

# DOCTORATE IN PHILOSOPHY MATHEMATICS AND STATISTICS AND SPECIALIZATION BIOINFORMATICS

## Overview

### Summary

- Degree offered: Doctorate in Philosophy (PhD)
- Registration status option: Full-time
- Language of instruction: English
- Primary program: PhD in Mathematics and Statistics
- Collaborative specialization: Bioinformatics
- 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

The programs prepare candidates for a variety of careers in teaching and research both within and outside of academia. Graduate students are actively involved in laboratory research, course work, and presentation of research seminars. Thus, they acquire autonomy in conducting research and in preparing publications. The programs create a stimulating and challenging environment which will allow students to achieve excellence in research. Graduates of the programs must demonstrate research skills and credibility as professionals in their area of research. The Department is a participating unit in the Bioinformatics collaborative program.

## Collaborative Program Description

Bioinformatics is an emerging and increasingly important scientific discipline dedicated to the pursuit of fundamental questions about the structure, function and evolution of biological entities through the design and application of computational approaches. Fundamental research in these areas is expected to increase our understanding of human health and disease which translates into innovation in industry. Bioinformaticians today must be able to appreciate significant research in other fields and therefore require an understanding of the basic principles of other disciplines. The degree awarded specifies the primary program and indicates "specialization in Bioinformatics."

## Main Areas of Research

- Genomics, transcriptomics, and proteomics
- Probability and statistics
- Discrete mathematics
- Machine learning

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

- Doctorate in Philosophy Mathematics and Statistics (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 academic regulations (<https://www.uottawa.ca/about-us/leadership-governance/policies-regulations/>) in effect for graduate studies.
- 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 either in English, French or both, depending on the language used by the professor and the members of his or her 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

Tel.: 613-562-5800 x 3145

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 science (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.
- The requirements outlined above are a minimum. The Admission Committee reserves the right to add any course considered essential in light of the student's background. The courses BNF 5106 and/or BNF 6100 could be added to the student's program 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 thesis director must be a member of the collaborative program.

## Language Requirements

Applicants must be able to understand and fluently speak the language of instruction 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 academic regulations (<https://www.uottawa.ca/about-us/leadership-governance/policies-regulations/>) in effect for graduate studies.
- Students must indicate in their initial application for admission to the master's program in Biochemistry that they wish to be accepted into the collaborative program in Bioinformatics. Students must be admitted in one of the primary programs participating in the collaborative program. Students will normally be informed about their acceptance into the collaborative program at the same time as being informed about their admission into the primary program.

- Research activities can be conducted either in English, French or both, depending on the language used by the professor and the members of his or her research group.

## Fast-Track from Master's to PhD

Students enrolled in the master's program in Mathematics and Statistics with specialization in Bioinformatics 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:

- Maintain an A- average during their graduate studies and in the last two years of undergraduate studies.
- Complete all the core courses required for the M.Sc.
- Demonstrate a satisfactory progress in the research program.
- Provide a written recommendation by the thesis supervisor.
- Provide a written recommendation by the Departmental Graduate Studies Committee.

Note: The transfer must take place within sixteen months of initial enrollment in the master's. Please note that the minimal admission average requirements for the doctoral program must also be met. Following transfer, all of the requirements of the doctoral program must be met.

## Program Requirements Doctorate with specialization

Students must meet the following requirements:

### Compulsory Courses:

18 optional course units in mathematics (MAT) at the graduate level	18 Units
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6 course units in Bioinformatics (BNF) at the 5000 or 8000 level <sup>1,2,3</sup>	6 Units
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### Seminar:

BNF 8166 Seminar in Bioinformatics <sup>4</sup>	3 Units
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### Comprehensive Examination:

#### Two options from the following: <sup>2,3</sup>

#### Option 1: Real Analysis

MAT 9900	Comprehensive Exam: Real Analysis I
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MAT 9901	Comprehensive Exam: Real Analysis II
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#### Option 2: Algebra

MAT 9902	Comprehensive Exam: Algebra I
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MAT 9903	Comprehensive Exam: Algebra II
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#### Option 3: Topology

MAT 9904	Comprehensive Exam: Topology I
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MAT 9905	Comprehensive Exam: Topology II
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#### Option 4: Differential Equations

MAT 9906	Comprehensive Exam: Differential Equations I
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MAT 9907	Comprehensive Exam: Differential Equations II
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#### Option 5: Discrete Mathematics

MAT 9908	Comprehensive Exam: Discrete Mathematics I
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MAT 9909	Comprehensive Exam: Discrete Mathematics II
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#### 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
<b>Comprehensive Examination:</b>	
MAT 9998	Advanced Comprehensive Examination
<b>Thesis:</b>	
THD 9999	Doctoral Thesis <sup>5,6</sup>

#### Note(s)

- <sup>1</sup> The Department may require students to take additional courses, depending on their backgrounds.
- <sup>2</sup> Students in the PhD with specialization in bioinformatics program who already have taken BNF 5106 and BNF 6100 (or only one of them) will be required to take two (or only one, respectively) of BNF 5107, BNF 5504, or BNF 8301.
- <sup>3</sup> The optional course units may be selected from other approved graduate courses in related disciplines approved by the Department.
- <sup>4</sup> The seminar course in bioinformatics involves a written report, the presentation of a seminar, and regular attendance at departmental seminars.
- <sup>5</sup> Successful presentation and defence of a research thesis on a topic in bioinformatics based on original research carried out under the supervision of a faculty member participating in the bioinformatics collaborative program.
- <sup>6</sup> Students are responsible for ensuring they have met all of the thesis requirements.

## Research

### Research at the University of Ottawa

Located in the heart of Canada's capital, a few steps away from Parliament Hill, the University of Ottawa ranks among Canada's top 10 research universities. Our research is founded on excellence, relevance and impact and is conducted in a spirit of equity, diversity and inclusion.

Our research community thrives in four strategic areas:

- Creating a sustainable environment
- Advancing just societies
- Shaping the digital world
- Enabling lifelong health and wellness

From advancing healthcare solutions to tackling global challenges like climate change, the University of Ottawa's researchers are at the forefront of innovation, making significant contributions to society and beyond.

### 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.

## Courses

### BNF 5104 Bioinformatics Laboratory (3 units)

Principles of organization, retrieval, manipulation, and analysis of molecular data in genomics, proteomics and transcriptomics. Hands-on analysis of these data to solve biological questions using quantitative and computational methods. This course is equivalent to BIOL 5104 at Carleton University. Prerequisites: Graduate standing and permission of the instructor

**Course Component:** Laboratory, Lecture

### BNF 5106 Bioinformatics (3 units)

Major concepts and methods of bioinformatics. Topics may include, but are not limited to: genetics, statistics & probability theory, alignments, phylogenetics, genomics, data mining, protein structure, cell simulation and computing.

**Course Component:** Lecture

### BNF 5107 Applied Bioinformatics (3 units)

Computational knowledge discovery in and the dynamic nature of cellular networks. Includes, but is not limited to, knowledge representation, large scale data integration, data mining and computational systems biology. This course is equivalent to BIOL 5516 at Carleton University.

**Course Component:** Lecture

### BNF 5504 Laboratoire de bioinformatique (3 crédits)

Principes d'organisation, de récupération, de manipulation et d'analyse de données moléculaires en génomique, protéomique et transcriptomique. Analyses pratiques de ces données pour résoudre des questions biologiques en utilisant des méthodes quantitatives et computationnelles.

**Volet :** Théorie et laboratoire

Les cours BPS 4504 et BNF 5504 ne peuvent être combinés pour l'obtention de crédits.

### BNF 5506 Bioinformatique (3 crédits)

Concepts et méthodes en bioinformatique. Les sujets abordés peuvent inclure, entre autres, la génétique, les statistiques et les théories des probabilités, les alignements, la phylogénétique, la génomique et la structure de protéines.

**Volet :** Cours magistral

### BNF 6100 MSc Seminar (3 units)

Current topics in bioinformatics presented by program professors and invited speakers. Oral presentation and written report required. Graded S (Satisfactory) / NS (Not satisfactory).

**Course Component:** Lecture

### **BNF 6500 Séminaire de maîtrise (3 crédits)**

Sujets courants en bioinformatique présentés par des professeurs membres du programme et des conférenciers invités. Présentation orale et rapport écrit requis. Noté S (satisfaisant) ou NS (non satisfaisant).

**Volet :** Cours magistral

### **BNF 8166 Seminar in Bioinformatics (3 units)**

Current research topics in bioinformatics presented by PhD students and invited speakers. Oral presentation required. Graded S (Satisfactory) / NS (Not satisfactory).

**Course Component:** Seminar

### **BNF 8301 Evolutionary Bioinformatics (3 units)**

Fundamental concepts in molecular evolution and hands-on experience with computer analysis of DNA sequences. Topics may include molecular sequence databases, multiple alignments and phylogenetic trees. This course is equivalent to BIOL 5201 at Carleton University.

**Course Component:** Lecture

Prerequisite: Graduate standing plus basic courses in genetics and evolution.

### **BNF 8766 Séminaire en bioinformatique (3 crédits)**

Sujets courants en bioinformatique présentés par des étudiants en PhD et des conférenciers invités. Présentation orale requise. Noté S (satisfaisant) ou NS (non satisfaisant).

**Volet :** Séminaire

### **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 3120 (MATH 3001).

### **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-Hölder 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 and probability measures, sigma-fields, random variables and distributions, expected values as Lebesgue integrals, change-of-variable formula, laws of large numbers, integral inequalities, convergence theorems, uniform integrability, product measures, Fubini's theorem, independence and related topics, Borel–Cantelli lemmas, maximal inequalities, modes of convergence, central limit theorem, characteristic functions. This course is equivalent to STAT 5708 at Carleton University.

**Course Component:** Lecture

Prerequisites: MAT 3120, MAT 3172 (MATH 3001, 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 STAT 5709 at Carleton University.

**Course Component:** Lecture

Prerequisite: MAT 5170.

### **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 pivotals; 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 5199 Nonparametric Statistics (3 units)**

Classical nonparametric techniques; nonparametric density estimation; nonparametric regression analysis: kernel estimators, orthogonal series estimators, smoothing splines; estimation of statistical functionals; nonparametric bootstrap; jackknife; elements of highdimensional statistical inference; multiple testing and false discovery. Statistical software will be used. This course is equivalent to STAT 5516 at Carleton University.

**Course Component:** Lecture

Prerequisite : MAT 5375 or MAT 5190.

### **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 STAT 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 Game 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 3520 (MATH 3001).

### **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 transcendentes. 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 de probabilité et mesures de probabilité, sigma-algèbres, variables aléatoires et répartitions, l'espérance mathématique définie comme une intégrale de Lebesgue, formule de changement de variable, lois des grands nombres, inégalités intégrales, théorèmes de convergence, intégrabilité uniforme, mesure produit, théorème de Fubini, indépendance et sujets liés à l'indépendance, lemmes de Borel-Cantelli, inégalités maximales, modes de convergence, théorème central limite, fonctions caractéristiques. Ce cours est équivalent à STAT 5708 à la Carleton University.

**Volet :** Cours magistral

Préalables : MAT 3520, MAT 3572 (MATH 3001, 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 1**

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 MAT5533. 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 MAT5505. Cet examen est l'examen final sur cours et est corrigé par les professeurs qui enseignent MAT 5505 et MAT5507 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 MAT5507. Cet examen est l'examen final du cours et est corrigé par les professeurs qui enseignent MAT5505 et MAT5507 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 MAT5570. Cet examen est l'examen final du cours et est corrigé par les professeurs qui enseignent MAT 5570 et MAT5571 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 MAT5571. Cet examen est l'examen final du cours et est corrigé par les professeurs qui enseignent MAT5570 et MAT5571 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