Graduate Program Handbook
2017–2018
Mathematics Department
Brandeis University

The Brandeis Mathematics Graduate Program provides instruction leading primarily to a Ph.D. in Mathematics. The program also offers a Master of Arts degree in Mathematics. The purpose of this handbook is to outline basic information and guidelines concerning the program. It is meant to complement various other sources which apply more broadly to all students at Brandeis University (e.g., the Brandeis University Bulletin, the Rights & Responsibilities Handbook, and information on Disabilities Services and Support) or to students in the Graduate School of Arts and Sciences (e.g., the GSAS Student Handbook and Handbook for Teaching Fellows). These are all available online.

This handbook will answer many, but probably not all, of your questions. Further questions about the graduate curriculum and requirements should be directed to the Graduate Advising Head, Joël Bellaïche. For issues related to undergraduate teaching, consult the Elementary Mathematics Coordinator, Becci Torrey. Concerning non-academic matters such as office assignments and payment of stipends, see the Mathematics Department administrator, Catherine Broderick.

1. The Ph.D. program

Students working towards a Ph.D. in mathematics form the core of the department's graduate program. In order to earn the degree, a student is required to write a dissertation demonstrating significant original research. Accomplishing this typically requires mathematical maturity and expertise well beyond the bachelor's degree. The aim of the Ph.D. program is to provide the necessary background and train students to become successful researchers. Most of the department's Ph.D. recipients pursue academic careers, and many are leading mathematicians.

The program begins with required courses on fundamental material. Students then move on to more advanced courses, including reading courses, that develop breadth and depth of understanding. After passing qualifying exams, students focus primarily on thesis research under the supervision of their thesis advisor. Students also go through a teaching apprenticeship program which trains them to become effective teachers and each student is required to teach their own section of precalculus or calculus for at least four semesters.

Ph.D. students making satisfactory progress towards their degree are ordinarily given five years of funding, including a full tuition scholarship and a stipend, so that they can focus on their studies and research.

1.1. **The first year program; required courses.**

Our first year program is devoted to the fundamentals in algebra, analysis and topology.

All students are required to master the material of the following courses: Math 131a,b (Algebra I and II), Math 141a,b (Real and Complex Analysis), Math 151a,b (Topology I and II), and Math 140a (Geometric Analysis). Syllabi for these courses are included as Appendix B. Each student is responsible for mastering the material in these courses. This requirement can be fulfilled in one of two ways:

(1) Take the course and earn a satisfactory grade (officially B- to A+, but grades in the B range are often signs of trouble).

(2) Place out of the course by demonstrating a thorough understanding of the "core topics" in the syllabus. This must be done during the first two weeks of the semester in which you want to place out of the course. The placement exam (which may be written or oral) is usually given by the faculty member who most recently taught the course. This year's examiners are listed in Appendix A. The Graduate Advising Head may also grant exemption from the course on the basis of evidence of having excelled in a similar course at another university.

The usual practice, which assumes a strong undergraduate preparation, is to take 131a,b, 141a,b, and 151a,b in the first year and 140a in the first semester of the second year. There are regular homework assignments in all these classes and most students find the workload heavy. You may find it useful to work together with your classmates. Students who place out of required courses are expected to take more advanced courses during their first year (see §1.2.1 below).

If you do not do well in the required courses, you should consider exploring options other than a Brandeis Ph.D. in Mathematics. In particular, it is department policy that to continue in good standing you must pass at least two out of the required courses each semester during your first year. If you do not, or if your performance in these courses is judged inadequate, you will be asked to withdraw from the program or warned that failure to improve your performance will result in your withdrawal (see §4.2).

In addition to taking required courses, first-year students are given grading assignments for undergraduate courses and are asked to participate in the department's evening tutoring program, which serves undergraduate students taking precalculus and calculus. In preparation for teaching in their second year and beyond, most graduate students participate in the Teaching Apprenticeship Program in the spring of their first year. Students whose native language is not English may be required to participate in the university's ELP (English Language Program) (see §1.4).

1.2. **The second and third years; coursework, qualifying and language exams, residency requirement, Master's degree.** In general, the second year is the time to finish up the course requirements and begin teaching. Students should also begin taking more advanced courses, including reading courses, and working on their major and minor qualifying exams. By the end of their third year, students should have completed their major and minor exams, as well as their language exams, and chosen a thesis area and advisor.

1.2.1. *Coursework.* In addition to completing any of the seven remaining required courses (which usually just means 140a), second year students must take the "Second Year Seminar" (Math 200a) in the spring semester. This course is less demanding than a lecture course, and is intended as a vehicle for students to gain experience reading research articles and giving talks. The idea is for each student to present a topic as one would in a research seminar. The material is chosen by the student in consultation with the instructor (usually the Graduate Advising Head), and should be taken from journal articles or preprints as opposed to textbooks. The talks should be understandable to the others in the seminar, so the speaker should not assume background beyond the required courses. The speaker can expect a lot of questions and discussion from the audience, as well as advice and feedback on the lectures from the instructor.

In addition to taking more advanced courses, students should begin taking reading courses in their second year. Reading courses are arranged with a professor by an individual student or a small group of students interested in a topic not covered in a standard lecture course. These courses are an essential part of the Ph.D. program and serve several purposes. They allow students to broaden the scope of their studies, develop independence, explore possible thesis areas in depth, and get to know possible advisors. They are also a vehicle for preparing for major and minor exams.

Students also begin attending departmental seminars more often in their second and third years (see §3.1).

Students in their second and third years are required to take at least three lecture courses per semester. Students may count a reading course towards the total each semester, but the Second Year Seminar and Teaching Practicum (see §1.4) do not count.

1.2.2. *Qualifying exams.* The qualifying exam consists of two parts: a major exam and a minor exam. For both exams, you choose an area of mathematics and ask a faculty member to be your examiner. For the minor exam, there are two options. First, you may enroll in any of the graduate elective courses and make an agreement with the faculty member teaching the course that it will be the vehicle for your minor exam. You should file a form with the department office in the first four weeks of the semester stating that you intend to use this course for your minor exam. In addition to the course work, you will meet occasionally with the examiner to discuss your progress, and you will present a talk on the topic of the course, either in class or in a departmental seminar. At the end of the semester, the examiner will administer an oral exam on the topic of the course. The second option is that you enroll in a reading course (numbered 299 or 399) with the examiner. In this option you will also present a talk on the topic of the reading course and the examiner will administer an oral exam.

For the major exam, you will enroll in a reading course with the examiner and, together with the examiner, plan a program of study that will prepare you for research. The major exam will usually take more than one semester and will be completed when the examiner determines that you are ready to begin work on a thesis topic. It is usually in the area in which you will do thesis research, and the examiner usually becomes your thesis advisor, though this is not always the case. A student may decide later to switch areas or advisors. It is also possible to change the minor exam topic to the major exam topic or vice-versa.

The aim of the major exam is to learn a topic in depth in preparation for thesis research. The minor exam topic is intended to provide some breadth; it should be distinct from the major area, though it can be related or have applications to it (for example, number theory and K-theory). The two examiners should be different faculty members.

At the completion of either exam, the examiner will fill out a form certifying that you have passed.

By the end of your second year, you should have chosen the topics and made substantial progress towards passing at least one of the exams. They should both be completed as early as possible during the third year so that thesis research can get under way.

1.2.3. *Language exam.* Students are advised to fulfill the language requirement by the end of their fourth year, preferably earlier. Students are required to have some knowledge of French, German, or Russian, for which the requirement is to be able to read mathematical literature in that language without difficulty. The department designates an examiner each year for each of these languages. The exam should be scheduled with the designated

examiner, and may be retaken several times without penalty. To pass the exam, you will need to translate a page of a mathematical paper or text in the language. To prepare for the exam, you should first acquire some basic skill in the language, and then read some mathematical texts carefully in an area of interest to learn the mathematical terms. The language examiner can provide suggestions for practice texts. You can also audit Brandeis undergraduate language courses, or take courses given by the graduate school tailored for graduate language exam preparation.

1.2.4. *Residency requirement.* The minimum academic residence requirement for the Ph.D. is three years.

1.2.5. *Master's degree.* Students who have successfully completed the seven required courses, passed a language exam (reading French, German, or Russian; see §1.2.3), and been in residence for at least 1 year are eligible for a Master's degree, and are encouraged to apply for it, without charge (see §2).

1.3. **The fourth and fifth years, the thesis, applying for jobs.** The emphasis in these years should of course be on finishing your thesis. Students should make significant progress on their theses in their fourth year. Exceptional students will complete their theses and graduate in four years. A student's final year is devoted primarily to writing up the thesis, applying for jobs and making the transition from a graduate student to a research mathematician.

1.3.1. *Time-to-degree.* Students are required to spend at least three years in the program in order to be eligible for a Ph.D. Up to one year of graduate work at another institution can be applied towards the requirement.

Some students finish in four years; most take five. Occasionally students take an extra semester or more. Scholarships and stipends are guaranteed through year four for students in good standing. Financial support in the fifth year is usually granted to all students who are making satisfactory progress on their theses. *Support beyond the fifth year is granted only under exceptional circumstances.* (See §4.3.)

Students who maintained good academic standing but did not complete the Ph.D. degree while funded may continue to work towards the degree. A total of up to eight years are allowed; students requiring more time can apply for an extension.

1.3.2. *Coursework.* In addition to enrolling in the Dissertation Research course (401d) with your advisor, you are encouraged to attend seminars and take at least one lecture course a semester, usually a "topics" course. While it is important to focus on your thesis problem, is also important to continue developing perspective and breadth in mathematics.

1.3.3. *The thesis.* A Ph.D. dissertation is an original and substantial piece of research. The thesis topic might be suggested by your advisor, or it may be your own choice approved by your advisor. While you are likely to work closely with your advisor, the research must be primarily yours in both ideas and details. The advisor's role is to *advise*, to listen to your ideas and provide feedback, to point you to relevant literature and, occasionally, to suggest possible approaches when you are stuck.

A student is sometimes interested in working with a mathematician at another university (for example, Harvard or MIT). If that person agrees to act as your advisor, you must also have an official advisor at Brandeis who monitors your progress.

1.3.4. *The defense.* Your dissertation examination committee needs to consist of at least three faculty members, approved by the Graduate Advising Head. Your advisor is the chair of the examination committee and will help choose the other members when the thesis is near completion. One committee member must come from outside the department. This is usually a mathematician at another institution, but it can also be a Brandeis faculty member from another department (for example, physics or computer science). You then need to coordinate the scheduling of the Final Oral Examination (or "thesis defense") with your committee. Copies of your thesis need to be given to the examination committee at least two weeks before the defense date. During the defense, you should give a short lecture (40–50 minutes) explaining the results in your thesis, and be prepared to answer questions about it. After the exam, the committee deliberates in private before informing you of the outcome. In the unlikely event that there are serious problems with the thesis, the committee is expected to identify them before the defense. In that case the defense would be rescheduled after the problems are resolved. It is not unusual, however, for the committee to request minor corrections to the thesis. If the committee requests *substantial* revisions, then these must be completed and and approved within six months or another defense is required.

There are various forms to file, procedures to follow, deadlines to meet, and fees to pay in order to be awarded the Ph.D. degree at the next graduation ceremony. Note in particular, that for graduation in May, the deadline for the thesis defense is in April. Please consult the Graduate School's Dissertation Guide at
`http://www.brandeis.edu/gsas/current/dissertation-guide/` for a list of these requirements.

1.3.5. *The job search.* Most of our students go on to successful academic careers after graduating, though some pursue non-academic careers. Be warned though that the application process can be time-consuming and emotionally draining.

Most application deadlines are between mid-December and mid-February, so you should begin working on your application in the fall of your final year. Job listings for most academic positions in the US and Canada are posted on the American Mathematical Society website at `http://www.ams.org/eims/` as well as at `http://www.mathjobs.org/`. The latter web site can be used to apply for jobs.

Most institutions request a description of your research, a curriculum vita (a brief academic version of a resume) and at least three letters of recommendation including one that specifically addresses your teaching skills. Some places ask for a statement of teaching philosophy as well. Your advisor will help you decide who to ask for research letters, and the Elementary Mathematics Coordinator usually writes a teaching letter. The application materials should be uploaded to `http://www.mathjobs.org/` or mailed directly to those departments which do not advertise there.

Do not underestimate the importance of demonstrating your teaching ability to potential employers. It is the most important factor when applying for jobs at most small colleges. It is also a major factor in hiring decisions in departments that emphasize research. It is even a significant factor when applying for non-academic jobs since it reflects on your communication skills. An outstanding teaching performance as a graduate student translates into strong teaching recommendations and student evaluations. The department provides excellent training and support to help you improve your teaching skills (see §1.4), but successful teaching requires a serious effort on your part as well.

Some students pursue non-academic careers after graduating. Department members will sometimes have ideas about people, including Brandeis alumni, whom you might contact for leads and advice. The university's Hiatt Career Center is another useful resource.

1.4. **Teaching.** Teaching is an integral part of the doctoral program in mathematics, as it will be in the career of most mathematicians. All mathematics Ph.D. students are expected to teach a section of calculus or precalculus for at least four semesters, usually beginning in their second year of study. The department provides each student with extensive training before beginning to teach, and ongoing advice and support when the student is teaching. The valuable training and experience in teaching is an important asset in the academic job market (see §1.3.5). There is a departmental Teaching Prize awarded each year in appreciation for dedication and skill in teaching mathematics.

The Elementary Mathematics Coordinator is the faculty member who oversees graduate student teaching of calculus and precalculus.

Students interested in designing and teaching upper-level undergraduate courses are encouraged to apply for a University Prize Instructorship (see §3.6).

Students should consult the GSAS Handbook for Teaching Fellows
`https://www.brandeis.edu/gsas/current/tf-resources/handbook/index.html`
for general information about graduate student teaching at Brandeis.

A few students are hired by the university each summer to teach undergraduate courses. Among eligible students who wish to do this, priority is given to those who have taught least in previous summers. Summer teaching does not count towards the teaching requirement.

Students who wish to teach outside Brandeis while supported by Brandeis must get approval from the department.

1.4.1. *Teaching Apprenticeship Program.* First-year students do not teach, but are expected to focus on the required courses and the adjustment to life as a graduate student. They are also required to grade for one undergraduate course per semester, and tutor one to two evenings per week in the department's drop-in tutoring program for students in precalculus or calculus. (They are paid for tutoring.)

In the spring of the first year, most first-year students participate in a three-week Teaching Apprenticeship Program. This program pairs each new student, the *apprentice*, with one who is currently teaching, the "coach"; the apprentice first visits several of the coach's classes, and then—working closely with the coach at each step—teaches three of his or her classes. The program is supervised by the Elementary Mathematics Coordinator.

Some students may not be ready for the Teaching Apprenticeship Program in their first year. Those whose native language is not English may need to focus on improving their English skills instead (see 1.4.5).

Students who complete the Teaching Apprenticeship Program may need to improve their teaching skills further before they are ready to teach their own section of precalculus or calculus. In that case, they participate in an extended apprenticeship program until they are ready.

1.4.2. *Teaching responsibilities.* Students usually begin teaching their own sections of calculus or precalculus in the fall of their second year. Graduate student instructors work closely with the faculty member overseeing the course (usually the Elementary Mathematics Coordinator), but nonetheless each graduate student has full responsibility for his or her section; this means preparing lectures, writing and grading quizzes, holding office hours,

and participating in the writing and grading of common exams. The Elementary Mathematics Coordinator is available to graduate students who have questions about teaching or who are trying to improve their teaching skills.

Every attempt is made to equitably distribute teaching duties and provide all students with adequate training and experience. Most students will teach each semester during their second and third years, so that they will teach a total of four semesters. Students who are not ready to teach in the fall of their second year will end up doing more teaching in their final years of graduate school. There are typically fewer sections of calculus taught by graduate students each spring semester than there are graduate students who are eligible to teach. (Students are eligible to teach if they have successfully completed the Teaching Apprenticeship Program, are enrolled with Resident or Post-Resident status, and are not restricted from teaching by an outside funding agency.) Students who have already taught the most semesters are given the first opportunity to opt out of teaching that semester. Among those who have taught the same number of semesters, students enrolled the longest are given priority. Ties are then broken by drawing straws. Students who are not teaching assist by grading undergraduate courses that semester. Final decisions on teaching assignments are made by the Elementary Mathematics Coordinator and the Graduate Advising Head.

1.4.3. *Teaching Practicum.* During the fall semester of each year, all graduate student instructors enroll in a Teaching Practicum (204a) to work on their teaching skills. As part of the course, the practicum instructor observes the classes taught by graduate students, evaluates their teaching performance and provides advice to improve their teaching skills. The TA Practicum also provides a few mandatory workshops on teaching skills, pedagogy, innovations or concerns.

1.4.4. *Mandatory training.* All new instructors and course assistants are required to attend the TF Orientation run by GSAS at the beginning of the fall semester. Most math graduate students will attend this at the beginning of their second year, right before they start teaching. All instructors, course assistants, graders and evening tutors are required to participate in Title IX training. Currently this might be fulfilled by attending the TF Orientation, but the University and/or GSAS may mandate additional training.

1.4.5. *The ELP program.* Students who are not fluent in English may need to improve their English skills before they are ready to teach. The university's English Language Program (or ELP) program helps one do this. The Director of English Language Programs will identify those students who would benefit from ELP classes. *If you are asked to take an ELP class, then attendance and participation are required in order to maintain good academic standing, and a passing grade is a university requirement for graduation.*

1.5. **Grading.** Students who are not teaching assist by grading one undergraduate course per semester. Graduate students graders are expected to grade homework for a class and may be asked to grade midterm exams as well. In large classes, they may also help the instructor in grading the final exam or proctoring the midterms or final. It is also expected that the students will hold two office hours per week.

1.6. **Course Assistantships.** The math department hires graduate students as Course Assistants (CAs) for some large undergraduate courses. These jobs are in addition to usual responsibilities (e.g., teaching or grading) and are compensated separately (not included in the stipend). The current rate is $ 1600 per semester for a half-CA, which has a work

expectation of 5 hours per week on average over the semester. CA responsibilities vary based on the needs of the instructor and the course, but can include things like: attending class (both so that the CA would be able to hold better office hours and to help out with in-class groupwork); holding office hours and/or recitations and/or review sessions outside of class; helping grade quizzes and exams; helping to proctor quizzes and exams; answering questions online (e.g., via Piazza – `https://piazza.com/`); helping to write quizzes, exams, worksheets, review material (e.g., contributing problems).

1.7. **Boston Area Graduate Consortium.** It is possible for Brandeis graduate students to cross-register for mathematics courses at Boston University, Boston College, and Tufts. Graduate students should check with their advisor and the Graduate Advising Head before cross-registering for courses. For information on cross-registering, see `http://www.brandeis.edu/gsas/students/cross.html`. Graduate students sometimes sit in on courses at Harvard or MIT, but it is not possible to formally cross-register for these courses.

2. The Master's degree

The mathematics department also admits a few students working towards a Master of Arts degree in Mathematics in preparation for a non-academic career or for eventual admission to a Ph.D. program. A limited amount of financial support is available to Master's degree students through the Graduate School of Arts and Sciences (see §4.3).

In order to earn a Master's Degree, students must pass with a satisfactory grade (B- to A+) or place out of eight courses including the seven courses required for Ph.D student (see §1.1; syllabi are in Appendix B) plus one extra course which may be a reading course. They must also pass a language exam in French, German or Russian (see §1.2.3), and be in residence for at least one year.

These requirements are ordinarily fulfilled in 2–4 semesters, depending on the student's preparation and courseload. There is no teaching requirement for Master's degree candidates, but they may be hired to grade undergraduate courses, and they may be allowed to participate in the teaching apprenticeship program.

Brandeis undergraduates can enroll in the combined B.A./M.A. program in order to earn a Master's degree at the same time as their Bachelor's degree. Students must formally apply in the spring preceding their final year as an undergraduate. The requirements are then as described above. Ph.D. students who have fulfilled the above requirements are also eligible to receive a Master's degree.

Students completing the requirements and wishing to receive the Master's degree need to file an Application to Graduate by the specified deadline.

3. Seminars and other activities

There are seminars and numerous other activities that graduate students benefit from, academically and otherwise. You are encouraged to take advantage of the opportunities available to you as a student in the department, at the university, and as part of the Boston area mathematical community.

3.1. **Seminars.** The department has a variety of (usually) weekly seminars. Some are intended to be accessible to all graduate students, while others require more background.

The *Everytopic Seminar* is intended to expose graduate students and undergraduates to research topics in mathematics and occasionally related areas, such as physics and computer science.

The *Graduate Student Seminar*, organized by the graduate students, is one in which the students lecture to each other on topics of interest and eat pizza.

The *Joint Brandeis-Harvard-MIT-Northeastern Colloquium* is a weekly event that rotates among the four universities and meets at Brandeis 2 or 3 times a semester. The speakers are leading mathematicians from around the world, and the talks are often accessible to graduate students. The department takes the speaker to dinner afterwards and subsidizes dinners for graduate students.

The *New Directions Lecture Series*, also known as the *NOSY* (for *Not Only Second Year*) *Seminar*, is a series of lectures or mini-courses offered in the fall semester of each year. They are given by faculty members and are designed to introduce students to a current area of research in more depth than is possible in a single seminar lecture. Second-year students are especially encouraged to attend this seminar, as it offers them an opportunity to learn about the research interests of faculty members.

The *Topology Seminar* tends to choose a theme for the semester and works as a learning seminar with participants taking turns giving talks. Outside speakers sometimes give talks as well.

The *Combinatorics Seminar* is an introductory seminar for combinatorics. The talk should be accessible to first year graduate students.

There are a number of informal learning seminars on topics of interest to students in a particular area. In the past academic year this included working seminars on dynamics and number theory, modular and automorphic forms, and other topics.

The Undergraduate Math Club sometimes organizes interesting and accessible interdisciplinary lectures.

There are many other seminars in the Boston area that are regularly attended by Brandeis faculty and students—MIT's Combinatorics Seminar, Harvard's Number Theory Seminar, the Harvard-MIT Algebraic Geometry seminar, Harvard's Gauge Theory and Topology Seminar, the Boston College Geometry and Topology Seminar, and the Boston University Algebra Seminar, to name a few. Students also sometimes informally attend classes given at other universities. Check with the instructor when doing this to make sure he or she doesn't mind.

3.2. **Travel funds.** Attending workshops and conferences is a useful way to learn mathematics, meet others in the field and let people know about your work. Ph.D. students who have settled on an area of research are encouraged to go to at least one during their graduate career.

The Mathematics Department makes $500/year available to each Ph.D. student for this purpose. Use of the funds requires permission of your thesis advisor or the Graduate Advising Head.

3.3. **The Jerome Levine Outstanding Thesis Award.** Every year the Jerome Levine Outstanding Thesis Award is given to the student who, in the opinion of the faculty, has written the best Ph.D. thesis in the past year.

3.4. **Summer support.** Though quieter than during the school year, the department still has a fair amount of activity during the summer, with many faculty and students still coming in regularly.

While everyone needs a break, we hope that you'll spend most of the summer pursuing your studies. However, the department cannot guarantee financial support to students during the summer months. It is therefore understandable that some of you will seek employment during the summer, and some of you will take the opportunity to travel home.

A few students are hired each summer to teach undergraduate mathematics courses (see §1.4). A few others sometimes find jobs on-campus that leave them time for mathematics.

The department also has some funding to support students working on their research during the summer. We will support a limited number of students for up to a month each. To be eligible, you must have taken all the required courses and you must be in residence and not otherwise employed during the period of support. To apply, you need to write a brief proposal describing your summer research plans. Awards will be based on merit, with priority given to those students who are not teaching in the summer and have not received summer support before. The two best proposals each year will be funded from the Harold L. Levine Endowed Fellowship Fund. This award is similar to the regular summer research fellowships that are funded by grants and other department funds, but has a somewhat higher amount.

3.5. **Social events.** The department's friendly and informal atmosphere fosters interaction among faculty and students and enhances the environment for learning and research. A variety of social events contribute to this atmosphere. There is an afternoon tea in the department lounge two days each week when classes are in session. Two or three Thursdays each semester, the Joint Colloquium (see §3.1) is held at Brandeis; it is preceded by a tea in the department and followed by dinner at a local restaurant. In addition there are several annual events, usually including a fall barbecue and a holiday party.

3.6. **GSAS, GSA and ISSO.** The mathematics graduate program is one of many that comprise Brandeis University's Graduate School of Arts and Sciences. GSAS is responsible for overseeing these programs. GSAS provides a variety of support services for graduate students. These include an orientation program, foreign language courses, and workshops throughout the year on topics such as dissertation preparation and the job search. GSAS handbooks and newsletters provide information on a variety of topics such as academic policy, teaching and funding opportunities. These funding opportunities include the graduate school's own Dissertation Year Fellowships and University Prize Instructorships. Mellon Dissertation Year Fellowships are intended mainly for non-science students, but mathematics students may be interested in applying for a University Prize Instructorship. These are competitive awards made to exceptional students to design and teach upper-level undergraduate courses. Mathematics students have won these awards in the recent years.

The Graduate Student Association is a student organization devoted to enhancing graduate student life and representing graduate student concerns at Brandeis. Among their activities are annual orientation events, a symposium on research conducted by graduate students, and a TGIF social event every Friday.

International students will also certainly avail themselves of the services of the International Students and Scholars Office, which assists with visa and immigration issues and helps international students adjust to life at Brandeis.

4. Administration

The Graduate Advising Head is responsible for overseeing the instruction and advising of graduate students in the mathematics department. This responsibility includes making recommendations to the university concerning admission, readmission, and funding of graduate students and the granting of graduate degrees. If the Graduate Advising Head is unavailable, or unable to address a particular concern, then the matter should be taken care of by the Department Chair. Academic grievance and petition procedures are described in the GSAS Student Handbook,
`https://www.brandeis.edu/gsas/current/gsas-student-guide/index.html`.

4.1. **Advising.** All students should meet with the Graduate Advising Head at the beginning of each semester to discuss courses and plans for the semester and progress towards the degree.

The Graduate Advising Head serves as the primary advisor for all incoming Ph.D. students. When a student begins working on major and minor exams, this role is assumed by the examiners (see §1.2.2), and then by the thesis advisor once one is chosen (see §1.3.3). The Elementary Mathematics Coordinator advises students on matters related to teaching.

All other graduate students are advised primarily by the Graduate Advising Head, in conjunction with the undergraduate advisor for joint B.A./M.A. students.

4.2. **Evaluation.** The mathematics faculty meets at the end of each semester to evaluate the graduate students. The academic performance and teaching performance of each student is reviewed. Each faculty member who has had significant contact with the student, in either a class, a reading course, dissertation work, or through undergraduate teaching, reports on the student's performance. Minor problems are handled informally by the Graduate Advising Head or the student's advisor. Major problems result in a letter to the student and a meeting with the Graduate Advising Head. These letters are usually quite serious and warn of the student's possible required withdrawal from the program if performance does not improve.

The following is a summary of requirements for Ph.D. students to maintain good academic standing. Failure to complete them in the suggested time frame can result in a warning to complete them by a specific date or risk withdrawal. See the relevant section of the handbook for more details.

- **Required courses:** Pass or place out of at least two per semester during first year. Complete during second year. (See §1.1.)
- **Second Year Seminar:** Pass during second year. (See §1.2.1.)
- **Other courses:** Pass at least three courses per semester during the first three years, not counting the Second Year Seminar and Teaching Practicum, but counting up to one reading course per semester. Take at least one lecture course per semester in remaining years. (See §1.2.1.)
- **Qualifying exams:** Make significant progress on the major or minor exam by the end of the second year. Complete both exams by the end of the third year. (See §1.2.2.)
- **Language exam:** Complete by the end of the fourth year. (See §1.2.3.)
- **Teaching:** Take and pass an ELP course if required. Complete the Teaching Apprenticeship Program. Teach when required (at least four semesters). Take the Teaching Practicum each fall when you are teaching. (See §1.4.)

- **Thesis:** Select an advisor and start a project by the end of the third year. Make significant progress by the end of the fourth year. (See §1.3.3.)

4.3. **Funding.** Ph.D. students who do not have outside funding are awarded a full tuition scholarship and a stipend by Brandeis. This funding is granted for four years as long as the student maintains good academic standing. A fifth year of support is usually awarded if the student is making satisfactory progress towards their thesis. Support for Ph.D. students beyond the fifth year, which may come from faculty NSF grants, is granted only under exceptional circumstances.

Ph.D. students are strongly encouraged to apply for fellowships for which they may be eligible. Students from the U.S. may be eligible for graduate fellowships from the NSF and other government agencies offering very generous stipends. Some foreign countries also offer fellowships to nationals for graduate study in the U.S.

Ph.D. students interested in teaching upper-level undergraduate courses should consider applying for a University Prize Instructorship (see §3.6).

M.A. students are eligible for financial aid from Brandeis in the form of reduced tuition, normally a reduction of 25% to 50%. Students should contact GSAS regarding this and other financial aid opportunities, such as student loans.

Financial aid opportunities for B.A./M.A. students are the same as for other undergraduates.

4.4. **The Ethics Course.** All students in the Division of Science are required by the university to take the formation to Responsible Conduct of Research. For more details about the formation, which includes the course CONT 300b commonly known as the "Ethics Course", see `http://www.brandeis.edu/ora/RCR/index.html`.

4.5. **Rights and Responsibilities.** The university's Rights and Responsibilities Handbook sets forth policies governing rules of conduct that apply to all Brandeis students. The Rights and Responsibilities Handbook also explains university policies, including those of Equal Opportunity and Affirmative Action. Brandeis is also committed to providing reasonable accommodations to community members with disabilities, as described in its publication on Disability Resources. For more information, students should contact the GSAS Disability Coordinator.

Within Brandeis, the Mathematics Department forms a strong community which values research and learning and cultivates an atmosphere of respect and support for fellow students, faculty and staff. As a graduate student in the department, it is part of your responsibility to help maintain that environment.

One aspect of this worth stressing is our dedication to teaching. The graduate students in mathematics have a reputation for sharing their enthusiasm for the subject and providing quality instruction to the undergraduates. We expect you to do your part to maintain that reputation and the strong teaching culture in the department.

On a less lofty note, we have to remember to take care of the physical environment as well as the intellectual one, and keep the shared offices, lounge, and kitchen reasonably clean.

At the end of each academic year, the graduate students elect three or four Graduate Student Representatives for the following year. These representatives have the additional responsibility of looking after graduate student interests within the department. This includes expressing the opinion of graduate students on matters such as hiring, course offerings and teaching assignment policies.

Appendix A: 2017-18 Graduate Program Who's Who

Administration:

Department Chair:	Dmitry Kleinbock
Graduate Advising Head:	Joël Bellaïche
Elementary Mathematics Coordinator:	Rebecca Torrey
Grad Student Representatives:	Angelica Deibel, Eric Hanson, McKee Krumpak, and Charlotte Morris-Wright

Language Examiners:

French:	Joël Bellaïche
German:	Gerry Schwarz
Russian:	Dmitry Kleinbock

Placement Examiners:

Algebra I (131a):	Joël Bellaïche
Algebra II (131b):	Olivier Bernardi
Geometric Analysis (140a):	Bong Lian
Real Analysis (141a):	Alan Mayer
Complex Analysis (141b):	Mark Adler
Topology I (151a):	Kiyoshi Igusa
Topology II (151b):	Ruth Charney

Appendix B: Syllabi for Required Courses

Math 131a: Algebra I

Core topics (always covered):

(1) Group theory:
   (a) Quick review of the basic theory (subgroups, homomorphisms, etc.).
   (b) Group actions, conjugacy classes, Sylow theorems.
   (c) Solvable and nilpotent groups.
   (d) Free groups, presentations.

(2) Categories: Basic notions of categories, functors and natural transformations are introduced and used as a language during the course.

(3) Rings and Modules:
   (a) Review of basic theory (subrings, ideals, fields, homomorphisms, etc.)
   (b) UFD's, PID's, polynomial rings.
   (c) Linear algebra over rings (free modules, tensor products, exterior and symmetric powers, determinants).
   (d) Finitely generated modules over a PID and applications.

(4) Field theory:
   (a) Field extensions, splitting fields, finite fields.
   (b) Separable and inseparable extensions, algebraic closure.
   (c) Fundamental theorem of Galois theory, solvability by radicals.

Additional topics. As time and inclination permits, one can go deeper into:

- Field theory (trace and norm, transcendental extensions, purely inseparable extensions, infinite Galois extensions, Kummer theory).
- Category theory (adjoint functors, Yoneda's lemma, limits).

Possible Texts:

Lang: *Algebra*

Jacobson: *Basic Algebra*

Math 131b: Algebra II

Core topics:

(1) Homological algebra: Exact sequences, complexes and homology, projective and injective modules, Ext and Tor.
(2) Commutative algebra: Chain conditions, Hilbert basis theorem, Nullstellensatz, localization.
(3) Representation theory (of finite groups): Maschke's theorem, Schur's Lemma, Frobenius reciprocity, characters.
(4) Noncommutative algebra: Semisimple rings and Wedderburn's theorem.

Additional topics. Additional 131a topics, or:

- Representation theory (representations of S_n, Brauer's theorem, representations in finite characteristic, representations of Lie groups).
- Commutative algebra/number theory (integrality, completion, DVR's, Dedekind domains).
- Commutative algebra/algebraic geometry (dimension theory, Noether normalization, the ideal-variety correspondence, primary decomposition).

Possible Texts: See 131a.

140a: Geometric Analysis

Core topics:

(1) Manifolds, change of coordinates, differential structure.
(2) Tangent bundle, derivations, vector fields, Lie bracket, tensors.
(3) Basics of vector bundles: normal bundles, pullback construction.
(4) Transversality and implicit function theorems.
(5) Picard theorem and Frobenius Theorem.
(6) Differential forms, closed and exact, Poincaré Lemma. Frobenius Theorem in differential form version.
(7) Integration, Stokes Theorem, orientations and volume elements, de Rham cohomology and theorem.

Additional topics.

- Basic Lie Groups: Lie algebra, one parameter subgroups, structural equations, left and right invariant vector fields.

Possible Texts:

Warner: *Foundations of Differentiable Manifolds and Lie groups*
Spivak: *A Comprehensive Introduction to Differential Geometry, vol. I*
Milnor: *Topology from the Differentiable Viewpoint*
Bott and Tu: *Differential Forms in Algebraic Topology*

Math 141a: Real Analysis

Core topics:

(1) Measure theory:
   (a) Measure spaces and measurable functions.
   (b) Integration and convergence theorems, Lebesgue measure, L^p-spaces.
   (c) Egorov, Lusin and Fubini Theorems.

(2) Metric spaces, general topology:
   (a) Complete and compact spaces, Baire category theorem.
   (b) Arzela-Ascoli theorem, application to Peano existence theorem.

(3) Banach spaces:
   (a) Normed linear spaces, Banach spaces, Hilbert spaces (basic theory).
   (b) Dual spaces, Hahn-Banach theorem, Riesz representation theorem.
   (c) Open mapping theorem, closed graph theorem.

(4) Fourier transforms and inversion.

Additional topics.

- Derivatives of measures, Radon-Nikodym theorem. Bounded variation, Lebesgue-Stieltjes integral, signed and complex measures, Hahn and Jordan decompositions, Helly's theorems. Fejer's theorem. Probability theory. Basic ergodic theory.

Possible Texts:

Kolmogorov/Fomin: *Introductory Real Analysis*
Lang: *Real and Functional Analysis*
Royden: *Real Analysis*
Rudin: *Real and Complex Analysis*

Math 141b: Complex Analysis

Core topics:

(1) Holomorphic functions in one variable (basic theory).
(2) Integration, Cauchy's theorem, Cauchy's formula.
(3) Open mapping, maximum principle.
(4) Power series, Weierstrass and Mittag-Leffler theorems.
(5) Linear transformations, conformal maps, Riemann mapping theorem.
(6) Elliptic functions, Weierstrass $\wp$-function.
(7) Harmonic and subharmonic functions, Dirichlet problem.

Additional topics.

- Introduction to Riemann surfaces. Connections with the theory of covering spaces and cohomology. Gamma and zeta functions. Picard's theorem. Runge's theorem. Inhomogeneous Cauchy-Riemann equation. Several complex variables (Hartog's theorem). Phragmén-Lindelöf theorem.

Possible Texts:

Ahlfors: *Complex Analysis*
Conway: *Functions of One Complex Variable*
Narasimhan/Nievergelt: *Complex Analysis in One Variable*

Math 151a: Topology I

Core topics:

(1) Covering Spaces and Fundamental Group (depending on class background, some or all may be skipped):
   (a) Basic Definitions (homotopy, fundamental group).
   (b) Existence and classification of covering spaces.
   (c) Correspondence between subgroups and covering spaces.
   (d) Van Kampen's theorem.

(2) Homology Theory:
   (a) Basic definitions of singular and simplicial homology.
   (b) Long exact sequence, excision, Mayer-Vietoris.
   (c) Homology of cell complexes and/or CW complexes.
   (d) Homology of basic spaces: sphere, projective spaces.

(3) Applications of homology:
   (a) Maps between spheres; degree of map.
   (b) Vector fields, fixed point theorems.
   (c) Separation theorems (Jordan Curve theorem).

Additional topics:

- Cohomology theory: Basic properties, cup and cap products.

Possible Texts:

Hatcher: *Algebraic Topology*

Greenberg and Harper: *Algebraic Topology: A First Course*

Munkres: *Elements of Algebraic Topology*

Math 151b: Topology II

Core topics:

(1) Cohomology theory (continuing from 151a if begun):
   (a) Basic properties.
   (b) Cup and cap products.
(2) Universal coefficients.
   (a) Tor and homology.
   (b) Ext and cohomology.
   (c) Künneth theorems.
(3) Poincaré duality.

Additional topics:

- Homotopy theory: Basic properties, Hurewicz theorem, path spaces, fibrations, Eilenberg-MacLane spaces and cohomology.

Possible Texts: See 151a.