MATHEMATICS AND STATISTICS

The MSc and PhD programs offer opportunities for advanced studies and research in the fields of:

- Applied Mathematics
- Applied Statistics

Although the two fields 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

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Graduate Faculty

This list may include Regular Graduate Faculty, Associated Graduate Faculty and/or Graduate Faculty from other universities.

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Graduate Faculty

Allan Willms
B.Math., M.Math. Waterloo, PhD Cornell - Professor
Graduate Faculty

MSc Program

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.

Program 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 courses from the three groups of core courses.

1. Group A
   - MATH*6020 Scientific Computing
2. Group B
   - MATH*6010 Analysis
   - MATH*6031 Functional Analysis
3. Group C
   - MATH*6051 Mathematical Modelling
   - MATH*6071 Biomathematics

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:

Code	Title	Credits
STAT*6801	Statistical Learning	0.50
STAT*6802	Generalized Linear Models and Extensions	0.50
STAT*6841	Computational Statistical Inference	0.50

It is required that students take the undergraduate course STAT*4340 Statistical Inference, 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.

Program 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):

Code	Title	Credits
STAT*6801	Statistical Learning	0.50
STAT*6841	Computational Statistical Inference	0.50

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.

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 (https://calendar.uoguelph.ca/graduate-calendar/collaborative-specializations/artificial-intelligence/) listing for more information.

One Health

Mathematics and Statistics participates in the collaborative specialization in One Health. Master's and Doctoral students wishing to undertake thesis research or their major research paper/project with an emphasis on one health are eligible to apply to register concurrently in Mathematics and Statistics and the collaborative specialization. Students should consult the One Health (https://calendar.uoguelph.ca/graduate-calendar/collaborative-specializations/one-health/) listing for more information.

Courses

MATH*6010 Analysis Unspecified [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
Location(s): Guelph

MATH*6011 Dynamical Systems I Unspecified [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
Location(s): Guelph

MATH*6012 Dynamical Systems II Unspecified [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
Location(s): Guelph

MATH*6020 Scientific Computing Unspecified [0.50]
This course covers the fundamentals of algorithms 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
Location(s): Guelph

MATH*6021 Optimization I Unspecified [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
Location(s): Guelph

MATH*6022 Optimization II Unspecified [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
Location(s): Guelph

MATH*6031 Functional Analysis Unspecified [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
Location(s): Guelph

MATH*6041 Partial Differential Equations I Unspecified [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
Location(s): Guelph

MATH*6042 Partial Differential Equations II Unspecified [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
Location(s): Guelph

MATH*6051 Mathematical Modelling Unspecified [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
Location(s): Guelph

MATH*6071 Biomathematics Unspecified [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
Location(s): Guelph

MATH*6091 Topics in Analysis Unspecified [0.50]
Selected topics from topology, real analysis, complex analysis, and functional analysis.
Department(s): Department of Mathematics and Statistics
Location(s): Guelph

MATH*6181 Topics in Applied Mathematics I Unspecified [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
Location(s): Guelph

MATH*6182 Topics in Applied Mathematics II Unspecified [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
Location(s): Guelph

MATH*6400 Numerical Analysis I Unspecified [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
Location(s): Guelph

MATH*6410 Numerical Analysis II Unspecified [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
Location(s): Guelph

MATH*6998 MSc Project in Mathematics Unspecified [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.
Department(s): Department of Mathematics and Statistics
Location(s): Guelph

STAT*6550 Computational Statistics Unspecified [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
Location(s): Guelph

STAT*6700 Stochastic Processes Unspecified [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
Location(s): Guelph

STAT*6721 Stochastic Modelling Unspecified [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.
Department(s): Department of Mathematics and Statistics
Location(s): Guelph

STAT*6761 Survival Analysis Unspecified [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
Location(s): Guelph

STAT*6801 Statistical Learning Unspecified [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
Location(s): Guelph

STAT*6802 Generalized Linear Models and Extensions Unspecified [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
Location(s): Guelph

STAT*6821 Multivariate Analysis Unspecified [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
Location(s): Guelph

STAT*6841 Computational Statistical Inference Unspecified [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
Location(s): Guelph

STAT*6860 Linear Statistical Models Unspecified [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
Location(s): Guelph

STAT*6920 Topics in Statistics Unspecified [0.50]
Department(s): Department of Mathematics and Statistics
Location(s): Guelph

STAT*6950 Statistical Methods for the Life Sciences Fall Only [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 is 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
Location(s): Guelph

STAT*6998 MSc Project in Statistics Unspecified [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.
Department(s): Department of Mathematics and Statistics
Location(s): Guelph