

# DOCTORATE IN PHILOSOPHY MATHEMATICS AND STATISTICS

## Summary

- Degree offered: Doctorate in Philosophy (PhD)
- Registration status option: Full-time
- Language of instruction: English
- Program option (expected duration of the program):
  - with thesis (12 full-time terms; 48 consecutive months)
- Academic units: Faculty of Science (<http://science.uottawa.ca/en/>), Department of Mathematics and Statistics (<http://science.uottawa.ca/mathstat/en/>), Ottawa-Carleton Institute of Mathematics and Statistics (OCIMS) (<http://science.uottawa.ca/mathstat/en/about-department/ottawa-carleton-institute/>).

## Program Description

### Ottawa-Carleton Joint Program

The University of Ottawa offers a rich academic environment to study mathematics and statistics under the supervision of professors who have gained an international reputation for their research. Most major fields of research in mathematics and statistics are represented within the Department of Mathematics and Statistics. Moreover, the Department is a participating unit in the master's level collaborative programs in bioinformatics and in biostatistics. Additional information about the Department and its programs is posted on the departmental website at [www.mathstat.uottawa.ca](http://www.mathstat.uottawa.ca).

Since 1984, the graduate programs in mathematics and statistics have been under the umbrella of the Ottawa-Carleton Institute of Mathematics and Statistics (OCIMS). The OCIMS consists of the School of Mathematics and Statistics at Carleton University and the Department of Mathematics and Statistics at the University of Ottawa. The two units have pooled together their resources to offer each year a large selection of graduate courses.

## Other Programs Offered Within the Same Discipline or in a Related Area

- Doctorate in Mathematics and Statistics Specialization in in Bioinformatics (PhD)
- Master of Science Mathematics and Statistics Concentration in Mathematics (MSc)
- Master of Science Mathematics and Statistics Concentration in Statistics (MSc)
- Master of Science Mathematics and Statistics Specialization in Bioinformatics (MSc)
- Master of Science Mathematics and Statistics Specialization in Biostatistics (MSc)

## Fees and Funding

- Program fees:

The estimated amount for university fees (<https://www.uottawa.ca/university-fees/>) associated with this program are available under

the section Finance your studies (<http://www.uottawa.ca/graduate-studies/programs-admission/finance-studies/>).

International students enrolled in a French-language program of study may be eligible for a differential tuition fee exemption (<https://www.uottawa.ca/university-fees/differential-tuition-fee-exemption/>).

- To learn about possibilities for financing your graduate studies, consult the Awards and financial support (<https://www.uottawa.ca/graduate-studies/students/awards/>) section.

## Notes

- Programs are governed by the general regulations (<http://www.uottawa.ca/graduate-studies/students/general-regulations/>) in effect for graduate studies at both universities.
- In accordance with the University of Ottawa regulation, students have the right to complete their assignments, examinations, research papers, and theses in French or in English.
- Research activities can be conducted in English or French or both depending on the language used by the professor and the members of the research group.

## Program Contact Information

Graduate Studies Office, Faculty of Science (<https://science.uottawa.ca/en/faculty-services/graduate-studies/>)

30 Marie-Curie Street, Gendron Hall,  
Room 181

Ottawa, Ontario, Canada

K1N 6N5

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Email: [gradsci@uOttawa.ca](mailto:gradsci@uOttawa.ca)

Twitter | Faculty of Science (<https://twitter.com/uOttawaScience/?lang=en>)

Facebook | Faculty of Science (<https://www.facebook.com/uOttawaScience/>)

## Admission Requirements

For the most accurate and up to date information on application deadlines, language tests and other admission requirements, please visit

the specific requirements (<https://www.uottawa.ca/graduate-studies/programs-admission/apply/specific-requirements/>) webpage.

## To be eligible, candidates must:

- Have a master's degree in mathematics and statistics (or equivalent) with a minimum average of 75% (B+).

Note: International candidates must check the admission equivalencies (<https://www.uottawa.ca/graduate-studies/international/study-uottawa/admission-equivalencies/>) for the diploma they received in their country of origin.

- Demonstrate a good academic performance in previous studies as shown by official transcripts, research reports, abstracts or any other documents demonstrating research skills.
- Meet the funding requirements.
- Identify at least one professor who is willing to supervise your research and thesis.
  - We recommend that you contact potential thesis supervisors as soon as possible.
  - To register, you need to have been accepted by a thesis supervisor.
  - The supervisor's name is required at the time of application.
  - The choice of supervisor will determine the primary campus location of the student. It will also determine which university awards the degree.

## Language Requirements

Applicants must be able to understand and fluently speak the language of instruction (French or English) in the program to which they are applying. Proof of linguistic proficiency may be required.

Applicants whose first language is neither French nor English must provide proof of proficiency in the language of instruction.

Note: Candidates are responsible for any fees associated with the language tests.

## Notes

- The admission requirements listed above are minimum requirements and do not guarantee admission to the program.
- Admissions are governed by the general regulations (<http://www.uottawa.ca/graduate-studies/students/general-regulations/>) in effect for graduate studies and by the general regulations of the Ottawa-Carleton Institute of Mathematics and Statistics (OCIMS).

## Fast-Track from Master's to PhD

Students enrolled in the master's program in mathematics and statistics at the University of Ottawa may be eligible to fast-track directly into the doctoral program without writing a master's thesis, provided the following conditions are met:

- Completion of two graduate courses (six units) with a grade of A- or better in each.
- Having completed with success one of the basic comprehensive exam.
- Satisfactory progress in the research program.

- Written recommendation by the supervisor and the advisory committee;
- Approval by the graduate studies committee.

Notes:

- The transfer must take place within sixteen months of initial enrollment in the master's.
- Following the transfer, all of the requirements of the doctoral program must be met: a total of 18 course units (including the units completed at the master's); the comprehensive exams; and a thesis.

## Program Requirements Doctorate

Requirements for this program have been modified. Please consult the 2018-2019 calendars (<http://catalogue.uottawa.ca/en/archives/>) for the previous requirements.

The Department may require students to take additional courses, depending on their backgrounds.

Students must meet the following requirements:

### Compulsory Courses:

18 optional course units in mathematics (MAT) at the graduate level <sup>1</sup>	18 Units
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### Two options from the following: <sup>2, 3</sup>

Option 1: Real Analysis

MAT 9900 Comprehensive Exam: Real Analysis I

MAT 9901 Comprehensive Exam: Real Analysis II

Option 2: Algebra

MAT 9902 Comprehensive Exam: Algebra I

MAT 9903 Comprehensive Exam: Algebra II

Option 3: Topology

MAT 9904 Comprehensive Exam: Topology I

MAT 9905 Comprehensive Exam: Topology II

Option 4: Differential Equations

MAT 9906 Comprehensive Exam: Differential Equations I

MAT 9907 Comprehensive Exam: Differential Equations II

Option 5: Discrete Mathematics

MAT 9908 Comprehensive Exam: Discrete Mathematics I

MAT 9909 Comprehensive Exam: Discrete Mathematics II

Option 6: Probability Theory

MAT 9910 Comprehensive Exam: Probability Theory I

MAT 9911 Comprehensive Exam: Probability Theory II

Option 7: Mathematical Statistics

MAT 9912 Comprehensive Exam: Mathematical Statistics I

MAT 9913 Comprehensive Exam: Mathematical Statistics II

### Comprehensive Examination:

MAT 9998	Advanced Comprehensive Examination <sup>3</sup>
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## Thesis:

THD 9999 Doctoral Thesis<sup>4,5</sup>

## Note(s)

- <sup>1</sup> The optional course units may be selected in related disciplines approved by the Department of Mathematics and Statistics.
- <sup>2</sup> A student changing his area of specialization is required to complete the advanced comprehensive examination in the new area within a time period specified by the thesis advisory committee.
- <sup>3</sup> Successful completion of all the advanced comprehensive examinations within 20 months from the initial registration.
- <sup>4</sup> Presentation and successful defense of a thesis based on an original research carried out under the direct supervision of a faculty member of the Institute.
- <sup>5</sup> Students are responsible for ensuring they have met all of the thesis requirements (<http://www.uottawa.ca/graduate-studies/students/theses/>).

## Minimum Requirements

The passing grade in all courses is B.

Students who fail two courses (equivalent to 6 units), or the thesis proposal, or the comprehensive exam, or whose research progress is deemed unsatisfactory are required to withdraw.

## Research

### Research Fields & Facilities

Located in the heart of Canada's capital, a few steps away from Parliament Hill, the University of Ottawa is among Canada's top 10 research universities.

uOttawa focuses research strengths and efforts in four Strategic Areas of Development in Research (SADRs):

- Canada and the World
- Health
- e-Society
- Molecular and Environmental Sciences

With cutting-edge research, our graduate students, researchers and educators strongly influence national and international priorities.

### Research at the Faculty of Science

The Faculty of Science has become a true centre of excellence in research through its world-class professors as well as its programs and infrastructure in Biology, Chemistry, Earth Sciences, Mathematics and Statistics, and Physics.

The research accomplished by its 140 internationally recognized professors, its approximately 400 graduate students and its dozens of postdoctoral researchers and visiting scientists has positioned the Faculty of Science as one of the most research intensive science faculties in Canada. Our professors have received many international and national awards including three NSERC Gerhard Herzberg Gold Medal winners and numerous Fellows of the Royal Society of Canada.

The Faculty of Science, through its strategic use of infrastructure programs, hosts world-class Core Facilities and is at the leading edge for the study of Catalysis, Experimental and Computational Chemistry,

Environmental Toxins, Nuclear Magnetic Resonance, Isotope Analysis, Molecular Biology and Genomics, X-Ray Spectrometry/Diffractometry, Geochemistry, Mass Spectrometry, Physiology and Genetics of Aquatic Organisms, and Photonics. The Faculty is also associated with the Fields Institute for research in mathematical science and the Centre de recherche mathématiques (CRM) at the Université de Montréal, providing a unique setting for mathematical research.

For more information, refer to the list of faculty members and their research fields on **Uniweb**.

**IMPORTANT: Candidates and students looking for professors to supervise their thesis or research project can also consult the website of the faculty or department (<https://www.uottawa.ca/graduate-studies/students/academic-unit-contact-information/>) of their program of choice. Uniweb does not list all professors authorized to supervise research projects at the University of Ottawa.**

## Courses

Not all of the listed courses are given each year. The course is offered in the language in which it is described.

Course codes in parentheses are for Carleton University. A 3-unit course at the University of Ottawa is equivalent to a 0.5-unit course at Carleton University.

### **MAT 5105 Discrete Applied Mathematics I: Gra. Theory (3 units)**

Paths and cycles, trees, connectivity, Euler tours and Hamilton cycles, edge colouring, independent sets and cliques, vertex colouring, planar graphs, directed graphs. Selected topics from one or more of the following areas: algebraic graph theory, topological theory, random graphs. This course is equivalent to MATH 5818 at Carleton University.

**Course Component:** Lecture

### **MAT 5106 Combinatorial Optimization (3 units)**

Network flow theory and related material. Topics will include shortest paths, minimum spanning trees, maximum flows, minimum cost flows. Optimal matching in bipartite graphs. This course is equivalent to MATH 5808 at Carleton University.

**Course Component:** Lecture

### **MAT 5107 Discrete Applied Mathematics II: Combinatorial Enumeration (3 units)**

Ordinary and exponential generating functions; product formulas; permutations; partitions; rooted trees; cycle index; WZ method. Lagrange Inversions; singularity analysis of generating functions and asymptotics. Selected topics from one or more of the following areas: random graphs, random combinatorial structures, hypergeometric functions. This course is equivalent to MATH 5819 at Carleton University.

**Course Component:** Lecture

### **MAT 5121 Introduction to Hilbert Space (3 units)**

This course is equivalent to MATH 5009 at Carleton University.

**Course Component:** Lecture

### **MAT 5122 Banach Algebras (3 units)**

This course is equivalent to MATH 5003 at Carleton University.

**Course Component:** Lecture

**MAT 5125 Real Analysis I (3 units)**

General measure and integral, Lebesgue measure and integration on  $\mathbb{R}$ , Fubini's theorem, Lebesgue-Radon-Nikodym theorem, absolute continuity and differentiation,  $L_p$ -Spaces. Selected topics such as Daniell-Stone theory. This course is equivalent to MATH 5007 at Carleton University.

**Course Component:** Lecture

Prerequisites: MAT 3125 (MATH 3001 and MATH 3002).

**MAT 5126 Real Analysis II (3 units)**

Banach and Hilbert spaces, bounded linear operators, dual spaces. Topics selected from: weak- and weak-topologies, Alaoglu's theorem, compact operators, differential calculus in Banach spaces, Riesz representation theorems. This course is equivalent to MATH 5008 at Carleton University.

**Course Component:** Lecture

Prerequisite: MAT 5125 (MATH 5007).

**MAT 5127 Complex Analysis (3 units)**

This course is equivalent to MATH 5005 at Carleton University.

**Course Component:** Lecture

**MAT 5131 Ordinary Differential Equations I (3 units)**

One or two specialized Linear systems, fundamental solution. Nonlinear systems, existence and uniqueness, flow. Equilibria, periodic solutions, stability. Invariant manifolds and hyperbolic theory. Topics taken from, but not limited to: perturbation and asymptotic methods, normal forms and bifurcations, global dynamics. This course is equivalent to MATH 5405 at Carleton University.

**Course Component:** Lecture

**MAT 5133 Partial Differential Equations I (3 units)**

First-order equations, characteristics method, classification of second-order equations, separation of variables, Green's functions.  $L_p$  and Sobolev spaces, distributions, variational formulation and weak solutions, Lax-Milgram theorem, Galerkin approximation. Parabolic PDEs. Wave equations, hyperbolic systems, nonlinear PDEs, reaction diffusion equations, infinite-dimensional dynamical systems, regularity. This course is equivalent to MATH 5406 at Carleton University.

**Course Component:** Lecture

Permission of the Department is required.

**MAT 5134 Topics in Differential Equations (3 units)**

This course is equivalent to MATH 5407 at Carleton University.

**Course Component:** Lecture

**MAT 5141 Algebra I: Rings and Modules (3 units)**

Noetherian and artinian modules and rings. Algebraic sets, vanishing ideals, Hilbert Basis Theorem, radical ideals, Hilbert Nullstellensatz. Localization of rings and modules. Tensor product of modules and algebras. Semisimple rings and modules, Schur's lemma, Jacobson Density Theorem, Artin-Wedderburn Theorem. Short exact sequences, free modules, projective modules, injective modules, flat modules. This course is equivalent to MATH 5107 at Carleton University.

**Course Component:** Lecture

**MAT 5142 Algebra II: Groups and Galois Theory (3 units)**

Group actions, class equation, Sylow theorems, central, composition and derived series, Jordan-Holder theorem, field extensions and minimal polynomials, algebraic closure, separable extensions, integral ring extensions, Galois groups, fundamental theorem of Galois theory, finite fields, cyclotomic field extensions, fundamental theorem of algebra, transcendental extensions. This course is equivalent to MATH 5109 at Carleton University.

**Course Component:** Lecture

**MAT 5143 Lie Algebras (3 units)**

This course is equivalent to MATH 5104 at Carleton University.

**Course Component:** Lecture

**MAT 5144 Commutative Algebra (3 units)**

Prime spectrum of a commutative ring (as a topological space); localization of rings and modules; tensor product of modules and algebras; Hilbert's Nullstellensatz and consequences for finitely generated algebras; Krull dimension of a ring; integral dependence, going-up, going-down; Noether Normalization Lemma and dimension theory for finitely generated algebras over a field; noetherian rings and Hilbert Basis Theorem; introduction to affine algebraic varieties and their morphisms. This course is equivalent to MATH 5001 at Carleton University.

**Course Component:** Lecture

**MAT 5145 Group Theory (3 units)**

This course is equivalent to MATH 5106 at Carleton University.

**Course Component:** Lecture

**MAT 5146 Rings and Modules (3 units)**

This course is equivalent to MATH 5103 at Carleton University.

**Course Component:** Lecture

**MAT 5147 Homological Algebra and Category Theory (3 units)**

This course is equivalent to MATH 5108 at Carleton University.

**Course Component:** Lecture

**MAT 5148 Groups Representations and Applications (3 units)**

This course is equivalent to MATH 5102 at Carleton University.

**Course Component:** Lecture

**MAT 5149 Algebraic Geometry (3 units)**

Brief overview of commutative algebra, Hilbert's Nullstellensatz, algebraic sets, and Zariski topology. Affine and projective varieties over algebraically closed fields. Regular functions and rational maps. Additional topics chosen from: the relation of varieties over complex numbers to complex analytic manifolds, genus, divisors, line bundles, Riemann-Roch Theorem, Bézout's Theorem. This course is equivalent to MATH 5002 at Carleton University.

**Course Component:** Lecture

**MAT 5150 Topics in Geometry (3 units)**

This course is equivalent to MATH 5201 at Carleton University.

**Course Component:** Lecture

**MAT 5151 Topology I (3 units)**

Topological spaces, product and identification topologies, countability and separation axioms, compactness, connectedness, homotopy, fundamental group, net and filter convergence. This course is equivalent to MATH 5205 at Carleton University.

**Course Component:** Lecture

**MAT 5152 Topology II (3 units)**

Covering spaces, homology via the Eilenberg-Steenrod axioms, applications, construction of a homology functor. This course is equivalent to MATH 5206 at Carleton University.

**Course Component:** Lecture

Prerequisites: MAT 3143 and MAT 5151 (MATH 3100 and MATH 5205).

**MAT 5155 Differentiable Manifolds (3 units)**

This course is equivalent to MATH 5208 at Carleton University.

**Course Component:** Lecture

**MAT 5158 Lie Groups (3 units)**

This course is equivalent to MATH 6104 at Carleton University.

**Course Component:** Lecture



**MAT 5160 Mathematical Cryptography (3 units)**

Analysis of cryptographic methods used in authentication and data protection, with particular attention to the underlying mathematics, e.g. Algebraic Geometry, Number Theory, and Finite Fields. Advanced topics on Public-Key Cryptography: RSA and integer factorization, Diffie-Hellman, discrete logarithms, elliptic curves. Topics in current research. This course is equivalent to MATH 5300 at Carleton University.

**Course Component:** Lecture

Prerequisite: undergraduate honours algebra, including group theory and finite fields.

**MAT 5161 Mathematical Logic (3 units)**

A basic graduate course in mathematical logic. Propositional and Predicate logic, Proof theory, Gentzen's Cut-Elimination, Completeness, Compactness, Henkin models, model theory, arithmetic and undecidability. Special Topics (time permitting) depending on interests of instructor and audience. This course is equivalent to MATH 5301 at Carleton University.

**Course Component:** Lecture

Prerequisite: Honours undergraduate algebra, analysis and topology (or permission of the instructor).

**MAT 5162 Mathematical Foundations of Computer Science (3 units)**

Foundations of functional languages, lambda calculi (typed, polymorphically typed, untyped), Curry-Howard Isomorphism, proofs-as-programs, normalization and rewriting theory, operational semantics, type assignment, introduction to denotational semantics of programs, fixed-point programming. Topics chosen from: denotational semantics for lambda calculi, models of programming languages, complexity theory and logic of computation, models of concurrent and distributed systems, etc. This course is equivalent to MATH 6807 at Carleton University.

**Course Component:** Lecture

Prerequisite: Honours undergraduate algebra and either topology or analysis. Some acquaintance with Logic useful.

**MAT 5163 Analytic Number Theory (3 units)**

This course is equivalent to MATH 5305 at Carleton University.

**Course Component:** Lecture

**MAT 5164 Algebraic Number Theory (3 units)**

This course is equivalent to MATH 5306 at Carleton University.

**Course Component:** Lecture

**MAT 5165 Theory of Automata (3 units)**

This course is equivalent to MATH 5605 at Carleton University.

**Course Component:** Lecture

**MAT 5167 Formal Language and Syntax Analysis (3 units)**

This course is equivalent to MATH/COMP 5807 at Carleton University.

**Course Component:** Lecture

**MAT 5168 Homology Theory (3 units)**

This course is equivalent to MATH 5202 at Carleton University.

**Course Component:** Lecture

**MAT 5169 Foundations of Geometry (3 units)**

This course is equivalent to MATH 5207 at Carleton University.

**Course Component:** Lecture

**MAT 5170 Probability Theory I (3 units)**

Probability spaces, random variables, expected values as integrals, joint distributions, independence and product measures, cumulative distribution functions and extensions of probability measures, Borel-Cantelli lemmas, convergence concepts, independent identically distributed sequences of random variables. This course is equivalent to STAT 5708 at Carleton University.

**Course Component:** Lecture

Prerequisites: MAT 3125 and MAT 3172 (MATH 3001, MATH 3002 and MATH 3500).

**MAT 5171 Probability Theory II (3 units)**

Laws of large numbers, characteristic functions, central limit theorem, conditional probabilities and expectation, basic properties and convergence theorems for martingales, introduction to Brownian motion. This course is equivalent to MATH 5709 at Carleton University.

**Course Component:** Lecture

Prerequisite: MAT 5170 (STAT 5708).

**MAT 5172 Topics in Stochastic Processes (3 units)**

This course is equivalent to STAT 5508 at Carleton University.

**Course Component:** Lecture

**MAT 5173 Stochastic Analysis (3 units)**

Brownian motion, continuous martingales and stochastic integration. This course is equivalent to STAT 5604 at Carleton University.

**Course Component:** Lecture

**MAT 5174 Network Performance (3 units)**

The course will focus on advanced techniques in performance evaluation of large complex networks. Topics may include classical queueing theory and simulation analysis; models of packet networks; loss and delay systems; blocking probabilities. This course is equivalent to STAT 5704 at Carleton University.

**Course Component:** Lecture

Prerequisite: Some familiarity with probability and stochastic processes and queueing, or permission of the instructor.

**MAT 5175 Robust Statistical Inference (3 units)**

This course is equivalent to STAT 5506 at Carleton University.

**Course Component:** Lecture

**MAT 5176 Advanced Statistical Inference (3 units)**

Pure significance tests; uniformly most powerful unbiased and invariant tests; asymptotic comparison of tests; confidence intervals; large sample theory of likelihood ratio and chi-square tests; likelihood inference; Bayesian inference. Topics such as empirical Bayes inference, fiducial and structural inference, resampling methods. This course is equivalent to STAT 5507 at Carleton University.

**Course Component:** Lecture

**MAT 5177 Multivariate Normal Theory (3 units)**

This course is equivalent to STAT 5500 at Carleton University.

**Course Component:** Lecture

**MAT 5180 Numerical Analysis for Differential Equations (3 units)**

Floating pointing arithmetic; numerical solution of ordinary differential equations; finite difference methods for partial differential equations; stability, consistency and convergence: von Neumann analysis, Courant-Friedrichs-Lewy condition, Lax theorem; finite element methods; boundary value problems and elliptic partial differential equations; spectral and Pseudo-spectral methods. This course is equivalent to MATH 5806 at Carleton University.

**Course Component:** Lecture

**MAT 5181 Data Mining I (3 units)**

Visualization and knowledge discovery in massive datasets; unsupervised learning: clustering algorithms; dimension reduction; supervised learning: pattern recognition, smoothing techniques, classification. Computer software will be used. This course is equivalent to STAT 5703 at Carleton University.

**Course Component:** Lecture

**MAT 5182 Modern Applied and Computational Statistics (3 units)**

Resampling and computer intensive methods: bootstrap, jackknife with applications to bias estimation, variance estimation, confidence intervals, and regression analysis. Smoothing methods in curve estimation; statistical classification and pattern recognition: error counting methods, optimal classifiers, bootstrap estimates of the bias of the misclassification error. This course is equivalent to STAT 5702 at Carleton University.

**Course Component:** Lecture

**MAT 5185 Asymptotic Methods of Applied Mathematics (3 units)**

Asymptotic series: properties, matching, application to linear and nonlinear differential equations. Asymptotic expansion of integrals: elementary methods, methods of Laplace, Stationary Phase and Steepest Descent, Watson's Lemma, Riemann-Lebesgue Lemma. Perturbation methods: regular and singular perturbation for differential equations, multiple scale analysis, boundary layer theory, WKB theory. This course is equivalent to MATH 5408 at Carleton University.

**Course Component:** Lecture

**MAT 5187 Topics in Applied Mathematics (3 units)**

This course is equivalent to MATH 5403 at Carleton University.

**Course Component:** Lecture

**MAT 5190 Mathematical Statistics I (3 units)**

Statistical decision theory; likelihood functions; sufficiency; factorization theorem; exponential families; UMVU estimators; Fisher's information; Cramer-Rao lower bound; maximum likelihood and moment estimation; invariant and robust point estimation; asymptotic properties; Bayesian point estimation. This course is equivalent to STAT 5600 at Carleton University.

**Course Component:** Lecture

Prerequisites: MAT 3172, MAT 3375. The courses MAT 5190, MAT 5375 cannot be combined for credits.

**MAT 5191 Mathematical Statistics II (3 units)**

Confidence intervals and pivots; Bayesian intervals; optimal tests and Neyman-Pearson theory; likelihood ratio and score tests; significance tests; goodness-of-fit tests; large sample theory and applications to maximum likelihood and robust estimation. This course is equivalent to STAT 5501 at Carleton University.

**Course Component:** Lecture

Prerequisite: MAT 5190.

**MAT 5192 Sampling Theory and Methods (3 units)**

Unequal probability sampling with and without replacement; unified theory of standard errors; prediction approach; ratio and regression estimation; stratification and optimal designs; multistage cluster sampling; double sampling; domains of study; post-stratification; non-response; measurement errors. Related topics. This course is equivalent to STAT 5502 at Carleton University.

**Course Component:** Lecture

**MAT 5193 Linear Models (3 units)**

Theory of non-full-rank linear models: estimable functions, best linear unbiased estimators, hypothesis testing, confidence regions; multi-way classification; analysis of covariance; variance component models: maximum likelihood estimation, MINQUE, ANOVA methods. Miscellaneous topics. This course is equivalent to STAT 5503 at Carleton University.

**Course Component:** Lecture

Prerequisite: MAT 4175 (MATH 4500) or MAT 5190 (STAT 5600).

**MAT 5194 Stochastic Processes and Times Series Analysis (3 units)**

This course is equivalent to STAT 5504 at Carleton University.

**Course Component:** Lecture

**MAT 5195 Design of Experiments (3 units)**

Overview of linear model theory; orthogonality; randomized block and split plot designs; Latin square designs; randomization theory; incomplete block designs; factorial experiments; confounding and fractional replication; response surface methodology. Miscellaneous topics. This course is equivalent to STAT 5505 at Carleton University.

**Course Component:** Lecture

Prerequisites: MAT 3375 and MAT 3376 or MAT 5190 (STAT 3505 and STAT 4500 or STAT 5600).

**MAT 5196 Multivariate Analysis (3 units)**

This course is equivalent to STAT 5509 at Carleton University.

**Course Component:** Lecture

**MAT 5197 Stochastic Optimization (3 units)**

Topics chosen from stochastic dynamic programming, Markov decision processes, search theory, optimal stopping. This course is equivalent to STAT 5601 at Carleton University.

**Course Component:** Lecture

Prerequisite: STAT 3506 or MAT 4371.

**MAT 5198 Stochastic Models (3 units)**

Markov systems, stochastic networks, queuing networks, spatial processes, approximation methods in stochastic processes and queuing theory. Applications to the modelling and analysis of computer-communications systems and other distributed networks. This course is equivalent to MATH 5701 at Carleton University.

**Course Component:** Lecture

**MAT 5301 Topics in Combinatorial Mathematics (3 units)**

This course is equivalent to MATH 5609 at Carleton University.

**Course Component:** Lecture

**MAT 5303 Linear Optimization (3 units)**

This course is equivalent to MATH 5801 at Carleton University.

**Course Component:** Lecture

**MAT 5304 Nonlinear Optimization (3 units)**

This course is equivalent to MATH 5803 at Carleton University.

**Course Component:** Lecture

**MAT 5307 Topics in Operations Research (3 units)**

This course is equivalent to MATH 5804 at Carleton University.

**Course Component:** Lecture

**MAT 5308 Topics in Algorithm Design (3 units)**

This course is equivalent to MATH 5805 at Carleton University.

**Course Component:** Lecture

**MAT 5309 Harmonic Analysis on Groups (3 units)**

This course is equivalent to MATH 6002 at Carleton University.

**Course Component:** Lecture

**MAT 5312 Topics in Topology (3 units)**

This course is equivalent to MATH 6201 at Carleton University.

**Course Component:** Lecture

**MAT 5313 Topics in Probability and Statistics (3 units)**

This course is equivalent to MATH 6507 at Carleton University.

**Course Component:** Lecture

**MAT 5314 Topics in Probability and Statistics (3 units)**

This course is equivalent to MATH 6508 at Carleton University.

**Course Component:** Lecture

**MAT 5315 Advanced Design of Surveys (3 units)**

**Course Component:** Lecture

**MAT 5317 Analysis of Categorical Data (3 units)**

Analysis of one-way and two-way tables of nominal data; multi-dimensional contingency tables, log-linear models; tests of symmetry, marginal homogeneity in square tables; incomplete tables; tables with ordered categories; fixed margins, logistic models with binary response; measures of association and agreement; biological applications. This course is equivalent to STAT 5602 at Carleton University.

**Course Component:** Lecture

**MAT 5318 Reliability and Survival Analysis (3 units)**

This course is equivalent to STAT 5603 at Carleton University.

**Course Component:** Lecture

**MAT 5319 Topics in Probability and Statistics (3 units)**

This course is equivalent to MATH 6507 at Carleton University.

**Course Component:** Lecture

**MAT 5324 Games Theory (3 units)**

This course is equivalent to MATH 5607 at Carleton University.

**Course Component:** Lecture

**MAT 5325 Topics in Information and Systems Science (3 units)**

This course is equivalent to MATH 5802 at Carleton University.

**Course Component:** Lecture

**MAT 5326 Topics in Analysis (3 units)**

This course is equivalent to MATH 6008 at Carleton University.

**Course Component:** Lecture

**MAT 5327 Topics in Algebra (3 units)**

This course is equivalent to MATH 6101 at Carleton University.

**Course Component:** Lecture

**MAT 5328 Topics in Analysis (3 units)**

This course is equivalent to MATH 6008 at Carleton University.

**Course Component:** Lecture

**MAT 5329 Topics in Analysis (3 units)**

This course is equivalent to MATH 6009 at Carleton University.

**Course Component:** Lecture

**MAT 5330 Topics in Algebra (3 units)**

This course is equivalent to MATH 6102 at Carleton University.

**Course Component:** Lecture

**MAT 5331 Topics in Algebra (3 units)**

This course is equivalent to MATH 6103 at Carleton University.

**Course Component:** Lecture

**MAT 5341 Quantum Computing (3 units)**

Space of quantum bits; entanglement. Observables in quantum mechanics. Density matrix and Schmidt decomposition. Quantum cryptography. Classical and quantum logic gates. Quantum Fourier transform. Shor's quantum algorithm for factorization of integers. This course is equivalent to MATH 5821 at Carleton University.

**Course Component:** Lecture

**MAT 5343 Mathematical Aspects of Wavelets and Digital Signal Processing (3 units)**

Lossless compression methods. Discrete Fourier transform and Fourier-based compression methods. JPEG and MPEG. Wavelet analysis. Digital filters and discrete wavelet transform. Daubechies wavelets. Wavelet compression. This course is equivalent to MATH 5822 at Carleton University.

**Course Component:** Lecture

Prerequisites: Linear algebra and Fourier series

**MAT 5361 Topics in Mathematical Logic (3 units)**

This course is equivalent to MATH 6806 at Carleton University.

**Course Component:** Lecture

**MAT 5375 Introduction to Mathematical Statistics (3 units)**

Limit theorems; sampling distributions; parametric estimation; concepts of sufficiency and efficiency; Neyman-Pearson paradigm, likelihood ratio tests; parametric and non-parametric methods for two-sample comparisons; notions of experimental design, categorical data analysis, the general linear model, decision theory and Bayesian inference. This course is essential for students in applied statistics. This course is equivalent to STAT 5610 at Carleton University.

**Course Component:** Lecture

The courses MAT 5190, MAT 5375 cannot be combined for credits.

**MAT 5505 Mathématiques discrètes appliquées I : Théorie des graphes (3 crédits)**

Chemins et cycles, arbres, connexité, parcours eulériens et cycles hamiltoniens, coloration des arêtes, ensembles indépendants et cliques, coloration des sommets, graphes planaires, graphes orientés. Sujets choisis parmi les thèmes suivants : théorie algébrique des graphes, théorie topologique des graphes, graphes aléatoires. Ce cours est équivalent à MATH 5818 à la Carleton University.

**Volet :** Cours magistral

**MAT 5506 Optimisation combinatoire (3 crédits)**

Théorie des flots et thèmes voisins. On traitera parmi d'autres les sujets suivants : chemins minimaux, arbres générateurs de coût minimal, flots de coût maximal, flots de coût minimal. Couplage optimal dans les graphes bipartis. Ce cours est équivalent à MATH 5808 à la Carleton University.

**Volet :** Cours magistral

**MAT 5507 Mathématiques discrètes appliquées II : Énumération combinatoire (3 crédits)**

Fonctions génératrices ordinaires et exponentielles; formules de produit; permutations; partitions; arborescences; indice de cycle; méthode WZ. Inversion de Lagrange; analyse des singularités des fonctions génératrices et leur comportement asymptotique. Sujets choisis parmi les thèmes suivants : graphes aléatoires, structures combinatoires aléatoires, fonctions hypergéométriques. Ce cours est équivalent à MATH 5819 à la Carleton University.

**Volet :** Cours magistral

**MAT 5521 Introduction aux espaces hilbertiens (3 crédits)**

Ce cours est équivalent à MATH 5009 à la Carleton University.

**Volet :** Cours magistral

**MAT 5522 Algèbres de banach (3 crédits)**

Ce cours est équivalent à MATH 5003 à la Carleton University.

**Volet :** Cours magistral

**MAT 5525 Analyse réelle I (3 crédits)**

Mesure et intégration, mesure de Lebesgue et intégration sur  $\mathbb{R}$ , théorème de Fubini, théorème de Lebesgue-Radon-Nikodym, continuité absolue et dérivation, espaces  $L_p$ . Chapitres choisis comme par exemple la théorie de Stone-Daniell. Ce cours est équivalent à MATH 5007 à la Carleton University.

**Volet :** Cours magistral

Préalables : MAT 3525 (MATH 3001 and MATH 3002).

**MAT 5526 Analyse réelle II (3 crédits)**

Espaces de Banach et de Hilbert, opérateurs linéaires bornés, espaces duals. Chapitres choisis parmi les suivants : topologies faibles, théorème d'Alaoglu, opérateurs compacts, calcul différentiel dans les espaces de Banach, théorèmes de représentation de Riesz. Ce cours est équivalent à MATH 5008 à la Carleton University.

**Volet :** Cours magistral

Prerequisite for MAT 5526

**MAT 5527 Analyse complexe (3 crédits)**

Ce cours est équivalent à MATH 5005 à la Carleton University.

**Volet :** Cours magistral

**MAT 5531 Équations différentielles ordinaires I (3 crédits)**

Ce cours est équivalent à MATH 5405 à la Carleton University.

**Volet :** Cours magistral

**MAT 5533 Équations aux dérivées partielles I (3 crédits)**

Ce cours est équivalent à MATH 5406 à la Carleton University.

**Volet :** Cours magistral

Prerequisite: An intermediate level course on Ordinary Differential Equations such as MAT 3130 Dynamical Systems or equivalent, or the permission of the School or Department.

**MAT 5534 Équations différentielles : Chapitres choisis (3 crédits)**

Ce cours est équivalent à MATH 5407 à la Carleton University.

**Volet :** Cours magistral

**MAT 5541 Algèbre I: Anneaux et modules (3 crédits)**

Modules et anneaux noethériens et artiniens. Ensembles algébriques, leurs idéaux, théorème de base de Hilbert, idéaux radicaux, Hilbert Nullstellensatz. Localisation des anneaux et des modules. Produit tensoriel des modules et des algèbres. Anneaux et modules semi-simples, le lemme de Schur, le théorème de densité de Jacobson, le théorème d'Artin-Wedderburn. Suites exactes courtes, modules libres, modules projectifs, modules injectifs, modules plats. Ce cours est équivalent à MATH 5107 à la Carleton University.

**Volet :** Cours magistral

**MAT 5542 Algèbre II: Groupes et la théorie de Galois (3 crédits)**

Actions de groupes, formule des classes, théorèmes de Sylow, séries centrales, de composition et dérivées, théorème de Jordan-Holder, extensions de corps et polynômes minimaux, fermeture algébrique, extensions séparables, intégralité, groupes de Galois, théorème fondamental de la théorie de Galois, corps finis, extensions cyclotomiques, théorème fondamental de l'algèbre, extensions transcendantes. Ce cours est équivalent à MATH 5109 à la Carleton University.

**Volet :** Cours magistral

**MAT 5543 Algèbre de lie (3 crédits)**

Ce cours est équivalent à MATH 5104 à la Carleton University.

**Volet :** Cours magistral

**MAT 5544 Algèbre commutative (3 crédits)**

Spectre premier d'un anneau commutatif (comme espace topologique); localisation des anneaux et des modules; produit tensoriel des modules et algèbres; théorème des zéros de Hilbert et conséquences pour les algèbres de type fini sur un corps; dimension de Krull d'un anneau; dépendance intégrale, théorèmes de « going-up » et « going-down »; lemme de normalisation de Noether et théorie de la dimension dans les algèbres de type fini sur un corps; anneaux noethériens et théorème « de la base » de Hilbert; introduction aux variétés algébriques affines et à leurs morphismes.

**Volet :** Cours magistral

**MAT 5545 Théorie des groupes (3 crédits)**

Ce cours est équivalent à MATH 5106 à la Carleton University.

**Volet :** Cours magistral

**MAT 5546 Anneaux et modules (3 crédits)**

Ce cours est équivalent à MATH 5103 à la Carleton University.

**Volet :** Cours magistral

**MAT 5547 Algèbre homologique et théorie des catégories (3 crédits)**

Ce cours est équivalent à MATH 5108 à la Carleton University.

**Volet :** Cours magistral

**MAT 5548 Représentation de groupes et applications (3 crédits)**

**Volet :** Cours magistral

**MAT 5549 Géométrie algébrique (3 crédits)**

Quelques notions d'algèbre commutative, théorème des zéros de Hilbert, ensembles algébriques, topologie de Zariski. Variétés affines et projectives sur un corps algébriquement clos. Fonctions régulières et applications rationnelles. Sujets choisis parmi : la relation entre les variétés algébriques complexes et les variétés analytiques complexes; genres; diviseurs; fibrés en droites; Théorèmes de Riemann-Roch et de Bézout.

**Volet :** Cours magistral

Prerequisite: MAT 3143

**MAT 5551 Topologie I (3 crédits)**

Espaces topologiques; topologie produit et topologie quotient; axiomes de dénombrabilité et axiomes de séparation; espaces compacts, connexes; homotopie, groupe fondamental; convergence des filtres et des suites généralisées. Ce cours est équivalent à MATH 5205 à la Carleton University.

**Volet :** Cours magistral

Prerequisite: MAT 3153 (MATH 3001).

**MAT 5552 Topologie II (3 crédits)**

Revêtements, homologie (axiomes d'Eilenberg-Steenrod), applications, construction d'une théorie de l'homologie. Ce cours est équivalent à MATH 5206 à la Carleton University.

**Volet :** Cours magistral

Prerequisites: MAT 3143 and MAT 5151 (MATH 3100 and MATH 5205).

**MAT 5555 Variétés différentielles (3 crédits)**

Ce cours est équivalent à MATH 5208 à la Carleton University.

**Volet :** Cours magistral

**MAT 5558 Groupes de Lie I (3 crédits)**

Ce cours est équivalent à MATH 6104 à la Carleton University.

**Volet :** Cours magistral

**MAT 5565 Théorie des automates I (3 crédits)**

Ce cours est équivalent à MATH 5605 à la Carleton University.

**Volet :** Cours magistral



**MAT 5567 Langages formels et analyse syntactique (3 crédits)**

Ce cours est équivalent à MATH/COMP 5807 à la Carleton University.

**Volet :** Cours magistral

**MAT 5568 Homologie (3 crédits)**

Ce cours est équivalent à MATH 5202 à la Carleton University.

**Volet :** Cours magistral

**MAT 5570 Théorie des probabilités I (3 crédits)**

Espaces probabilisés, variables aléatoires, l'espérance mathématique définie comme une intégrale, lois conjointes, indépendance et mesure produit, répartitions et extensions de mesures de probabilité, lemmes de Borel-Cantelli, notions de convergence, suites de variables aléatoires indépendantes et équidistribuées. Ce cours est équivalent à STAT 5708 à la Carleton University.

**Volet :** Cours magistral

Prerequisites: MAT 3125 and MAT 3172 (MATH 3001, MATH 3002 and MATH 3500).

**MAT 5571 Théorie des probabilités II (3 crédits)**

Lois des grands nombres, fonctions caractéristiques, théorème-limite central, probabilité et espérance conditionnelles, propriétés élémentaires et théorèmes de convergence des martingales, introduction au mouvement brownien. Ce cours est équivalent à MATH 5709 à la Carleton University.

**Volet :** Cours magistral

Prerequisite: MAT 5170 (STAT 5708).

**MAT 5572 Processus stochastique : Chapitres choisis (3 crédits)**

Ce cours est équivalent à STAT 5508 à la Carleton University.

**Volet :** Cours magistral

**MAT 5576 Inférence statistique (3 crédits)**

Tests de signification pure; tests uniformément les plus puissants sans biais et sans variance; comparaison asymptotique des tests; intervalles de confiance; théorie des grands échantillons et tests du carré chi; inférence de la vraisemblance; inférence de Bayes; inférence empirique de Bayes; induction fiduciaire et structurale; méthodes de répétition de l'échantillonnage. Ce cours est équivalent à STAT 5507 à la Carleton University.

**Volet :** Cours magistral

Préalables : MAT 4170 ou l'équivalent, et MAT 5191.

**MAT 5577 Analyse multivariée normale (3 crédits)**

Ce cours est équivalent à STAT 5500 à la Carleton University.

**Volet :** Cours magistral

**MAT 5580 Analyse numérique I pour les équations différentielles (3 crédits)**

Arithmétique des nombres à virgule flottante; solution numérique des équations différentielles ordinaires; méthode des différences finies pour les équations aux dérivées partielles; stabilité, consistance et convergence : analyse de von Neumann, condition de Courant-Friedrichs-Lewy, théorème de Lax; méthode des éléments finis : problèmes aux limites et équations aux dérivées partielles elliptiques; méthodes Spectrale et Pseudo-Spectrale.

**Volet :** Cours magistral

**MAT 5590 Statistique mathématiques I (3 crédits)**

Théorie de la décision statistique; fonctions de vraisemblance; suffisance; théorème de factorisation; familles exponentielles; Estimateurs UMVU; Fonction d'information de Fisher; Limite inférieure de Cramer-Rao; maximum de vraisemblance et estimation du moment; estimation ponctuelle invariante et robuste; propriétés asymptotiques; Estimation ponctuelle bayésienne. Ce cours est équivalent au cours STAT 5600 à l'Université Carleton.

**Volet :** Cours magistral

Préalables : MAT 3172, MAT 3375. Les cours MAT 5775, MAT 5190 ne peuvent être combinés pour l'obtention de crédits.

**MAT 5591 Statistique mathématiques II (3 crédits)**

Intervalles de confiance et pivots; Intervalles bayésiens; tests optimaux et théorie de Neyman-Pearson; tests de vraisemblance et de Rao score; tests de signification; tests d'adéquation; théorie basée sur de grands échantillons et applications au maximum de vraisemblance et estimation robuste. Ce cours est équivalent à STAT 5501 à la Carleton University.

**Volet :** Cours magistral

Préalable : MAT 5590.

**MAT 5593 Modèles linéaires (3 crédits)**

Théorie des modèles linéaires des rangs non-exhaustifs : fonctions estimables, meilleurs estimateurs linéaires sans biais, vérification des hypothèses, régions de confiance; classification multidimensionnelle; analyse de la covariance; modèles de composantes de variance; méthode du maximum de vraisemblance; méthode MINQUE, ANOVA; sujets divers. Ce cours est équivalent à STAT 5503 à la Carleton University.

**Volet :** Cours magistral

Prerequisite for MAT 5593

**MAT 5595 Plan d'expériences (3 crédits)**

Aperçu de la théorie du modèle linéaire; orthogonalité; blocs complets avec randomisation totale, plans split plot; plans de carré latin; théorie du caractère aléatoire; plans de blocs incomplets; expériences factorielles; la théorie de la randomisation; les effets confondus et la replication fractionnelle; méthodologie de la surface de réponse; sujets divers.

**Volet :** Cours magistral

**MAT 5596 Analyse multivariée (3 crédits)**

Cours visant à donner à l'étudiant la possibilité d'entreprendre de la recherche mathématique dans le contexte d'un projet en collaboration avec un organisme parrain des secteurs public ou privé. Inclut des séminaires sur des sujets pertinents au projet de l'étudiant. Note finale de S (satisfaisant) ou NS (non satisfaisant) décidée par le professeur responsable du cours en consultation avec le superviseur du stage, fondée sur le contenu mathématique et sur la présentation orale et écrite des résultats. Ce cours est équivalent à STAT 5509 à la Carleton University.

**Volet :** Cours magistral

Préalable : Permission de l'Institut.

**MAT 5597 Optimisation stochastique (3 crédits)**

Ce cours est équivalent à STAT 5601 à la Carleton University.

**Volet :** Cours magistral

Prerequisite: STAT 3506 or MAT 4371.

**MAT 5598 Modèles stochastiques (3 crédits)**

Ce cours est équivalent à MATH 5701 à la Carleton University.

**Volet :** Cours magistral

**MAT 5709 Analyse harmonique sur les groupes (3 crédits)**

Ce cours est équivalent à MATH 6002 à la Carleton University.

**Volet :** Cours magistral

**MAT 5712 Topologie : Chapitres choisis (3 crédits)**

Ce cours est équivalent à MATH 6201 à la Carleton University.

**Volet :** Cours magistral

**MAT 5713 Topics in Probability and Statistics (3 crédits)**

Ce cours est équivalent à MATH 6507 à la Carleton University.

**Volet :** Cours magistral

**MAT 5714 Théories problèmes et statistique (3 crédits)**

Ce cours est équivalent à MATH 6508 à la Carleton University.

**Volet :** Cours magistral

**MAT 5715 Planification des sondages (3 crédits)**

**Volet :** Cours magistral

**MAT 5726 Analyse : Chapitres choisis (3 crédits)**

Ce cours est équivalent à MATH 6008 à la Carleton University.

**Volet :** Cours magistral

**MAT 5727 Algèbre - chapitres choisis : Introduction à la géométrie algébrique (3 crédits)**

Ce cours est équivalent à MATH 6101 à la Carleton University.

**Volet :** Cours magistral

**MAT 5728 Analyse : Chapitres choisis (3 crédits)**

Ce cours est équivalent à MATH 6008 à la Carleton University.

**Volet :** Cours magistral

**MAT 5729 Analyse : Chapitres choisis (3 crédits)**

Ce cours est équivalent à MATH 6009 à la Carleton University.

**Volet :** Cours magistral

**MAT 5730 Analyse : Chapitres choisis (3 crédits)**

Ce cours est équivalent à MATH 6102 à la Carleton University.

**Volet :** Cours magistral

**MAT 5731 Analyse : Chapitres choisis (3 crédits)**

Ce cours est équivalent à MATH 6103 à la Carleton University.

**Volet :** Cours magistral

**MAT 5761 Logique mathématique : Chapitres choisis (3 crédits)**

Ce cours est équivalent à MATH 6806 à la Carleton University.

**Volet :** Cours magistral

**MAT 5775 Introduction à la statistique mathématique (3 crédits)**

L'inférence statistique; distributions des statistiques classiques et les théorèmes central limites qui s'y rapportent; estimation paramétrique; statistique suffisante; estimateur efficace; paradigme Neyman-Pearson, tests de rapport de vraisemblance; méthodes paramétrique et non paramétrique pour la comparaison de deux échantillons; planification des expériences, analyse des données catégoriques, modèles linéaires généralisés, théorie de la décision et inférence Bayésienne. Ce cours est essentiel au étudiant(e)s en statistique appliquée. Ce cours est équivalent au cours STAT 5610 à l'Université Carleton.

**Volet :** Cours magistral

Les cours MAT 5775, MAT 5590 ne peuvent être combinés pour l'obtention de crédits.

**MAT 5990 Séminaire / Seminar (3 crédits / 3 units)**

Ce cours est équivalent à MATH 5900 à la Carleton University. / This course is equivalent to MATH 5900 at Carleton University.

**Volet / Course Component:** Cours magistral / Lecture

**MAT 5990S M.Sc. Séminaire / Seminar M.A. (3 crédits / 3 units)**

**Volet / Course Component:** Cours magistral / Lecture

**MAT 5990T Séminaire / Seminar (3 crédits / 3 units)**

**Volet / Course Component:** Cours magistral / Lecture

**MAT 5991 Travaux dirigés / Directed Studies (3 crédits / 3 units)**

Ce cours est équivalent à MATH 5901 à la Carleton University. / This course is equivalent to MATH 5901 at Carleton University.

**Volet / Course Component:** Recherche / Research

**MAT 5992 Seminar in Biostatistics (3 crédits / 3 units)**

Students work in teams on the analysis of experimental data or experimental plans. The participation of experimenters in these teams is encouraged. Student teams present their results in the seminar, and prepare a brief written report on their work.

**Volet / Course Component:** Cours magistral / Lecture

**MAT 5996 Stage de recherche / Research Internship (3 crédits / 3 units)**

Cours visant à donner à l'étudiant la possibilité d'entreprendre de la recherche mathématique dans le contexte d'un projet en collaboration avec un organisme parrain des secteurs public ou privé. Inclut des séminaires sur des sujets pertinents au projet de l'étudiant. Note finale S (satisfaisant) ou NS (non satisfaisant), à décider par le professeur responsable du cours en consultation avec le superviseur du stage, fondée sur le contenu mathématique et sur la présentation orale et écrite des résultats. / Project-oriented course affording students the opportunity to undertake research in applied mathematics as a cooperative project with governmental or industrial sponsors. Project work and seminars on related topics. Grade S (Satisfactory) or NS (Not satisfactory) to be assigned based upon the mathematical content as well as upon the oral and written presentation of results, and to be determined by the professor in charge of the course in consultation with the internship supervisor.

**Volet / Course Component:** Cours magistral / Lecture

**MAT 6990 Séminaire / Seminar (3 crédits / 3 units)**

Ce cours est équivalent à MATH 6900 à la Carleton University. / This course is equivalent to MATH 6900 at Carleton University.

**Volet / Course Component:** Cours magistral / Lecture

**MAT 6991 Travaux dirigés / Directed Studies (3 crédits / 3 units)**

Ce cours est équivalent à MATH 6901 à la Carleton University. / This course is equivalent to MATH 6901 at Carleton University.

**Volet / Course Component:** Recherche / Research

**MAT 6997 Projet en mathématiques et statistique / Project in Mathematics and Statistics (6 crédits / 6 units)**

Projet en mathématiques et statistique dirigé par un professeur approuvé par le directeur des études supérieures et donnant lieu à la rédaction d'un rapport approfondi (30-40 pages approx). Noté S (satisfaisant) ou NS (non satisfaisant) par le directeur du projet et un autre professeur nommé par le directeur des études supérieures en mathématiques et statistique. Le projet est normalement complété en une session. Ce cours est équivalent à MATH 5910 à la Carleton University. / Project in mathematics and statistics supervised by a professor approved by the director of graduate studies and leading to the writing of an in-depth report (approx. 30-40 pages). Graded S (Satisfactory) or NS (Not satisfactory) by the supervisor and by another professor appointed by the director of graduate studies in mathematics and statistics. The project will normally be completed in one session. This course is equivalent to MATH 5910 at Carleton University.

**Volet / Course Component:** Recherche / Research

Permission of the Department is required.

**MAT 9900 Examen de synthèse: Analyse réelle I / Comprehensive Exam: Real Analysis I**

Cet examen porte sur le contenu du cours MAT 5525. Cet examen est l'examen final du cours et est corrigé par les professeurs qui enseignent MAT 5525 et MAT 5526 dans l'année académique. Noté S (satisfaisant) ou NS (non satisfaisant). / This exam covers the content of the course MAT 5125. This exam is the final exam of the course and is graded by the professors who teach MAT 5125 and MAT 5126 in the academic year. Graded S (satisfactory) or NS (not satisfactory).

**Volet / Course Component:** Recherche / Research

**MAT 9901 Examen de synthèse: Analyse réelle II / Comprehensive Exam: Real Analysis II**

Cet examen porte sur le contenu du cours MAT 5526. Cet examen est l'examen final du cours et est corrigé par les professeurs qui enseignent MAT 5525 et MAT 5526 dans l'année académique. Noté S (satisfaisant) ou NS (non satisfaisant). / This exam covers the content of the course MAT 5126. This exam is the final exam of the course and is graded by the professors who teach MAT 5125 and MAT 5126 in the academic year. Graded S (satisfactory) or NS (not satisfactory).

**Volet / Course Component:** Recherche / Research

**MAT 9902 Examen de synthèse: Algèbre I / Comprehensive Exam: Algebra I**

Cet examen porte sur le contenu du cours MAT 5541. Cet examen est l'examen final du cours et est corrigé par les professeurs qui enseignent MAT 5541 et MAT 5542 dans l'année académique. Noté S (satisfaisant) ou NS (non satisfaisant). / This exam covers the content of the course MAT 5141. This exam is the final exam of the course and is graded by the professors who teach MAT 5141 and MAT 5142 in the academic year. Graded S (satisfactory) or NS (not satisfactory).

**Volet / Course Component:** Recherche / Research

**MAT 9903 Examen de synthèse: Algèbre II / Comprehensive Exam: Algebra II**

Cet examen porte sur le contenu du cours MAT 5542. Cet examen est l'examen final de ce cours et est corrigé par les professeurs qui enseignent MAT 5541 et MAT 5542 dans l'année académique. Noté S (satisfaisant) ou NS (non satisfaisant). / This exam covers the content of the course MAT 5142. This exam is the final exam of the course and is graded by the professors who teach MAT 5141 and MAT 5142 in the academic year. Graded S (satisfactory) or NS (not satisfactory).

**Volet / Course Component:** Recherche / Research

**MAT 9904 Examen de synthèse: Topologie I / Comprehensive Exam: Topology I**

Cet examen porte sur le contenu du cours MAT 5551. Cet examen est l'examen final du cours et est corrigé par les professeurs qui enseignent MAT 5551 et MAT 5552 dans l'année académique. Noté S (satisfaisant) ou NS (non satisfaisant). / This exam covers the content of the course MAT 5151. This exam is the final exam of the course and is graded by the professors who teach MAT 5151 and MAT 5152 in the academic year. Graded S (satisfactory) or NS (not satisfactory).

**Volet / Course Component:** Recherche / Research

**MAT 9905 Examen de synthèse: Topologie II / Comprehensive Exam: Topology II**

Cet examen porte sur le contenu du cours MAT 5552. Cet examen est l'examen final du cours et est corrigé par les professeurs qui enseignent MAT 5551 et MAT 5552 dans l'année académique. Noté S (satisfaisant) ou NS (non satisfaisant). / This exam covers the content of the course MAT 5152. This exam is the final exam of the course and is graded by the professors who teach MAT 5151 and MAT 5152 in the academic year. Graded S (satisfactory) or NS (not satisfactory).

**Volet / Course Component:** Recherche / Research

**MAT 9906 Examen de synthèse: Équations différentielles I / Comprehensive Exam: Differential Equations I**

Cet examen porte sur le contenu du cours MAT 5531. Cet examen est l'examen final du cours et est corrigé par les professeurs qui enseignent MAT 5531 et MAT 5533 dans l'année académique. Noté S (satisfaisant) ou NS (non satisfaisant). / This exam covers the content of the course MAT 5131. This exam is the final exam of the course and is graded by the professors who teach MAT 5131 and MAT 5133 in the academic year. Graded S (satisfactory) or NS (not satisfactory).

**Volet / Course Component:** Recherche / Research

**MAT 9907 Examen de synthèse: Équations différentielles II / Comprehensive Exam: Differential Equations II**

Cet examen porte sur le contenu du cours MAT 5533. Cet examen est l'examen final du cours et est corrigé par les professeurs qui enseignent MAT 5531 et MAT 5533 dans l'année académique. Noté S (satisfaisant) ou NS (non satisfaisant). / This exam covers the content of the course MAT 5133. This exam is the final exam of the course and is graded by the professors who teach MAT 5131 and MAT 5133 in the academic year. Graded S (satisfactory) or NS (not satisfactory).

**Volet / Course Component:** Recherche / Research

**MAT 9908 Examen de synthèse: Mathématiques discrètes I / Comprehensive Exam: Discrete Mathematics I**

Cet examen porte sur le contenu du cours MAT 5505. Cet examen est l'examen final sur cours et est corrigé par les professeurs qui enseignent MAT 5505 et MAT 5507 dans l'année académique. Noté S (satisfaisant) ou NS (non satisfaisant). / This exam covers the content of the course MAT 5105. This exam is the final exam of the course and is graded by the professors who teach MAT 5105 and MAT 5107 in the academic year. Graded S (satisfactory) or NS (not satisfactory).

**Volet / Course Component:** Recherche / Research

**MAT 9909 Examen de synthèse: Mathématiques discrètes II / Comprehensive Exam: Discrete Mathematics II**

Cet examen porte sur le contenu du cours MAT 5507. Cet examen est l'examen final du cours et est corrigé par les professeurs qui enseignent MAT 5505 et MAT 5507 dans l'année académique. Noté S (Satisfaisant) et NS (non satisfaisant). / This exam covers the content of the course MAT 5107. This exam is the final exam of the course and is graded by the professors who teach MAT 5105 and MAT 5107 in the academic year. Graded S (satisfactory) or NS (not satisfactory).

**Volet / Course Component:** Recherche / Research

**MAT 9910 Examen de synthèse: Théories des probabilités I / Comprehensive Exam: Probability Theory I**

Cet examen porte sur le contenu du cours MAT 5570. Cet examen est l'examen final du cours et est corrigé par les professeurs qui enseignent MAT 5570 et MAT 5571 dans l'année académique. Noté S (satisfaisant) et NS (non satisfaisant). / This exam covers the content of the course MAT 5170. This exam is the final exam of the course and is graded by the professors who teach MAT 5170 and MAT 5171 in the academic year. Graded S (satisfactory) or NS (not satisfactory).

**Volet / Course Component:** Recherche / Research

**MAT 9911 Examen de synthèse: Théories des probabilités II / Comprehensive Exam: Probability Theory II**

Cet examen porte sur le contenu du cours MAT 5571. Cet examen est l'examen final du cours et est corrigé par les professeurs qui enseignent MAT 5570 et MAT 5571 dans l'année académique. Noté S (satisfaisant) ou NS (non satisfaisant). / This exam covers the content of the course MAT 5171. This exam is the final exam of the course and is graded by the professors who teach MAT 5170 and MAT 5171 in the academic year. Graded S (satisfactory) or NS (not satisfactory).

**Volet / Course Component:** Recherche / Research

**MAT 9912 Examen de synthèse: Statistique mathématiques I /**

**Comprehensive Exam: Mathematical Statistics I**

cet examen porte sur le contenu du cours MAT5590. Cet examen est l'examen final du cours et est corrigé par les professeurs qui enseignent MAT5590 et MAT5591 dans l'année académique. Noté S (satisfaisant) ou NS (non satisfaisant). / This exam covers the content of the course MAT 5190. This exam is the final exam of the course and is graded by the professors who teach MAT 5190 and MAT 5191 in the academic year. Graded S (satisfactory) or NS (not satisfactory).

**Volet / Course Component:** Recherche / Research

**MAT 9913 Examen de synthèse: Statistique et mathématiques II /**

**Comprehensive Exam: Mathematical Statistics II**

Cet examen porte sur le contenu du cours MAT5591. Cet examen est l'examen final du cours et est corrigé par les professeurs qui enseignent MAT5590 et MAT5591 dans l'année académique. Noté S (satisfaisant) ou NS (non satisfaisant). / This exam covers the content of the course MAT 5191. This exam is the final exam of the course and is graded by the professors who teach MAT 5190 and MAT 5191 in the academic year. Graded S (satisfactory) or NS (not satisfactory).

**Volet / Course Component:** Recherche / Research

**MAT 9998 Examen de synthèse avancé / Advanced Comprehensive Examination**

Le syllabus pour l'examen de synthèse avancé est déterminé par le comité consultatif de thèse (CCT). Le syllabus devrait être fourni à l'étudiant au moins six mois avant la date de l'examen. Le syllabus doit contenir la forme, le contenu et les attentes pour l'examen de synthèse avancé. L'examen de synthèse avancé peut être écrit ou/et oral. Noté S (satisfaisant) ou NS (non satisfaisant). / The syllabus of the advanced comprehensive examination is prescribed by the thesis advisory committee (TAC). The syllabus should be given to the student at least six months before the date of the examination. The syllabus must provide the form, contents and expectations for the advanced comprehensive examination. The advanced comprehensive examination can be written and/or oral. Graded S (satisfactory) or NS (non satisfactory).

**Volet / Course Component:** Recherche / Research