate studies or other members of the graduate committee, to develop a plan to remedy this situation. Such remedies may include regular tutoring by a faculty member, retaking a qualifying exam class, taking a different qualifying exam class, or dropping to a Masters program as described above (when appropriate).

Students who transfer to the Ph.D. program from the Master’s program will normally have their deadlines set 1 year later with respect to when they started the graduate program, see Subsection 3.6.1.

### 3.4.1.4 Maximum exam attempts

There is no limit on maximum exam attempts.

### 3.4.1.5 Responsible faculty

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.
3.4. Exams

That person selects, for each exam, two members of the tenure line faculty to be in charge of the exams and the final exam for the corresponding course. One of those two members should be the faculty member who taught the corresponding course, if possible. Thus there are two responsible faculty.

(A) The faculty who taught the course.

(B) Another faculty member assigned to this duty.

The course instructor (A) has final responsibility for the final exam for their course but is expected to discuss the final exam for the course with the other responsible faculty member (B). Faculty member (B) has final responsibility for the exam given 4 weeks after the end of the course, but should likewise discuss the exam with the course instructor (A). These or other faculty members may also be asked to be involved in the August exam, in which case they should work together.

3.4.1.6 Nature of the examinations

The test in each area is a written test of two hours duration. The level of the test should be comparable to that of the corresponding 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 Chapter 5. Copies of past examinations are available at

http://math.utah.edu/grad/qualexams.html

However, notice that starting in August 2020, the exams are broken up by semester. Thus, for example, there is a one exam on Real Analysis and a different exam on Complex Analysis. Before August 2020, most exams were based on two semesters, so for instance there was a combined exam on Real and Complex Analysis.

All examinations are proctored.

3.4.1.7 Grading of the tests

After all the tests in a given area have been graded, the two faculty responsible for the test decide what is to be a passing score on the examination. Student identities are not revealed to the graders.

3.4.1.8 Announcement of results

Under normal circumstances, the student is informed within one week after the end of the examinations of the passing score on each test and is allowed to examine their tests.

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3.4.1.9 Appeals

The Graduate Committee handles all appeals. In particular, grading of examinations may be disputed, and exceptions to these rules can be granted. A student wishing to make an appeal does so through his or her Initial Academic Mentor, advisor, Supervisory Committee or the Director of Graduate Studies. Those 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: see Subsection 3.1.4.

3.4.2 Oral qualifying examinations

Ph.D. students are required to take an oral qualifying examination, and some Master's degree students may also be required to take such an exam, depending on their program. 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.²

Responsibility for scheduling the examination rests jointly with the student and their 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 their 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 their Supervisory Committee’s 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:

Coursework: The student answers questions based on their 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.

Research Proposal: The student makes a presentation of a background topic related to their proposed research or directly on their preliminary research. The student proposes the plan for the rest of the Ph.D. research and demonstrates they have the requisite background by answering questions related to the presentation/proposal/background topic.

Some supervisory committees might require a written research proposal and/or as with the coursework exam, a written syllabus of the topics covered on the exam. The Mathematical Biology Group has additional requirements.

²It is possible to appeal this, but such appeals must be granted by both the Graduate Committee and the Dean of the Graduate School.
3.4. Exams

for the written project proposal which accompanies their oral exam. See their website

http://www.math.utah.edu/research/mathbio/

for more details.

3.4.2.1 When to schedule oral qualifying exams

All Ph.D. students are required to:

• Have passed or scheduled their oral qualifying exam by January of their third year in the program. In particular, this means that students must have chosen their advisor and formed their committee by this time.

• Have passed their oral qualifying exam before their fourth year in the program.

The Director of Graduate Studies should be informed if there is a change to the date the exam is scheduled. Annual renewal-of-support letters include expectations of when students should pass their oral qualifying exam. Failure to meet the deadlines above, or other deadlines in the letter of support, which may supersede those deadlines, will typically lead to termination from the program. Exact deadline is dependent largely on the type of exam being given.

Students who transfer to the Ph.D. program from the Master’s program will normally have these deadlines set 1 year later with respect to when they started the graduate program, see Subsection 3.6.1.

3.4.3 Final oral examination

The final oral examination for Ph.D. students, and some Master’s degree students, sometimes called the “Thesis Defense,” is distinct from the oral qualifying examination. This examination consists of a public thesis defense. The Supervisory Committee meets in private after the defense to vote on final approval.

3.4.4 Students starting before May 2020.

Graduate students who started before May 2020 have the following rules.

• Students who have passed their written qualifying exams are still considered to have passed their qualifying exams.

• We expect that students will work in the following hybrid system below. However, if there are particular unforeseen problems with doing this for a student (such as might disadvantage a student, particularly around the timing of the probability exam), the student should ask the Graduate Director to work with them to address their concerns. Any changes to the rules below will be reviewed by the graduate committee on a case by case basis.

Last revision: June 22, 2020, 15:08 MDT
1. Any written preliminary exams passed before August 2020 count as 2 exams passed at a high level, this includes the Probability exam.
2. Students take exams which are based upon one semester of study.
3. They will need to pass 4 at a high level and pass 2 more exams.

- The deadline for passing written preliminary exams is set at 2.5 years. Note this is extended relative to the system of exams after August 2020.
- The deadline for passing the oral qualifying exam is whatever it is set to in the most recent letter of support. However, the expectation for students in pure mathematics is they pass this by January in their third year. Students in applied mathematics are normally expected to pass this by January in their fourth year. Note, this is a different schedule than what is expected for students who entered in August 2020 or later.

### 3.5 Evaluation and dismissal of graduate students

At the beginning of Spring Semester, all graduate students are evaluated by the Graduate Committee on the progress in their study toward a degree. The Graduate Committee also evaluates teaching performance at this time. There are two issues being decided:

- continuation in the program; and
- continued financial support in the form of a Teaching Assistantship and tuition benefit.

It is possible that a student may be allowed to continue progressing towards a degree without funding, for instance, without a Teaching or Research Assistantship. A student may also be responsible for his or her tuition costs, especially if the student has used up the tuition benefit: see Subsection 3.2.1.

Decisions to continue or award Teaching Assistantships, and to continue in the program, are based on both teaching performances and on academic performance. Notification of renewals or nonrenewals are distributed by April 15. These letters also contain individualized academic performance expectations for each student for future years.

### 3.5.1 Academic performance

The academic requirements, specified throughout the Graduate Bulletin, are considered by the Graduate Committee in Spring Semester for students in the graduate program. Below is a list of common conditions that cause a student to be academically deficient within the Ph.D. program. If a student satisfies any of the conditions below, then the student is academically deficient unless there is
a previous written arrangement for deviation from the corresponding requirement. Failure to promptly address these issues or other issues will normally lead to termination from the program.

- Failure to have passed at least four written qualifying exams at a high level by January of their second year. See When to take exams.

- Failure to have passed all written qualifying exams before their third year. See When to take exams.

- Failure to have passed or scheduled, by January in the third year, the oral qualifying exam. While the exam does not have to be taken by this point, it must be scheduled in consultation with the student’s advisor and Supervisory Committee. See When to schedule oral qualifying exams. Thus the student’s advisor and committee must be in place by this point.

- Failure to have passed the oral qualifying examination before the fourth year of study.

- Failure to have passed oral or written qualifying exams by the time specified in the most-recent letter of support (or other most-recent letter from the Graduate Committee).

- Failure to graduate by the date specified in the most-recent letter of support (or other most-recent letter from the Graduate Committee).

- Failure to meet other individualized requirements specified in letters of support or other letters written by the Graduate Committee or Director of Graduate Studies.

- Failure to select an advisor by January of their third year: see Advisors.

- Failure to maintain a 3.0 grade point average (required by the Graduate School if the student is to continue to receive the tuition benefit).

- Failure to conduct research at a level needed to complete a Ph.D. See also the guidelines on the student/advisor relationship in Subsection 3.5.3.

Note, students who transfer to the Ph.D. program from the Master’s program will normally have their deadlines set 1 year later than those deadlines outlined above, with respect to when they started the graduate program, see Subsection 3.6.1.

### 3.5.2 Appeals

Students who fall behind in any of these categories, or who fail to meet other requirements specified for their program, must promptly appeal to the Graduate Committee if they wish to continue in the program. Such deficiencies may be pointed out to the student in the annual letter of support, or in most cases, even earlier.
The content of the appeal should include a letter to the Graduate Committee explaining a plan to correct the deficiency. It should also include a letter from the student’s advisor or academic mentor and may include additional evidence. Appeals are considered by the Graduate Committee on a case-by-case basis. The Graduate Committee may accept the plan to correct the deficits, accept the plan after revisions, decide to dismiss the student, or withdraw financial support. The student may also be put on a schedule with more-frequent evaluations by the Graduate Committee. A student who loses financial support in the form of a Teaching Assistantship may still be eligible for support in the form of a Research Assistantship, typically from his or her advisor. A student may also enlist the aid of the Graduate Student Advisory Committee (GSAC) to help in the process, see Subsection 3.1.4.

If a student is dismissed from the program in the middle of the academic year, the student is usually allowed to complete that academic year. In the case that the student is in the Ph.D. program, the student is usually allowed to obtain a Master’s degree, if the program requirements have been met.

If a student is not satisfied with a decision made after an appeal to the Graduate Committee, the student may appeal to the decision to the Department Chair, and further as specified in Policy 6-400 of the Student Code.

### 3.5.3 Guidelines on the student/advisor relationship

A student or advisor may terminate the student/advisor relationship because of dissatisfaction. If a student wishes to terminate the student–advisor relationship, the student should notify the advisor, the Director of Graduate Studies, and the Graduate Program Coordinator. However, in most cases it is recommended that the student discusses the situation with the Director of Graduate Studies before making this decision. If a faculty advisor is dissatisfied with the research effort of a student, the faculty advisor should make every effort to communicate the concerns he or she may have at an early stage of the dissatisfaction. If deficiencies persist, the faculty member should identify to the student in writing the unsatisfactory aspects of the student’s research performance and allow the student a reasonable time (typically at least 30 days) to correct the deficiencies. A copy of this letter should be sent to the Graduate Committee. If the deficiencies are corrected, the faculty advisor should notify the student in writing again with a copy of the letter sent to the Graduate Committee. If the deficiencies still persist, the student should expect that the student/advisor relationship is terminated. This may also lead to termination of financial support or termination from the program if the student is unable to find a new academic advisor.

### 3.5.4 Teaching Assistant performance

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. Further appeals may be made as specified in University Policy 6-309.

3.6 **Combining Master’s and Ph.D. programs**

There are two ways to combine the Ph.D. program and the various Master’s programs available.

3.6.1 **Continuing to the Ph.D. program from the Master’s program**

Some students in the Master’s program are admitted with the expectation that they will continue to the Ph.D. program. They may have also started in the Ph.D. program and dropped to the masters program in order to take prerequisite courses.

The details of how to automatically transfer to the Ph.D. program will be included in their letter of admission to the graduate program, if the student falls into this case. One standard requirement for such students is that:

- They need at least two high passes and one pass by January in their second year to continue to the Ph.D. program.

Master’s students not in the above category, but 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 Apply Yourself (AY) to the Graduate School. Applicants to the Ph.D. Program must arrange three letters of recommendation to support their applications. 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.

Masters students who transfer to the Ph.D. program will typically be 1 year behind Ph.D. students who entered at the same time. Thus all deadlines for finishing written and oral exams will be 1 year later. For example, such students, after transferring to the Ph.D. program will need to:

- Pass at least 4 written exams at the high level by January of their third year in the graduate program.
- Complete all written exams before their fourth year in the graduate program.
• Have completed or scheduled their oral exam before their fifth year in the
graduate program.

Compare with Subsubsection 3.4.1.2 and Subsubsection 3.4.2.1.

3.6.2 Earning a Master’s degree while in the Ph.D. program

Students who have directly entered the Ph.D. Program can frequently earn a
Master’s degree along the way. 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
student’s Program of Study for the Master’s Degree Form. Students should list
the minimum number of course credits (30), in their M.S. programs of study
forms. The course requirements for the Ph.D. must be satisfied by the remaining
courses.

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.

3.6.3 Entering the Ph.D. program with a Master’s degree

Most students who enter the Ph.D. program do not have a previous Master’s
degree. However, if an entering student does have a Master’s then typically
that student will be promised 4 years of support upon entrance to the program,
instead of 5. Such students do not have different timelines for passing their
oral qualifying or written preliminary exams. Some details about their normal
progress timeline changes though, see Subsection 3.7.2 for more details. One
particularly important goal for such students is to identify an advisor as quickly
as possible.

3.7 Timelines for normal academic progress

This section supplies brief timelines for normal academic progress for students
in the Ph.D. and regular Master’s programs.

3.7.1 Masters of Arts and Master of Science degrees

Financial support for the Master’s program is limited to two years.

• Year 1
  – Meet with the Director of Graduate Studies to form a plan upon entering
the program.
3.7. Timelines for normal academic progress

– Find an advisor and form 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.*

– Discuss with your advisor your chosen area of study and Master’s degree project if applicable.

**• Year 2 — Fall**

– 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.

– Talk with members of your Committee about plans for your comprehensive examination.

**• Year 2 — Spring**

– File the Request for **Supervisory Committee** and Application for Admission to Candidacy for a Master’s Degree forms for the Graduate School with the Mathematics Graduate Program Coordinator.

– Schedule any final oral exams or thesis defenses. Students writing theses must pay particularly close attention to the deadlines available at http://gradschool.utah.edu/thesis/

### 3.7.2 Ph.D. degree

Below is a recommended timeline for students attempting to complete the Ph.D. degree and who did not previously earn a Master’s degree in Mathematics at the University of Utah. suggested dates earlier than the required dates for passing the qualifying exams listed for written exams and oral exams. Also see Continuing to Ph.D. program from Master’s program for information about the timelines for students continuing from the Master’s program to the Ph.D. program.

The length of financial support corresponds to the students expected academic timeline. In particular, student who entered with a Master’s degree are expected to graduate in 4 years, and those who entered with a Bachelor’s degree are expected to graduate in 5 years.

In some cases this can be extended by one year to 5-years or 6 years respectively (depending on whether the student has a previous Master’s degree), and, in extremely unusual cases, it can be partially extended to 6-years or 7 years, respectively.

The timeline below does not depend on the type of support a student receives. Students are expected to graduate in 5 years (or 4, if they have a Master’s degree) whether or not they are supported by the department as TA, whether they are supported by their advisor as an RA, or whether they are supported with a Fellowship.

**• Year 1**
3. Graduate study

- Take 2–3 qualifying exam courses.
- Pass at least 1 written preliminary exam at a high level (or obtain A in the course), and 1 more written preliminary exam (or obtain a B+ or higher in the course) by January.
- Pass at least 3 written preliminary exams at a high level and obtain at least 1 more pass by the August before your second year.
- Think about choosing your advisor. If you have a previous Master’s degree, choose your advisor if at all possible.

• Year 2

- Choose your advisor!
- Form your Supervisory Committee.
- Pass at least 4 written qualifying exams at a high level, by January.
- Pass remaining written qualifying exams by the August before your third year.
- Take more advanced classes.
- Start thinking about, and perhaps even pass, your oral qualifying exam.
- Start working on/towards research.

• Year 3

- Continue to work on research.
- Form your Supervisory Committee if not already done. This must be done by January.
- Schedule or pass your oral qualifying exam by January.
- Pass your oral qualifying exam before August of your fourth year.

• Year 4

- Continue to work on research.
- Discuss with your advisor plans to graduate next year.
- If you have a previous Master’s degree, then the steps from year 5 (applying for jobs, applying to graduate, writing your thesis, scheduling your defense, and submitting your thesis), should all be done in year four.

• Year 5

- Continue to work on research.
- During the Fall Semester, apply to graduate with the Graduate Program Coordinator.
- Apply for jobs in the Fall Semester (if appropriate).

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3.8 Outside employment

- Start writing your thesis in the Fall Semester.
- Schedule your thesis defense in the first two months of Spring Semester if you plan to graduate in Spring. Otherwise schedule your thesis defense in or before April if you plan to graduate in Summer.
- Submit all your thesis material to the Thesis Office well in advance of their deadlines.

3.8 Outside employment

Graduate students supported by a TA, RA, or fellowship are expected to work full time on their duties and towards the completion of their degree. Supported students are not permitted to be employed while also working as a TA, RA, or under fellowship, unless prior approval is first obtained from the Graduate Committee.

3.9 Gaining other skills

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 programs. Familiarity with one or more computer-algebra systems, and the $\LaTeX$ and $\LTX$ 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.

3.9.1 Courses from other departments

In general, 5000-, respectively 6000-, level courses from other departments (e.g., courses in Biology, Chemistry, Computer Science, Economics, Physics & Astronomy, etc.) can be applied to fulfill the course requirements for the Master’s, respectively Ph.D., program in Mathematics. Permission to include such courses must be obtained from the student’s Committee. Some of these courses may charge differential tuition.

3.10 Applying to graduate study

Instructions for applying to graduate study in the Mathematics Department at the University of Utah, including information about GRE and TOEFL SCORES, are available at

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3.11 Housing in Salt Lake City

The University accepts applications for on-campus residence hall and University student apartment housing.

Student residence halls provide a single room, with a shared bathroom and kitchen. For current information, visit https://housing.utah.edu/housing-options/graduate-housing, or contact Office of Housing and Residential Living, 5 Heritage Center, University of Utah, Salt Lake City, UT 84112-2036, (801) 587-2002.

Apartment housing for both married and single undergraduate and graduate students is available on campus. Visit http://www.apartments.utah.edu/ for current information, or contact University Student Apartments, 1945 Sunnyside Avenue, Salt Lake City, UT 84108, (801) 581-8667.

Off-campus house and apartment listings can be found in the classified sections of

- the Salt Lake Tribune (http://www.sltrib.com/),
- the Deseret News (http://www.desnews.com/),
- the Daily Utah Chronicle (http://www.dailyutahchronicle.com/) student newspaper, and
- on radio and television station KSL (http://www.ksl.com/).
This chapter lists the degree requirements for the Ph.D. degree, as well as the various Master’s degrees offered.

4.1 Master of Arts and Master of Science degrees

4.1.1 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. Visit http://gradschool.utah.edu/graduate-catalog/degree-requirements for information on the Ph.D. degree requirements.

A number of forms must be filed, and certain time limitations are to be observed. The student is responsible for submitting forms on time.

Each Master’s candidate is assigned an Initial Academic Mentor upon entering the program but is expected to formally choose an advisor during their first year. This mentor or advisor has the primary responsibility of guiding and evaluating the candidate’s progress through the Master’s program: see Subsection 3.3.2 for more information. During the first year, the Master’s candidate also forms a Supervisory Committee which assists with the same task: see Section 3.3.

A student can receive a Master’s degree in either pure or applied mathematics.

4.1.2 Departmental requirements — pure mathematics

Requisites for the Master’s degree in pure mathematics are listed in the following subsections.

4.1.2.1 Course requirements — pure mathematics

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

• Math 5210 (real analysis).
4. Degree requirements

- 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.
- 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.

4.1.2.2 Graduation requirements — pure mathematics

There are four options to satisfy the graduation requirements for the Master’s degree. The particular option utilized is decided by the student’s Supervisory Committee.

1. **Qualifying Exam Option.** Pass four of the written qualifying exams (corresponding to 4 semesters of work)and take at least 30 semester hours of approved courses. The exams are comprehensive and serve as the required final exam. See Section 3.4 for more details on those exams.

   OR

2. **Research or Curriculum Project Option.** Write a Research or Curriculum Project and take at least 39 semester hours of approved courses. Students choosing this Non-Thesis Project Option may take up to 10 semester hours of Math 6960 Special Projects. The Non-Thesis 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, 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).
4.2. Master of Statistics (Mathematics) program

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 non-thesis option, and the basis for its selection, shall be included with the student’s proposed program. The 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.

4.1.3 Departmental requirements — applied mathematics

Requisites for the Master’s degree in applied mathematics are given in the following subsections.

4.1.3.1 Course requirements — applied mathematics

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.

4.1.3.2 Graduation requirements — applied mathematics

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

4.1.4 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.

4.1.5 Transfer credit

Upon the approval of the Master’s Committee, at most nine hours of nonmatriculated 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.

4.2 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
4. Degree requirements

Statistics Committee and the Departmental Admissions Committee. The degree, Master of Statistics (Mathematics), is awarded by the Mathematics Department.

4.2.1 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.

4.2.2 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 the 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.”

For more information on the MSTAT program, see the Mathematics Information Sheet available at

http://mstat.utah.edu/degree-options/mathematics.php

4.3 Master of Science in Mathematics Teaching

For information about the Master of Science in Mathematics Teaching, see the prerequisites and requirements at

http://www.math.utah.edu/mathed/master_mt.html

Students may also contact Paula Tooman (mailto:tooman@math.utah.edu) for administrative information, and Tommaso de Fernex (mailto:defernex@math.utah.edu) for academic program information.

\(^1\)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.
### 4.4 Professional Master of Science and Technology, Computational and Data Science Track

The mission of the Computational and Data Science Track of the PMST program is to prepare students for professional positions in business, industry, and government, because demand for computational and data-science specialists is rapidly increasing with the growth of large sets of data. For many businesses and industries, developing mathematical models, employing numerical methods, and using data visualization has become increasingly important for innovative scientific research.

The Computational and Data Science Track incorporates graduate coursework from different mathematical and computer-science disciplines to reflect the breadth of computational and mathematical tools employed to solve real-world problems.

The Computational and Data Science Track of the PMST Program is a professional interdisciplinary program that, together with graduate courses in mathematics and computing, includes courses in management and communication. PMST students are required to complete an internship with a company, organization, or governmental agency. The business component serves to develop leadership and management skills that are highly valued by industry, and helps to prepare students for a career and professional development.

For more information, visit the PMST and CDS websites at

http://pmst.utah.edu
http://pmst.utah.edu/computational-and-data-science-track/

More details about the program, and examples of curricula within specific concentration areas, can be found at


Students with a background in mathematics, physics, computer science, or engineering are encouraged to apply.

### 4.5 Doctor of Philosophy degree

#### 4.5.1 Graduate School requirements

Visit

http://gradschool.utah.edu/graduate-catalog/degree-requirements

for information on the Ph.D. degree requirements.

Last revision: June 22, 2020, 15:08 MDT
4.5.2 Departmental requirements

4.5.2.1 Advisors and Supervisory Committee

An Initial Academic Mentor is appointed for each prospective student prior to the first semester of graduate study. During the first two years in the program, the student must select an advisor and form a Supervisory Committee. See Section 3.3 for more details on the composition and function of this committee.

4.5.2.2 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 Math 7970, 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.

4.5.2.3 Written preliminary examinations

The Written Ph.D. Preliminary Examinations are the same as the Master’s Qualifying Examinations from Option #1. Ph.D. students must pass 4 written exams at a high level, by January of their second year and must pass at least two more exams before the third year. See Section 3.4 for more details on these exams, as well as more detailed timelines. Note that course performance can replace these exams.

4.5.2.4 Oral qualifying examination

Ph.D. students are required to take an oral qualifying examination. See Subsection 3.4.2 for more details.

4.5.2.5 Foreign language requirements

The Department of Mathematics does not have foreign language requirements for a Ph.D. degree.

4.5.2.6 Final oral examination

Ph.D. students must perform a final oral examination, sometimes called a “Thesis Defense”. See Subsection 3.4.3.
4.5. **Doctor of Philosophy degree**

4.5.2.7 *Teaching requirements of Ph.D. candidate*

The Department requires each graduate student who is studying toward a Ph.D. degree to teach a minimum of *two* courses, or equivalent tutorials, or laboratory supervisions to be carried out over a minimum of *one* year and a maximum of *six* years, whenever appropriate.

4.5.3 **Time limit**

The time limit for completion of degree requirements for the Ph.D. degree, as set by the Department, is *seven* years. 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. See Subsection 3.2.1 for more details.

4.5.4 **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

http://gradschool.utah.edu/current_students/graduation-overview-for-doctoral-candidates

Thesis information may be found at

http://gradschool.utah.edu/thesis/

*A Handbook for Theses and Dissertations* is available at

http://gradschool.utah.edu/thesis/handbook/
4. Degree requirements
This chapter discusses the material that is expected to be mastered for the written examinations that all graduate students must pass before completing their research programs.

5.1 Math 6040 – Probability

5.1.1 Topics

- 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.

5.1.2 Texts

5.2 **Math 6210 – Real Analysis**

5.2.1 **Topics**


- **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.

5.2.2 **Texts**


5.3 **Math 6220 – Complex Analysis**

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5.3.1 Topics


5.3.2 Texts


5.4 Math 6310 – Algebra I

- **Rings**: ideals, quotient rings, group 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.

- **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.

- **Commutative ring theory**: 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.
5. Syllabi for qualifying examinations

5.4.1 Texts


5.5 Math 6320 – Algebra II

Problems on this exam will require usage of the topics from 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, nilpotent groups, solvability of $p$-groups, classical matrix groups, automorphism groups, Jordan–Holder theorem, free groups, presentations of groups.

- **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.

- **Representation theory**: representations of finite groups and finite dimensional algebras, complete reducibility, Maschke’s theorem, characters, orthogonality relations.

5.5.1 Texts

The texts for Algebra II are the same as for Algebra I, see Subsection 5.4.1.

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5.6 **Math 6410 – Ordinary differential equations**

### 5.6.1 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.

### 5.6.1.1 Texts


5.7 **Math 6420 – Partial differential equations**

### 5.7.1 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.
5. Syllabi for qualifying examinations

- **Waves and vibrations**: General concepts, e.g., 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; 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.

5.7.1 Texts


5.8 Math 6510 – Differentiable Manifolds

5.8.1 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: \( \mathbb{R}^n \), \( S^n \), \( T^n \), \( \mathbb{R}P^n \), \( \mathbb{C}P^n \), Stiefel manifolds, Grassmannians, the notion of Lie groups and basic examples, e.g., \( \text{GL}_n(\mathbb{R}) \), \( \text{SL}_n(\mathbb{R}) \), \( \text{SO}(n) \), \( \text{SL}_n(\mathbb{C}) \), \( \text{SO}(p, q) \), 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).
5.9. Math 6520 – Algebraic Topology

- Normal bundle, tubular neighborhood theorem, Whitney embedding theorem.
- Intersection theory mod 2, Jordan–Brouwer.
- Orientations, \( \mathbb{R}P^n \) 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.

5.8.2 Texts


5.9 Math 6520 – Algebraic Topology

5.9.1 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: \( S^n \), \( \mathbb{C}P^n \), \( \mathbb{R}P^n \), \( T^n \), graphs, surfaces. \( \text{SL}_n(\mathbb{R}) \) deformation retracts to \( \text{SO}(n) \).
- Ch 1: free products of groups and amalgams, fundamental group, van Kampen, computing \( \pi_1 \) of cell complexes and standard spaces, covering spaces, lifting properties, deck group, Galois correspondence, free properly discontinuous actions, Lie groups have abelian \( \pi_1 \), covering space of a Lie group is a Lie group, \( \text{SO}(2) = S^1 \), \( \text{SO}(3) = \mathbb{R}P^3 \), \( \text{SL}_2(\mathbb{R}) \).
5. Syllabi for qualifying examinations

- Ch 2: Δ 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, Brouwer’s fixed point theorem, invariance of domain, \( H_1(X) = \pi_1(X)_{ab} \).

- 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 \( S_2 \cup S_4 \) and \( \mathbb{C}P^2 \) 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., \( H_i(M) \otimes H^{n-i}_c(M) \rightarrow \mathbb{R} \), induced by \( \omega \otimes \eta \mapsto \int_M \omega \wedge \eta \), say for \( M \) with finite good cover (see Spivak, Ch 11).

5.9.2 Texts


5.10 Math 6610 – Analysis of Numerical Methods I

5.10.1 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.

- **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.
5.10.2 Texts

The texts for Math 6610 are the same as those for Math 6620, see Subsection 5.11.2.

5.11 Math 6620 – Analysis of Numerical Methods II

Note that many of the topics below require mastery of the material from Analysis of Numerical Methods I. Problems on this exam will frequently require extensive usage of the topics also covered on that exam.

5.11.1 Topics

- **Interpolation and approximation**: Polynomial, rational, Fourier series; Spline-based methods for interpolation and approximation; Quadrature; Orthogonal polynomials.

- **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.

5.11.2 Texts


5. Syllabi for qualifying examinations


5.12 Math 6710 – Applied Linear Operator and Spectral Methods

5.12.1 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; 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.
5.13. Math 6720 – Applied Complex Variables and Asymptotic Methods

5.13.1 Topics

- Theory of complex variables: Analytic function theory, integral theorems, Taylor and Laurent series, singularities.

- Applications of complex variables: Contour integration, Conformal mapping, Fourier transform in complex domain, Argument principle.


5.13.2 Texts


\section*{5.14 Math 6824 – Statistical Inference I}


\subsection*{5.14.1 Texts}


\section*{5.15 Math 6828 – Statistical Inference II}


\subsection*{5.15.1 Texts}

The texts are the same as for Statistical Inference I, see Subsection 5.14.1.
Recent Ph.D. students

This chapter records our doctoral students of the past three decades to show their fields of study, graduate advisors, and the initial job positions that they moved to after graduation.

<table>
<thead>
<tr>
<th>Ph.D. Graduate</th>
<th>Research Area</th>
<th>Advisor</th>
<th>Post-graduate position</th>
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</thead>
<tbody>
<tr>
<td>Matteo Altavilla</td>
<td>Algebraic Geometry</td>
<td>Bertram</td>
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<tr>
<td>Hanna Astephan</td>
<td></td>
<td>Wortman</td>
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<tr>
<td>Kevin Childers</td>
<td>Number Theory</td>
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<td>Huy Dinh</td>
<td>Applied Mathematics</td>
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<td>Pinches Dirnfeld</td>
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<td>Iyengar</td>
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<td>Priscilla Elizondo</td>
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<td>Fogelson</td>
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<td>Gaoyang (Bridget) Fan</td>
<td>Mathematical Biology</td>
<td>Bressloff</td>
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<tr>
<td>Elizabeth Fedak</td>
<td>Mathematical Biology</td>
<td>Adler</td>
<td>Postdoc, University of Utah</td>
</tr>
<tr>
<td>Samantha Hill</td>
<td>Mathematical Biology</td>
<td>Adler</td>
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<tr>
<td>Hyunjoong Kim</td>
<td>Mathematical Biology</td>
<td>Bressloff</td>
<td>Simons Postdoctoral Fellow in the Center for Mathematical Biology, University of Pennsylvania</td>
</tr>
</tbody>
</table>
6. Recent Ph.D. students

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<thead>
<tr>
<th>Name</th>
<th>Field</th>
<th>Advisor</th>
<th>Position</th>
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<tbody>
<tr>
<td>Sabine Lang</td>
<td>Representation Theory</td>
<td>Savin</td>
<td>Teaching Assistant Professor, University of Denver</td>
</tr>
<tr>
<td>Janina Letz</td>
<td>Commutative Algebra</td>
<td>Iyengar</td>
<td>Postdoc, University of Bielefeld, Germany</td>
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<tr>
<td>Erin Linebarger</td>
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<td>Narayan</td>
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<td>Kathryn Link</td>
<td>Mathematical Biology</td>
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<tr>
<td>Dapeng Mu</td>
<td>Algebraic Geometry</td>
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<td>Patrick Murphy</td>
<td>Mathematical Biology</td>
<td>Bressloff</td>
<td>Postdoctoral Research Assistant, Rice University</td>
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<tr>
<td>Sergazy Nurbavliyev</td>
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<td>Rassoul-Agha</td>
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<td>Marcus Robinson</td>
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<td>Schwede</td>
<td>Visiting Professor, Reed College, Oregon</td>
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<td>Rebecca Terry</td>
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<td>Kiersten Utsey</td>
<td>Applied Mathematics</td>
<td>Keener</td>
<td>Research Associate II, Metrum Research Group</td>
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<tr>
<td>Ziwen Zhu</td>
<td>Algebraic Geometry</td>
<td>de Fernex</td>
<td>Boya Postdoctoral Fellow, Peking University</td>
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**2019**

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<th>Name</th>
<th>Field</th>
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<tr>
<td>Adam Brown</td>
<td>Representation Theory</td>
<td>Trapa</td>
<td>Institute for Science and Technology (IST), Vienna, Austria</td>
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<td>Huachen Chen</td>
<td>Algebraic Geometry</td>
<td>Bertram</td>
<td>Lecturer at UCSB</td>
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<td>James Farre</td>
<td>Geometry/Topology</td>
<td>Bromberg</td>
<td>NSF Postdoctoral Research Fellow, Yale University</td>
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<tr>
<td>Stefano Filipazzi</td>
<td>Algebraic Geometry</td>
<td>Hacon</td>
<td>Hedrick Assistant Adjunct Professor, UCLA</td>
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<tbody>
<tr>
<td>Erjuan Fu</td>
<td>Algebraic Geometry</td>
<td>Lee &amp; Clemens</td>
<td>Postdoc, Yau Mathematical Sciences Center, Tsinghua University, China</td>
</tr>
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<td>Greg Handy</td>
<td>Mathematical Biology</td>
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<td>Postdoctoral Associate, University of Pittsburgh</td>
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<td>Commutative Algebra</td>
<td>Singh</td>
<td>University of Kentucky</td>
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<td>Daniel Smolkin</td>
<td>Commutative Algebra</td>
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<td>Weicong Su</td>
<td>Probability</td>
<td>Khoshneisan</td>
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<td>Ryan Viertel</td>
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<td>Osting</td>
<td>Senior Member of the Technical Staff, Sandia National Laboratories</td>
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<td>Dawei Wang</td>
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<td>Hanlei Zhu</td>
<td>Statistics</td>
<td>Horváth</td>
<td>Strategist Associate, Goldman Sachs</td>
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<td>Leonard Carapezza</td>
<td>Dynamical Systems</td>
<td>Chaika</td>
<td>Utah International Charter School, Salt Lake City, UT</td>
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<td>Anna Miller</td>
<td>Biology/Natural Sciences</td>
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<td>Moffitt Cancer Center, Tampa, FL</td>
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<td>Anna Macquarie Romanova</td>
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<td>University of Sydney, Sydney, NSW, Australia</td>
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<td>Laura Strube</td>
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<td>Center for Systems Immunology, Polytechnic Institute and State University, Blacksburg, VA</td>
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<td>Honglu Fan</td>
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<td>ETH Zürich, Switzerland</td>
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<td>Christian Sampson</td>
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Last revision: June 22, 2020, 15:08 MDT
6. Recent Ph.D. students

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<tr>
<th>Name</th>
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<th>Institution</th>
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<tr>
<td>Yuan Wang</td>
<td>Algebraic Geometry</td>
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<td>Northwestern University, Evanston, IL</td>
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<td>Bin Xu</td>
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<td>Keyvan Yaghmayi</td>
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<td>Eric Jason Albright</td>
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Kenneth (Jack) Jeffries  Commutative Algebra  Singh  University of Michigan, Ann Arbor, MI
Predrag Krtolica  Applied Mathematics  A. Cherkaev & Treibergs  University of Utah, Salt Lake City, UT
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 Hawai at Manoa, Honolulu, HI

2014
Kei Yuen Chan  Representation Theory  Trapa  University of Amsterdam, The Netherlands
Chih-Chieh Chen  \( \kappa \) Theory  Savin
Sarah Cobb  Geometric Group Theory  Wortman  Midwestern State University, Wichita Falls, TX
Veronika Ertl  Algebraic Geometry  Nizioł and Savin
Brendan Kelly  Geometric Group Theory  Wortman
Michał Kordy  Applied Mathematics  E. Cherkaev  University of Utah, Salt Lake City, UT
Sonya Leibman  Geometric Group Theory  Bestvina  Online Image, Murray, UT
Ross Magi  Mathematical Biology  Keener
Brian Mann  Geometric Group Theory  Bestvina
James Moore  Mathematical Biology  Adler  Georgia Tech, Atlanta, GA
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6. Recent Ph.D. students

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, Salt Lake City, UT
Yuan Zhang        Applied Mathematics        A. Cherkaev   Universidad de Castilla-La Mancha, Cuidad Real, Spain

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### 6. Recent Ph.D. students

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6. Recent Ph.D. students

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</thead>
<tbody>
<tr>
<td>2003</td>
<td>Emina Alibegović</td>
<td>Geom Group Theory</td>
<td>Bestvina</td>
<td>University of Michigan, Ann Arbor, MI</td>
</tr>
<tr>
<td></td>
<td>Anca Mustata</td>
<td>Algebraic Geometry</td>
<td>Clemens</td>
<td>University of British Columbia, Vancouver, BC, Canada</td>
</tr>
<tr>
<td></td>
<td>Andrei Mustata</td>
<td>Algebraic Geometry</td>
<td>Bertram</td>
<td>University of British Columbia, Vancouver, BC, Canada</td>
</tr>
<tr>
<td></td>
<td>Bradford Peercy</td>
<td>Mathematical Biology</td>
<td>Keener</td>
<td>Rice University, Houston, TX</td>
</tr>
<tr>
<td></td>
<td>Matthew Rudd</td>
<td>PDE</td>
<td>Schmitt</td>
<td>University of Texas at Austin, TX</td>
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<tr>
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<td>Inbo Sim</td>
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<td>Schmitt</td>
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<tr>
<td>2002</td>
<td>Nicholas Cogan</td>
<td>Mathematical Biology</td>
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<td>Tulane University, New Orleans, LA</td>
</tr>
<tr>
<td></td>
<td>Martin Deraux</td>
<td>Complex Geometry</td>
<td>Toledo</td>
<td>Purdue University, West Lafayette, IN</td>
</tr>
<tr>
<td></td>
<td>Sonjong Hwang</td>
<td>Topology</td>
<td>Kapovich</td>
<td></td>
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<tr>
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<td>Blake Thornton</td>
<td>Geometric Topology</td>
<td>Kleiner</td>
<td>Westminster College, Salt Lake City, UT</td>
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<tr>
<td></td>
<td>Sung Yil Yoon</td>
<td>Topology</td>
<td>Bestvina</td>
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<tr>
<td>2001</td>
<td>Eric Cytrynbaum</td>
<td>Math Physiology</td>
<td>Keener</td>
<td>Institute for Theoretical Dynamics, University of California/Davis, CA</td>
</tr>
<tr>
<td></td>
<td>Miguel Dumett</td>
<td>PDE</td>
<td>Keener</td>
<td>Lawrence Livermore National Laboratory, Livermore, CA</td>
</tr>
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<td></td>
<td>Michael Hohn</td>
<td>Numerical Analysis</td>
<td>Folias</td>
<td>Lawrence Berkeley National Laboratory, Berkeley, CA</td>
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<tr>
<td></td>
<td>Jian Kong</td>
<td>Algebraic Geometry</td>
<td>Bertram</td>
<td>The Johns Hopkins University, Baltimore, MD</td>
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<tr>
<td></td>
<td>İsmail Küçük</td>
<td>Applied Mathematics</td>
<td>E. Cherkaev</td>
<td>American University, Sharjah, and Sakarya University, Turkey</td>
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<tr>
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<td>Chong Keat Arthur Lim</td>
<td>Rep Theory</td>
<td>Miličić</td>
<td>University of Minnesota, Minneapolis, MN</td>
</tr>
<tr>
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<td>Xiangdong Xie</td>
<td>Geom Group Theory</td>
<td>Kleiner</td>
<td>Washington University, St. Louis, MO</td>
</tr>
<tr>
<td></td>
<td>Chung Seon Yi</td>
<td>Mathematical Biology</td>
<td>Fogelson</td>
<td>Virginia Polytechnic Institute and State University, Blacksburg, VA</td>
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<tr>
<td>2000</td>
<td>Peter Brinkmann</td>
<td>Geom Group Theory</td>
<td>Gersten</td>
<td>University of Illinois/ Urbana–Champaign, IL</td>
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<tr>
<td></td>
<td>Chin-Yi Chan</td>
<td>Algebra</td>
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Last revision: June 22, 2020, 15:08 MDT
### 6. Recent Ph.D. students

<table>
<thead>
<tr>
<th>Name</th>
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<tbody>
<tr>
<td>Irina Grabovsky</td>
<td>Statistics</td>
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<td>National Board of Medical Examiners, Jacksonville, FL</td>
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<tr>
<td>Sean Sather-Wagstaff</td>
<td>Comm Algebra</td>
<td>Roberts</td>
<td>University of Illinois/Urbana–Champaign, IL</td>
</tr>
<tr>
<td>Haoyu Yu</td>
<td>Mathematical Biology</td>
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<td>University of Minnesota, Minneapolis, MN</td>
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#### 1999

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<tbody>
<tr>
<td>Kristina Bogar</td>
<td>Applied Mathematics</td>
<td>Keener</td>
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<tr>
<td>Charles Harris</td>
<td>Analysis</td>
<td>Tucker</td>
<td>University of Utah, Salt Lake City, UT</td>
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<td>Jon Jacobsen</td>
<td>PDE</td>
<td>Schmitt</td>
<td>Pennsylvania State University, State College, PA</td>
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<td>Elizabeth Jones</td>
<td>Comm Algebra</td>
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<td>University of Utah, Salt Lake City, UT</td>
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<tr>
<td>Nikolaos Tzolias</td>
<td>Algebraic Geometry</td>
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<td>Oklahoma State University, Stillwater, OK</td>
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<tr>
<td>Toshio Yoshikawa</td>
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#### 1998

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<tbody>
<tr>
<td>Hsungrow Chan</td>
<td>Differential Geom</td>
<td>Treiberg</td>
<td>National Tsing Hua University, Hsinchu, Taiwan</td>
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<tr>
<td>Chi Kan Chen</td>
<td>Applied Mathematics</td>
<td>Fife</td>
<td>University of Utah, Post Doctoral</td>
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<tr>
<td>Jeffrey L. Fletcher</td>
<td>Geo Group Theory</td>
<td>Gersten</td>
<td>Louisiana State University, Alexandria, LA</td>
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<tr>
<td>Takayasu Kuwata</td>
<td>Algebraic Geometry</td>
<td>Kollár</td>
<td>Tokyo Denki University, Tokyo, Japan</td>
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<tr>
<td>Andrew L. Kuharsky</td>
<td>Mathematical Biology</td>
<td>Fogelson</td>
<td>Tulane University, New Orleans, LA</td>
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<tr>
<td>Timothy J. Lewis</td>
<td>Mathematical Biology</td>
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<td>New York University, NYC, NY</td>
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<td>Natasa Macura</td>
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<td>Bestvina</td>
<td>University of Michigan, Ann Arbor, MI</td>
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<td>Eric Marland</td>
<td>Mathematical Biology</td>
<td>Keener</td>
<td>University of California/Davis, CA</td>
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<tr>
<td>Igor Mineyev</td>
<td>Group Theory</td>
<td>Gersten</td>
<td>Max-Planck-Institute für Mathematik, Bonn, Germany</td>
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<tr>
<td>Min Xie</td>
<td>Applied Mathematics</td>
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1997

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<td>Yongnam Lee</td>
<td>Algebraic Geometry</td>
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<tr>
<td>Richard Mayer</td>
<td>Algebraic Geometry</td>
<td>Carlson</td>
<td>University of Massachusetts, Amherst, MA</td>
</tr>
<tr>
<td>Laura Smithies</td>
<td>Rep Theory</td>
<td>Taylor</td>
<td>Kent State University, Kent, OH</td>
</tr>
<tr>
<td>Peter Spiro</td>
<td>Mathematical Biology</td>
<td>Othmer</td>
<td>Incyte Pharmaceuticals, Wilmington, DE</td>
</tr>
<tr>
<td>Nien-Tzu Wang</td>
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1996

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<tr>
<td>José Burillo</td>
<td>Group Theory</td>
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<td>Tufts University, Medford, MA</td>
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<tr>
<td>Shirnping Chen</td>
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<td>Toledo</td>
<td>Trilogy Technologies Inc., Taiwan</td>
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<tr>
<td>Ionut Ciocan-Fontanine</td>
<td>Algebraic Geometry</td>
<td>Bertram</td>
<td>Mittag-Leffler Institut, Djursholm, Sweden</td>
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### 1995

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<tr>
<td>Alberto Castro</td>
<td>Geometry</td>
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<td>Mt. Holyoke College, MA</td>
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<tr>
<td>Adam J. Chmaj</td>
<td>PDE</td>
<td>Fife</td>
<td>Brigham Young University, Provo, UT (Post Doctoral) and Utah State University, Logan, UT (Post Doctoral)</td>
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<tr>
<td>Ha Dang</td>
<td>Applied Mathematics</td>
<td>Fife</td>
<td>University of Utah, Salt Lake City, UT</td>
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<tr>
<td>Sándor Kovács</td>
<td>Algebraic Geometry</td>
<td>Kollár</td>
<td>MIT, Cambridge, MA</td>
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<td>Vy Khoi Le</td>
<td>Nonlinear Analysis</td>
<td>Schmitt</td>
<td>University of Colorado, Boulder, CO</td>
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<td>Lingyan Ma</td>
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<td>Horváth</td>
<td>University of Georgia, Athens, GA</td>
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<td>Uwe Mayer</td>
<td>PDE</td>
<td>Korevaar</td>
<td>Brown University, Providence, RI</td>
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<td>Pavle Pandžić</td>
<td>Lie Groups</td>
<td>Miličić</td>
<td>MIT, Cambridge, MA</td>
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<td>Romuald Sawicz</td>
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<td>University of California/Irvine, CA</td>
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<tr>
<td>Robert Van Kirk</td>
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<td>Henry’s Ford Foundation, Island Park, ID</td>
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### 1994

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<tr>
<td>Aldo Bernasconi</td>
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<td>Gersten</td>
<td>Chile (not in academia)</td>
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<tbody>
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<td>John M. O’Reilly</td>
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<td>Bronx Community College, NYC, NY</td>
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<td>Robert Shalla</td>
<td>Lie Groups</td>
<td>Miličić</td>
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<tr>
<td>Timothy Bratten</td>
<td>Lie Groups</td>
<td>Hecht</td>
<td>Argentina</td>
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<tr>
<td>Robert Dillon</td>
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<td>Othmer</td>
<td>Tulane University, New Orleans, LA</td>
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<td>Azniv Kasparian</td>
<td>Algebraic Geometry</td>
<td>Carlson</td>
<td>University of Sofia, Bulgaria</td>
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<td>Joo Kim Mok</td>
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<td>Mason</td>
<td>University of South Korea</td>
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<tr>
<td>Ming He</td>
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<td>Ethier</td>
<td>Weber State University, Ogden, UT</td>
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<td>Jeffrey McGough</td>
<td>Differential Equations</td>
<td>Schmitt</td>
<td>University of Nevada, Reno, NV</td>
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<tr>
<td>Endre Szabó</td>
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<td>Universität Bayreuth, Germany</td>
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<td>Yuanhua Tang</td>
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<td>Othmer</td>
<td>Cornell University, Ithaca, NY</td>
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<tr>
<td>Randall Westhoff</td>
<td>Algebraic Geometry</td>
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<td>Bemidji State University, Bemidji, MN</td>
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**1992**

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<tr>
<td>Mario R. Candia</td>
<td>Real and Complex Geometry</td>
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<td>In industry, Chicago, IL</td>
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<tr>
<td>Gregory R. Conner</td>
<td>Algebra and Number Theory</td>
<td>Gersten</td>
<td>Brigham Young University, Provo, UT</td>
</tr>
<tr>
<td>Alessio Corti</td>
<td>Algebraic Geometry</td>
<td>Kollár</td>
<td>MSRI, Berkeley, CA</td>
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<tr>
<td>David J. Eyre</td>
<td>Applied Mathematics</td>
<td>Fife</td>
<td>University of Minnesota, Minneapolis, MN</td>
</tr>
<tr>
<td>Tina Ma</td>
<td>Statistics</td>
<td>Mason</td>
<td>Pharmaco LSR, Inc., Austin, TX</td>
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Last revision: June 22, 2020, 15:08 MDT
### Recent Ph.D. students

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<tr>
<th>Name</th>
<th>Field</th>
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<th>University/Institution</th>
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<tbody>
<tr>
<td>Denise White</td>
<td>Finite Groups</td>
<td>Gross</td>
<td>Westminster College, Salt Lake City, UT</td>
</tr>
<tr>
<td>Guangyan Yin</td>
<td>Applied Mathematics</td>
<td>Stenger</td>
<td>Stenger</td>
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<tr>
<td><strong>1991</strong></td>
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<tr>
<td>Jorge Devoto</td>
<td>Topology</td>
<td>Braam</td>
<td>International Centre for Theoretical Physics (ICTP), Trieste, Italy</td>
</tr>
<tr>
<td>Kenneth Ferguson</td>
<td>Topology/Geometry</td>
<td>Stern</td>
<td>First Quadrant, Pasadena, CA</td>
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<tr>
<td>Christopher Grant</td>
<td>Applied Mathematics</td>
<td>Fife</td>
<td>Georgia Tech, Atlanta, GA</td>
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<td>Elham Izadi</td>
<td>Algebraic Geometry</td>
<td>Clemens</td>
<td>Harvard University, Cambridge, MA</td>
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<td>Tucker</td>
<td>Indiana University at Southbend, IN</td>
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<tr>
<td>Yonghao Ma</td>
<td>Algebra</td>
<td>Roberts</td>
<td>Southwest Texas State University, San Marcos, TX</td>
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<tr>
<td>Cameron Wickham</td>
<td>Ring Theory</td>
<td>Roberts</td>
<td>Southwestern Missouri State University, Springfield, MO</td>
</tr>
<tr>
<td>James Wiskin</td>
<td>Group Theory</td>
<td>Gross</td>
<td>University of Utah, Salt Lake City, UT</td>
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| 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                        |

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<tbody>
<tr>
<td>1989</td>
<td>David M. Austin</td>
<td>Topology</td>
<td>Institute for Advanced Study, Princeton, NJ and Grand Valley State University, Allendale, MI</td>
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<tr>
<td></td>
<td>Luis Hernandez Lamoneda</td>
<td>Geometry</td>
<td>Toledo University of Chicago, Chicago, IL</td>
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<td>Jesus Jimenez Reyes</td>
<td>Complex Geometry</td>
<td>University of California/Riverside, CA</td>
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<td>Frederick Phelps</td>
<td>Applied Mathematics</td>
<td>Keener Oxford University, Oxford, UK</td>
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<tr>
<td>1988</td>
<td>Mladen Božičević</td>
<td>Lie Groups</td>
<td>Rutgers University, New Brunswick, NJ</td>
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<tr>
<td></td>
<td>Paul J. Joyce</td>
<td>Stochastic Processes</td>
<td>Tavaré University of South California, Los Angeles, CA</td>
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<td>Thomas Nordhaus</td>
<td>Applied Mathematics</td>
<td>Keener</td>
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<td>Marc Stromberg</td>
<td>Numerical Analysis</td>
<td>Stenger Texas Tech University, Lubbock, TX</td>
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<td>James D. Walker</td>
<td>Applied Mathematics</td>
<td>Folias Southwest Research Institute, San Antonio, TX</td>
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<td></td>
<td>Miljenko Zabčić</td>
<td>Lie Groups</td>
<td>Hecht MIT, Cambridge, MA</td>
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<td></td>
<td>Bertram Zinner</td>
<td>Applied Mathematics</td>
<td>Keener Auburn University, Auburn, AL</td>
</tr>
<tr>
<td>1987</td>
<td>Paul R. Arner</td>
<td>CAGD</td>
<td>Barnhill SDRC (Structural Dynamics Research Corporation), Cincinnati, OH</td>
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6. Recent Ph.D. students

<table>
<thead>
<tr>
<th>Name</th>
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<tbody>
<tr>
<td>Phillip J. Barry</td>
<td>CAGD</td>
<td>Barnhill</td>
<td>University of Waterloo, Waterloo, ON, Canada</td>
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<td>Bernard Bialecki</td>
<td>Numerical Analysis</td>
<td>Stenger</td>
<td>University of Kentucky, Lexington, KY</td>
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<tr>
<td>Roger Chen</td>
<td>Differential Geometry</td>
<td>Li</td>
<td>University of Toledo, Toledo, OH</td>
</tr>
<tr>
<td>J. Don Dockery</td>
<td>Applied Mathematics</td>
<td>Keener</td>
<td>Utah State University, Logan, UT</td>
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<td>Greg A. Harris</td>
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<td>Auburn University, Auburn, AL</td>
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<td>Nela Lakoš</td>
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<td>Ohio State University, Columbus, OH</td>
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<td>Dennis Malm</td>
<td>Algebra</td>
<td>Goodearl</td>
<td>Northwest Missouri State University, Maryville, MO</td>
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<tr>
<td>Bruce R. Piper</td>
<td>CAGD</td>
<td>Barnhill</td>
<td>Rensselaer Polytechnic Institute, Troy, NY</td>
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<td>Masaji Watanabe</td>
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<td>Othmer</td>
<td>Universität Stuttgart, Germany</td>
</tr>
<tr>
<td>Diana Woodward</td>
<td>Applied Mathematics</td>
<td>Hoppenstead</td>
<td>Michigan State University, East Lansing, MI</td>
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