

MATHEMATICS

Department of Computer Science and Mathematics

FACULTY

ASSOCIATE PROFESSOR(S)

Y. Feng, B.E. (Anhui), M.E. (Chinese Academy of Sciences), Ph.D. (Montreal);
G. Townsend, B.Sc. (Lake Superior State), M.Sc. (Waterloo), Ph.D. (Graz, Austria);
S. Xu, B.Sc., M.Sc. (Peking), M.Sc. (Windsor), Ph.D. (Liege), Ph.D. (Wayne State)

ASSISTANT PROFESSOR(S)

G. W. Davies, B.Eng., M.Eng. (Royal Military College);
E. W. James, B.S. (University of Texas, Arlington), Ph.D. (Iowa State University);

ADJUNCT PROFESSOR(S)

F. Coccimiglio, B.A. (Laurentian-Algoma);
F. Gougeon, B.Sc., M.Sc. (Ottawa), Ph.D. (Waterloo);
D. Hammond, B.Arch. (Carleton);
F. J. J. MacWilliam, B.A. (Laurentian), M. Math. (Waterloo), M.Ed. (Victoria), B.Ed. (Laurentian - Nipissing);
S. Narayan, B.Sc. (Banaras Hindu), M.Sc. (California-Riverside), Ph.D. (Waterloo);
K. Peltsch, B.Math. (Hons) (Waterloo), M.Sc. (Western Ontario), M.B.A. (Lake Superior State);
C. Whitfield, B.Sc. (Eng), M.Sc. (Queen's), Ph.D. (Case Western Reserve)

SESSIONAL FACULTY

M. DeFazio, B.Sc. (Hons) (Brock), M.A., Ph.D. (York);
D. Lawson, B.Sc. (Toronto), M.Math. (Waterloo), Ph.D. (Waterloo);
Lan Li, B.Sc. of CS (Windsor), M.A. of CS (Wayne State);
R. McTaggart, B.Sc. (Eng) (Waterloo), B.Sc. (Laurentian - Algoma), M.A. (Michigan State);
S. Silberberg-Pochtaruk, B.Sc. (Laurentian-Algoma), M.MSc. (Waterloo);
R. Pepin, B.Sc. (Quebec-Trois-Rivieres), B.Ed. (Laurentian), M.Ed. (Toronto), Ph.D. (Laval)

AFFILIATE RESEARCH PROFESSOR(S)

D. Swayne, B.Sc. (Waterloo), M.A. (York), Ph.D. (Waterloo)

PROFESSOR(S) EMERITUS

M. A. Keppel-Jones, B.Sc. (Natal), B.A. (Hons) (Toronto), M.Sc. (Queen's), Ph.D. (Cornell);
J. J. Rajnovich, B.A. (Hons), M.A. (Toronto), B.Sc. (LSSU), M.Sc. (McMaster), Ph.D. (Western Ontario);

MATHEMATICS DEGREE REQUIREMENTS

Please refer to the general regulations pertaining to academic programs.

GENERAL INFORMATION

- For entry into the Mathematics program, it is recommended that secondary school students include calculus and one other mathematics course in their program at the OAC/U level.
- Students lacking OAC/U level calculus will be required to complete MATH 1912 before enrolling in MATH 1036.
- Students with a credit in calculus, but with a grade of less than 60% are advised to take MATH 1912 before proceeding to MATH 1036.
- When selecting courses students should pay particular attention to the prerequisites for courses they may wish to take in later years.
- All upper year students must have their programs approved by the department before registration.
- Students wishing to concentrate in Mathematics will not be allowed credit for the following: MATH 1911/1912.
- Students registered in degree programs in Mathematics or Computer Science may not receive credit for any "Introductory Statistics" courses as listed in the general regulations for the B.A. except under such special circumstances as may be approved by the Committee on Academic Regulations and Petitions
- Students in B.A. programs must include a minimum of 24 credits of electives from the Arts.
- Students in B.Sc. programs must include 12 credits of electives from subjects in the Humanities and Social Sciences and 12 credits of electives from subjects in Science with at least three credits in each of two subjects other than Mathematics.

BACHELOR OF ARTS (General) Single Major MATHEMATICS

First Year

- MATH 1036/1037*, 1056/1057*, COSC 1046
- 15 additional credits, of which 6 must be from Group I (Humanities) and 6 from Group II (Social Sciences)

Second Year

- MATH 2066, MATH 2037, MATH 2056/2057, MATH 2236
- 15 elective credits (*see note 8 above*)

Third Year

- MATH 3036, 3416 and 6 additional credits of third year MATH
- 18 elective credits

*Minimum grade of 60% required.

BACHELOR OF ARTS (General) Combined Major MATHEMATICS

A combined major in Mathematics and Computer Science, in the three-year B.A. program, requires:

- MATH 1036/1037*, 1056/1057*, 2037, 2056, 2066
- COSC 1046/1047*, 2006/2007, 2406
- 6 credits from among COSC 3106, 3127, 3406, 3407
- MATH 3416 and 3 credits in third year MATH/COSC

The Mathematics requirements for a combined major with another subject are:

- MATH 1036/1037*, 1056/1057*, 2066, 2037, 2056, either 2057 or 2236, and 6 credits of third year MATH
- 3 credits from among COSC 1046, 1701, 2831

*Minimum grade of 60% required.

BACHELOR OF SCIENCE (General) Single Major MATHEMATICS

First Year

- MATH 1036/1037*, 1056/1057*, COSC 1046
- CHMI 1006 (or 1041), and PHYS 1006/1007
- 6 elective credits

Second and Third Years

- MATH 2037, 2056/2057, 2066, 2236, MATH 3036, 3416 and 6 credits in third year MATH
- 33 elective credits

*Minimum grade of 60% required.

BACHELOR OF SCIENCE (General) Combined Major MATHEMATICS

A combined major in Mathematics and Computer Science, in the B.Sc. (General) requires:

- MATH 1036/1037*, 1056/1057*, 2037, 2056, 2066
- COSC 1046/1047*, 2006/2007, 2406
- CHMI 1006 (or 1041) and PHYS 1006/1007
- 6 credits from among COSC 3106, 3127, 3406, 3407
- MATH 3416 and 3 additional credits of third year MATH.

The Mathematics requirements for a combined major with another subject in the B.Sc. (General) are:

- MATH 1036/1037*, 1056/1057*, 2037, 2056, 2066
- CHMI 1006 (or 1041), and PHYS 1006/1007
- Either MATH 2057 or 2236, and 6 credits of third year MATH
- 3 credits from among COSC 1046, 1701, 2831

*Minimum grade of 60% required.

MINOR IN MATHEMATICS

A minor in Mathematics is available to students who are qualifying for a degree program. In all cases, students will be expected to respect all course prerequisite requirements.

The minor in Mathematics consists of the following:

24 credits in MATH, not MATH 1911/1912

More information on minors is available in Chapter Three: Academic Policies, Procedures and Regulations.

MATHEMATICS COURSE DESCRIPTIONS

MATH 1036 Calculus I

This is a problem-solving course in which an extensive treatment of differential calculus and an introduction to integral calculus is given. The course covers limits, continuity and differentiation of functions including exponential, logarithmic, trigonometric and inverse trigonometric functions. Emphasis is placed on practical applications of the derivative such as graph sketching, extrema and related rate problems. Other topics will include: anti-derivatives; area under curves; indeterminate forms and l'Hopital's rule. *Prerequisite: OAC or 4U credit in Calculus or equivalent (MCV4U and/or MHF4U). (LEC 3, TUT 1) (3 cr)*

MATH 1037 Calculus II

This course begins with various techniques of integration, applications of the integral to areas between curves, and arc length of curves (including polar curves), volumes of solids of revolution, volumes by slicing and areas of surfaces of revolution. The course continues with solving some first-order differential equations and concludes with improper integrals and aspects of functions of several variables. *Prerequisite: MATH 1036. (LEC 3, TUT 1) (3 cr)*

MATH 1056 Discrete Mathematics I

This course will cover the following topics: elementary logic; set theory and functions; equivalence relations; partial orders; mathematical induction; combinatorics (including permutations, combinations, selections, and distributions); binomial theorem; formal power series and generating functions; partial fractions and the solution of elementary recurrence relations. *Prerequisite: OAC or 4U Math credit or equivalent. (LEC 3, TUT 1) (3 cr)*

MATH 1057 Linear Algebra I

This course will cover the following topics: simultaneous linear equations; matrices and determinants; vector spaces and linear transformations; eigenvalues and eigenvectors; applications to analytic geometry and complex numbers. *Prerequisite: OAC or 4U Math credit or equivalent. (LEC 3, TUT 1) (3 cr)*

MATH 1911 Finite Mathematics

The following topics will be studied: introductory algebra and trigonometry; matrices and systems of linear equations; descriptive statistics and elementary probability. *Antirequisite: Students registered in degree programs in Mathematics or Computer Science or B.Sc. or B.Eng. programs may not receive credit for MATH 1911 except under such special circumstances as may be approved by the Committee on Academic Regulations and Awards. As a prerequisite, this course is equivalent to the Finite Mathematics OAC and may not be taken by students with credit in the Finite Mathematics OAC. Prerequisite: Grade 12 Mathematics or permission of the department. Students may not retain credit if OAC or U Math has been completed. (LEC 3, TUT 1) (3 cr)*

MATH 1912 Elementary Calculus

The differentiation and integration of simple functions will be studied. *Students registered in degree programs in Mathematics or Computer Science or B.Sc. or B.Eng. programs may not receive credit for MATH 1912 except under such special circumstances as may be approved by the Committee on Admissions, Promotions and Requests. As a prerequisite, this course is equivalent to the Calculus OAC and may not be taken by students with credit in the Calculus OAC. Prerequisite: Grade 12 Mathematics or permission of the department. Students may not retain credit if OAC or U Math has been completed. (LEC 3, TUT 1) (3 cr)*

MATH 2037 Advanced Calculus

This course begins with a review of vectors, lines, and planes. This is followed by a study of scalar functions of several variables including such topics as: multiple integration; Jacobians; gradient and application to curves, surfaces and volumes. Vector functions will be studied with particular attention given to: divergence, curl, the theorems of Green, Gauss and Stokes and applications. *Prerequisite: MATH 1037 and MATH 1057. (LEC 3, TUT 1) (3 cr)*

MATH 2056 Discrete Mathematics II

This course will cover the following topics: countability of sets; first order logic; algebra of relations; graph theory (including path problems, chromatic number, trees, planarity, directed graphs and directed trees); recurrence relations; $O(f)$, $o(f)$, and $\sim(f)$ notations. *Prerequisite: MATH 1056. (LEC 3, TUT 1) (3 cr)*

MATH 2057 Linear Algebra II

This course begins with a review of matrix algebra and systems of linear equations. This is followed by abstract vector spaces and linear transformations including eigenvalues and eigenvectors, norms and inner products. Selected applications will be included. *Prerequisite: MATH 1057 and 2056. (LEC 3) (3 cr)*

MATH 2066 Introduction to Differential Equations

This course begins with a rigorous treatment of first order linear DEs, higher order DEs with constant coefficients, systems of first order linear DEs, the Laplace transform, Taylor series solutions, and an introduction to Fourier Series. *Prerequisite: MATH 1037. (LEC 3) (3 cr)*

MATH 2086 Geometry

This course will begin with a review of analytical geometry. It will continue with an axiomatic study of euclidean, affine, and projective geometries. Topics will include transformations, co-ordinatisation, and computational geometry. *Prerequisite: MATH 1056 and 1057.*

MATH 2261 Statistics for Scientists

An introduction to probability and statistics with emphasis on the design of experiments in the Sciences is given. *Prerequisite: MATH 1036 or MATH 1912. Students registered in degree programs in Mathematics or Computer Science may not receive credit for MATH 2261 except under such special circumstances as may be approved by the Committee on Academic Regulations and Awards. (LEC 3, TUT 1) (3 cr)*

MATH 2236 Probability and Statistics I

This course is intended for students majoring in Mathematics or Computer Science. The laws of probability, discrete distributions (hypergeometric, binomial, Poisson), continuous distribution (uniform, normal, gamma family) and the Central Limit theorem are studied. Students are introduced to the statistical techniques of hypothesis testing and estimation as they relate to means, variances, proportions, and frequency tables. An introduction to stochastic processes, including applications to queuing problems and simulation, is provided. *Prerequisite: MATH 1037 and MATH 1056. (LEC 3) (3 cr)*

MATH 3036 Real Analysis I

This course begins with a rigorous treatment of the real number system including completeness. It then goes on to cover sequences and series, limits, continuous functions, differentiability, Riemann integration, sequences of functions and the topology of \mathbb{R} . The course concludes with an introduction to metric spaces. *Prerequisite: MATH 2066 and 2037. (LEC 3) (3 cr)*

MATH 3046 Complex Analysis

This course will begin with the following topics: functions of a complex variable; analyticity, the Cauchy-Riemann equations, special functions (trigonometric, exponential, hyperbolic and logarithmic), compositions, mappings, inverse and branch functions. This is followed by contour integration, the Cauchy-Goursat theorem, Cauchy's integral formula, singularities, an introduction to residue theory and Laurent series, Liouville's Theorem and the fundamental theorem of algebra. *Prerequisite: MATH 2037. (LEC 3) (3 cr)*

MATH 3056 Algebra I

This course will present a study of algebraic systems including partially ordered sets, lattices, boolean algebras, monoids, groups, rings and fields. *Prerequisite: MATH 2056. (LEC 3) (3 cr)*

MATH 3236 Probability and Statistics II

This course studies the mathematical foundations of probability and statistics: approximations, distribution theory, generating functions, multivariate distributions, transformations, principles of estimation. Students are also introduced to topics such as correlation and regression, analysis of variance, non-parametric methods. *Prerequisite: MATH 2236 and MATH 2037. (LEC 3) (3 cr)*

MATH 3416 Numerical Methods

This course begins with a study of number systems, errors and the numerical solution of non-linear equations and systems of linear equations. Further topics will include Lagrange and spline interpolation, numerical integration and differentiation and an introduction to the numerical solution of ordinary differential equations. *Prerequisite: MATH 1057, MATH 2066, and COSC 1046. (Cross-listed with COSC 3416) (LEC 3) (3 cr)*

MATH 3426 Theory of Computing

Finite automata and regular languages. Models of computation and undecidability. Chomsky hierarchy. Semantics of programming languages. *Prerequisites: COSC 2006, MATH 2056. Students cannot retain credit for both MATH 3426 and COSC 3106. (LEC 3) (3 cr)*

MATH 3706 Directed Studies

This course consists of a detailed study of a topic in Mathematics under the direction of a faculty member. The material will normally be consistent with a third year MATH course not formally listed in the department's current offerings. The course will involve some combination of assignments, mid-terms, a final exam, a seminar, and a formal final report. *Prerequisite: Permission of the department and of the prospective faculty member. (EXP 3) (3 cr)*

STATISTICS COURSES**STAT 2126 Introduction to Statistics**

This course provides an introduction to basic statistical concepts and techniques that are common to all disciplines in the Social Sciences. The principle topics include data collection and description, the characteristics and features of the normal probability distribution, the formulation and testing of hypotheses, linear correlation and regression analyses. *Students may not retain credit for STAT 2126 and one of PSYC 2126, SOCI 2126, GEOG 2026, POLI 2126. (LEC 2, TUT 1) (3 cr)*

STAT 2606 Business Statistics

Statistics and Probability, statistical measures of central tendency and dispersion, graphical and numerical measures, random variables and probability distributions, binomial, Poisson, and normal distributions. The central limit theorem, point estimation, confidence levels, test of hypothesis, correlation. *Students may not retain credit for STAT 2606 and one of ADMN 2606, ECON 2126. (LEC 3) (3 cr)*