

# MATHEMATICS AND STATISTICS (MATH)

The department offers a selection of courses from the following list each academic year. Course offerings for the current academic year can be found on the Department of Mathematics and Statistics website (<http://www.queensu.ca/mathstat/graduate/current-graduate/>).

All courses are 3.0 credit units, except MATH 898, 899 and 999, and STAT 888, 898, 899 and 999, which are 6.0 credit units.

## Courses in Mathematics

### **MATH 800 Seminar**

Students are expected to participate in a weekly seminar in which they are required to present material on a topic that relates to their research.

### **MATH 801 Graph Theory**

An introduction to graph theory, one of the central disciplines of discrete mathematics. Topics include: graphs, subgraphs, trees, connectivity, Euler tours, Hamiltonian cycles, matchings, independent sets, cliques, colourings, and planarity. (Offered jointly with MATH 401.) Three term-hours; lectures.

EXCLUSION: MATH 401

### **MATH 802 Enumerative Combinatorics**

Enumerative combinatorics is concerned with counting the number of elements of finite sets with prescribed conditions. The techniques covered include inclusion-exclusion, bijective proofs, double-counting arguments, recurrence relations, and generating functions. (Offered jointly with MATH 402.) Three term hours; lectures.

EXCLUSION: MATH 402

### **MATH 806 Introduction to Coding Theory**

Construction and properties of finite fields. Polynomials, vector spaces, block codes over finite fields. Hamming distance and other code parameters. Bounds relating code parameters. Cyclic codes and their structure as ideals. Weight distribution. Special codes and their relation to designs and projective planes. Decoding algorithms. (Offered jointly with MATH/MTHE 406.) Three term-hours; lectures.

EXCLUSIONS: MATH 406, MTHE 406

### **MATH 812 Topics in Number Theory**

Subject matter may vary from year to year. Three term-hours; lectures.

### **MATH 813 Introduction to Algebraic Geometry**

An introduction to the study of systems of polynomial equations in one or many variables. Topics covered include

the Hilbert basis theorem, the Nullstellensatz, the dictionary between ideals and affine varieties, and projective geometry (Offered jointly with MATH 413). Three term-hours; lectures. EXCLUSION: MATH 413

### **MATH 818 Number Theory and Cryptography**

Time estimates for arithmetic and elementary number theory algorithms (division algorithm, Euclidean algorithm, congruences), modular arithmetic, finite fields, quadratic residues. Design of simple cryptographic systems; public key, RSA systems. Primality and factoring: pseudoprimes, Pollard's rho-method, index calculus. Elliptic curve cryptography. (Offered jointly with MATH/MTHE 418.) Three term hours; lectures.

EXCLUSIONS: MATH 418, MTHE 418

### **MATH 827 Introduction to Deterministic Dynamical Systems**

Topics include: global properties of flows and diffeomorphisms; invariant sets and dynamics; bifurcations of fixed and periodic points; stability and chaos. (Offered jointly with MATH 427.) Three term-hours; lectures.

EXCLUSION: MATH 427

### **MATH- 829 Functional Analysis**

A generalization of linear algebra and calculus to infinite dimensional spaces. Now questions about continuity and completeness become crucial, and algebraic, topological, and analytical arguments need to be combined. We focus mainly on Hilbert spaces and the need for Functional Analysis will be motivated by its application to Quantum Mechanics. (Offered jointly with MATH 429.) Three term hours; lectures.

EXCLUSION: MATH 429

### **MATH 830 Control Theory**

This course covers core topics in both classical and modern control theory. Review of classical control theory using frequency methods. Linearization, existence and uniqueness of trajectories for nonlinear and linear systems. Feedback and stability. Lyapunov stability criteria. Controllability, observability, minimal realizations, feedback stabilization, observer design. Optimal control theory, the linear quadratic regulator, dynamic programming. (Offered jointly with MTHE 430.) Three term-hours; lectures. (3.0 credit units)

EXCLUSION: MTHE 430

### **MATH 833 Continuum Mechanics**

Continuum mechanics lays the foundations for the study of the mechanical behavior of solids and fluids. Topics include vector and tensor analysis, stress, strain and deformation, and balance laws with constitutive models for applications



in fluid mechanics and elasticity. (Offered jointly with MTHE 433.) Three term hours; lectures.

EXCLUSION: MATH 433

### **MATH 834 Optimization Theory with Applications to Machine Learning**

Theory of convex sets and functions; separation theorems; primal-dual properties; geometric treatment of optimization problems; algorithmic procedures for solving constrained optimization programs; applications of optimization theory to machine learning. (Offered jointly with MATH/MTHE 434.)

EXCLUSIONS: MTHE 434, MATH 434

### **MATH 835 Mathematical Biology**

This is a course in advanced mathematical methods used to construct models of biological phenomena in ecology, epidemiology, and evolutionary biology. The course will focus on population models, starting with individual-based models based on assumptions on the distribution of individual traits, then scaling up to stochastic models for small populations and deterministic models for large populations. Three term-hours; lectures.

### **MATH 836 Lagrangian Mechanics, Dynamics, and Control**

Geometric modelling, including configuration space, tangent bundle, kinetic energy, inertia, and force. Euler-Lagrange equations using affine connections. The last part of the course develops one of the following three applications: mechanical systems with nonholonomic constraints; control theory for mechanical systems; equilibria and stability. (Offered jointly with MATH/MTHE 439) Three term-hours; lectures.

EXCLUSIONS: MATH 439, MTHE 439

### **MATH 837 Topics in Applied Mathematics**

Subject matter may vary from year to year. Three term-hours; lectures.

### **MATH 838 Topics in Mathematical Biology**

Subject matter may vary from year to year. Three term-hours; lectures.

### **MATH 844 Differentiable Manifolds**

Differentiable structures, smooth manifolds and submanifolds, immersions and submersions, vector fields and differential forms, orientation and integration, de Rham cohomology. Three term-hours; lectures.

### **MATH 872 Optimization and Control of Stochastic Systems**

This course concerns the optimization, control, and stabilization of dynamical systems under probabilistic uncertainty with applications in engineering systems

and applied mathematics. Topics include: controlled and control-free Markov chains and stochastic stability; martingale methods for stability and stochastic learning; dynamic programming and optimal control for finite horizons, infinite horizons, and average cost problems; partially observed models, non-linear filtering and Kalman Filtering; linear programming and numerical methods; reinforcement learning and stochastic approximation methods; decentralized stochastic control, and continuous-time stochastic control. (Offered jointly with MTHE 472.) Three term -hours, fall or winter; lectures. (3.0 credit units) EXCLUSION: MTHE 472

### **MATH 874 Information Theory**

An introduction to the fundamental principles of the theory of communication. Topics include: information measures, entropy, mutual information, divergence; modeling of information sources, discrete memoryless sources, Markov sources, entropy rate, source redundancy, fundamentals of lossless data compression, block encoding, variable-length encoding, Kraft inequality, design of Shannon-Fano and Huffman codes; fundamentals of channel coding, channel capacity, noisy channel coding theorem, channels with memory, lossless information transmission theorem; continuous-alphabet sources and channels, differential entropy, capacity of discrete-time and band-limited continuous-time Gaussian channels; rate-distortion theory, lossy data compression, rate-distortion theorem, lossy information transmission theorem. (Offered jointly with MATH/MTHE 474). Three term hours; lectures. EXCLUSIONS: MATH 474, MTHE 474

### **MATH 877 Data Compression and Source Coding: Theory and Algorithms**

Topics include: arithmetic coding, universal lossless coding, Lempel-Ziv and related dictionary based methods, rate distortion theory, scalar and vector quantization, predictive and transform coding, applications to speech and image coding. (Offered jointly with MATH/MTHE 477.) Three term hours; lectures. (3.0 credit units) EXCLUSIONS: MATH 477, MTHE 477

### **MATH 884 Data Networks**

This course covers performance models for data networking, delay models and loss models; analysis of multiple access systems, routing, and flow control; multiplexing; priority systems; satellite multiple access, wireless networking, wireless sensor networks. Knowledge of networking protocols is not required. (Offered jointly with MATH/MTHE 484.) Three term hours; lectures. EXCLUSIONS: MATH 484, MTHE 484

### **MATH 891 Core Course in Analysis I**

This course provides basic knowledge in real and complex analysis at the graduate level on the following topics: Lebesgue measure and integration theory; elementary Hilbert space theory; examples of Banach space techniques. Three term-hours, fall; lectures.

**MATH 892 Core Course in Analysis II**

This course provides basic knowledge in real and complex analysis at the graduate level on the following topics: basic theory of Fourier transforms; basic elements of spectral theory and Banach algebras; complex analysis. Three term-hours, winter; lectures.

**MATH 893 Core Course in Algebra I**

This course provides basic knowledge in algebra at the graduate level on the following topics: elementary theory of groups; elementary theory of rings and modules; Galois theory. Three term-hours, fall; lectures.

**MATH 894 Core Course in Algebra II**

This course provides basic knowledge in algebra at the graduate level on the following topics: representation theory of finite groups through characters; advanced theory of modules; advanced theory of rings. Three term-hours, winter; lectures.

**MATH 895 Core Course in Probability Theory**

This course provides basic knowledge in probability at the graduate level. Topics will include: basic notions and concepts of Probability Theory; characteristic functions; law of large numbers and central limit theorem; martingales; stochastic processes. Three term-hours, winter; lectures.

**MATH 896 Core Mathematical Statistics I**

This course provides basic knowledge in mathematical statistics at the graduate level. Topics will include: Classical and Bayesian inference, Multivariate Gaussian distribution and its applications in Statistics; decision theory; basic techniques of non-parametric estimation. Three term-hours, fall; lectures.

**MATH 897 Core Mathematical Statistics II**

This course provides basic knowledge in mathematical statistics at the graduate level. Topics will include: Weak convergence in metric spaces; Delta method; Method of moments; M-estimation; Asymptotic normality and efficiency; Likelihood ratio test; U statistics; Bootstrap; Applications in statistics. Three term-hours, winter; lectures.

**MATH 898 Master's Project**

**MATH 899 Master's Thesis Research**

**MATH-901 Research Institute Course**

Advanced topics course, normally offered in the summer term, by a research institute in Canada or abroad can be

taken for credit with the permission of the Supervisor and Coordinator of Graduate Studies and in cooperation with Institute organizers. Grades are assigned on a PASS - FAIL basis.

**MATH-902 Topics in Algebra**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-903 Topics in Algebra**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-905 Topics in Algebra**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-912 Topics in Number Theory**

Subject matter will vary from year to year. Three term-hours; seminar or reading course.

**MATH-913 Topics in Number Theory**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-915 Topics in Number Theory**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-922 Topics in Analysis**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-923 Topics in Analysis**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-925 Topics in Analysis**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-932 Topics in Applied Mathematics**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-933 Topics in Applied Mathematics**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-935 Topics in Applied Mathematics**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-936 Topics in Control Theory**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-937 Topics in Control Theory**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-939 Topics in Control Theory**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-942 Topics in Topology and Geometry**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-943 Topics in Topology and Geometry**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-945 Topics in Topology and Geometry**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-972 Topics in Communication Theory**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-973 Topics in Communication Theory**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-975 Topics in Communication Theory**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**MATH-999 Ph.D. Thesis Research**

## COURSES IN PROBABILITY AND STATISTICS

**STAT 853 Statistical Inference**

Decision theory and Bayesian inference; principles of optimal statistical procedures; maximum likelihood principle; large sample theory for maximum likelihood estimates; principles of hypotheses testing and the Neyman-Pearson theory; generalized likelihood ratio tests; the chi-square, t, F and other distributions. (Offered jointly with STAT 463.) Three term hours; lectures.

EXCLUSION: STAT 463

**STAT 854 Statistical Spectrum Estimation**

Many systems evolve with an inherent amount of randomness in time and/or space. The focus of this course is on developing and analyzing methods for analyzing time series. Because most of the common time-domain methods are unreliable, the emphasis is on frequency-domain methods, i.e. methods that work and expose the bias that plagues most time-domain techniques. Slepian sequences (discrete prolate spheroidal sequences) and

multi-taper methods of spectrum estimation are covered in detail. (Offered jointly with MTHE 454.) Three term-hours; lectures.

EXCLUSION: MTHE 454

**STAT 855 Stochastic Processes and Applications**

Markov chains, birth and death processes, random walk problems, elementary renewal theory, Markov processes, Brownian motion and Poisson processes, queuing theory, branching processes. (Offered jointly with MTHE/STAT 455.) Three term hours; lectures.

EXCLUSIONS: MTHE 455, STAT 455

**STAT 856 Bayesian Analysis**

This course is an introduction to Bayesian analysis and decision theory. Topics covered will include: elements of decision theory; Bayesian point estimation, set estimation, and hypothesis testing; special priors; computations for Bayesian analysis. (Offered jointly with STAT 456.)

EXCLUSION: STAT 456

**STAT 857 Statistical Learning II**

Introduction to the theory and application of statistical algorithms. Topics may include classification, smoothing, model selection, optimization, sampling, supervised and unsupervised learning. (Offered jointly with STAT 457).

EXCLUSION: STAT 457

**STAT 862 Statistical Learning I**

A working knowledge of the statistical software R is assumed. Classification; spline and smoothing spline; regularization, ridge regression, and Lasso; model selection; treedbased methods; resampling methods; importance sampling; Markov chain Monte Carlo; Metropolis-Hasting algorithm; Gibbs sampling; optimization. (Offered jointly with STAT 462.)

EXCLUSION: STAT 462

**STAT 864 Discrete Time Series Analysis**

Autocorrelation and autocovariance, stationarity; ARIMA models; model identification and forecasting; spectral analysis. Applications to biological, physical and economic data. (Offered jointly with STAT 464.) Three term-hours; lectures.

EXCLUSION: STAT 464.

**STAT 865 Quality Management**

An overview of the statistical and lean manufacturing tools and techniques used in the measurement and improvement of quality in business, government and industry today. Topics include management and planning tools, Six Sigma approach, statistical process charting, process capability analysis, measurement system analysis. (Offered jointly with STAT 465.) Three term-hours; lectures.

EXCLUSION: STAT 465

**STAT 866 Statistical SAS Programming**

Introduction to the basic knowledge in programming, data management, and exploratory data analysis using SAS software: data manipulation and management; output delivery system; advanced text file generation, statistical procedures and data analysis, macro language, structure query language, and SAS applications in clinical trial, administrative financial data. (Offered jointly with STAT 466). Three term-hours; lectures.

EXCLUSION: STAT 466

**STAT 871 Sampling and Experimental Design**

Simple random sampling; Unequal probability sampling; Stratified sampling; Cluster sampling; Multi-stage sampling; Analysis of variance and covariance; Block designs; Fractional factorial designs; Split-plot designs; Response surface methodology; Robust parameter designs for products and process improvement. (Offered jointly with STAT 471.) Three term hours; lectures.

EXCLUSION: STAT 471.

**STAT 873 Generalized Linear Models**

An introduction to advanced regression methods for binary, categorical, and count data. Major topics include maximum-likelihood method, binomial and Poisson regression, contingency tables, log linear models, and random effect models. The generalized linear models will be discussed both in theory and in applications to real data from a variety of sources. (Offered jointly with STAT 473.)

EXCLUSION: STAT 473

**STAT 886 Survival Analysis**

Introduces the theory and application of survival analysis: survival distributions and their applications, parametric and nonparametric methods, proportional hazards models, counting process and proportional hazards regression, planning and designing clinical trials. (Offered jointly with STAT 486.) Three term-hours; lectures.

EXCLUSION: STAT 486

**STAT 888 Master's Practicum**

Under the guidance of the supervisor, students will carry out a practicum project in a health research group/site and practise biostatistical methods and data analysis, or conduct methodology research in a biostatistical project. Students will summarize the results of the project in a written report that will be reviewed and orally defended.

**STAT 898 Master's Project**

**STAT 899 Master's Thesis Research**

**STAT 952 Topics in Probability**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**STAT 953 Topics in Probability**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**STAT 955 Topics in Probability**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**STAT 962 Topics in Statistics**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**STAT 963 Topics in Statistics**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**STAT 965 Topics in Statistics**

Subject matter will vary from year to year. Three term-hours; Seminar or reading course.

**STAT 999 Ph.D. Thesis Research**