Graduate Program in

Mathematics & Statistics

2020-2021

IMPORTANT DATES FOR 2020-2021

COMMENCEMENT OF CLASSES:

September 9, 2020 Fall Term and Fall/Winter Term classes start

Each half course (3.0) should have at least 36 hours of classes and each full course (6.0) should have at least 72 hours of classes.

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

INCOMPLETES: **A grade of 'I' must be removed within two months of the reporting date for a half-course or within four months of the reporting date for a full-course. Extension of this time is possible only upon successful petition to the Faculty of Graduate Studies Petitions Committee. If the grade of 'I' is not removed by the end of the specified period, it will become a grade of 'F'.**

ORIENTATION FOR GRADUATE STUDENTS: September 2020 (TBD)

Faculty of Graduate Studies - (regulations/important dates & deadlines): http://gradstudies.yorku.ca

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 Regular M.A. Program with specialization in applied mathematics, pure mathematics, theoretical statistics, applied statistics or probability.
2. The M.Sc. Program in Applied & Industrial Mathematics.
3. The Doctoral Program.

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

This calendar describes these Programs, giving entrance and degree requirements for each. It also describes the research interests of the faculty members associated with the Graduate Program in Mathematics and Statistics, provides information about financial support available to graduate students and gives a description of the courses to be offered in the Fall/Winter 2018-2019.

If you have further questions about the Graduate Program in Mathematics and Statistics, please direct them to: Graduate Program in Mathematics and Statistics, N520B Ross, York University, 4700 Keele Street, Toronto, Ontario, Canada, M3J 1P3, telephone (416) 736-5250 ext. 33974.

The Faculty of Graduate Studies webpage: http://gradstudies.yorku.ca/

SUMMARY OF GRADUATE PROGRAMS

The Regular M.A. 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 such areas as algebra, analysis, topology, differential equations, numerical methods, foundations of mathematics, probability, operations research, mathematical and applied statistics are offered regularly.

The Program provides solid preparation for admission to a Ph.D. 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 M.Sc. Program in Applied & Industrial Mathematics

The M.Sc. 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 Dong Liang (dliang@yorku.ca).

The Graduate Diploma in Financial Engineering

The Financial Engineering Diploma 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 Honmei Zhu (hmzhu@mathstat.yorku.ca).

Graduate Diploma in Mathematics Education

The Graduate Diploma in Mathematics Education focuses on mathematics education as an area of study grounded in critical examination of teaching practice, learning theories, and curriculum, and supported by analyses of socio-cultural, equity, and gender issues in the teaching and learning of mathematics. It is designed to provide opportunities for graduate level study of theories and research in Mathematics Education, as well as enriched mathematical experiences and reflection on the practice of mathematics, to practising teachers and administrators and to people in the community whose work involves developing mathematical literacies.

The Graduate Diploma in Mathematics Education is jointly offered by the Graduate Program in Education and the Graduate Program in Mathematics and Statistics. The diploma will provide a recommended pathway towards future Ph.D. studies in Mathematics Education. For more information, contact Mike Zabrocki (zabrocki@mathstat.yorku.ca).

The Ph.D. Program

Students in the Ph.D. 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 appears below.

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

FACULTY MEMBERS BY FIELD OF INTEREST

ALGEBRA

R.G. Burns, Ph.D. (A.N.U.). Combinatorial group theory, general group theory.
Y. Gao, Ph.D. (Saskatchewan). Infinite dimensional Lie algebras, representation theory, vertex operators, homology of algebras, Lie algebras associated with the other nonassociative structures, mathematical physics.
P. Ingram, Ph.D. (U.B.C.). Number theory, diophantine geometry, dynamical systems.
A. Nenashev, Ph.D. (Steklov Mathematical Institute). Algebraic K-theory, cohomology theories for algebraic varieties, in particular Witt theory for schemes and algebraic cobordism.

See also S.D. Promislow (under Analysis); J. Steprans and W. Tholen (under Foundations); and N. Bergeron, A. Chan, and M. Zabrocki (under Discrete Mathematics).

ANALYSIS

P.C. Gibson, Ph.D. (Calgary). Applied harmonic analysis (time-frequency analysis and applications to seismic imaging, PDE and signal processing), inverse problems (matrix analysis, orthogonal polynomials, discrete geometry and applications to oscillating systems).
S.D. Promislow, Ph.D. (U.B.C.) F.S.A. Functional analysis, group theory, actuarial mathematics.
M. Roy, Ph.D. (Goettingen). Ergodic theory, dynamical systems, fractal geometry.
P. Skoufranis, Ph.D. (UCLA). Operator theory, C*-algebras, free probability.
M.W. Wong, Ph.D. (Toronto). Functional analysis, pseudo-differential operators, partial differential equations.
J. Wu, Ph.D. (Hunan). Functional differential equations, nonlinear functional analysis, dynamical systems, mathematical biology and neural networks.

See also H. Huang and HP. Zhu (under Applied Mathematics); and I. Farah (under Foundations).

GEOMETRY

A. Ivic Weiss, Ph.D. (Toronto). Discrete and combinatorial geometry, regular polytopes.
W.J. Whiteley, Ph.D. (M.I.T.). Discrete geometry and its applications, rigidity (static and kinematic) of frameworks, multivariate splines, polyhedral combinatorics, matroid theory, logic and invariant theory, geometric reasoning.

See also N. Bergeron (under Discrete Mathematics).

ALGEBRAIC AND DIFFERENTIAL TOPOLOGY

S.O. Kochman, Ph.D. (Chicago). Homology operations, cobordism theories, computer assisted computation of stable stems.

FOUNDATIONS

I. Farah, Ph.D. (Toronto). Set theory, combinatorics, applications to analysis.
J. Steprans, Ph.D. (Toronto). Set theory, infinitary combinatorics, forcing, applications to algebra.
P. Szeptycki, Ph.D. (Toronto). Set-theoretic topology, applications of set-theoretic methods to general topology.
W. Tholen, Ph.D. (Münster). Category theory and its applications to algebra, topology and theoretical computer science.

S. Watson, Ph.D. (Toronto). Set-theoretic topology, general topology, set-theoretic combinatorics, counterexamples.

DISCRETE MATHEMATICS

N. Bergeron, Ph.D. (California at San Diego). Algebraic combinatorics.
A. Chan, Ph.D. (Waterloo). Algebraic combinatorics.
M. Zabrocki, Ph.D. (California at San Diego). Algebraic combinatorics.

See also A. Ivic Weiss and W. Whiteley (under Geometry).

PROBABILITY AND STOCHASTIC PROCESSES

M. Chen, Ph.D. (Northwestern). Stochastic Programming, Robust Optimization, Large Scale Optimization, Network Optimization, Interior Point Method, Quadrature, Industrial Applications of Operations Research.
E. Furman, Ph.D. (Haifa). Distribution theory, dependencies, multivariate analysis, actuarial and economic pricing, financial risk measurement.
H. Ku, Ph.D. (Seoul). Mathematical finance and applied probability: pricing and hedging derivative securities, measures of risk, and risk management.
A. Kuznetsov, Ph.D. (Toronto). Stochastic processes, mathematical finance, special functions, numerical analysis.
N. Madras, Ph.D. (Cornell). Random walks, mathematical models in physics and biology, combinatorics, Monte Carlo methods.
T.S. Salisbury, Ph.D. (U.B.C.). Brownian motion, Markov processes.

See also H. Jankowski (under Statistics).

STATISTICS

Y. Fu, Ph.D. (Waterloo). Mixture models, asymptotics, biostatistics, statistical genetics and empirical likelihood.
X. Gao, Ph.D. (Ottawa). Biostatistics, nonparametrics, large sample theory, statistical computing, statistical methods for genetic analysis, including genetic linkage mapping, QTL analysis, micro array data analysis, etc.
H. Jankowski, Ph.D. (Toronto). Nonparametric methods, empirical processes, stochastic processes, interacting particle systems.
W. Liu, Ph.D. (UBC). Missing data, measurement errors, longitudinal data, mixed-effects models, and biostatistics.
H. Massam, Ph.D. (McGill). Differential techniques in inference, optimization in statistics.
G. Monette, Ph.D. (Toronto). Statistical inference, interactive statistical graphics.
S.X. Wang, Ph.D. (UBC). Likelihood methods and statistical data mining.
A.C.M. Wong, Ph.D. (Toronto). Statistical inference.
Y. Wu, Ph.D. (Pittsburgh). Multivariate analysis, robust statistics, statistical signal processing.

See also E. Furman and S. Guiasu (under Probability and Stochastic Processes).

APPLIED MATHEMATICS

J. Grigull, Ph.D. (Göttingen). Computational biology, gene expression studies, bioinformatics, exploratory and predictive statistical tools and probabilistic models.
J, Heffernan, Ph.D. (UWO). Mathematical immunology, mathematical epidemiology, monte carlo simulations, differential equations, HIV, Influenza, Measles, STIs.
M. Haslam, Ph.D. (UWO). Computational electromagnetism, rough surface scattering, numerical analysis, scientific computing.
H. Huang, Ph.D. (UBC). Scientific computing, numerical analysis, computational fluid dynamics, mathematical modeling, industrial mathematics.
D. Liang, Ph.D. (Shandong). Numerical analysis of partial differential equations, numerical simulations, scientific computing, computational fluid dynamics.
K.R. Maltman, Ph.D. (Toronto). Theoretical physics.
S. Moghadas, Ph.D. (Sharif UT). Infectious Disease Modelling, Pathogen-Host Dynamics, Computational Biology, Epidemiology and Public Health, Ecological

Interactions, Normal Forms and Index Theories, Non-Standard Methods, Convergence Properties, Stability and Bifurcation Analysis, Asymptotic Behaviour.

E.J.J. van Rensburg, Ph.D. (Cambridge). Mathematical modelling in physics and biology.

Z. Yang, Ph.D. (Toronto). Efficiency evaluation: evaluating the value of IT investments and its impact on the social and economical environment, software project evaluation, business failure prediction, data mining.

Hongmei Zhu, Ph.D. (Waterloo). Digital signal and image processing, biomedical and financial applications, time-frequency/scale analysis, microlocal analysis, numerical computations, differential equations.

Huaiping Zhu, Ph.D. (Montreal). Differential equations, dynamical systems and Hilbert's 16th problem, mathematical modelling and analysis in biology and epidemiology.

See also M. Chen, E. Furman and N. Madras (under Probability and Stochastic Processes), W. Whiteley (under Geometry), and J. Wu (under Analysis).

I. Moyles, Ph.D. (UBC). Mathematics Applications Consortium for Science and Industry.

J. D. Kong, Ph.D. (U of A). Mathematical Biology, Infectious Disease Modelling, Impact of Environmental Stressors and Harvesting on Species Distribution and Abundance Modelling, Stoichiometry-based Ecological Interactions Modelling, Risk Assessment of Oil Sands Pollution, Data Science, Differential Equations, Dynamical Systems.

HISTORY OF MATHEMATICS AND MATHEMATICS EDUCATION

I. Kleiner, Ph.D. (McGill). Nineteenth and early twentieth century mathematics, relations between the history and the pedagogy/teaching of mathematics.

See also P.C. Gibson, (under Analysis), S. Kochman, (under Algebraic and Differential Topology), T. MacHenry (Adelphi University), Number Theory and Combinatorics, W. J. Whiteley, (under Geometry)

Contact information for faculty members is available at:
http://mathstats.info.yorku.ca/people/faculty/

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 Regular M.A. Program

(i) Admission Requirements

See the section on General Admission Requirements. Most successful applicants have a standing of B+ or higher, a fact which reflects the number of good applicants to the Program. In addition to having sufficiently high standing, students are expected to have completed certain core courses in mathematics or statistics as undergraduates.

(ii) 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.

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).

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

(a) 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).

(b) 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 Modeling (Math 6931 3.0), Mathematical Epidemiology (Math 6936 3.0).

(c) 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).

(d) 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).

(e) 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).

f) 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 work Requirement

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 (50 minute presentation and ½ 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 (a), (b), (c), (d), (e) and nine credits of additional course work for option (f).

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 M.A. 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, Animals and Biohazardous 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 doing 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:

http://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 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. All members of the supervisory committee must be present at both talks.

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

Seminar Requirement

In addition to the above, students who choose option (a), (b), (c), (d) or (f) as their core course requirement must fulfill the seminar requirement (Math 6004 0.0). Students who choose option (e) 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.** Attendance sheets are available in N520B Ross (Graduate Program Office).

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

M.Sc. 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 M.Sc. degree in Applied and 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 Modeling (Math 6931 3.0), Practicum in Industrial and Applied Mathematics (Math 6937 3.0), another three 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 **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/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:
http://gradstudies.yorku.ca/current-students/thesis-dissertation/forms/

The Guidelines for the Preparation and Examination of Thesis and Dissertation are available at:
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Graduate students doing 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:
http://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 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. 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 the student and supervisor 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 Masters 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.

Graduate Diploma in Financial Engineering (Type 2 - Concurrent)

(i) Admission Requirements

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

Applicants may indicate their interest in pursuing the Graduate Diploma in Financial Engineering at the same time they apply to the regular master's or doctoral program in Mathematics & Statistics, or they may submit a separate application for the diploma during the first term in which they are registered in the regular 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 masters 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 1: 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 2: 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 by Survey Paper (Math 6001) program 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 fulfillment 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 & 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, Mathematics 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.** Attendance sheets are available in N520B Ross.

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.

The Doctoral Program

(i) Admissions Requirements

See the section on General Admission Requirements. To be considered for admission as a Ph.D. student, students must have completed an acceptable Master's degree or must have completed one year of comparable work, with a B+ average (high second class) or better. The admission process is very selective and not all students meeting this requirement will be admitted.

Applicants should obtain at least three letters of recommendation by academics who know them well. Applications are considered by the Ph.D. Program 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 Ph.D. program must submit an on-line application and supporting documentation.

(ii) Degree Requirements

Five major components make up the degree requirements for the Ph.D. in Mathematics and Statistics. These are 1) coursework 2) comprehensive

exams 3) dissertation subject oral 4) dissertation proposal 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 checklist for completion.

Projected Timeline/Checklist for Completion

Progress requirements	Completed by				
Advising appointment	Annual				
Progress report	Annual				
Comprehensive exams	End of 3rd term				
Supervisor confirmed	End of 5th term				
Course requirements	End of 6th term				
Supervisory committee approved	End of 6th term				
Dissertation subject oral	End of 6th term				
Statistics practicum/ comprehensive exam	(Statistics stream only) End of 6th term				
Dissertation proposal	No less than 6 months before oral examination				
Dissertation colloquium	Normally 12th term				
Oral examination	Normally 12th term				

The details of these requirements are listed below.

Course Requirement and Comprehensive Examinations

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, at the discretion of the graduate program director, the Ph.D. committee and the supervisor.

Course credits: A student will not receive credit for more than two half integrated courses to satisfy the course and specialization requirements towards the Ph.D. 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 Examinations

Students will declare a specialization in pure mathematics or 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 Modeling (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 Ph.D. 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 Ph.D. Committee for evaluation.

Current Masters students who plan to apply for admission to the Ph.D. Program may also wish to take some of the comprehensive exams. These grades (PASS or FAIL) will be counted if the students are admitted to the Ph.D. 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 will occur within the second year of study. 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.
The student is responsible for ensuring that the proposal and TD1 form reaches the Dean of Graduate Studies by the above timeline.

York University is committed to the highest standards of integrity in research. All projects involving the use of Human Subjects, Animals and Biohazardous 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 doing Dissertations, 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:
http://gradstudies.yorku.ca/current-students/thesis-dissertation/research-ethics/

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

Guidelines for the Preparation and Examination of Dissertations are available at:
http://gradstudies.yorku.ca

Dissertation Evaluation

1. *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.

2. *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: (http://gradstudies.yorku.ca/current-students/thesis-dissertation/oral-examination/) 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.

(iii) Progress Report

All students enrolled in a Ph.D. 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.

(iv) Deadlines for Meeting Requirements

Students are expected to finish the comprehensive exam requirement in the first year of their Ph.D.

studies. The Dissertation Subject Oral should be taken within the second year of study. 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.

(v) 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 Ph.D. Program 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 Ph.D. Program 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 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 student and supervisor to ensure that all degree requirements are met.

ACCEPTABLE GRADES FOR GRADUATE STUDENTS

Faculty of Graduate Studies regulations regarding acceptable grades:
http://www.gradstudies.yorku.ca

REGISTRATION AND BALANCE OF DEGREE FEES

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

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

After 3 terms of full-time study, the status of an M.A. student will be part-time.

Full-time M.Sc. students must register and pay fees for a minimum of six terms.

After 6 terms of full-time study, the status of an M.Sc. student will be part-time.

Part-time M.A. students must register and pay fees for a minimum of six terms. Part-time M.Sc. 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 six terms.

Part-time Doctoral students must register and pay fees for a minimum of twelve terms.

Students who successfully complete a Masters or Ph.D. 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 Director for more than four weeks of any term in which they are registered.

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

http://gradstudies.yorku.ca

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 M.A. students who are offered financial support will receive this support in year one of full-time studies. Full-time M.Sc. students who are offered financial support will receive this support in year one and year two of full-time studies. Full-time Ph.D. 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 encouraged to apply for external scholarships. These include NSERC scholarships and OGS scholarships. The latter are open to visa students.

York 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 either the Master's or Doctoral level 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.

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
1. 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.
2. 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.
3. 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.

4. Where the major substance or data of a coauthored 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.

5. Anyone otherwise entitled to be acknowledged as a coauthor 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.

6. 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.

7. Supplying minor editorial work for a student's dissertation, thesis, or research paper is not, in itself, sufficient to warrant co-authorship.

8. 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.

9. 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

10. 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.

11. 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.

12. 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.

13. 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.

14. 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.

15. 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 16 through 19 below must be observed.

16. 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.

17. All individual agreements must explicitly state that they are subject to applicable Collective Agreements and all University regulations in force at the time.

18. 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.

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

COURSE OUTLINES - FALL/WINTER

2020-2021

Math 6004 0.0 MATHEMATICS 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.

Math 6040 3.0W SET THEORY

Introduction to axiomatic and combinatorial set theory with a focus on applications: Axioms of Zermelo Fraenkel Set Theory, cardinality, ordinal and cardinal numbers, transfinite induction and recursion, special sets of reals, topics in combinatorial set theory including Ramsey Theory, trees, Martin's Axiom and other topics.

Textbook: Ken Kunen, *Set Theory*, College Publications.

Course Director: P. Szeptycki, N522 Ross
(416) 736-5250

Math 6121 3.0F APPLIED ALGEBRA

Group theory and representation theory: Jordan-Holder Theorem, Sylow's Theorem, Representation of finite groups and characters;
Preliminary notions in ring theory: Euclidian domain, principal ideal domain and polynomial rings;
Grobner bases with an emphasis on algorithmic aspects and computational geometry: solving polynomial system of equations, application to robotics and computational geometry;
Modules over PID (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;

Prerequisite: equivalent of undergraduate second year Linear Algebra and some knowledge of basic concepts in algebra (group, ring), or permission of the instructor.

Course Director: N. Bergeron, Victor Phillip
Dahdaleh Building, 2029
(416) 736-2100, ext. 33968

Math 6122 3.0W ALGEBRA II

Introduction to category theory: categories, functors, basic constructions and some simple results. Many motivating examples should be presented; further 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.

Course Director: Y. Gao, S624 Ross
(416) 736-2100, ext. 33952

Math 6280 3.0F MEASURE THEORY

A measure on a collection of subsets of a set is a function with certain desirable properties that describes the size of each element of the collection. Given a measure it is possible to define an integral of specific functions against the measure thereby generalizing the Riemann integral. Both measures and this integration theory are essential concepts in probability theory and analysis.

In this course, we will begin defining the notion of a measure and developing methods for constructing measures. Subsequently, we will study specific functions known as measurable functions and prove results such as Lusin's Theorem and Egoroff's Theorem. Measurable functions will permit an integration theory and the study of many additional topics, such as Fatou's Lemma, the Dominated Convergence Theorem, Fubini's Theorem, Hahn and Jordan decompositions,the Radon-NikodymTheorem, the Lebesgue Density Theorem, and Lp-spaces. This course is one of the options for a comprehensive exam in the pure mathematics stream.

Prerequisites: Basic knowledge from real analysis along with knowledge of metrics and norms is recommended.

Optional Text: *Real Analysis*, Royden and Fitzpatrick, 4th edition, Pearson 2010.

Course Director. Madras, S616 Ross
(416) 736-2100, ext. 33971

Math 6340 3.0W ORDINARY DIFFERENTIAL EQUATIONS

This is an advanced introduction to a number of topics in ordinary differential equations. The topics will be chosen from the following: existence and uniqueness theorems, qualitative theory, stability theory, bifurcation theory and dynamical systems, boundary value problems, asymptotic methods. The lectures will survey the above topics and students will be expected to make an in-depth study of some of them by doing assignments and projects.

Students should have a thorough knowledge of undergraduate analysis and linear algebra to the level of MATH 2220 and MATH 3210. It would be desirable that they have taken an advanced undergraduate course in differential equations. Some exposure to real analysis, complex analysis and topology would be desirable also.

Text: Lawrence Perko, *Differential Equations and Dynamical Systems*, Springer-Verlag, 2007, or later edition.

References:
- V. I. Arnold, *Ordinary Differential Equations*, Springer-Verlag, 1992.
- F. Brauer and J.A. Nohel, *The Qualitative Theory of Ordinary Differential Equations*, Dover.
- E. A. Coddington and N. Levinson, *Theory of*
- *Ordinary Differential Equations*, Krieger, 1984.
- J. K. Hale, *Ordinary Differential Equations*, Krieger, Malabar, Florida, 1980.
- J. K. Hale and H. Kocak, *Dynamics and Bifurcations*, Springer 1991.
- J. Guckenheimer and P. Holmes, *Nonlinear Oscillations, Dynamical Systems, and Bifurcations of Vector Fields* (Applied Mathematical Sciences Vol. 42), Springer-Verlag, New York, 1986.
- M. W. Hirsch, S. Smale, and R. Devaney, *Differential Equations, Dynamical Systems, and an Introduction to Chaos*, 2nd Edition.
- D. W. Jordan & P. Smith, *Nonlinear ordinary differential equations*, Oxford University Press 1977.
- James Liu, *A First Course in the Qualitative Theory of Differential Equations*, Prentice Hall, 2003.

Course Director: HP. Zhu , N618 Ross
(416) 736-2100, ext. 66095

Math 6350 3.0F PARTIAL DIFFERENTIAL EQUATIONS

A survey of techniques and results for a selection of partial differential equations arising in mathematical physics. The emphasis will be on first and second order equations, and will include both classical and more modern results. In addition to the Laplace, heat and wave operators, the course will address the requisite theory of distributions, Fourier analysis and Sobolev spaces. Time permitting, selected topics such as scattering theory or nonlinear equations may be also be covered.
Course Director: P. Gibson, S626 Ross
(416) 736-2100, ext. 33930

Math 6461 3.0W FUNCTIONAL ANALYSIS I

Functional analysis is the study of infinite-dimensional topological vector spaces over the real and complex fields and continuous linear operators between such spaces, combining the methods of linear algebra, analysis, measure theory, and topology.

The following topics will be covered:
Topological vector spaces; Normed spaces; Banach spaces; Baire Category Theorem; Closed Graph Theorem; Open Graph Theorem; Classical Banach spaces ($C(X)$, c_0, ℓ_p, ℓ_∞, $L_p(X,\mu)$, $L_\infty(X,\mu)$); Hilbert space. Local convexity; Hahn--Banach extension and separation theorems; Weak topologies; Compactness; Dual spaces; Riesz representation theorems; Krein-Milman theorem; Stone-Weierstrass theorem; Bounded linear operators; Operators on a Hilbert space; Spectral theorem for compact operators.

We will not be following any particular text. There is a large number of excellent texts in functional analysis. Here is a partial list.
- W. Rudin, *Functional Analysis*.

- G.K. Pedersen, *Analysis Now.*
- R.J. Zimmer, *Essential results of functional analysis*.
- J.B. Conway, *A course in functional analysis*.
- C.D. Aliprantis, K. Border, *Infinite Dimensional Analysis: A Hitchhiker's Guide* (a comprehensive text, but don't feel intimidated).
- B. Simon, *Convexity: An analytic approach* (as you can guess by the title, not exactly what we are doing but this text is an excellent supplement).

Course Director: I. Farah, N533 Ross
(416) 736-2100 ext. 66093

Math 6540 3.0 W GENERAL TOPOLOGY I

A topological space is a set together with a collection of subsets which describe which points in the space are close together. Given a topological space, one can generalize the notion of continuous function as seen in previous analysis courses and thereby develop a richer function theory. From graph theory to functional analysis, topological methods illuminate a number of diverse areas of modern mathematics.

In this course, we will cover the most fundamental topics in general topology, such as compactness, connectedness, separation axioms, compactifications, Baire Category Theorem, Stone-Weierstrass Theorem, Tietze Extension Theorem, Tychonoff Theorem, nets and filters, and metrization theorems. This course is one of the options for a comprehensive exam in the pure mathematics stream.

Prerequisites: Basic knowledge from real analysis along with some knowledge of metrics and norms is recommended.

Optional Texts: Theodore W. Gamelin and Robert E. Greene, Introduction to Topology, 2nd edition, Dover Publications, 1999; James Munkres, Topology, 2nd edition, Prentice Hall, 1999.

Course Director: P. Skoufranis, S625 Ross
(416) 736-2100, ext. 66088

Math 6602 3.0F STOCHASTIC PROCESSES
(Math 4430 3.0`

This course covers discrete and continuous stochastic processes in modeling and simulation, with a view towards advanced techniques in estimation. While Brownian motion and derived processes are part of the classical corpus in applied mathematics and mathematical physics, and are utilized in finance modeling, renewed interest focuses on high-dimensional and discrete point processes. Topic areas in applications to be covered here include reliability, business planning, first passage times, computational biology/ bioinformatics and machine learning. Students will choose project themes for a survey/research report and presentation in class: Familiarity with elementary use of Matlab or R will be assumed.

Integrated with the undergraduate course MATH 4430 3.0

Prerequisites: Basic knowledge from real analysis and linear algebra; MATH 2030

Textbook: Mark A. Pinsky & Samuel Karlin: *An Introduction to Stochastic Modeling* (2011). The textbook will be complemented by a selection of original articles from the literature in applied mathematics & statistics, science and algorithm development.

Course director: T. Salisbury; N536 Ross
(416) 736-2100, ext. 33921

Math 6620 3.0F 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. Special topics such as graphical models will be touched upon if time permits.

Text: Mathematical Statistics by Jun Shao

Course Director: Y. Fu, N633 Ross
(416) 736-2100, ext. 33772

Math 6621 3.0W 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.
Prerequisite: Math 6620 3.0 or equivalent, or with permission of instructor.
Grades will be based on a combination of tests, presentations and final examination.

Course Director: Y. Wu, N534 Ross
(416) 736-2100, ext. 22554

Math 6622 3.0W GENERALIZED LINEAR MODELS

Generalized Linear Models (GLMs) extend linear models to situations where the response variable is not continuous. Consequently, these models are popular for analysis in the common scenarios of response variables which are binary, categorical, counts, proportions, or directions. GLMs have become a big part of the ``statistical toolbox" for biostatistical work, and are widely used in other areas as well. In this course, we will cover generalized linear models, generalized estimating equations and high dimensional regression.

Text: P. McCullagh & J.A. Nelder, *Generalized Linear Models*, Chapman and Hall/CRC, 1989.

Course Director: W. Liu, N601B Ross
(416) 736-2100 ext. 33767

Math 6627 3.0W PRACTICUM IN STATISTICAL CONSULTING

The overall objectives of Math 6627 - statistical consulting practicum 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.

Course Director: X. Gao, N623 Ross
(416) 736-2100 ext. 66097

Math 6630 3.0F 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.

Text: Geof H. Givens & Jennifer A. Hoeting, Computational Statistics, 2nd edition, Wiley, 2012.

Course Director: X. Gao, N623 Ross
(416) 736-2100, ext. 66097

Math 6632 3.0F MULTIVARIATE STATISTICS
(Math 4630 3.0)

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, and factor analysis and cluster analysis, if time permits.

Grades will be based on a combination of tests, final examination, plus a project.

Prerequisites: Math 3132 and Math 3330 or equivalent

Texts:

- Robust Multivariate Analysis, Publisher: Springer; 1st ed. 2017 edition (November 28, 2017)
- Multivariate Statistical Modelling Based on Generalized Linear Models, Publisher: Springer; 2nd edition (April 20, 2001)

Course Director: A. Wong, 2041 Victor Phillip Dahdaleh Building
(416) 736-2100, ext. 33497

Math 6633 3.0F THEORY AND METHODS OF TIME SERIES ANALYSIS

(Math 4130B 3.0)

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.
Grades will be based on a combination of tests, final examination, plus a project.

The textbook is
Time Series Analysis and Its Applications
With R Examples
4th edition by Shumway, Robert H., Stoffer, David S.
Springer, 2017
ISBN 978-3-319-52452-8

Course Director: Y. Wu, N534 Ross
(416) 736-2100, ext. 22554

Math 6641 3.0W SURVIVAL ANALYSIS

We start with some parametric models and show how censored data can be incorporated in the analysis. Then we proceed to nonparametric methods and discuss Kaplan-Meier and Actuarial estimators. Semiparametric models, proportional hazards model and time dependent covariates will also be discussed.

Evaluation will be based on a combination of assignments, midterm exam, final exam and a project.

Prerequisites: AS/SC/AK/MATH 3131 3.0; either AS/SC/MATH 3033 3.0 or AS/SC/AK/MATH 3330 3.0.
Course Director: A. Wong, 2041 TEL
(416) 736-2100, ext. 33497

Math 6644 3.0F STATISTICAL LEARNING

This is a graduate level course in statistical learning with a focus on linear and non-linear regression methods and various classification methods. The syllabus includes multiple regression, logistic regression and regularization methods such as ridge regression ad lasso. It will also include random forest and support vector machine. The framework of deep learning algorithms will be also be covered. Cross-validation and bootstrap will be covered as well. Students will be working on projects with real data.

Text: Christopher M. Bishop, *Pattern Recognition and Machine Learning*,

Course Director: S. Wang, N625 Ross
(416) 736-2100, ext. 33938

Math 6650 3.0F DATA SCIENCE

This course is a modern overview of the data science from the perspective of statistics and application. The course covers relevant computational platforms and analytical tools necessary to analyze large data sets (with the understanding that the tools which are relevant change over time) including R and SAS. This course gives students the experience that they need to implement the techniques and theorems learned in the statistics courses of regression and applied statistics to analyze real and complex data sets. It will also provide an overview of basic computational skills relevant to data science such as data structure, basic principles of algorithms, computational complexity and basic principles of designing a relational database structure. Data mining techniques such as clustering and classification will also be covered in the course.

References:
- Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython– by Wes McKinney (Author)
- R for Data Science: Import, Tidy, Transform, Visualize, and Model Data, 2017 by Hadley Wickham (Author), Garrett Grolemund (Author)

Course Director: S. Wang, N625 Ross
(416) 736-2100, ext. 33938

Math 6651 3.0F ADVANCED NUMERICAL METHODS (Math 4141 3.0)

Topics include: Numerical methods for solving ordinary differential equations; optimization problems: steepest descents, conjugate gradient methods; approximation theory: least squares, orthogonal polynomials, Chebyshev and Fourier approximation, Pade approximation.

The final grade will be based on assignments, a project and a final examination.
Prerequisite: A previous course in Numerical Methods.

Course Director: D. Liang, 225 Petrie
(416) 736-2100, Ext. 77743

Math 6652 3.0W NUMERICAL SOLUTIONS TO DIFFERENTIAL EQUATIONS

Review of partial differential equations; well-posed boundary-value problems; finite difference approximations of derivatives. Parabolic equations: reduction to dimensionless form; solution by explicit method, Crank-Nicholson method, and theta method. Elliptic equations: review of Jacobi and Gauss-Seidel method; successive over-relaxation method; multigrid method. Hyperbolic equations: linear wave equation; method of characteristics. Parabolic equations in 2 and 3D: alternating-Direction Implicit method; Convergence and stability of solution methods.

Although less elegant than the analytic methods studied in Math 6269 3.0, Advanced Topics in Analysis, the numerical methods studied here are applicable to a much wider variety of spatial domains, and are therefore of wide use in industrial calculations of heat flows, diffusion, fluid dynamics, stresses in solids, and electromagnetic fields and waves.

We will use MATLAB to carry out the numerical computations. Licensed copies are installed on university computers, and remote access (from home) is available. Each student may obtain an account and an access card to the Grad Lab (N604 Ross).

Course Director: M. Haslam, S621 Ross
(416) 736-2100 ext. 44645

Math 6655 (Math 4650) 3.0F FEEDBACK CONTROL SYSTEMS

Control theory stems from the fundamental idea of modifying a dynamical system to achieve a desired goal. From this, many questions arise such as modeling a tractable control system, designing an appropriate control objective, finding an optimal control, and testing the performance and robustness of the controlled system, which lends to a rich course in control theory. This course is an introduction to control theory from a mathematical and engineering perspective. In fact, this course is cross listed with Lassonde/ESSE so the class demographic will consist of a mixture of math students and engineering students. Topics include representation and solutions of control systems, defining controllability, stability analysis of a controlled system, controller design and optimal control. Applications are addressed throughout the course including time spent in a laboratory setting (see attached pictures). Knowledge of complex analysis, ordinary differential equations and linear algebra is needed. Knowledge of MATLAB is an asset.

Course Director: A.Chow, S620 Ross
(416) 736-2100 ext. 33902

Math 6904 3.0F MODERN OPTIMIZATION

This course introduces graduate students to modern optimization theories and programming practice. Students shall learn how to analyze the mathematical structure of a new optimization problem from their research and choose or revise a related algorithm accordingly.

Prerequisites: MATH 2001 or equivalent; MATH 2022 or MATH 2222 or equivalent; MATH 2310 or equivalent; CSE 1560 or equivalent. Course credit exclusion: GS/MATH 6901.

Topics include convex analysis, KKT, constrain qualification, Lagrange duality, Levenberg-Marquardt method, Interior Point Method, Lasso, Logistic regression, SVM, Maximum likelihood, portfolio optimization.

Text: Wilhelm Forst and Dieter Hoffmann, *Optimization – Theory and Practice*, Springer 2010.
Note: York library has the eBook of this textbook through SpringerLink.

Course Director: M. Chen, N628 Ross
(416) 736-2100, ext. 22591

Math 6910 3.0 STOCHASTIC CALCULUS IN FINANCE

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

Prerequisite: A basic knowledge of calculus and probability theory (random variables, expectation, variance) will be assumed. The necessary concepts from measure theory and stochastic processes will be introduced as they are needed.

Text: Steven E. Shreve, *Stochastic Calculus for Finance II: Continuous-Time Models*, Springer.

Course Director: H. Ku, N505 Ross
(416) 736-5250, ext. 66091

Math 6911 3.0W NUMERICAL METHODS IN FINANCE

This course deals mainly with finite difference methods and Monte Carlo techniques and their applications in Mathematical Finance. More specifically, we will cover (i) stability and convergence for explicit, implicit and Crank-Nicolson finite difference schemes for solving the heat equation; (ii) finite difference schemes for solving PDEs in local volatility model; (iii) pricing European options and computing implied volatility surface in local volatility model; (iv) Monte Carlo techniques and variance reduction methods: conditional Monte Carlo, importance sampling, control variate method; (v) discrete time delta-hedging in Black-Scholes model; (vi) computing Greeks using Monte Carlo techniques; (vii) pricing American options in binomial and Black-Scholes models. If time permits, we will also discuss Longstaff-Schwartz method for pricing American options.

Course Director: Hm. Zhu, **Petrie Science and Engineering Building, 214**
(416) 736-2100 ext. 55493

Math 6931 3.0F MATHEMATICAL MODELING

This course will explore the principles of mathematical modelling and develop mathematical models motivated by various case studies in science and other fields. We will discuss the modelling philosophy including how, when, and why to model certain processes. We will review and develop various techniques to solve models including non-dimensionalisation, differential equations, stability, stochastic modelling, simulations, and asymptotic analysis. By the end of this course, students should be able to identify modelling problems and develop models to explain them. They should recognize and use techniques needed to address modelling questions.

Text: None, course notes will be provided.

Course Director: I. Moyles, S519 Ross
416-736-2100 (ext. 33994)

Math 6937 3.0W PRACTICUM IN INDUSTRIAL AND APPLIED MATHEMATICS

This practicum course will be based on problems from industry or other applications. Each time, a problem will be presented to students in class either by an industrial researcher or a faculty member. 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.

Corequisites/Prerequisites:
Calculus and Analysis such as Math 3210 or equivalent and Differential Equations such as Math 2270 or equivalent, Math 6931 and Math 6651 or their equivalents.

There are no fixed textbook and references. However, some background materials will be available before the presentation from the industrial partner and/or a faculty member. Students are expected to learn necessary techniques as required pertaining to the study objectives.

Course Director: J. Wu, N613 Ross
(416) 736-2100, ext. 33116