# 2018-2019 Graduate Calendar

The information published in this Graduate Calendar outlines the rules, regulations, curricula, programs and fees for the 2018-2019 academic year, including the Summer Semester 2018, Fall Semester 2018 and the Winter Semester 2019.

For your convenience the Graduate Calendar is available in PDF format.

If you wish to link to the Graduate Calendar please refer to the Linking Guidelines.

The University is a full member of:

• Universities of Canada

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| December 13, 2018 | Revision 2 |
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# Disclaimer

The Office of Graduate Studies has attempted to ensure the accuracy of this on-line Graduate Calendar. However, the publication of information in this document does not bind the university to the provision of courses, programs, schedules of studies, fees, or facilities as listed herein.

# Limitations

The University of Guelph reserves the right to change without notice any information contained in this calendar, including any rule or regulation pertaining to the standards for admission to, the requirements for the continuation of study in, and the requirements for the granting of degrees or diplomas in any or all of its programs.

The university will not be liable for any interruption in, or cancellation of, any academic activities as set forth in this calendar and related information where such interruption is caused by fire, strike, lock-out, inability to procure materials or trades, restrictive laws or governmental regulations, actions taken by the faculty, staff or students of the university or by others, civil unrest or disobedience, Public Health Emergencies, or any other cause of any kind beyond the reasonable control of the university.

The University of Guelph reaffirms section 1 of the Ontario Human Rights Code, 1981, which prohibits discrimination on the grounds of race, ancestry, place of origin, colour, ethnic origin, citizenship, creed, sex, sexual orientation, handicap, age, marital status or family status.

The university encourages applications from women, aboriginal peoples, visible minorities, persons with disabilities, and members of other under-represented groups.

# Introduction

## Collection, Use and Disclosure of Personal Information

Personal information is collected under the authority of the University of Guelph Act (1964), and in accordance with Ontario's Freedom of Information and Protection of Privacy Act (FIPPA) http://www.e-laws.gov.on.ca/DBLaws/Statutes/English/90f31_e.htm. This information is used by University officials in order to carry out their authorized academic and administrative responsibilities and also to establish a relationship for alumni and development purposes. Certain personal information is disclosed to external agencies, including the Ontario Universities Application Centre, the Ministry of Advanced Education and Skills Development, and Statistics Canada, for statistical and planning purposes, and is disclosed to other individuals or organizations in accordance with the Office of Registrarial Services Departmental Policy on the Release of Student Information. For details on the use and disclosure of this information call the Office of Registrarial Services at the University at (519) 824-4120 or see https://www.uoguelph.ca/registrar/

## Statistics Canada - Notification of Disclosure

For further information, please see Statistics Canada's web site at http://www.statcan.gc.ca and Section XIV Statistics Canada.

## Address for University Communication

Depending on the nature and timing of the communication, the University may use one of these addresses to communicate with students. Students are, therefore, responsible for checking all of the following on a regular basis:

### Email Address

The University issued email address is considered an official means of communication with the student and will be used for correspondence from the University. Students are responsible for monitoring their University-issued email account regularly.

### Home Address

Students are responsible for maintaining a current mailing address with the University. Address changes can be made, in writing, through Registrarial Services.

## Name Changes

The University of Guelph is committed to the integrity of its student records, therefore, each student is required to provide either on application for admission or on personal data forms required for registration, his/her complete, legal name. Any requests to change a name, by means of alteration, deletion, substitution or addition, must be accompanied by appropriate supporting documentation.

## Student Confidentiality and Release of Student Information Policy Excerpt

The University undertakes to protect the privacy of each student and the confidentiality of his or her record. To this end the University shall refuse to disclose personal information to any person other than the individual to whom the information relates where disclosure would constitute an unjustified invasion of the personal privacy of that person or of any other individual. All members of the University community must respect the confidential nature of the student information which they acquire in the course of their work.

Complete policy at https://www.uoguelph.ca/secretariat/office-services/university-secretariat/university-policies .

# Table of Contents

# Mathematics and Statistics

The objective of the graduate program is to offer opportunities for advanced studies and research in the fields of:

- Applied Mathematics
- Applied Statistics

Although the two fields within the program have different requirements in terms of specific courses and qualifying examination areas, there is a considerable degree of interaction and commonality between them, from both philosophical and practical viewpoints. Philosophically, this commonality relates to the methodology of constructing and validating models of specific real-world situations. The major areas of specialization in applied mathematics are dynamical systems, mathematical biology, numerical analysis and operations research. Applied statistics encompasses the study and application of statistical procedures to data arising from real-world problems. Much of the emphasis in this field concerns problems originally arising in a biological setting. The major areas of specialization include linear and nonlinear models; bioassay; and survival analysis, life testing and reliability.

## Administrative Staff

**Chair**
Dr. Julie Horrocks (438 MacNaughton, Ext. 56556)
jhorrock@uoguelph.ca

**Graduate Program Coordinator**
Zeny Feng (540 MacNaughton, Ext. 53294)
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**Graduate Program Assistant**
Susan McCormick (440 MacNaughton, Ext. 56553/52155)
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## Graduate Faculty

**R. Ayesha Ali**
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**Daniel A. Ashlock**
BSc Kansas, PhD California Institute of Technology - Professor

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BSc, MSc, PhD Guelph - Associate Professor

**Edward M. Carter**
BSc, MSc, PhD Toronto - Professor

**Monica Cojocaru**
BA, MSc Bucharest, PhD Queen's - Associate Professor

**Gerarda Darlington**
BSc, MSc Guelph, PhD Waterloo - Professor

**Lorna Deeth**
BSc, MSc, PhD Guelph - Assistant Professor

**Matthew Demers**
BSc, MSc, PhD Guelph - Assistant Professor

**Anthony F. Desmond**
BSc, MSc National University of Ireland (U.C.C.), PhD Waterloo - Professor

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Dipl. Math (MSc), PhD Munich Univ. of Tech. - Professor and Canada Research Chair

**Zeny Feng**
BSc York, MA, PhD Waterloo - Associate Professor

**Marcus R. Garvie**
MS Sussex, MS Wales, MS Reading, PhD Durham - Associate Professor

**Stephen Gismondi**
BSc, MSc, PhD Guelph - Associate Professor

**Julie Horrocks**
BSc Mount Allison, BFA Nova Scotia College of Art & Design, MMath, PhD Waterloo - Professor and Chair

**Peter T. Kim**
BA Toronto, MA Southern California, PhD California (San Diego) - Professor

**David Kribs**
BSc Western, MMath, PhD Waterloo - Professor and University Research Chair

**Herb Kunze**
BA, MA, PhD Waterloo - Professor

**Anna T. Lawniczak**
MSc Wroclaw, PhD Southern Illinois - Professor

**Kim Levere**
BA, PhD Guelph - Assistant Professor

**Khurram Nadeem**
BSc, MSc Karachi, PhD Alberta - Assistant Professor

**Rajesh Pereira**
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**Gary J. Umphrey**
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**Allan Willms**
BMath, MMath Waterloo, PhD Cornell - Associate Professor

**Bei Zeng**
BSc, MSc Tsinghua, PhD M.I.T. - Associate Professor

## Associated Graduate Faculty

**Robert Deardon**
BSc Exeter, MSc Southampton, PhD Reading - Associate Professor, University of Calgary

**Stephanie Dixon**
BSc McMaster, MSc, PhD Guelph - Adjunct Faculty at University of Western Ontario, London Health Sciences Centre

**William Langford**
BSc Queens, PhD Caltech - University Professor Emeritus, Mathematics and Statistics, University of Guelph

**William Smith**
BASc, MASc Toronto, MSc PhD Waterloo - University Professor Emeritus, Mathematics and Statistics, University of Guelph

**Edward Thommes**
BSc Alberta, PhD Queens - Adjunct Professor, Mathematics and Statistics, University of Guelph/Health Outcome Manager, GlaxoSmithKline Canada

## MSc Program

The department offers an MSc degree in the fields of : 1) mathematics; or 2) statistics.

### Admission Requirements

For the MSc Degree Program, applicants will normally have either

i) an honours degree with an equivalent to a major in the intended area of emphasis.
or

ii) an honours degree with the equivalent of a minor in the intended area of emphasis, as defined in the University of Guelph Undergraduate Calendar.

Strong applicants with more diverse backgrounds will also be considered but are encouraged to contact the Graduate Program Coordinator or a potential advisor before applying.

Note that the department's undergraduate diploma in applied statistics fulfils the requirement of a minor equivalent in statistics.

### Degree Requirements

Students enrol in one of two study options: 1) thesis, or 2) course work and major research project.

All programs of study must include the appropriate core courses (see below). Students who have obtained prior credit for a core course or its equivalent will normally substitute a departmental graduate course at the same or higher level, with the approval of the Graduate Program Coordinator. The remaining prescribed courses are to be selected from either graduate courses or 400-level undergraduate courses. Courses taken outside of this department must have the prior approval of the Graduate Program Committee.

#### Thesis

Students must complete at least 2.0 credits (four courses) plus a thesis.

#### Course Work and Major Research Project (MRP)

Students must complete at least 3.0 credits (six courses), 2.0 of which must be for graduate-level courses plus successful completion, within two semesters either MATH*6998 MSc Project in Mathematics or STAT*6998 MSc Project in Statistics.

### Mathematical Area of Emphasis

All candidates for the MSc with a mathematical area of emphasis are required to include in their program of study at least two of the core courses. The core courses are:

| | | |
|---|---|---|
| MATH*6010 | [0.50] | Analysis |
| MATH*6020 | [0.50] | Scientific Computing |
| MATH*6051 | [0.50] | Mathematical Modelling |

For an MSc by thesis at least three MATH courses must be taken, for an MSc by course work and major research project at least four MATH courses must be taken.

### Statistical Area of Emphasis

All candidates for the MSc with a statistical area of emphasis are required to include in their program of study at least two of the core courses.

The core courses are:

| | | |
|---|---|---|
| STAT*6801 | [0.50] | Statistical Learning |
| STAT*6802 | [0.50] | Generalized Linear Models and Extensions |
| STAT*6841 | [0.50] | Computational Statistical Inference |

It is required that students take the undergraduate course Statistical Inference, STAT*4340, if this course or its equivalent has not previously been taken. For an MSc by thesis at least three STAT courses must be taken, for an MSc by course work and major research project at least four STAT courses must be taken.

# PhD Program

## Admission Requirements

Normally a candidate for the PhD degree program must possess a recognized master's degree obtained with high academic standing. The Departmental Graduate Program Committee will consider applications for direct entry to PhD and for transfer from MSc to PhD. In any event, a member of the department's graduate faculty must agree to act as an advisor to the student.

## Degree Requirements

The PhD degree is primarily a research degree. For that reason, course work commonly comprises a smaller proportion of the student's effort than in the master's program. Course requirements are as follows:

### Applied Mathematics

Students must successfully complete 2.0 graduate course credits; i.e. four graduate courses. At least three of these courses must be graduate level MATH courses. Depending upon the student's academic background, further courses may be prescribed. All courses are chosen in consultation with the advisory committee. Additional courses may be required at the discretion of the advisory committee and/or the departmental Graduate Program Committee. With departmental approval, some courses given by other universities may be taken for credit. Courses taken outside of this department must have the prior approval of the Graduate Program Committee.

### Applied Statistics

Students must successfully complete 2.0 graduate-course credits. At least three of these courses must be graduate level STAT courses. Depending upon the student's academic background, further courses may be prescribed. Students must take the following courses as part of the four required courses (providing that these courses were not taken as part of the student's master's-degree program):

| STAT*6801 | [0.50] | Statistical Learning |
| STAT*6841 | [0.50] | Computational Statistical Inference |

All courses are chosen in consultation with the student's advisory committee. Additional courses may be required at the discretion of the advisory committee and/or the departmental Graduate Program Committee. With departmental approval, some courses given by other universities may be taken for credit. Courses taken outside of this department must have the prior approval of the Graduate Program Committee.

## Interdepartmental Programs

### Biophysics MSc/PhD Program

The Department of Mathematics and Statistics participates in the MSc/PhD programs in biophysics. Please consult the Biophysics listing for a detailed description of the graduate programs offered by the Biophysics Interdepartmental Group.

### Bioinformatics MBNF/MSc/PhD Programs

The Department of Mathematics and Statistics participates in the MBNF/MSc/PhD programs in Bioinformatics. Please consult the Bioinformatics listing for a detailed description of these graduate programs and a list of the graduate faculty involved.

## Collaborative Specializations

### Artificial Intelligence

The Department of Mathematics and Statistics participates in the collaborative specialization in Artificial Intelligence. MSc students wishing to undertake thesis research with an emphasis on artificial intelligence are eligible to apply to register concurrently in Mathematics and Statistics and the collaborative specialization. Students should consult the Artificial Intelligence listing for more information.

## Courses

## Mathematics

### MATH*6010 Analysis U [0.50]

Half the course covers metric spaces, normed linear spaces, and inner product spaces, including Banach's and Schauder's fixed point theorems, Lp spaces, Hilbert spaces and the projection theorem. The remaining content may include topics like operator theory, inverse problems, measure theory and spectral analysis.

*Department(s):*    Department of Mathematics and Statistics

### MATH*6011 Dynamical Systems I U [0.50]

Basic theorems on existence, uniqueness and differentiability; phase space, flows, dynamical systems; review of linear systems, Floquet theory; Hopf bifurcation; perturbation theory and structural stability; differential equations on manifolds. Applications drawn from the biological, physical, and social sciences.

*Department(s):*    Department of Mathematics and Statistics

### MATH*6012 Dynamical Systems II U [0.50]

The quantitative theory of dynamical systems defined by differential equations and discrete maps, including: generic properties; bifurcation theory; the center manifold theorem; nonlinear oscillations, phase locking and period doubling; the Birkhoff-Smale homoclinic theorem; strange attractors and deterministic chaos.

*Department(s):*    Department of Mathematics and Statistics

### MATH*6020 Scientific Computing U [0.50]

This course covers the fundamentals of algoithms and computer programming. This may include computer arithmetic, complexity, error analysis, linear and nonlinear equations, least squares, interpolation, numerical differentiation and integration, optimization, random number generators, Monte Carlo simulation; case studies will be undertaken using modern software.

*Department(s):*    Department of Mathematics and Statistics

### MATH*6021 Optimization I U [0.50]

A study of the basic concepts in: linear programming, convex programming, non-convex programming, geometric programming and related numerical methods.

*Department(s):*    Department of Mathematics and Statistics

### MATH*6022 Optimization II U [0.50]

A study of the basic concepts in: calculus of variations, optimal control theory, dynamic programming and related numerical methods.

*Department(s):*    Department of Mathematics and Statistics

### MATH*6031 Functional Analysis U [0.50]

Hilbert, Banach and metric spaces are covered including applications. The Baire Category theorem is covered along with its consequences such as the open mapping theorem, the principle of uniform boundedness and the closed graph theorem. The theory of linear functionals is discussed including the Hahn-Banach theorem, dual spaces, and if time permits, weak topologies or generalized functions. Basic operator theory is covered including topics such as adjoints, compact operators, the Frechet derivative and spectral theory. A brief introduction to the concepts of measure and integration required for some of the aforementioned topics is also included. Offered in conjunction with MATH*4220. Extra work is required of graduate students.

*Restriction(s):*    Credit may be obtained for only one of MATH*4220 or MATH*6031
*Department(s):*    Department of Mathematics and Statistics

### MATH*6041 Partial Differential Equations I U [0.50]

Classification of partial differential equations. The Hyperbolic type, the Cauchy problem, range of influence, well- and ill-posed problems, successive approximation, the Riemann function. The elliptic type: fundamental solutions, Dirichlet and Neumann problems. The parabolic type: boundary conditions, Green's functions and separation of variables. Introduction to certain non-linear equations and transformations methods. Offered in conjunction with MATH*4270. Extra work is required for graduate students.

*Restriction(s):*    Credit may be obtained for only one of MATH*4270 or MATH*6041
*Department(s):*    Department of Mathematics and Statistics

### MATH*6042 Partial Differential Equations II U [0.50]

A continuation of some of the topics of Partial Differential Equations I. Also, systems of partial differential equations, equations of mixed type and non-linear equations.

*Department(s):*    Department of Mathematics and Statistics

### MATH*6051 Mathematical Modelling U [0.50]

The process of phenomena and systems model development, techniques of model analysis, model verification, and interpretation of results are presented. The examples of continuous or discrete, deterministic or probabilistic models may include differential equations, difference equations, cellular automata, agent based models, network models, stochastic processes.

*Department(s):*    Department of Mathematics and Statistics

### MATH*6071 Biomathematics U [0.50]

The application of mathematics to model and analyze biological systems. Specific models to illustrate the different mathematical approaches employed when considering different levels of biological function.

*Department(s):*    Department of Mathematics and Statistics

### MATH*6091 Topics in Analysis U [0.50]

Selected topics from topology, real analysis, complex analysis, and functional analysis.

*Department(s):*    Department of Mathematics and Statistics

### MATH*6181 Topics in Applied Mathematics I U [0.50]

This course provides graduate students, either individually or in groups, with the opportunity to pursue topics in applied mathematics under the guidance of graduate faculty. Course topics will normally be advertised by faculty in the semester prior to their offering. Courses may be offered in any of lecture, reading/seminar, or individual project formats.

*Department(s):*    Department of Mathematics and Statistics

**MATH*6182 Topics in Applied Mathematics II U [0.50]**

This course provides graduate students, either individually or in groups, with the opportunity to pursue topics in applied mathematics under the guidance of graduate faculty. Course topics will normally be advertised by faculty in the semester prior to their offering. Courses may be offered in any of lecture, reading/seminar, or individual project formats.

*Department(s):* Department of Mathematics and Statistics

**MATH*6400 Numerical Analysis I U [0.50]**

Topics selected from numerical problems in: matrix operations, interpolation, approximation theory, quadrature, ordinary differential equations, partial differential equations, integral equations, nonlinear algebraic and transcendental equations.

*Department(s):* Department of Mathematics and Statistics

**MATH*6410 Numerical Analysis II U [0.50]**

One or more topics selected from those discussed in Numerical Analysis I, but in greater depth.

*Department(s):* Department of Mathematics and Statistics

**MATH*6998 MSc Project in Mathematics U [1.00]**

This course is intended for students in the course-based MSc program in Mathematics. The MSc project will be written under the supervision of a faculty member and will normally be completed within one or two semesters. Once completed, students will submit a final copy of their project to the Department and give an oral presentation of their work.

*Restriction(s):* Restricted to MSC.MAST:L-MATH students in Mathematics
*Department(s):* Department of Mathematics and Statistics

## Statistics

**STAT*6550 Computational Statistics U [0.50]**

This course covers the implementation of a variety of computational statistics techniques. These include random number generation, Monte Carlo methods, non-parametric techniques, Markov chain Monte Carlo methods, and the EM algorithm. A significant component of this course is the implementation of techniques.

*Department(s):* Department of Mathematics and Statistics

**STAT*6700 Stochastic Processes U [0.50]**

The content of this course is to introduce Brownian motion leading to the development of stochastic integrals thus providing a stochastic calculus. The content of this course will be delivered using concepts from measure theory and so familiarity with measures, measurable spaces, etc., will be assumed.

*Department(s):* Department of Mathematics and Statistics

**STAT*6721 Stochastic Modelling U [0.50]**

Topics include the Poisson process, renewal theory, Markov chains, Martingales, random walks, Brownian motion and other Markov processes. Methods will be applied to a variety of subject matter areas. Offered in conjunction with STAT*4360. Extra work is required for graduate students.

*Restriction(s):* Credit may be obtained for only one of STAT*4360 or STAT*6721
*Department(s):* Department of Mathematics and Statistics

**STAT*6761 Survival Analysis U [0.50]**

Kaplan-Meier estimation, life-table methods, the analysis of censored data, survival and hazard functions, a comparison of parametric and semi-parametric methods, longitudinal data analysis.

*Department(s):* Department of Mathematics and Statistics

**STAT*6801 Statistical Learning U [0.50]**

Topics include: nonparametric and semiparametric regression; kernel methods; regression splines; local polynomial models; generalized additive models; classification and regression trees; neural networks. This course deals with both the methodology and its application with appropriate software. Areas of application include biology, economics, engineering and medicine.

*Department(s):* Department of Mathematics and Statistics

**STAT*6802 Generalized Linear Models and Extensions U [0.50]**

Topics include: generalized linear models; generalized linear mixed models; joint modelling of mean and dispersion; generalized estimating equations; modelling longitudinal categorical data; modelling clustered data. This course will focus both on theory and implementation using relevant statistical software. Offered in conjunction with STAT*4050/4060. Extra work is required for graduate students.

*Restriction(s):* Credit may be obtained for only one of STAT*4050 or STAT*4060 or STAT*6802
*Department(s):* Department of Mathematics and Statistics

**STAT*6821 Multivariate Analysis U [0.50]**

This is an advanced course in multivariate analysis and one of the primary emphases will be on the derivation of some of the fundamental classical results of multivariate analysis. In addition, topics that are more current to the field will also be discussed such as: multivariate adaptive regression splines; projection pursuit regression; and wavelets. Offered in conjunction with STAT*4350. Extra work is required for graduate students.

*Restriction(s):* Credit may be obtained for only one of STAT*4350 or STAT*6821
*Department(s):* Department of Mathematics and Statistics

**STAT*6841 Computational Statistical Inference U [0.50]**

This course covers Bayesian and likelihood methods, large sample theory, nuisance parameters, profile, conditional and marginal likelihoods, EM algorithms and other optimization methods, estimating functions, Monte Carlo methods for exploring posterior distributions and likelihoods, data augmentation, importance sampling and MCMC methods.

*Department(s):* Department of Mathematics and Statistics

**STAT*6860 Linear Statistical Models U [0.50]**

Generalized inverses of matrices; distribution of quadratic and linear forms; regression or full rank model; models not of full rank; hypothesis testing and estimation for full and non-full rank cases; estimability and testability; reduction sums of squares; balanced and unbalanced data; mixed models; components of variance.

*Department(s):* Department of Mathematics and Statistics

**STAT*6920 Topics in Statistics U [0.50]**

*Department(s):* Department of Mathematics and Statistics

**STAT*6950 Statistical Methods for the Life Sciences F [0.50]**

Analysis of variance, completely randomized, randomized complete block and latin square designs; planned and unplanned treatment comparisons; random and fixed effects; factorial treatment arrangements; simple and multiple linear regression; analysis of covariance with emphasis on the life sciences. STAT*6950 and STAT*6960 are intended for graduate students of other departments and may not normally be taken for credit by mathematics and statistics graduate students.

*Department(s):* Department of Mathematics and Statistics

**STAT*6998 MSc Project in Statistics U [1.00]**

This course is intended for students in the course-based MSc program in Statistics. The MSc project will be written under the supervision of a faculty member and will normally be completed within one or two semesters. Once completed, students will submit a final copy of their project to the Department and give an oral presentation of their work

*Restriction(s):* Restricted to MSC.MAST:L-STAT students in Statistics
*Department(s):* Department of Mathematics and Statistics