YORK UNIVERSITÉ UNIVERSITY

Graduate Calendar

Mathematics and Statistics

2022-2023

Contents

Commencement of Classes

Fall	September 7, 2022
Winter	January 9, 2023

Orientation for Graduate Students

September 13, 2022

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Faculty of Graduate Studies regulations, important dates, and deadlines:
http://gradstudies.yorku.ca

Graduate Program in Mathematics and Statistics: https://www.yorku.ca/science/mathstats/graduate-programs/

Introduction

York University offers the following graduate programs in mathematics and statistics which lead to Master of Arts or Doctor of Philosophy degrees:

1. The MA program with specialization in applied mathematics, pure mathematics, theoretical statistics, applied statistics, data science, or probability.
2. The MSc program in Applied & Industrial Mathematics.
3. The doctoral program.

Students who are enrolled in the MA program can also apply for a graduate diploma in financial engineering.

This calendar describes these programs and provides details of entrance and degree requirements. It also provides information about financial support available to graduate students, as well as outlines of graduate courses to be offered in Summer 2022, Fall 2022, and Winter 2023.

Summary of Graduate Programs

The MA Program

This program is suitable for those students who want to undertake graduate study in mathematics or statistics. To be admitted, students must hold an honours degree in mathematics or statistics, or have an equivalent background.

Students can take courses in a wide variety of fields. Courses in areas such as algebra, analysis, topology, differential equations, numerical methods, applications of logic and set theory, probability, operations research, mathematical and applied statistics are offered regularly.

The program provides solid preparation for admission to a PhD program at York or other North American universities. It is also a suitable program for students who wish to expand their knowledge of mathematics or statistics beyond what they learned at the undergraduate level but who do not want to continue beyond the master's level.

The program is available on a full-time or part-time basis. Full-time students with a good background can usually complete their degree in three terms (there are fall, winter and summer terms each year) while those with a weaker background may require four or five terms. Note that limited courses will be offered in the summer term.

The MSc Program in Applied & Industrial Mathematics

The MSc in Applied & Industrial Mathematics has been designed as a two-year program. Students are required to take a certain set of core courses and the practicum. In the practicum, students will model physical problems that involve interpretations of experimental data, mathematical formulation of problems, analyses of the mathematical problems, and interpretations of the results. The program will culminate in a thesis. For more information, contact the program coordinator: Jianhong Wu (wujh@yorku.ca).

The Graduate Diploma in Financial Engineering

This program is a collaborative program established through the cooperation of the Schulich School of Business and the Department of Mathematics & Statistics. This diploma must be awarded concurrently with a master's degree in mathematics & statistics. Financial engineering is one of the fastest growing areas of applied mathematics. The Financial Engineering Diploma program allows students to acquire both the theoretical knowledge and specialized skills needed to develop new financial instruments. Students who successfully complete this program find careers in the financial sector. For more information, contact program coordinator Michael Chen (chensy@yorku.ca).

The PhD Program

Students in the PhD program take advanced level course work and write a dissertation (thesis) containing original research results. Members of the program have expertise in a wide variety of areas in mathematics, statistics and related disciplines. A detailed listing of the faculty and their fields of interest available at:

https://www.yorku.ca/science/mathstats/faculty-and-instructors/

To be admitted as a PhD student, an applicant must have a master's degree in mathematics or statistics, or must have completed at least one year of comparable studies.

Program Regulations

General Admission Requirements

To be considered for admission to the graduate program in mathematics and statistics, an applicant must be a graduate of a recognized university, with at least a B (second class) standing, or have equivalent qualifications. The average is normally based on all grades over the previous two full years of study. In practice, applicants who are admitted usually have a higher average than the stated minimum requirement, especially in their mathematics and statistics courses.

Applicants are required to demonstrate competence in English if they come from a country where English is not the main language. A minimum score of 79-82 (TOEFL IBT) or 6.5 (IELTS Academic Module) is required.

Applicants are not required to take the Graduate Record Examinations (GRE).

The MA Program

1) *Admission Requirements*

See the section on General Admission Requirements. To be considered for admission in the MA program, the student must have a minimum average of B. Most successful applicants have a standing of at least B+. In addition to having sufficiently high standing, students are expected to have completed certain core courses in mathematics or statistics as undergraduates.

2) *Degree Requirements*

Students must complete: the core course requirement; the thesis, survey paper (6001 0.0) or additional course work requirement; and the seminar requirement (6004 0.0). These are described below.

3) *Core Courses Requirements*

Each student is required to take one of the following sets of courses, to be chosen with the approval of the program director. (The last digit in the course number indicates the number of credits).

For any option chosen, no more than one-third of courses can be integrated, and all students must include among their courses one of the following sets:

i) Pure Mathematics Stream: Applied Algebra (Math 6121 3.0), Algebra II (Math 6122 3.0), Functional Analysis I (Math 6461 3.0), and either Measure Theory (Math 6280 3.0), Complex Analysis (Math 6300 3.0), Introduction to Harmonic Analysis (Math 6420 3.0), Functional Analysis II (Math 6462 3.0), Topology I (Math 6540 3.0), Algebraic Topology I (Math 6550 3.0) or Probability Theory (Math 6605 3.0).

ii) Applied Mathematics Stream: Four courses chosen from Applied Algebra (Math 6121 3.0), Ordinary Differential Equations (Math 6340 3.0), Partial Differential Equations (Math 6350 3.0), Stochastic Processes (Math 6602 3.0), Probability Models (Math 6604 3.0), Advanced Numerical Methods (Math 6651 3.0), Numerical Solutions to Differential Equations (Math 6652 3.0), Modern Optimization (Math 6904 3.0), Stochastic Calculus in Finance (Math 6910 3.0), Numerical Methods in Finance (Math 6911 3.0), Harmonic Analysis and Image Processing (Math 6920 3.0), Mathematical Modelling (Math 6931 3.0), Mathematical Epidemiology (Math 6936 3.0).

iii) Probability Stream: Stochastic Calculus in Finance (Math 6910 3.0); either Probability Theory (Math 6605 3.0) or Measure Theory (Math 6280 3.0); either Stochastic Processes (Math 6602 3.0) or Probability Models (Math 6604 3.0); and one of Mathematical Statistics (Math 6620 3.0), Applied Statistics I (Math 6630 3.0) or Numerical Methods in Finance (Math 6911 3.0).

iv) Theoretical Statistics Stream: Mathematical Statistics (6620 3.0), Generalized Linear Models (6622 3.0), Applied Statistics I (6630 3.0), and either Advanced Mathematical Statistics (6621 3.0) or Probability Theory (6605 3.0).

v) Applied Statistics Stream: Mathematical Statistics (6620 3.0), Generalized Linear Models (6622 3.0), Applied Statistics I (6630 3.0), either Applied Statistics II (6631 3.0) or Introduction to Bayesian Statistics (6635 3.0) or Survival Analysis (6641 3.0) or Applied Longitudinal Data Analysis (Math 6642 3.0), and Practicum in Statistical Consulting (6627 3.0).

vi) Data Science Stream: Mathematical Statistics (6620 3.0), Generalized Linear Models (6622 3.0), Applied Statistics I (6630 3.0), Data Science (6650 3.0), and either Data Mining (6636 3.0) or Statistical Learning (6644 3.0).

Thesis, Survey Paper or Additional Course Requirements

Each student must meet one of the following requirements:

a) Write a master's thesis under the supervision of an approved faculty member, give an oral presentation to the program (30 minute presentation and 1½ hours question and answer period), and defend it before an examining committee. In addition to Faculty regulations regarding thesis examination, the thesis candidate gives two talks in a student colloquium (20-minute presentations followed by question and answer period), one outlining work in progress and one presenting the final results. This is done prior to the final defense.

b) Submit a survey paper (Math 6001 0.0) written under a faculty advisor and give an oral presentation (a 50-minute presentation with a half-hour question and answer period), and take six credits of additional course work. Two copies of the final version of the survey paper, with the faculty advisor's confirmation, must be submitted to the program one week after the oral presentation.

c) Take twelve credits of additional course work for options (i)-(iv) and nine credits of additional course work for option (vi).

The courses selected to meet the above requirements must be graduate-level Math courses with first digit 6. Students may with permission from the graduate program director, use courses in other graduate programs such as computer science, physics and astronomy or economics to meet the requirements. Permission forms are available at:

http://gradstudies.yorku.ca/

Course credits: a student will not receive credit for more than 2 half integrated courses towards the MA degree. Students may not take or receive credit for an integrated course at the graduate level if they took it at York or elsewhere at the undergraduate level.

NOTE: Thesis proposals (including bibliography) must be forwarded for approval to the Dean of Graduate Studies not less than three months prior to the date set for the oral examination of the completed thesis. All thesis proposals must be submitted along with the Thesis and Dissertation Proposal form (TD1) available at:

http://gradstudies.yorku.ca/current-students/thesis-dissertation/forms/

to the graduate program office, N520B Ross, for approval by the graduate program director and by the Dean of Graduate Studies. The student is responsible for ensuring that the proposal and TD1 form reaches the Dean of Graduate Studies by the above timeline.

The student's thesis proposal shall consist of a listing of the student's supervisory committee, a detailed description of the thesis, and a bibliography.

The supervisor/supervisory committee form (to be submitted along with the TD1 form) is available at:

http://gradstudies.yorku.ca/current-students/thesis-dissertation/forms/

The guidelines for the preparation and examination of thesis and dissertation are available at:

http://gradstudies.yorku.ca/

York University is committed to the highest standards of integrity in research. All projects involving the use of human subjects, animal and biohazard materials are subject to review by the appropriate university committee. York University has formulated policies for the conduct of research involving all three of these areas. Graduate student research involving human participants which takes place as part of a graduate course or Major Research Project (MRP) is reviewed and approved at the graduate program level. Master's theses and dissertations are reviewed by the Faculty of Graduate Studies and the Office of Research Ethics, and all such research proposals and informed consent documents must be approved by York University's Human Research Participants Committee (HPRC) before students may proceed with their research.

Graduate students writing theses, in which research involving human participants occurs shall familiarize themselves with York University's policies about the use of human participants. All research involving human

participants is governed by the senate policy on Research Involving Human Participants. Details regarding the ethics review procedures for thesis/dissertation research involving human participants is available on the Faculty of Graduate Studies research ethics web page:

https://gradstudies.yorku.ca/current-students/thesis-dissertation/research-ethics/

The graduate program director will recommend the membership of the examining committee to the Faculty of Graduate Studies. The "Recommendation for Oral Exam" form available at: (http://gradstudies.yorku.ca/current-students/thesis-dissertation/forms/) must be completed and submitted to the graduate program office (N520B Ross) for approval by the graduate program director and be received by the Dean of Graduate Studies not less than 15 working days before the date set for the oral defense. This deadline is strictly enforced by the Faculty of Graduate Studies.

At the final defense, the student will give an oral presentation to the program (30-minute presentation and one-and-half hours question and answer period), and defend it before an examining committee.

In addition to faculty regulations regarding thesis examination, the thesis candidate gives two talks in a student colloquium (20-minute presentations followed by question and answer period), one outlining work in progress and one presenting the final results. This is done prior to the final defense. All members of the supervisory committee must be present at both talks.

It is the responsibility of both the supervisor and student to ensure that all degree requirements are met.

Seminar Requirement

In addition to the above, students who choose option (i)-(iv) or (vi) as their core course requirement must fulfill the seminar requirement (Math 6004 0.0). Students who choose option (v) are exempt as they do the Practicum in Statistical Consulting (Math 6627 3.0) in place of this. To fulfill the seminar requirement students must present two one-hour seminars. For each seminar, the topic is chosen in conjunction with a faculty member (different supervisor for each talk), who will then grade the talk on a pass-fail basis. Topics can be chosen from any branch of mathematics, but should not be taken directly from the student's course work, survey paper or thesis, although they can be related to such material. The two talks can be from different areas of mathematics or the same area, but the second talk should not just be a continuation of the first. Talks must be separated by one week, must be announced to the department at least one week before the talk is given, and must have at least 3 members of the York university community present in addition to the supervisor. In addition to giving the talks, students must attend the talks of other students in the seminar. Documented evidence of attendance at six such talks is required.

Students may substitute another half-course for the seminar (MATH 6004) if they are pursuing their MA by Survey Paper (Math 6001) or by Thesis.

Additional Information on Survey Paper and Seminar for MA Program

i) *What is expected from students in survey paper*?

Students are expected to identify a faculty member who agrees to supervise them for a survey paper. A final report of the survey paper, approved by the supervisor, must be submitted.

Note: Electronic submission of the final report would suffice.

ii) *How to find a supervisor*?

While the department will make efforts to provide the necessary support, students are responsible for finding their own supervisor for seminar and/or survey paper. Guidelines are detailed at:

https://gradstudies.yorku.ca/current-students/thesis-dissertation/thesis/masters-supervision/#section2b

iii) *How are grades reported*?

The grade for survey paper is pass or fail, and must be submitted by the following dates:

- Fall Term: January 15 (3.0 or 6.0 credit course)
- Fall/Winter and Winter Term: May 15 (3.0 or 6.0 credit course)
- Summer Term: September 15 (3.0 or 6.0 credit course)

iv) *How to confirm attendance in a seminar*?

The host (generally a faculty member) must sign the attendance form found at:

https://www.yorku.ca/science/mathstats/wp-content/uploads/sites/62/2021/04/Seminar_Attendance.pdf

v) *What is acceptable as a seminar*?

Students can attend seminars by other students or faculty members, colloquia, DSO of PhD students, and thesis or dissertation defence.

NOTE: MA Students who are taking Math 6001 (Survey Paper) or Math 6004 (Seminar) should enrol in the term of completion.

For graduation, MA students are required to complete the MA Checklists relevant to their stream. The checklists are available at:

https://www.yorku.ca/science/mathstats/resources/

The MSc Program in Applied & Industrial Mathematics (2 year)

i) *Admission Requirements*

An honours degree in mathematics (or equivalent background) with a minimum B standing may qualify the student for admission as a candidate to the program leading to the MSc degree in Applied & Industrial Mathematics. Students whose first language is not English must demonstrate an acceptable command of English. A minimum score of 79-82 (TOEFL IBT) or

6.5 (IELTS Academic Module) is required.

ii) *Degree Requirements*

Students must complete:

Advanced Numerical Methods (Math 6651 3.0), Mathematical Modelling (Math 6931 3.0), Practicum in Industrial and Applied Mathematics (Math 6937 3.0), another 3-credit course appropriate to the student's program of study approved by the student's supervisory committee, and a thesis (see below) which must be defended before an examining committee in accordance with the regulations of the Faculty of Graduate Studies.

NOTE: The student's thesis proposal (including bibliography) must be forwarded for approval to the Dean of Graduate Studies not less than 3 months prior to the date set for the oral examination of the completed thesis. All Thesis proposals must be submitted along with the Thesis/Dissertation Research Submission form (TD1) available at

http://gradstudies.yorku.ca/current-students/thesis-dissertation/forms/

to the graduate program office, N520B Ross, for approval by the graduate program director and be received by the Dean of Graduate Studies. The student is responsible for ensuring that the proposal and TD1 form reaches the Dean of Graduate Studies by the above timeline.

The student's thesis proposal shall consist of a listing of the student's supervisory committee, a detailed description of the thesis, and a bibliography.

The supervisor/supervisory committee form (to be submitted along with the TD1 form) is available at:

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must be completed and submitted to the graduate program office (N520B Ross) for approval by the graduate program director and be received by the Dean of Graduate Studies not less than 15 working days before the date set for the oral defense. This deadline is strictly enforced by the Faculty of Graduate Studies.

At the final defense, the student will give an oral presentation to the program (30-minute presentation and one-and-half hours question and answer period), and defend it before an examining committee.

In addition to faculty regulations regarding thesis examination, the thesis candidate gives two talks in a student colloquium (20-minute presentations followed by question and answer period), one outlining work in progress and one presenting the final results. This is done prior to the final defense. All members of the supervisory committee must be present at both talks.

Full-time students will complete degree requirements by the end of the 2nd year (6 terms). Part-time students will complete the degree requirements by the end of 12 terms.

It is the responsibility of both the supervisor and student to ensure that all degree requirements are met.

Course credits: a student will not receive credit for more than 2 half integrated courses towards the master's degree. Students may not take or receive credit for an integrated course at the graduate level if they took it at York or elsewhere at the undergraduate level.

The Graduate Diploma in Financial Engineering (Type 2 - Concurrent)

i) *Admission Requirements*

The Graduate Diploma in Financial Engineering is completed in conjunction with the master's or doctoral program in mathematics and statistics. Students must first apply and be accepted to the MA or doctoral program in mathematics and Statistics.

Applicants may indicate their interest in pursuing the Graduate Diploma in Financial Engineering at the same time they apply to the MA or doctoral program in mathematics and statistics, or they may submit a separate application for the diploma during the first term in which they are registered in the master's or doctoral program. For further information and application process please visit http://mathstats.info.yorku.ca/gradprogram/diplomas/

ii) *Diploma Requirements*

The requirements for the Graduate Diploma in Financial Engineering may be completed in conjunction with the master's program requirements.

The requirements for the diploma are as follows:

a) Successful completion of the following courses:

- MATH 6910 3.0, Stochastic Calculus in Finance
- MATH 6911 3.0, Numerical Methods in Finance
- SB FINE 6200 3.0, Investments
- SB FINE 6800 3.0, Options, Futures, and Other Derivative Securities
- SB FNEN 6820 3.0, Advanced Derivative Securities
- SB FNEN 6850 3.0, Fixed Income Securities
- SB OMIS 6000 3.0, Models and Applications in Operational Research

NOTE: MATH 6910, MATH 6911, and OMIS 6000, may be used to satisfy the MA by Coursework or MA by Survey Paper (Math 6001) program requirements.

NOTE: Students with little or no background in finance may find it beneficial to take ECON 5030, Econometrics of Financial Markets, as background for the finance courses listed above.

b) In addition to the course requirements, diploma students must complete one of the following: (i) subject to availability, an internship of at least 10 weeks duration in a financial institution, or (ii) a research project.

NOTE: Students in the MA program by Survey Paper (Math 6001) option who decide to fulfill the above requirement through completion of a research project may request that the diploma research project also be used toward fulfilment

of the MA survey paper requirement. Such requests must be made in writing to the financial engineering coordinator, accompanied by the confirmation from the student's faculty advisor that the diploma research project is of acceptable quality to meet the MA by Survey Paper program requirements. Such requests will be considered by the financial engineering coordinator only if the diploma research project contains substantial mathematics content, equivalent to that expected of students in the MA by Survey Paper program option.

c) Diploma seminar requirement: Students who did not complete MATH 6627 3.0, Practicum in Statistical Consulting, as part of their mathematics and statistics degree program requirements are required to give a talk on their internship or research paper to fulfill the diploma seminar requirement. Such students should enrol in MATH 6004, Seminar, in order to receive a grade. The talk must be announced to the department at least one week before the talk is given, and must have at least 3 members of the York university community present in addition to the supervisor. In addition to giving the talk, students must attend the talks of other students in the seminar. Documented evidence of attendance at six such talks is required.

Diploma Length

Students typically require four consecutive terms to complete the coursework for Mathematics & Statistics degree program and Type 2 Graduate Diploma in Financial Engineering, and then go on to complete the internship or research project, normally in one term.

Additional inquiries may be communicated with the diploma program coordinator Michael Chen (chensy@yorku.ca).

The PhD Program

The Department of Mathematics and Statistics offer PhD programs in applied mathematics, pure mathematics, and statistics.

i) *Admissions Requirements*

See the section on General Admission Requirements. To be considered for admission as a PhD student, students must have completed an acceptable master's degree or must have completed one year of comparable work, with a minimum B+ average. The admission process is very selective and not all students meeting this requirement will be admitted. A complete application file is required for the applicant to be considered.

Applicants should obtain at least three letters of recommendation by academics who know them well. Applications are considered by the PhD Committee, which makes its recommendations to the graduate program director. The director will then make a recommendation to the Faculty of Graduate Studies.

Current master's students who wish to apply for admission to the PhD program must submit an on-line application and supporting documentation. Internal promotion from master's to PhD program may be possible at the discretion of the graduate program director.

ii) *Degree Requirements*

Five major components make up the degree requirements for the PhD in mathematics and statistics. These are (1) coursework; (2) comprehensive exams; (3) dissertation subject oral; (4) dissertation proposal; and (5) dissertation oral exam (proceeded by the dissertation colloquium). Students can complete these degree requirements in 4 years and the following is the projected timeline and or completion.

The details of these requirements are listed below.

Course Requirement and Comprehensive Examination

Students must successfully complete 12 credits at the graduate level. The courses must be chosen with the approval of the program director. Up to 12 additional credits may be required based on the recommendation of the supervisor, and at the discretion of the PhD committee and the graduate program director. Determination of such additional credits will be made during the first semester of the PhD program and communicated with the students.

NOTE: A PhD student may submit a petition under the following circumstances.

i) A required course has already been completed through a previous degree. The petition may request replacement of another 6000 level course to satisfy the requirements of the PhD program with the completion of a minimum of 12 credits.

ii) The contents of additional credits recommended by the program have been covered in previous courses successfully

completed by the student. The petition may request to waive such additional credits.

A petition must be submitted within the first semester of the PhD program, and must be supplemented with detailed syllabus for each course. The graduate program director may require a letter of course equivalency for approval of the petition.

Course credits: A student will not receive credit for more than two half integrated courses to satisfy the course and specialization requirements towards the PhD degree. Students may not take or receive credit for an integrated course at the graduate level if they took it at York or elsewhere at the undergraduate level.

Comprehensive Examination

Students will declare a specialization in one of the areas of pure mathematics, applied mathematics, or statistics, and write comprehensive examinations in subjects which are appropriate to the chosen specialization. In addition, statistics students will complete a statistical consulting requirement.

A doctoral candidate must satisfy their comprehensive exam requirement by completing the exams in the first year of study. Students need not enrol in the course nor attend lectures in order to write the exam for comprehensive credit. The comprehensive exams are as follows:

(1) Complex Analysis (MATH 6300)

(2) Measure Theory (MATH 6280)

(3) Functional Analysis (MATH 6461)

(4) Applied Algebra (MATH 6121)

(5) Algebra II (MATH 6122)

(6) Commutative Algebra (MATH 6130)

(7) General Topology (MATH 6540)

(8) Algebraic Topology (MATH 6550)

(9) Ordinary Differential Equations (MATH 6340)

(10) Partial Differential Equations (MATH 6350)

(11) Number Theory (MATH 6110 or MATH 6115)

(12) Probability Theory (MATH 6605)

(13) Category Theory (MATH 6180)

(14) Differential Geometry (MATH 6530)

(15) Set Theory (MATH 6040)

(16) Advanced Numerical Methods (MATH 6651)

(17) Numerical Solutions to Differential Equations (MATH 6652)

(18) Mathematical Modelling (MATH 6931)

(19) Mathematical Statistics (MATH 6620)

(20) Advanced Mathematical Statistics (MATH 6621)

(21) Generalized Linear Models (MATH 6622)

(22) Applied Statistics I (MATH 6630)

NOTE: While not all courses will be offered annually, course offerings will be responsive to student need. Exams may be taken in a year in which the course is not offered.

Candidates must declare themselves to be in one of these three streams: applied mathematics, pure mathematics, or statistics streams. Candidates will decide which comprehensive exams to complete with the approval of their supervisor and the graduate program director.

Pure mathematics students must complete at least one exam from 1-3, one exam from 4-6, one exam from 7-11, plus one additional exam.

Applied mathematics students must complete exam 18, at least one exam from 9 or 10, at least one exam from 16 or 17, plus one additional exam.

Statistics students must complete exams 19, 20, 21 and 22. In addition, statistics students must fulfill a practicum requirement. This requirement is usually completed in the second year of study.

Part-time students will have to pass at least 6 credits per year, and will have to complete the comprehensive exams by the end of their second year of enrolment.

Students are required to consult with the program director to make their course and exam selections. In certain extreme cases of difficulty due to scheduling, the PhD Committee will designate certain other courses as substitutes, arrange for reading courses, or modify the timing requirements. Comprehensive exams will be closed book in-class exams. Students who are not enrolled in a course but elect to take a comprehensive exam should contact the instructor regarding the time and place of the exam. All comprehensive exams are submitted to the PhD Committee for evaluation.

Current master's students who plan to apply for admission to the PhD program may also wish to

take some of the comprehensive exams. The grades (PASS or FAIL) will be counted if the students are admitted to the PhD program.

NOTE: A student cannot fail any one comprehensive exam more than once, and not more than a total of 3 comprehensive exams.

Practicum Requirement for Statistics Stream

The purpose of the practicum is to prepare students for the transition from statistics theory to the application of statistics through consulting and collaboration. The requirement for statistics students consists of two parts. The first part is the completion of MATH 6627 3.0 or an equivalent consulting course from another university, approved by the graduate program director. Further details regarding the requirements for the course can be found in the course description for MATH 6627 3.0. The second part is the comprehensive exam in consulting.

Specialization Requirement and Dissertation Subject Oral

Students in the doctoral program must demonstrate depth of knowledge in their field of specialization. The candidate must pass an oral examination (Dissertation Subject Oral), which may occur within the second year of study and before the end of 6th semester. In preparation for this examination, the student shall, in consultation with the tentative supervisory committee, decide on a dissertation subject and a syllabus of materials. The syllabus of materials shall consist of those theoretical results, techniques, examples, etc. in the student's area which are deemed most likely by the tentative supervisory committee to be useful in research on the dissertation subject.

The tentative supervisory committee must approve the dissertation subject and agree that a command of the syllabus of materials will enable the student to pursue original research in that subject. A date for the examination will be set by the tentative supervisory committee in consultation with the candidate.

The Dissertation Subject Oral shall consist of a 30-minute oral presentation of the dissertation subject and a question period, up to one hour in length. All members of the student's supervisory committee must be present. Members of the graduate program may attend the examination and may ask questions on the presentation or on the syllabus of materials. The Dissertation Subject Oral should be announced to the department and the syllabus made available to the supervisory committee members in advance.

At the end of the question period, the tentative supervisory committee shall judge the examination as successful or unsuccessful. In the latter case, the student may try again after additional study. If a student decides to change the dissertation subject, then an examination in the new subject will be required.

Upon the successful completion of the examination, the tentative supervisory committee will recommend approval of the candidate's research proposal. The student's dissertation proposal (including bibliography) must be submitted along with the Thesis/ Dissertation Research form (TD1) available at:

http://gradstudies.yorku.ca/current-students/thesis-dissertation/forms/

to the graduate program office, N520B Ross, for approval by the graduate program director and be received by the Dean of Graduate Studies not less than six months prior to the date set for the oral examination of the completed dissertation.

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Guidelines for the preparation and examination of dissertations are available at:

http://gradstudies.yorku.ca

Departmental guidelines are available at:

https://www.yorku.ca/science/mathstats/wp-content/uploads/sites/62/2020/10/Guidelines-for-Supervision-of-Graduate-Students-1.pdf

Dissertation Evaluation

- *Dissertation Colloquium*

Upon completion of work on the dissertation, the supervisory committee, in consultation with the candidate, will set a date (at least 25 working days prior to the oral exam) for a preliminary examination thereof (dissertation colloquium).

The examination will consist of an oral presentation of the dissertation, of at most one hour's duration, and a question period, up to one hour in length. Members of the graduate program in mathematics and statistics may attend the examination and may ask questions related to the candidate's dissertation. At the end of the question period the supervisory committee shall judge the examination. In the case of failure, a detailed rationale must be given to the candidate. The candidate may repeat the examination, but only after an interval of at least one month. Supervisory committee members must be present.

- *Dissertation Oral Examination*

An oral examination (30 minute presentation and 2 hour question and answer period) on the candidate's dissertation will be conducted according to Faculty regulations. See "Guidelines for Preparation and Examination of Theses and Dissertations" for details. The graduate program director will recommend the membership of the examining committee to the Faculty of Graduate Studies. The completed "Recommendation for Oral Exam" form available at: (https://gradstudies.yorku.ca/current-students/thesis-dissertation/dissertation/) must be submitted to the graduate program office (N520B Ross) for approval by the graduate program director and be received by the Dean of Graduate Studies not less than 20 working days before the date set for the oral. This deadline is strictly enforced by the Faculty of Graduate Studies.

Faculty members and graduate students may attend the oral examination. They may, at the discretion of the chair of the examining committee, participate in the questioning, but only members of the examining committee may be present for the evaluation and for the vote at the conclusion of the examination.

Progress Report

All students enrolled in a PhD program are required to complete an annual research progress report detailing the achievements of the previous year and the objectives for the next year. Permission to continue to register in the program depends on a satisfactory report.

Deadlines for Meeting Requirements

Students are expected to finish the comprehensive exam requirement in the first year of their PhD studies. The Dissertation Subject Oral may be taken within the second year of study, but must be within the first 6 semesters. Students who are in the statistics stream should also finish the practicum requirement in the second year of study. The dissertation itself should be completed within two years of the Dissertation Subject Oral, although one additional year may be allowed by permission.

Supervisory Committees

Upon admission to the doctoral program, each student will be assigned a tentative supervisor from the graduate program. The assignment will be made by the PhD Committee. The student will decide upon a study plan in consultation with the tentative supervisor.

Dissertation Supervisory Committee

When a student has successfully written the comprehensive examinations, the tentative supervisor in consultation with the student, will appoint a supervisory committee to be approved by the PhD Committee. The student will decide upon a continuing program of study in consultation with the supervisory committee. A dissertation supervisory committee shall be recommended by the graduate program director

to the Dean of Graduate Studies after the student has successfully taken the Dissertation Subject Oral, in accordance with the faculty regulations.

A supervisor must be recommended by the graduate program director for approval by the Dean of Graduate Studies no later than the end of the fifth term of study (end of second term of PhD II). Students will not be allowed to register in the seventh term of study (the onset of PhD III) unless a supervisor has been approved.

A supervisory committee must be recommended by the appropriate graduate program director for approval by the Dean of Graduate Studies no later than the end of the eighth term of study (end of second term of PhD III). Students will not be allowed to register in the tenth term of study (the onset of PhD IV) unless a supervisory committee has been approved.

The supervisor/supervisory committee form is available at:

http://gradstudies.yorku.ca/current-students/thesis-dissertation/forms/

Dissertation Examining Committee

A dissertation examining committee will be appointed according to Faculty regulations (www.gradstudies.yorku.ca). It is the responsibility of the supervisor and student to ensure that all degree requirements are met.

Acceptable Grades for Graduate Students

Faculty of Graduate Studies regulations regarding acceptable grades:

https://gradstudies.yorku.ca/current-students/regulations/courses-grading/

Registration and Balance of Degree Fees

http://gradstudies.yorku.ca/current-students/regulations/fees/

Important Notes

Full-time MA students must register and pay fees for a minimum of three terms.

If MA program is not completed with 3 semesters of full-time study, the status of an MA student will be automatically part-time for any additional terms. Part-time students are not eligible for funding. Note that registration in Financial Engineering Diploma **will not** extend the period of full-time study for MA program.

Full-time MSc students must register and pay fees for a minimum of 6 terms.

If MSc program is not completed with 6 semesters of full-time study, the status of an MSc student will be automatically part-time for any additional terms. Part-time students are not eligible for funding.

Part-time MA students must register and pay fees for a minimum of 6 terms. Part-time MSc students must register and pay fees for a minimum of 12 terms.

Full-time doctoral students must register and pay fees for a minimum of 6 terms.

Part-time doctoral students must register and pay fees for a minimum of 12 terms.

Students who successfully complete a master's or PhD program in less time than the program length, will, prior to convocation be responsible for payment of a balance of degree fee. For the calculation of balance of fees, one full term is equivalent to two part-time terms.

Full-time students may not be absent from the campus without the permission of the program director for more than four weeks of any term in which they are registered.

Students are responsible to be aware of the Faculty of Graduate Studies regulations:

http://gradstudies.yorku.ca

Key timelines in the PhD program

- Petition for credit transfer: must be within the first semester
- Comprehensive exams: must be completed within the first 3 semesters
- Supervisor: must be recommended and approved before the end of 5th semester
- Supervisory committee: must be recommended and approved before the end of 8th semester
- Dissertation Subject Oral: must be completed before the end of 6th semester
- Colloquium: must be within the semester of Dissertation Oral Examination, and at least 25 days prior to the oral examination

Financial Support

Most full-time students are offered some financial support in the form of a teaching assistantship and/or a research assistantship. Full-time MA students who are offered financial support will receive this support in year one of full-time studies. Full-time MSc students who are offered financial support will receive this support in year one and year two of full-time studies. Full-time PhD students who are offered financial support will continue to receive this support for four years provided their studies are proceeding in a satisfactory manner.

In addition to York support, students are urged to seek financial support from external sources. Part-time students are not eligible for financial support.

External Scholarships

Students with high averages are strongly encouraged to apply for external scholarships. These include NSERC and OGS scholarships. For NSERC scholarships, the student must be a citizen or permanent residence of Canada. The OGS is open to all students, including international (visa) students.

York Graduate Scholarships

A limited number of entrance scholarships are awarded to outstanding full-time students. These are valid for the first year of study only at the master's or doctoral level and are not renewable.

York Recruitments Awards

A limited number of recruitment awards may be available for outstanding full-time students. These awards are intended to bring high calibre students to the graduate program; they are valid for the first year of MA/MSc and PhD programs only and are not renewable.

Bursaries

Full-time registered graduate students who are paying full-time fees and have financial need may apply to the Faculty of Graduate Studies for a bursary.

Type of Support at Admission

Type of Support	Degree Program		
	MA	MSc	PhD
TA	0.75/year	0.75/year	1/year
TA top-up to	0.875/year	0.875/year	—
RA	—	Yes	Yes
YGF	Yes	Yes	Yes
YGS	—	Limited (requires minimum A GPA)	
Recruitment Award	Limited (requires minimum A GPA)		

Intellectual Property Policy

The Faculty of Graduate Studies recognizes the mission of the university to seek, preserve, and disseminate knowledge and to conduct research in a fair, open, and morally responsible manner.

In such regard, the Faculty of Graduate Studies believes that intellectual property rights are divided among several interests, and that the rights and obligations of various claimants should be specified, fairly regulated, and that disputes arising may be mediated. All parties students and faculty are expected to behave in an ethically appropriate manner beyond their immediate graduate student/supervisory relationship, to encompass intellectual property rights, dissemination of research data, and in making decisions on authorship and publication of joint research.

Because of the varied cultural aspects and practices that differ among the graduate programs, each program is responsible for enacting and enforcing this policy of appropriate ethical practices on intellectual property rights, in compliance with the Faculty Policy on Intellectual Property for Graduate Programs. Programs which choose not to enact their own specific policy are bound by the Faculty Policy on Intellectual Property for Graduate Programs, which can be found here:

http://gradstudies.yorku.ca/current-students/thesis-dissertation/general-requirements/

Application of the Faculty of Graduate Studies Intellectual Property Policy

The purpose of this section is to allow programs to enact a variant policy, to take into account normative practices and procedures of a discipline that may not be adequately described in the Faculty Policy on Intellectual Property for Graduate Programs. Programs will have an obligation to inform their students and faculty of the existence of the program policy, and especially of the nature of any special conditions, or of the Faculty Policy on Intellectual Property for Graduate Programs, if a program does not elect to formulate their own policy.

In the production of a program policy, no program may impose unreasonable or unusual conditions on any student or faculty member as a condition of admission to, or participation or teaching in a program. Furthermore, no individual agreement between a faculty member and a graduate student will impose unreasonable or unusual conditions on the student.

To ensure that the unequal power and influence of the faculty member in the supervisor/student relationship does not overwhelm the student, the Executive Committee of the graduate program will review all individual agreements to ensure that this condition is respected. The policy of each program must ensure that the Executive Committee of the Graduate Program may annul any individual agreement, and/or ask for redrafting of an agreement, where they consider that this condition has not been respected.

The program policy will be entitled 'Intellectual Property Policy of the Graduate Program in ……..', and must be submitted to the Faculty of Graduate Studies for approval by the Executive Committee and Council within three months after approval of the Faculty Policy on Intellectual Property for Graduate Programs.

The Faculty Policy for Graduate Programs on Intellectual Property Relationships between Graduate Students and Their Supervisors

The following clauses, concerning authorship, publication and individual agreements, relating to graduate students and their supervisors, are to serve as the Faculty Policy on Intellectual Property for Graduate Programs who wish to devise their own policy, principles and practices. Clauses 1 through 15, either in their entirety or reworded, must be included in all graduate programs' policies. If clauses are reworded, the programs must ensure that the spirit of the Faculty wording is encompassed. The clauses may be augmented if the programs so wish. All program policies, which will be expected to have an appropriate preamble, are subject to the approval of the Faculty of Graduate Studies Executive Committee and Council.

Authorship

- Authorship can only be credited to those who make substantial intellectual contributions to a piece of work. Accepting the addition of an author who has not made a significant intellectual contribution to the piece of work is not ethical for authors.

- Authors accept not only credit but also responsibility for their work and, in particular, for ensuring that the work conforms to appropriate standards of Academic Honesty.
- Generally, the order of authors' names in a publication should reflect the substance of their relative contributions to the work, with priority going to those who made the greatest or most significant contribution. Supervisors should discuss the issue of authorship, and what factors may determine the final order of authorship, normally before commencing the work.
- Where the major substance or data of a co-authored publication is based on a portion of a graduate student's work, the student will normally be the first author. The supervisor, or joint authors should be prepared to offer a rationale in cases where the student is not listed as the first author. Where the work has been written up in a dissertation or thesis or paper before the research is published, the publication will normally cite the dissertation, thesis, or paper on which it is based.
- Anyone otherwise entitled to be acknowledged as a co-author may forfeit that right if they leave the project before substantially completing it. In such cases their contribution to the work shall nonetheless be acknowledged in an appropriate manner by the author(s), for example in the acknowledgements section of the publication.
- Providing financial support for a student's dissertation, thesis, or research paper is not, in itself, sufficient to warrant authorship. Only where intellectual input is provided beyond financial support, should co-authorship be considered.
- Supplying minor editorial work for a student's dissertation, thesis, or research paper is not, in itself, sufficient to warrant co-authorship.
- If a student is employed as a Research Assistant in circumstances where the work done in the course of that employment is not intended to and does not in fact become part of work done for the degree requirements, then the student may not normally claim co-authorship and does not own the data, except through a prior agreement that is consistent with the general principles above.
- If a student is employed as a Research Assistant in circumstances where the work done in the course of that employment becomes part of the thesis/dissertation/ research paper, the student may, at a minimum, claim co-ownership of the data but as the author of the thesis/ dissertation/ research paper owns the overall copyright.

Publication

- The university has an important duty, grounded in the public interest, to seek, preserve and disseminate knowledge. Therefore, authors should attempt to publish their work in a timely fashion. In cases where work must be kept confidential and unpublished for a time, the period of delay should normally be no more than one year from the date of acceptance of a thesis or dissertation, and should in no circumstances extend beyond two years from that date.
- Publications by graduate students and faculty must give full and proper acknowledgment to the contribution of other students or faculty, or others to their work, notwithstanding that such contribution may not warrant authorship. Such contributions should be substantial, in accordance with the particular discipline, and may include items such as original ideas that led directly to the research work, or requested commentary that resulted in significant changes to the research.
- Normally, all co-authors or co-owners of the data need to concur in publishing or presenting the work. Co-authors should agree to the time or place of presentation or publication of their jointly authored work prior to the presentation or publication, but such agreement should not be unreasonably withheld. The inability of the author(s) to contact another co-author prior to presentation at a meeting or seminar should not prevent work from being publicly disseminated, provided they make reasonable efforts to contact all contributors to obtain prior agreement.
- To verify research materials or data, there must be provisions for access. Supervisors and sponsors may, with agreement of the student, retain the original materials provided. Under such circumstances

students shall normally be presented on request with complete and usable copies of those materials.

- Where there has been significant substantive and intellectual contribution by the supervisor to the research, the intellectual property emanating thereof shall normally be the joint property of graduate students and their supervisor or sponsor for the masters or doctoral project in which the materials were created. When the physical research materials embody intellectual property, the student should have reasonable access to this material. Agreements concerning research materials and data should be made, where possible, before the commencement of research.
- Students shall not use in their dissertations, theses or papers data or results generated by someone else without first obtaining permission from those who own the materials.

Individual agreements

- Students and faculty may enter into individual agreements that modify their intellectual property rights. If they do so, the provisions of clauses below must be observed.
- Individual agreements should specify any financial relations and associated rights and obligations, provisions for ownership and control of original data and research materials, authorship, publication, and presentation.
- All individual agreements must explicitly state that they are subject to applicable Collective Agreements and all University regulations in force at the time.
- All individual agreements must be completed within four months of a student starting a significant portion of the research for a thesis or dissertation, or within four months of the student joining a laboratory. In the case for students joining a specific laboratory to undertake research with a specific supervisor, the supervisor should indicate prior to the arrival of the student the nature of any agreement expected to be entered into between the supervisor and the student.
- All individual agreements will be reviewed by the Executive Committee of the graduate program to ensure that the agreement does not impose any unreasonable or unusual conditions on the student. The Executive Committee of the graduate program may annul any individual agreement or ask for redrafting where this condition has not been respected.

Education and Information

Education is a most powerful tool to promote appropriate ethical behaviour in the graduate student/supervisor relationship, especially concerning intellectual property rights, dissemination of research data, authorship, and publication of joint research. Moreover, a suitable educational session to inform graduate students of their rights and obligations concerning intellectual property and associated aspects would go a long way to ensuring that potential conflicts are eliminated before intervention is required. Therefore, graduate programs should present an educational and information session to incoming graduate students on such matters as part of their orientation. To assist in this task, graduate programs should use the section of the report of the Task Force on Intellectual Property entitled "Intellectual Property and the Graduate Student at York", and ensure that copies of this section are provided to all new faculty and incoming graduate students. Furthermore, the graduate programs would find an educational session useful to continually update faculty members on what documentation may or should be included in appropriate individual agreements. To ensure that the educational session is held, graduate programs are required to include in their intellectual property policy the following statement:

That graduate program in ..... will normally hold an information session on ethical aspects of research including intellectual property rights, and related issues, during the orientation session for new incoming graduate students. All new students and faculty will be provided with copies of the most recent edition of the document entitled "Intellectual Property and the Graduate Student at York."

Dispute Resolution

In such a complex area, disputes may arise even among people of good will, for example, out of conflicting understandings of fact, or interpretations of the law, faculty or program regulations, or individual agreements.

The primary role of the Faculty of Graduate Studies should be to provide general directives

and principles governing the graduate student/ supervisory relationship, to educate and inform parties about their rights and appropriate behaviour, and to assist parties in mediating disputes. The latter imply that the parties can probably come to a voluntary and informed agreement between themselves. Generally, the imposition of resolutions by a Faculty or by arbitrators is far less satisfactory. Therefore, the following mediative process is suggested as a means of resolving disputes.

In disputes arising out of Program Policies or Individual Agreements, parties should initiate a complaint in writing, and bring it to the attention of the program director of the program in which the student is enrolled, with a copy to the Dean of the Faculty of Graduate Studies.

The program director should arrange an informal meeting of the parties to discuss the substance of the dispute, the possibility of negotiating an agreement at the program level, and to determine the necessity of approaching the Faculty for assistance. At the meeting, the parties shall be informed that they may at their own expense, seek legal remedy. At any point, if any party chooses to proceed in law, the mediative role of the program or faculty shall end.

If the parties choose to proceed to mediation, a mediator acceptable to the parties, preferably from outside the graduate program will be used, unless all parties agree to mediation by the Program Director. In cases where the nature of the dispute involves a requirement for technical knowledge of the matter, the Program Director may form a hearing committee consisting of herself/himself and necessary experts in the subject matter who preferably come from outside the graduate program. In assisting the parties in mediation, the program director or mediator must have regard to the fact that students and faculty generally stand in a relation of unequal power, and thus ensure that any agreement reached is consistent with the general principles of the report of the Task Force on intellectual Property.

If the dispute cannot be settled by mediation within the program, and on request of the parties, the Dean of the Faculty of Graduate Studies or his or her representative shall review the initial attempt at mediation, and if warranted may proceed with a new attempt at mediation, subject to the same conditions as stated above. In matters outside of ownership of intellectual property, the Faculty may direct how a settlement should be reached.

For further information and updates please visit:

http://gradstudies.yorku.ca/current-students/thesis-dissertation/general-requirements/

Course Outlines S/F 2022, W 2023

MATH 6004 0.0 S/F/W
Seminar

This course provides students with a chance to work independently and to present the results of their work to other students. Each student gives two one-hour seminars on topics arranged with two different faculty members. The topics may be related to other courses the student is taking, but should not actually be covered in those courses. They may be in the same field or two different fields. Students are expected to submit a written report prior to presenting each seminar. The seminars are graded separately and the course is graded on a pass/fail basis. Students in the course are expected to attend all seminars.

Main Source
Determined by the supervisor

Course Director
Supervisors, one per Seminar

MATH 6110 3.0 W
Algebraic Number Theory

This course will be an introduction to analytic number theory, focussing on the Prime Number Theorem and related results. In particular, we will prove the Prime Number Theorem, discuss primes in arithmetic progressions, Dirichlet characters and series, and the Riemann zeta function. Time allowing, we will also cover some topics in Diophantine approximation.

Main Source
Lecture notes will be provided
T.M. Apostol, Introduction to Analytic Number Theory

Course Director
Patrick Ingram, Ross S615

MATH 6121 3.0 F
Applied Algebra

Linear Algebra (Recall crash course, Graduate level): THM: For any fin. Gen. vector space V (over C) V has a basis B (ORDERED); $dim(V) = |B| = n$ is well defined; $L : V \to C^n$ where $L(v) = [v]$ is an isomorphism. THM: For Linear transformation $T : V \to W$, and fixed respective basis. There is a Unique matrix $[T]$ such that LoT=MoL; All question about T can be answered using algorithms on matrix $[T]$; End(V) = Mat($n \times n$); Aut(V) = Gl(n). Aut(V)=Gl(n); Direct sum and tensor product has corresponding operations on basis and linear transformations; Group Theory and Representation Theory; Recall: Group, morphism, subgroup, G-sets (and G-morphisms), Isomorphisms Theorems and quotient groups; Jordan-Holder Theorem; Sylow Theorem; Representation of finite groups and characters (over C); Maske's Theorem; Schur's lemma; Structure of the space of G -endomorphisms; Structure of the inner space of characters on G; Final Theorem: the number of irreducible representations for G equal the number of conjugacy classes of G; Preliminary notions in ring: definitions; Euclidian domain; Principal ideal domain; Polynomial rings; Grobner basis with emphasis on algorithmic aspect and computational geometry; solving polynomial system of equations (with some application to robotics and computational geometry); Modules over PID (Advanced linear algebra); Chinese Remainder Theorem; Classification of finitely generated modules over PID; Classification of finitely generated abelian groups; rational canonical form; and Jordan canonical form.

Main Source
D.S. Dummit, R.M. Foote, Abstract Algebra, Willey (2004).
T. W. Hungerford, Algebra, GTM Springer (2003).
D.A. Cox, et al., An Introduction to Computational Algebraic Geometry and Commutative Algebra UTM Springer (2007).
(B. Sagan, The Symmetric Group, Springer-Verlag GTM (2001)

Course Director
Nantel Bergeron, DB2029

MATH 6122 3.0 W
Algebra II

Ring and module theory; more on ideals (primes, irreducible, maximal, etc), UFD, injective and projective modules, semi-simple rings and Wedderburn's Theorem; introduction to algebraic geometry: varieties, radical ideals, Hilbert's nullstellensatz; Fields theory and Galois theorems: field extensions, splitting fields, automorphism group of fields, Galois correspondence, Galois groups of polynomials, solving polynomials with radicals; and introduction to category theory.

Main Source
T.W. Hungerford, Algebra, Graduate Texts in Mathematics 73

Course Director
Yun Gao, Ross S624

MATH 6280 3.0 W
Measure Theory

A measure is a function that assigns numbers to subsets of a given set, subject to certain conditions. Intuitively, the measure of a set corresponds in some sense to the size of the set. For example, the Lebesgue measure of a set of the plane is the area of the set for those sets that have a classically defined area, and it also extends the definition of area to a much wider class of sets. Measures are also important in probability theory, where subsets correspond to "events" and measures assign probabilities to events. More generally, measure theory is central to analysis, since measures are used to construct integrals, and conversely integrals give rise to measures. This course begins with the classical theory of Lebesgue measure and Lebesgue integration on the real line. We then examine the general theory of measures on abstract spaces. It will be assumed that each student has taken an undergraduate course in mathematical analysis. Topics include: Sigma-algebras, measure spaces, measurable functions, outer measure and measurability, extension theorems, integration, convergence theorems, signed measures, Hahn-Jordan decomposition, Radon-Nikodym theorem, product measures, Fubini theorem, Lp spaces.

Main Source
D.L. Cohn, Measure Theory by, 2nd Ed., Birkhauser 2013.

Course Director
Neal Madras, Ross S616

MATH 6300 3.0 F
Complex Analysis

Complex differentiability, power series, Cauchy-Riemann equations, Cauchy integral theorem, harmonic functions, residues, contour integration, theorems of Liouville, Jensen, Morera, Rouché, Hurwitz, meromorphic functions, Weierstrass products, Montel's theorem, Riemann zeta-function, Weierstrass P-function, Riemann mapping theorem, Hardy space.

Main Source
L.V. Ahlfors, Complex analysis. An introduction to the theory of analytic functions of one complex variable. Intl. Series in Pure and Applied Mathematics. McGraw-Hill Book Co., 3rd Ed., 1978.

Course Director
Peter Gibson, Ross S626

MATH 6340 3.0 W
Ordinary Differential Equations

This course will cover general properties of differential equations: existence, uniqueness and continuity theorems; linear systems and stability; Floquet theory; local theory of nonlinear systems; qualitative theory, Lyapunov stability, limit sets and attractors; linearization and invariant manifolds, Hartman-Grobman theorem; planar systems and Poincaré-Bendixon theory, phase plane analysis; periodic solutions and their stability, limit cycles and Poincaré map; normal form theory; bifurcation theory; nonlinear dynamics and applications in physics, finance and biology.

Main Source
Lawrence Perko, Differential Equations and Dynamical Systems, 3rd Edition, Springer
Lecture notes of selected topics will be provided

Course Director
Huaiping Zhu, Ross N618

MATH 6350 3.0 F
Partial Differential Equations

This is a first course in the modern theory of partial differential equations at the graduate level. We begin the course with Fourier analysis and tempered distributions on Euclidean spaces. Then we introduce the calculus of pseudo-differential operators in order to study the weak solutions of Poisson equations on Euclidean spaces driven by elliptic pseudo-differential operators. Sobolev spaces are constructed to measure the global regularity of weak solutions of partial differential equations governed by elliptic pseudo-differential operators on Euclidean spaces.

Main Source
M.W. Wong, An Introduction to Pseudo-Differential Operators, Third Edition, World Scientific, 2014.

Course Director
Man Wah Wong, Ross N626

MATH 6461 3.0 F
Functional Analysis I

Finally - linear algebra meets calculus, in infinite-dimensional space! Passing grade: 60/100 Topological vector spaces. Normed spaces. Banach spaces. Baire Category Theorem. Closed Graph Theorem. Open Graph Theorem. Classical Banach spaces $(C(X), c_0, \ell_p, \ell_\infty, \ell_p$ for $1 < p < \infty)$. Hilbert space. Local convexity. Hahn--Banach theorems. Weak topologies. Compactness. Dual spaces. The duals of $c_0, \ell_1, \ell_2, \ell_p$ for $1 < p < \infty$. Banach-Alaoglu theorem. Convexity. Krein-Milman theorem. Stone-Weierstrass theorem. Kakutani-Markov theorem. Bounded linear operators. Operators on Hilbert space. Spectral theorem for compact operators.

Main Source
J.B. Conway, A course in functional analysis
G.K. Pedersen, Analysis Now (Springer GTM, 118)
W. Rudin, Functional Analysis.

Course Director
Ilijas Farah, Ross N517

MATH 6462 3.0 W
Functional Analysis II

The course in focused on the theory of Schauder bases in Banach spaces and properties of ℓ_p and L_p spaces with regards to their subspaces, decompositions, and their local linear structure. These fundamental examples provide a starting point for understanding these notions in the context of general Banach spaces. If time permits it, subjects such as Tsirelson's Banach space, Krivine's Theorem, and Dvoretsky's Theorem will be covered as well. These topics explore to what extend canonical structure can expected to be found in an arbitrary Banach space. To follow this course, an understanding of Functional Analysis, Topology, and Measure Theory is necessary and some grasp of Probability Theory is useful.

Main Source
F. Albiac and N. Kalton, Topics in Banach space Theory, Springer 2006

Course Director
Pavlos Motakis, Ross S618

MATH 6540 3.0 F
General Topology I

Topological spaces, basis for topology, continuous functions (equivalent def's for metric) product topology (including infinite), metric spaces quotient spaces. complete metric spaces, Baire spaces connectedness, compactness, compactness in metric spaces and applications, generalizations of compactness: countable compactness, sequential compactness, local compactness etc…, countability axioms, separation axioms, normal spaces, Urysohn Lemma and Tietze Extension Theorem, Tychonoff Theorem, Urysohn Metrization and Nagata-Smirnov Metrization, compactifications including the one-point and Stone-Cech compactification, paracompactness, net convergence, filter convergence, ultrafilters, function spaces, Stone-Weierstrass Theorem

Main Source
Munkres, James R.; Topology, second edition. Prentice Hall (2000)
Willard, S.; General Topology, Dover.

Course Director
Paul Szeptycki, Ross N634

MATH 6620 3.0 F
Mathematical Statistics

The topics of the course include fundamentals of statistical inference such as exponential families of distributions, various methods of estimation with frequentists or Bayesian methods, the principles of hypothesis testing and confidence regions. The course begins with coverage of the required probability theory. Special topics will be touched upon if time permits.

Main Source
Shao J, Mathematical Statistics, Springer

Course Director
Hanna Jankowski, DB2038

MATH 6621 3.0 W
Advanced Mathematical Statistics

This course will cover a broad range of limit theorems useful in mathematical statistics, along with methods of proof and techniques of application. It will begin with a variety of tools and foundations basic to asymptotic theory in statistics. Then, the asymptotic properties of the following statistics are considered: (a) The usual statistics computed from a sample; (b) the statistics concocted as transformations of vectors of more basic statistics; (c) statistics arising in classical parametric inference and contingency table analysis; (d) U-statistics. As time and interest permit, further related topics may also be covered.

Main Source
Shao J, Mathematical Statistics, Springer 2nd edition 2003

Course Director
Yuehua Wu, DB2036

MATH 6622 3.0 W
Generalized Linear Models

Generalized Linear Models (GLMs) are an extension to linear models where the response variable is not continuous. These models are commonly used for analysis where the response variables are binary, categorical, proportions, or counts. GLMs play a crucial role in statistics and can be widely applied in industry, government, and banks as well as other areas. Tentative topics will include: review of linear models; formulation of GLMs; link functions; iterative least squares algorithms; deviance and asymptotic theory; model selection; residuals and quasi-likelihood; generalized linear mixed models.

Main Source
A.J. Dobson, A.G. Barnett, An Introduction to Generalized Linear Models, 3rd edition, Chapman and Hall/CRC Press 2008

Course Director
Wei Liu, Ross N601B

MATH 6627 3.0 W
Practicum in Statistical Consulting

The overall objectives of this course is to provide statistics students with practical consulting and communication skills, such as how to present results verbally and in a written report, and how to work cooperatively with other researchers. It provides training in statistical consulting. Applications of commonly encountered statistical methods are explored in the consulting environment.

Main Source
Lecture notes will be provided

Course Director
Xin Gao, Ross N623

MATH 6630 3.0 F
Applied Statistics I

This course aims at enhancing the computational ability of students in analyzing data through the use of numerical techniques and statistical software. The courses covers a variety of computational techniques including numerical optimization, EM algorithm for missing data, Delta method, Monte Carlo simulation, Markov chain Monte Carlo method, Bootstrap and permutation. The course requires students to solve practical problems via computer programming of R and provide formal presentations on their analysis.

Main Source
G.H. Givens, J.A. Hoeting, Computational Statistics, 2nd edition, Wiley 2012

Course Director
Xin Gao, Ross N623

MATH 6632 3.0 F
Multivariate Statistics

We will study methods of analysis for data which consist of observations on a number of variables. The primary aim will be interpretation of the data, starting with the multivariate normal distribution and proceeding to the standard multivariate inference theory. Sufficient theory will be developed to facilitate an understanding of the main ideas. This will necessitate a good background in matrix algebra, and some knowledge of vector spaces as well. Computers will be used extensively, and familiarity with elementary use of SAS will be assumed. Topics covered will include multivariate normal population, inference about means and linear models, principal component analysis, canonical correlation analysis, and some discussion of discriminant analysis, factor analysis and cluster analysis.

Main Source
Johnson RA, Wichern DW, Applied Multivariate Statistical Analysis, 6th edition Wiley 2008

Course Director
Augustine Wong, DB2041

MATH 6633 3.0 F
Time Series Analysis

In this course, we will study many statistical techniques for the analysis of time series data. The core topics include time dependence and randomness, trend, seasonality and error, stationary processes, ARMA and ARIMA processes, multivariate time series models and state-space models. We will use statistical software R for data analysis.

Main Source
Shumway RH, Stoffer DS, Time Series Analysis and Its Applications With R Examples, 4th edition, Springer

Course Director
Yuehua Wu, DB2036

MATH 6641 3.0 W
Survival Analysis

We will begin with the basics of survival analysis including censoring. Then we will proceed to nonparametric methods and discuss various non-parametric methods such as the Kaplan-Meier estimator. Next we will discuss semi-parametric models including proportional hazards models as well as time dependent covariates. R will be used extensively in this course. We will go into both the theoretical and practical aspects of survival analysis.

Main Source
E. Lee, J. Wang, Statistical Methods for Survival Data Analysis

Course Director
Kevin McGregor, Ross N636

MATH 6643 3.0 S
Applications of Mixed Models

Mixed models are widely applied to analyze longitudinal data, in which outcomes are repeated measurements over time on the same subjects. This course provides a detailed overview of mixed models for the analysis of longitudinal data. The main topics include exploring longitudinal data, marginal models, linear/nonlinear mixed effects models, and generalized linear mixed models. If time permits, missing problems in longitudinal data will be discussed as well.

Main Source
P. Diggle, P. Heagerty, K. Liang, S.Zeger (2002). Analysis of Longitudinal Data (second edition). Oxford nd University Press.
L. Fahrmeir, G. Tutz, (2000). Multivariate Statistical Modeling Based on Generalized Linear Models. Springer-Verlag, New York.

Course Director
Wei Liu, Ross N601B

MATH 6650 3.0 F
Data Science

This course gives a general introduction to Data Science. It gives an answer to "What is Data Science" and "What is/isn't a Data Science project". It goes through the main steps of a Data Science project explaining the theoretical and/or practical aspects, and using different Statistical and technological tools. It gives a general idea of data exploration, statistical analysis, machine learning, data visualization, among other steps present in the Data Science cycle. The main part of the course is in Python. Each student (in groups) will deliver a data science project as a result of their learning.

Main Source
Lecture notes will be provided

Course Director
Jairo Diaz-Rodriguez, Ross N637

MATH 6651 3.0 F
Advanced Numerical Methods

Topics in this course include: Numerical methods for solving ordinary differential equations including initial-value problems and boundary-value problems; Optimization problems: golden method, simplex method, steepest descents, conjugate gradient methods including nonlinear conjugate gradient methods; Approximation theory: least squares, orthogonal polynomials, Chebyshev approximation, Fourier approximation and Fast Fourier Transforms, and Pade approximation.

Main Source
Lecture notes will be provided

Course Director
Dong Liang, Petrie 225

MATH 6652 3.0 W
Numerical Solutions to Differential Equations

Introduction to the Matlab computing language with application to numerical integration and linear algebra. Overview of numerical methods for ordinary differential equations including Runge-Kutta methods and application to dynamical systems. Review of partial differential equations; well-posed boundary-value problems; finite difference approximations of derivatives. Parabolic equations: reduction to dimensionless form; solution by explicit and implicit methods, including the Crank-Nicholson method. Elliptic equations: review of Jacobi and Gauss-Seidel method; successive over-relaxation method, Alternating Direction Implicit Method. Hyperbolic equations: linear and nonlinear wave equations; explicit, implicit and multistep methods. Convergence and stability of solution methods.

Main Source
Lecture notes will be provided

Course Director
Michael Haslam, Ross S620

MATH 6902 3.0 F
Stochastic Programming

The course will teach stochastic programming models for making scientific decisions under uncertainty. Important industrial application cases from banking, insurance, investment, public health, etc., will be introduced as well. Efficient numerical algorithms, such as the two and multi stage L-shaped method, progressive hedging, etc., will be studied in detail as well.

Main Source
J. Birge, F. Louveaux, Introduction to stochastic programming,, Springer.

Course Director
Michael Chen, BD2034

MATH 6910 3.0 F
Stochastic Calculus in Finance

This course will introduce the basic ideas and methods of stochastic calculus and apply these methods to financial models, particularly the pricing and hedging of derivative securities. We start by introducing the concepts of arbitrage and risk-neutral pricing in a discrete-time setting, then move to more sophisticated continuous-time models. Along the way we cover the following mathematical topics: Brownian motion, Stochastic integrals, Ito's formula, Martingales and Girsanov transformations. We will also cover interest-rate models and more advanced topics, if time permits.

Main Source
S. Shreve, Stochastic Calculus for Finance II: Continuous Time Models, Springer 2010

Course Director
Tom Salisbury, Ross N621A

MATH 6910 3.0 W
Stochastic Calculus in Finance (Schulich)

The objective of this course is to provide the students with knowledge of the stochastic calculus that underlies the pricing and hedging of derivative instruments, including stochastic integrals and stochastic differential equations. We will introduce martingales, Brownian motion, Itô's integrals and Itô's formula, in the context of the Black-Scholes option pricing model. Then we will study exponential martingales and the Girsanov theorem in the context of risk neutral measures. Topics include: (i) General probability theory; (ii) Information and conditioning; (iii) Brownian motion; (iv) Stochastic calculus; (iv) Risk-neutral pricing.

Main Source
Shreve S, Stochastic Calculus for Finance II: Continuous Time Models, Springer 2010

Course Director
Jingyi Cao, DB2031

MATH 6911 3.0 W
Numerical Methods in Finance

Black-Scholes model, Black-Scholes partial differential equation (PDE). Finite difference schemes for solving heat equation: explicit, implicit and Crank-Nicolson schemes, their stability and convergence. Solving PDEs in local volatility model and pricing Asian options in Black-Scholes model using finite-difference schemes. Discrete time delta-hedging in Black-Scholes model. Monte Carlo techniques, variance reduction: conditional Monte Carlo, importance sampling, control variate method. Examples: Asian options and barrier options in Black-Scholes model. Computing Greeks using Monte Carlo techniques. Pricing and hedging American options in binomial and Black-Scholes models.

Main Source
P. Brandimarte, Numerical Methods in Finance and Economics: A MATLAB-Based Introduction, Wiley-Interscience; 2nd edition (2006)

Course Director
Alexey Kuznetsov, Ross N628

MATH 6931 3.0 F
Mathematical Modelling

This course will explore the principles of mathematical modelling and develop models motivated by various case studies in natural sciences and other fields. We will review the philosophy and methodology of modelling; then look at deterministic models using ordinary and partial differential equations followed by stochastic models; explore analytic and computational techniques for solving and analysing models to address case studies from which they arise.

Main Source
Lecture notes will be provided.
S.M. Moghadas, M. Jaberi-Douraki, (2018). Mathematical Modelling: A Graduate Textbook. John Wiley & Sons.
C. Eck, et al., (2017). Mathematical modeling. Springer.
A.C. Fowler, (1997). Mathematical models in the applied sciences. Cambridge University Press.
S. Howison, (2005). Practical applied mathematics: modelling, analysis, approximation. Cambridge university press.
R.A. Illner, et al., (2005). Mathematical modelling: a case studies approach (Vol. 27). American Mathematical Soc.

Course Director
Iain Moyles, Ross S519

MATH 6937 3.0 W
Practicum in Industrial and Applied Mathematics

This practicum course will be based on interdisciplinary and real-life application problems. Each time, a problem will be presented to students in class. The students are required to use the methods they have been learning from Math 6931 (Mathematical Modeling) to derive a reasonable mathematical model, to analyze and solve the model both analytically and numerically. Students will be encouraged to work in groups. Evaluation will be based on individual reports and group presentations.

Main Source
Lecture notes will be provided, consisting of selected book chapters, published papers, and online information relevant to the interdisciplinary and real-life application problems.

Course Director
Jianhong Wu, Ross N614

MATH 6936 3.0 W
Mathematical Epidemiology

The mathematical modeling of infectious diseases is studied on two different scales: between individuals in a population (epidemiology) and within an infected individual (immunology). The objective of this course is to present a detailed introduction to the mathematical modeling of the infectious disease in both epidemiological and immunological contexts. Topics include: immune system components (i.e. T-cell activation, clearance of infection, etc), pathogen characteristics (i.e. HIV, influenza, etc), intervention strategies (i.e. drug therapy and vaccination) and model development (i.e. continuous and discrete time models, computer simulations, stochastic and deterministic model, etc). The fundamental predictors of infection, the basic reproductive ratio and initial growth rate will be introduced. Relationships between immunological characteristics and epidemiological effects, such as disease transmission and acquirement of immunity, are also discussed.

Main Source
Lecture notes will be provided based on a number of resources:
Anderson RM, May RM, Infectious diseases of humans, Oxford University Press 1991
Diekmann O, Heesterbeek JAP, Mathematical Epidemiology of Infectious Diseases: model building, analysis and interpretation. Wiley series in mathematical and computational biology 2000
Nowak MA, May RM, Viral Dynamics: Mathematical principles of immunology and virology, Oxford University Press 2000
Wodarz D, Killer Cell Dynamics: mathematical and computational approaches to immunology, Springer 2007
Brauer F, van den Driessche P., Wu J, Mathematical Epidemiology, Springer 2008.
Keeling MJ, Rohani P, Modelling Infectious Diseases in Human and Animals. Princeton University Press, 2007.

Course Director
Jane Heffernan, Ross N615

Graduate Courses S/F 2022, W 2023

Summer 2022			
Course #	**Course Title**	**Day and time**	**Instructor**
MATH 6643	Applications of Mixed Models	Tue-Thu, 10:00-13:00	Wei Liu

Fall 2022			
Course #	**Course Title**	**Day and time**	**Instructor**
MATH 6121	Applied Algebra	Tue-Thu, 10:00-11:30	Nantel Burgeron
MATH 6300	Complex Analysis	Mon-Wed, 10:00-11:30	Peter Gibson
MATH 6350	Partial Differential Equations	Tue-Thu, 13:00-14:30	Man Wah Wong
MATH 6461	Functional Analysis I	Mon-Wed, 11:30-13:00	Ilijas Farah
MATH 6540	Topology I	Mon-Wed, 13:00-14:30	Paul Szeptycki
MATH 6602	Stochastic Processes	Wed-Fri, 11:30-13:00	Jorg Grigull
MATH 6620	Mathematical Statistics	Mon-Wed, 10:00-11:30	Hannah Jankowski
MATH 6630	Applied Statistics I	Tue-Thu, 10:00-11:30	Xin Gao
MATH 6632/4630	Multivariate Statistics	Tue-Thu, 16:00-17:30	Augustine Wong
MATH 6633/4130B	Time Series Analysis	Tue-Thu, 13:00-14:30	Yuehua Wu
MATH 6650	Data Science	Mon-Wed, 16:00-17:30	Jairo Diaz-Rodriguez
MATH 6651/4141	Advanced Numerical Methods	Tue-Thu, 14:30-16:00	Dong Liang
MATH 6902	Stochastic Programmimg	Tue-Thu, 11:30-13:00	Michael Chen
MATH 6910	Stochastic Calculus in Finance	Fri, 14:30-17:30	Tom Salisbury
MATH 6931	Mathematical Modeling	Mon-Wed, 13:00-14:30	Iain Moyles

Winter 2023			
Course #	**Course Title**	**Day and time**	**Instructor**
MATH 6110	Analytic Number Theory	Mon-Wed, 16:00-17:30	Patrick Ingram
MATH 6122	Algebra II	Tue-Thu, 14:30-16:00	Yun Gao
MATH 6280	Measure Theory	Tue-Thu, 10:00-11:30	Neal Madras
MATH 6340	Ordinary Differential Equations	Wed, 14:30-17:30	Huaiping Zhu
MATH 6462	Functional Analysis II	Mon-Wed, 11:30-13:00	Pavlos Motakis
MATH 6621	Advanced Mathematical Statistics	Tue-Thu, 14:30-16:00	Yuehua Wu
MATH 6622	Generalized Linear Models	Tue-Thu, 11:30-13:00	Wei Liu
MATH 6627	Practicum in Statistical Consulting	Mon-Wed, 10:00-11:30	Xin Gao
MATH 6641/4130K	Survival Analysis	Mon-Wed, 16:00-17:30	Kevin McGregor
MATH 6644	Statistical Learning	Mon-Wed, 13:00-14:30	Steven Wang
MATH 6652	Numerical Solutions to Differential Equations	Mon-Wed, 13:00-14:30	Michael Haslam
MATH 6655	Feedback Control Systems	Tue-Thu, 16:00-17:30	Ryan Orszulik
MATH 6671	Computational Methods in Mathematical Biology	Mon-Wed, 13:00-14:30	Seyed Moghadas
MATH 6910	Stochastic Calculus in Finance (Schulich)	Mon, 19:00-22:00	Jingyi Cao
MATH 6911	Numerical Methods in Finance	Tue, 19:00-22:00	Alexey Kuznetsov
MATH 6936	Mathematical Epidemiology	Mon-Wed, 10:00-11:30	Jane Heffernan
MATH 6937	Practicum in Industrial and Applied Mathematics	Tue, 14:30-17:30	Jianhong Wu