Biostatistics

- **M.Sc. Mathematics: Specialization in Biostatistics (Collaborative program)**

M.Sc. Mathematics: Specialization in Biostatistics (Collaborative program)

About the Program

The Specialization in Biostatistics is an interdisciplinary area of research linking statistics, biology, medicine, and health sciences. The specialization is intended to prepare a student for a career as a biostatistician in a health-related industry, or for a doctoral program in biostatistics.

The program is administered by a committee of representatives from the primary departments, which include the Department of Epidemiology and Community Medicine at the University of Ottawa, the Department of Mathematics and Statistics at Carleton University and the Department of Mathematics and Statistics at the University of Ottawa. Application is made to the primary department most appropriate to the student's research interests. The title of the degree will specify the discipline of the participating unit with specialization in biostatistics.

Academic Regulations

See the General Regulations section of this Calendar.

Admission Requirements

Honours B.Sc. with high honours standing (or the equivalent) in statistics and experience in the analysis of data. Students in this stream follow a program with an emphasis in clinical trial design or epidemiologic methodology.

Students should normally apply for acceptance in the Specialization in Biostatistics at the same time as they apply for admission into the master's program in Mathematics. If accepted into the regular program, the student will then be considered by the program coordinators for admission into the Specialization.

Students intending to apply for admission to the Specialization should normally contact prospective thesis supervisors before submitting the application and establish a thesis supervisor and research topic.

Program Requirements

M.Sc. Mathematics: Specialization in Biostatistics - Thesis option (5.0 credits)

1. 3.5 credits	3.5
2. 0.5 credit in:	0.5
STAT 5902 [0.5] Seminar in Biostatistics	
3. 1.0 credit in Thesis	1.0
Total Credits	5.0

M.Sc. Mathematics: Specialization in Biostatistics - Coursework option (5.0 credits)

1. 4.5 credits in courses	4.5
2. 0.5 credit in:	0.5
STAT 5902 [0.5] Seminar in Biostatistics	
Total Credits	5.0

Unless prior approval by the Director of the collaborative program has been obtained, students in the M.Sc. Mathematics program should take EPI 5240, EPI 5241, EPI 6178, EPI 6278, STAT 5600 (MAT 5375) or STAT 5610 (MAT 5375), and STAT 5501 (MAT 5191) or STAT 5602 (MAT 5317). The remaining courses should be in Mathematics and Statistics at the graduate level. The degree awarded will in each case specify the discipline of the participating unit with Specialization in Biostatistics.

Most of the program requirements must be fulfilled in English. Students may write papers, submit theses and write examinations in both English and French.

Thesis

The thesis may contain new research in the area of mathematics and statistics or provide a review of the literature in one area. The thesis normally will be on statistics applied to health or biology; for example, the development of a new statistical procedure, the design of a new experiment or the analysis of data. The thesis should extend beyond the routine analysis of data. The supervisor and other members of the examination board may be drawn from faculty members in either epidemiology or mathematics and statistics or in other related departments.

Related Courses

Not all of the following courses are offered in a given year. For an up-to-date statement of course offerings and to determine the term of offering, visit central.carleton.ca. University of Ottawa course numbers (in parentheses, three letters followed by four numbers) follow the Carleton course number. Consult the relevant courses section for a full description of each course.

Biostatistics

STAT 5902 (MAT 5992)	Seminar in Biostatistics

Mathematics, Statistics

MATH 5909 (MAT 7999)	M.Sc. Thesis
STAT 5501 (MAT 5191)	Mathematical Statistics II
STAT 5600 (MAT 5190)	Mathematical Statistics I
STAT 5602 (MAT 5317)	Analysis of Categorical Data
STAT 5610 (MAT 5375)	Introduction to Mathematical Statistics
STAT 5902 (MAT 5375)	Seminar in Biostatistics

Epidemiology

- EPI 5240 Epidemiology I
- EPI 5241 Epidemiology II
- EPI 5330 Vital and Health Statistics
- EPI 6178 Clinical Trials
- EPI 6278 Advanced Clinical Trials

Mathematics (MATH) Courses

MATH 5003 [0.5 credit] (MAT 5122)
Banach Algebras
Commutative Banach algebras; the space of maximal ideals; representation of Banach algebras as function algebras and as operator algebras; the spectrum of an element. Special types of Banach algebras: for example, regular algebras with involution, applications.

MATH 5005 [0.5 credit] (MAT 5127)
Complex Analysis
Complex differentiation and integration, harmonic functions, maximum modulus principle, Runge's theorem, conformal mapping, entire and meromorphic functions, analytic continuation.

MATH 5007 [0.5 credit] (MAT 5125)
Real Analysis I (Measure Theory and Integration)
General measure and integral, Lebesgue measure and integration on R, Fubini's theorem, Lebesgue-Radon-Nikodym theorem, absolute continuity and differentiation, LP-spaces. Selected topics such as Daniell-Stone theory. Also offered, with different requirements, as MATH 4007 for which additional credit is precluded.
Prerequisite(s): MATH 3001 or permission of the School.

MATH 5008 [0.5 credit] (MAT 5126)
Real Analysis II (Functional Analysis)
Banach and Hilbert spaces, bounded linear operators, dual spaces. Topics selected from: weak-topologies, Alaoglu's theorem, compact operators, differential calculus in Banach spaces, Riesz representation theorems. Also offered, with different requirements, as MATH 4003 for which additional credit is precluded.
Prerequisite(s): MATH 4007 or MATH 5007 (MAT 5125) or permission of the School.

MATH 5009 [0.5 credit] (MAT 5121)
Introduction to Hilbert Space
Geometry of Hilbert Space, spectral theory of linear operators in Hilbert Space.
Prerequisite(s): MATH 3001 and MATH 4003.

MATH 5102 [0.5 credit] (MAT 5148)
Group Representations and Applications
An introduction to group representations and character theory, with selected applications.

MATH 5103 [0.5 credit] (MAT 5146)
Rings and Modules
Generalizations of the Wedderburn-Artin theorem and applications, homological algebra.

MATH 5104 [0.5 credit] (MAT 5143)
Lie Algebras
Basic concepts: ideals, homomorphisms, nilpotent, solvable, semi-simple. Representations, universal enveloping algebra. Semi-simple Lie algebras: structure theory, classification, and representation theory.
Prerequisite(s): MATH 5107 (MAT 5141) and MATH 5109 (MAT 5142) or permission of the School.

MATH 5106 [0.5 credit] (MAT 5145)
Group Theory
Fundamental principles as applied to abelian, nilpotent, solvable, free, and finite groups; representations. Also offered, with different requirements, as MATH 4106, for which additional credit is precluded.
Prerequisite(s): MATH 3106 or permission of the School.

MATH 5107 [0.5 credit] (MAT 5141)
Algebra I
Groups, Sylow subgroups, finitely generated abelian groups. Rings, field of fractions, principal ideal domains, modules. Polynomial algebra, Euclidean algorithm, unique factorization.
Prerequisite(s): permission of the School.

MATH 5108 [0.5 credit] (MAT 5147)
Homological Algebra and Category Theory
Axioms of set theory, categories, functors, natural transformations; free, projective, injective and flat modules; tensor products and homology functors, derived functors; dimension theory. Also offered, with different requirements, as MATH 4108 for which additional credit is precluded.
Prerequisite(s): MATH 3106 and MATH 3158 or permission of the School.

MATH 5109 [0.5 credit] (MAT 5142)
Algebra II
Field theory, algebraic and transcendental extensions, finite fields, Galois groups. Modules over principal ideal domains, decomposition of a linear transformation, Jordan normal form.
Prerequisite(s): MATH 5107 (MAT 5141) and permission of the School.

MATH 5201 [0.5 credit] (MAT 5150)
Topics in Geometry
Various axiom systems of geometry. Detailed examinations of at least one modern approach to foundations, with emphasis upon the connections with group theory.
Prerequisite(s): permission of the School.

MATH 5202 [0.5 credit] (MAT 5168)
Homology Theory
The Eilenberg-Steenrod axioms and their consequences, singular homology theory, applications to topology and algebra.
Prerequisite(s): MATH 4205 or MATH 5205 (MAT 5151).

MATH 5205 [0.5 credit] (MAT 5151)
Topology I
Topological spaces, product and identification topologies, countability and separation axioms, compactness, connectedness, homotopy, fundamental group, net and filter convergence. Also offered, with different requirements, as MATH 4205 for which additional credit is precluded.
Prerequisite(s): MATH 3001 or permission of the School.

MATH 5206 [0.5 credit] (MAT 5152)
Topology II
Covering spaces, homology via the Eilenberg-Steenrod Axioms, applications, construction of a homology functor. Also offered, with different requirements, as MATH 4206 for which additional credit is precluded.
Prerequisite(s): MATH 3106, MATH 3158 and MATH 5205 (MAT 5151) or permission of the School.

MATH 5207 [0.5 credit] (MAT 5169)
Foundations of Geometry
A study of at least one modern axiom system of Euclidean and non-Euclidean geometry, embedding of hyperbolic and Euclidean geometries in the projective plane, groups of motions, models of non-Euclidean geometry.
Prerequisite(s): MATH 3106 (may be taken concurrently) or permission of the School.

MATH 5208 [0.5 credit] (MAT 5155)
Differentiable Manifolds
A study of differentiable manifolds from the point of view of either differential topology or differential geometry. Topics such as smooth mappings, transversality, intersection theory, vector fields on manifolds, Gaussian curvature, Riemannian manifolds, differential forms, tensors, and connections are included.
Prerequisite(s): MATH 3001 or permission of the School.

MATH 5300 [0.5 credit] (MAT 5160)
Mathematical Cryptography
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.
Prerequisite(s): undergraduate honours algebra, including group theory and finite fields.

MATH 5301 [0.5 credit] (MAT 5161)
Mathematical Logic
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.
Prerequisite(s): Honours undergraduate algebra, analysis and topology or permission of the instructor.

MATH 5305 [0.5 credit] (MAT 5163)
Analytic Number Theory
Dirichlet series, characters, Zeta-functions, prime number theorem, Dirichlet's theorem on primes in arithmetic progressions, binary quadratic forms.
Prerequisite(s): MATH 3057 or permission of the School.

MATH 5306 [0.5 credit] (MAT 5164)
Algebraic Number Theory
Algebraic number fields, bases, algebraic integers, integral bases, arithmetic in algebraic number fields, ideal theory, class number. Also offered, with different requirements, as MATH 4306 for which additional credit is precluded.
Prerequisite(s): MATH 3158 or permission of the School.

MATH 5403 [0.5 credit] (MAT 5187)
Topics in Applied Mathematics

MATH 5405 [0.5 credit] (MAT 5131)
Ordinary Differential Equations
Linear systems, fundamental solution. Nonlinear systems, existence and uniqueness, flow. Equilibria, periodic solutions, stability. Invariant manifolds and hyperbolic theory. One or two specialized topics taken from, but not limited to: perturbation and asymptotic methods, normal forms and bifurcations, global dynamics.
Prerequisite(s): MATH 3008 or permission of the School.

MATH 5406 [0.5 credit] (MAT 5133)
Partial Differential Equations
First-order equations, characteristics method, classification of second-order equations, separation of variables, Green's functions. Lp and Sobolev spaces, distributions, variational formulation and weak solutions, Lax-Milgram theorem, Galerkin approximation. Parabolic PDEs. Wave equations, hyperbolic systems, nonlinear PDEs, reactiondiffusion equations, infinite-dimensional dynamical systems, regularity.
Prerequisite(s): MATH 3008 or permission of the School.

MATH 5407 [0.5 credit] (MAT 5134)
Topics in Partial Differential Equations
Theory of distributions, initial-value problems based on two-dimensional wave equations, Laplace transform, Fourier integral transform, diffusion problems, Helmholtz equation with application to boundary and initial-value problems in cylindrical and spherical coordinates. Also offered, with different requirements, as MATH 4701 for which additional credit is precluded.
Prerequisite(s): MATH 5406 or permission of the School.

MATH 5408 [0.5 credit] (MAT 5185)
Asymptotic Methods of Applied Mathematics
Asymptotic series: properties, matching, application to 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.
Prerequisite(s): MATH 3057 and at least one of MATH 3008 and MATH 3705, or permission of the School.

MATH 5605 [0.5 credit] (MAT 5165)
Theory of Automata
Algebraic structure of sequential machines, de-composition of machines; finite automata, formal languages; complexity. Also offered, with different requirements, as MATH 4805/COMP 4805 for which additional credit is precluded.
Prerequisite(s): MATH 2100 or permission of the School.

MATH 5607 [0.5 credit] (MAT 5324)
Game Theory
Two-person zero-sum games; infinite games; multi-stage games; differential games; utility theory; two-person general-sum games; bargaining problem; n-person games; games with a continuum of players. Also offered, with different requirements, as MATH 4807 for which additional credit is precluded.
Prerequisite(s): MATH 3001 or permission of the School.

MATH 5609 [0.5 credit] (MAT 5301)
Topics in Combinatorial Mathematics
Prerequisite(s): permission of the School.

MATH 5801 [0.5 credit] (MAT 5303)
Linear Optimization
Linear programming problems; simplex method, upper bounded variables, free variables; duality; postoptimality analysis; linear programs having special structures; integer programming problems; unimodularity; knapsack problem.
Prerequisite(s): course in linear algebra and permission of the School.

MATH 5802 [0.5 credit] (MAT 5325)
Introduction to Information and Systems Science
Introduction to the process of applying computers in problem solving. Emphasis on the design and analysis of efficient computer algorithms for large, complex problems. Applications: data manipulation, databases, computer networks, queuing systems, optimization.
Also listed as SYSC 5802, COMP 5802 and ISYS 5802.

MATH 5803 [0.5 credit] (MAT 5304)
Nonlinear Optimization
Methods for unconstrained and constrained optimization problems; Kuhn-Tucker conditions; penalty functions; duality; quadratic programming; geometric programming; separable programming; integer nonlinear programming; pseudo-Boolean programming; dynamic programming.
Prerequisite(s): permission of the School.

MATH 5804 [0.0 credit] (MAT 5307)
Topics in Operations Research

MATH 5805 [0.05 credit] (MAT 5308)
Topics in Algorithm Design

MATH 5806 [0.5 credit] (MAT 5180)
Numerical Analysis
Error analysis for fixed and floating point arithmetic; systems of linear equations; eigen-value problems; sparse matrices; interpolation and approximation, including Fourier approximation; numerical solution of ordinary and partial differential equations.
Prerequisite(s): permission of the School.

MATH 5807 [0.5 credit] (MAT 5167)
Formal Language and Syntax Analysis
Computability, unsolvable and NP-hard problems. Formal languages, classes of language automata. Principles of compiler design, syntax analysis, parsing (top-down, bottom-up), ambiguity, operator precedence, automatic construction of efficient parsers, LR, LR(O), LR(k), SLR, LL(k). Syntax directed translation.
Also listed as COMP 5807.
Prerequisite(s): MATH 5605 or MATH 4805 or COMP 3002, or permission of the School.

MATH 5808 [0.5 credit] (MAT 5305)
Combinatorial Optimization I
Network flow theory and related material. Topics will include shortest paths, minimum spanning trees, maximum flows, minimum cost flows. Optimal matching in bipartite graphs.
Prerequisite(s): permission of the School.

MATH 5809 [0.5 credit] (MAT 5306)
Combinatorial Optimization II
Topics include optimal matching in non-bipartite graphs, Euler tours and the Chinese Postman problem. Other extensions of network flows: dynamic flows, multicommodity flows, and flows with gains, bottleneck problems. Matroid optimization. Enumerative and heuristic algorithms for the Traveling Salesman and other "hard" problems.
Prerequisite(s): MATH 5808.

MATH 5818 [0.5 credit] (MAT 5105)
Discrete Applied Mathematics I: Graph Theory
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 graph theory, random graphs.
Prerequisite(s): MATH 3855 or permission of the School.

MATH 5819 [0.5 credit] (MAT 5107)
Discrete Applied Mathematics II: Combinatorial Enumeration
Ordinary and exponential generating functions, product formulas, permutations, 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.
Prerequisite(s): MATH 3855 or permission of the School.

MATH 5821 [0.5 credit] (MAT 5341)
Quantum Computing
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.
Prerequisite(s): MATH 1102, or permission of the School.

MATH 5822 [0.5 credit] (MAT 5343)
Mathematical Aspects of Wavelets and Digital Signal Processing
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. Also offered, with different requirements, as MATH 4822, for which additional credit is precluded.
Prerequisites: Linear algebra and Fourier series, or permission of the School.
Prerequisite(s): Linear algebra and Fourier series, or permission of the School.

MATH 5900 [0.5 credit] (MAT 5990)
Seminar

MATH 5901 [0.5 credit] (MAT 5991)
Directed Studies

MATH 5903 [0.5 credit]
Project
Intended for students registered in Information and Systems Science and M.C.S. programs. Students pursuing the non-thesis option will conduct a study, analysis, and/or design project. Results will be given in the form of a typewritten report and oral presentation.

MATH 5906 [0.5 credit] (MAT 5993)
Research Internship
This course affords students the opportunity to undertake research in mathematics as a cooperative project with governmental or industrial sponsors. The grade will be based upon the mathematical content and upon oral and written presentation of results.
Prerequisite(s): permission of the graduate director.

MATH 5908 [1.5 credit] (MAT 5993)
M.Sc. Thesis in Information and Systems Science
Also listed as COMP 5908, ISYS 5908, SYSC 5908.

MATH 5909 [2.0 credits]
M.Sc. Thesis

MATH 5910 [1.0 credit] (MAT 6097)
Project in Mathematics and Statistics
Project in mathematics and statistics supervised by a professor approved by the graduate director resulting in a major report (approximately 30-40 pages), together with a short presentation on the report. Graded by the supervisor and another professor appointed by the graduate director. The project will normally be completed in one term. Precludes additional credit for MATH 5909.
Prerequisite(s): approval of the graduate director.

MATH 6002 [0.5 credit] (MAT 5309)
Harmonic Analysis on Groups
Transformation groups; Haar measure; unitary representations of locally compact groups; completeness and compact groups; character theory; decomposition.

MATH 6008 [0.5 credit] (MAT 5326)
Topics in Analysis

MATH 6009 [0.5 credit] (MAT 5329)
Topics in Analysis

MATH 6101 [0.5 credit] (MAT 5327)
Topics in Algebra

MATH 6102 [0.5 credit] (MAT 5330)
Topics in Algebra

MATH 6103 [0.5 credit] (MAT 5331)
Topics in Algebra

MATH 6104 [0.5 credit] (MAT 5158)
Lie Groups
Matrix groups: one-parameter groups, exponential map, Campbell-Hausdorff formula, Lie algebra of a matrix group, integration on matrix groups. Abstract Lie groups.
Prerequisite(s): MATH 5007 and PADM 5107 or permission of the School.

MATH 6201 [0.5 credit] (MAT 5312)
Topics in Topology

MATH 6507 [0.5 credit] (MAT 5313)
Topics in Probability & Stats

MATH 6508 [0.5 credit] (MAT 5314)
Topics in Probability & Stats

MATH 6806 [0.5 credit] (MAT 5361)
Topics in Mathematical Logic

MATH 6807 [0.5 credit] (MAT 5162)
Mathematical Foundations of Computer Science
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.
Prerequisite(s): honours undergraduate algebra and either topology or analysis, permission of the instructor or some acquaintance with logic.

MATH 6900 [0.5 credit] (MAT 6990)
Seminar

MATH 6901 [0.5 credit] (MAT 6991)
Directed Studies

MATH 6909 [7.0 credits] (MAT 6991)
Ph.D. Thesis

Statistics (STAT) Courses

STAT 5500 [0.5 credit] (MAT 5177)
Multivariate Normal Theory
Multivariate normal distribution properties, characterization, estimation of means, and covariance matrix. Regression approach to distribution theory of statistics; multivariate tests; correlations; classification of observations; Wilks' criteria.
Prerequisite(s): STAT 3559.

STAT 5501 [0.5 credit] (MAT 5191)
Mathematical Statistics II
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. Also offered, with different requirements, as STAT 4507 for which additional credit is precluded.
Prerequisite(s): STAT 4500 or STAT 5600 or permission of the School.

STAT 5502 [0.5 credit] (MAT 5192)
Sampling Theory and Methods
Unequal probability sampling with and without replacement; unified theory for standard errors; prediction approach; ratio and regression estimation; stratification and optimal designs; multistage cluster sampling; double sampling; domains of study; post-stratification; nonresponse; measurement errors; related topics.
Prerequisite(s): STAT 4502 or permission of the School.

STAT 5503 [0.5 credit] (MAT 5193)
Linear Models
Theory of non full rank linear models; estimable functions, best linear unbiased estimators, hypotheses testing, confidence regions; multi-way classifications; analysis of covariance; variance component models; maximum likelihood estimation, Minque, Anova methods; miscellaneous topics.
Prerequisite(s): STAT 4500 or STAT 5600 or permission of the School.

STAT 5504 [0.5 credit] (MAT 5194)
Stochastic Processes and Time Series Analysis
Stationary stochastic processes, inference for stochastic processes, applications to time series and spatial series analysis.
Prerequisite(s): STAT 4501 or permission of the School.

STAT 5505 [0.5 credit] (MAT 5195)
Design of Experiments
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.
Prerequisite(s): STAT 3553 and STAT 4504 or STAT 4500 or STAT 5600 or permission of the School.

STAT 5506 [0.5 credit] (MAT 5175)
Robust Statistical Inference
Tests for location, scale, and regression parameters; derivation of rank tests; distribution theory of linear rank statistics and their efficiency. Robust estimation of location, scale and regression parameters; Huber's M-estimators, Rank-methods, L-estimators. Influence function. Adaptive procedures.
Prerequisite(s): STAT 4500 or STAT 5600 or permission of the School.

STAT 5507 [0.5 credit] (MAT 5176)
Advanced Statistical Inference
Pure significance test; 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; fiducial and structural methods; resampling methods.
Prerequisite(s): STAT 4507 or STAT 5501 or permission of the School.

STAT 5508 [0.5 credit] (MAT 5172)
Topics in Stochastic Processes
Course contents will vary, but will include topics drawn from Markov processes. Brownian motion, stochastic differential equations, martingales, Markov random fields, random measures, and infinite particle systems, advanced topics in modeling, population models, etc.
Prerequisite(s): STAT 3506 or STAT 4501, or permission of the School.

STAT 5509 [0.5 credit] (MAT 5196)
Multivariate Analysis
Multivariate methods of data analysis, including principal components, cluster analysis, factor analysis, canonical correlation, MANOVA, profile analysis, discriminant analysis, path analysis.
Prerequisite(s): STAT 4500 or STAT 5600 or permission of the School.

STAT 5600 [0.5 credit] (MAT 5190)
Mathematical Statistics I
Statistical decision theory; likelihood functions; sufficiency; factorization theorem; exponential families; UMVU estimators; Fisher's information; Cramer-Rao lower bound; maximum likelihood, moment estimation; invariant and robust point estimation; asymptotic properties; Bayesian point estimation. Also offered, with different requirements, as MATH 4500 for which additional credit is precluded.
Prerequisite(s): STAT 3559 or permission of the School.

STAT 5601 [0.5 credit] (MAT 5197)
Stochastic Optimization
Topics chosen from stochastic dynamic programming, Markov decision processes, search theory, optimal stopping.
Prerequisite(s): STAT 3506 or permission of the School.

STAT 5602 [0.5 credit] (MAT 5317)
Analysis of Categorical Data
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.
Prerequisite(s): STAT 4500 or STAT 5600, STAT 4507 or STAT 5501, or permission of the School.

STAT 5603 [0.5 credit] (MAT 5318)
Reliability and Survival Analysis
Types of censored data; nonparametric estimation of survival function; graphical procedures for model identification; parametric models and maximum likelihood estimation; exponential and Weibull regression models; nonparametric hazard function models and associate statistical inference; rank tests with censored data applications.
Prerequisite(s): STAT 4500 or STAT 5600, STAT 4507 or STAT 5501 or permission of the School.

STAT 5604 [0.5 credit] (MAT 5173)
Stochastic Analysis
Brownian motion, continuous martingales, and stochastic integration.
Prerequisite(s): STAT 4501 or STAT 5708 or permission of the School.

STAT 5610 [0.5 credit] (MAT 5375)
Introduction to Mathematical Statistics
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.
Precludes additional credit for STAT 5600.
Prerequisite(s): STAT 3553 and STAT 2559 or permission of the School.

STAT 5701 [0.5 credit] (MAT 5198)
Stochastic Models
Markov systems, stochastic networks, queuing networks, spatial processes, approximation methods in stochastic processes and queuing theory. Applications to the modeling and analysis of computer-communications systems and other distributed networks. Also offered, with different requirements, as STAT 4508 for which additional credit is precluded.
Prerequisite(s): STAT 3506 or permission of the School.

STAT 5702 [0.5 credit] (MAT 5182)
Modern Applied and Computational Statistics
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.
Prerequisite(s): permission of the instructor.

STAT 5703 [0.5 credit] (MAT 5181)
Data Mining
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.
Prerequisite(s): permission of the instructor.

STAT 5704 [0.5 credit] (MAT 5174)
Network Performance
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.
Prerequisite(s): some familiarity with probability and stochastic processes and queueing, or permission of the instructor.

STAT 5708 [0.5 credit] (MAT 5170)
Probability Theory I
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.
Prerequisite(s): MATH 3001, and STAT 3558 is strongly recommended, or permission of the School.

STAT 5709 [0.5 credit] (MAT 5171)
Probability Theory II
Laws of large numbers, characteristic functions, central limit theorem, conditional probabilities and expectations, basic properties and convergence theorems for martingales, introduction to Brownian motion.
Prerequisite(s): STAT 5708 (MAT 5170) or permission of the School.

STAT 5902 [0.5 credit] (MAT 5992)
Seminar in Biostatistics
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.

STAT 5904 [0.5 credit]
Statistical Internship
This project-oriented course allows students to undertake statistical research and data analysis projects as a cooperative project with governmental or industrial sponsors. Practical data analysis and consulting skills will be emphasized. The grade will be based upon oral and written presentation of results.
Prerequisite(s): permission of the graduate director.

Summer session: some of the courses listed in this Calendar are offered during the summer. Hours and scheduling for summer session courses will differ significantly from those reported in the fall/winter Calendar. To determine the scheduling and hours for summer session classes, consult the class schedule at central.carleton.ca

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