CS 486 Introduction to Quantum Computing 3-3-0
Qubits and quantum states, unitary operations, quantum gates and circuits, measurement, and basic quantum complexity concepts. Core algorithms such as Deutsch–Jozsa, Grover search, and Shor factoring are studied, along with an introduction to quantum error correction and quantum cryptographic protocols. Students gain practical experience through simulation and implementation of quantum circuits and algorithms using standard quantum computing frameworks.
Prerequisites: CS 304, MAT 108

CS 498 Capstone Project 6-0-0
This two-semester capstone course is the culminating project experience for senior undergraduate Computer Science students. Under faculty supervision, students work individually or in small teams to design and complete a substantial independent project that integrates knowledge and skills acquired throughout the program. Projects will be evaluated on clarity of assumptions, robustness under failure, and correctness of reasoning, in addition to functional outcomes. The course culminates in a formal written report and a public presentation or demonstration. This course fulfills the capstone requirement for the Cybersecurity Concentration.
Prerequisite: permission of the department

CS 499F Honours Dissertation 6-0-0
The student is required to complete a theoretical or applied project. The subject is arranged with the student's supervisor during the first four weeks of term. A written dissertation is required as well as two seminar presentation.
Note: This course is open only to final year Computer Science Honour Students in the dissertation stream, and only by permission of the department

Mathematics

Faculty

Madjid Allili,
B.Sc.(Algiers), M.Sc., Ph.D.(Sherbrooke);
Professor

Thomas Brüstle,
B.Sc., (Ludwig-Maximilians), M.Sc.,
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François Huard,
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Senior Instructor

Scosha Merovitz,
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Special Instructor
Chair of the Department

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Program Overview

Mathematics is the language of the sciences, a language which allows scientists to quantify, model, understand and predict behaviour in an enormously diverse range of phenomena of interest. Simultaneously, Mathematics is often regarded as an art, as it is the creative study of patterns and of problem solving. Mathematics covers a wide range of disciplines including algebra, analysis, combinatorics and discrete mathematics, and differential equations. In first-year courses, mathematics students are joined by other science students, particularly from Physics and Computer Science. In the advanced courses, classes are very small, and some are given on an individual or tutorial basis.

The highest level of specialization is Honours, and Honours programs prepare students for direct entry into graduate work leading to a Master's or Ph.D. degree. All honours mathematics students have an opportunity to study independently and thus develop their reading and problem solving skills, and there is some chance to pursue special interests. The Majors programs provide students with an excellent general preparation for the career world, while not preventing entrance into graduate school (sometimes after a qualifying year). The Majors programs have sufficient electives to allow students to combine their major with a second major or at least a minor (the least specialized type of program) in another discipline. Students are encouraged to add a minor or major and many do so. Popular choices include computer science, physics, music, English, French, Spanish, drama, and philosophy. The Department of Mathematics offers several specialized, interdisciplinary programs, jointly with other departments, including Hispanic Studies and the School of Education.

First-year Calculus requirement

All Mathematics students require six course credits of Calculus studies, normally in their first year. Students with a Québec collegial diploma (DEC) shall be granted advance credit for these courses if they have completed a course in Differential Calculus and a course in Integral Calculus at CEGEP. If one or both of these courses were not completed at CEGEP, they must be completed at Bishop's and advanced credits shall be reduced accordingly. Students entering four-year programs in Mathematics with a grade 12 diploma (or equivalent) must register in MAT 191 and MAT 192 in their first year. These courses are included in the 120 total credit requirement.

First-year Physics requirement

Mathematics students pursuing the Bachelor of Science (B.Sc.) degree require six course credits of introductory physics studies in their first year. Students in the Bachelor of Arts (B.A.) degree program are exempt from this requirement. Students with any DEC are exempt from this requirement if they have completed two introductory Physics courses, Mechanics, and Electricity and Magnetism, at CEGEP. If one or both of these courses were not completed, they must be completed at Bishop's and advanced credits shall be reduced accordingly. Students entering four-year B.Sc. programs in Mathematics with a grade 12 diploma (or equivalent) must register in PHY 191 and PHY 192 in their first year.

Humanities requirement

Students must complete six course credits of humanities studies, normally in their first year at Bishop's. Students who have a Québec Collegial Diploma (DEC), students admitted as "Mature Students", and 2nd Bachelor's degree students are all exempt from this requirement. To meet the Humanities requirement, the two Humanities optional courses (6 credits) can be selected from any Humanities courses. It is recommended that at least one of these courses be a writing intensive course.

Humanities and Social Sciences requirement

In addition to the Humanities requirement above, all students are required to complete at least three credits in either the Faculty of Humanities or the Faculty of Social Sciences. Students with program combinations which require more than 72 credits are exempt from this requirement.

Please refer to the Natural Sciences Faculty page for information on Faculty Requirements.

Computer Science requirement

All Mathematics majors and honours students are required to complete the course CS 211 Programming Methodology.

Science Elective requirement

Mathematics students pursuing a Bachelor of Science degree must complete three courses (at least nine course credits) of science electives in their degree program. Students in any B.A. degree program are exempt from this requirement.

Mathematics Electives

Mathematics students (in any program) may not include courses from the list: MAT 190, MAT 191, MAT 192, MAT 196, MAT 197 as mathematics elective credits. Courses at the 460 level are only open to Honours students.

The course MAT 196 is not accepted for credit for any Science or Mathematics degree. The course MAT 190 may be taken for credit by Biology, Biochemistry, Chemistry, and Neuroscience students prior to receiving credits for MAT 191. Other Bishop's students cannot take MAT 190 for credit without permission from their Departmental Chair.

Mathematics courses MAT 190, MAT 191, MAT 192, MAT 196, MAT 197, may not be taken for credit by students who have already passed equivalent course(s) elsewhere. Students in Science programs, including Mathematics B.A., may receive a maximum of three credits in elementary statistic courses.

Matemáticas en Español

This is a unique program combining a Major in Mathematics, a Minor in Hispanic Studies as well as one year of Spanish immersion at the Universidad San Francisco de Quito in Ecuador. Contact the Chair of the department for more details.

Mathematics Honours (99 credits for B.Sc., 84 credits for B.A.) HONMAT

Normally a student is admitted to an Honours program after completing a minimum of 12 credits in Mathematics courses with an average of at least 70% and having achieved an average of 65% in all courses taken at Bishop's.

To continue in an Honours program the student must obtain an average of at least 70% in Mathematics courses in each academic year.

In order to graduate with a Mathematics Honours degree, the student must have an overall average of 70% in all Mathematics courses.

Requirements:

U1 (normally): MAT 191, MAT 192, Humanities options (6 credits)*, PHY 191 & PHY 192 (for B.Sc. only).

MAT 108, MAT 200, MAT 206, MAT 207, MAT 209, MAT 220, CS 211, MAT 310, MAT 313, MAT 314, MAT 315, MAT 317, MAT 322, MAT 323

6 optional credits of Mathematics courses at the 100 level or higher,

9 optional credits of Mathematics courses at the 300 level or higher,

6 optional credits of Mathematics courses at the 400 level or higher,

6 optional credits of Mathematics courses at the 460 level,

3 credits to satisfy the Arts and Science requirement.

B.Sc. students must include at least 9 additional Science credits among their options.

**Students with a CEGEP DEC or mature students will be granted exemption credits for these courses.*

Total credits:

B.Sc.: 72 Mathematics, 6 Physics, 3 Computer Science, 9 Science options, 6 Humanities, 3 Arts and Science options, 21 credits of free electives

B.A.: 72 Mathematics, 3 Computer Science, 6 Humanities, 3 Arts and Science options, 36 credits of free electives

Recommended schedule:

	Fall	Winter
Year 1		
(for students in a four-year program or lacking some CEGEP requirements)		
	MAT 191	MAT 192
	PHY 191 (B.Sc. students)	PHY 192 (B.Sc. students)
	Humanities elective	elective
	elective (B.A. students)	elective (B.A. students)
	Humanities elective	elective
	Arts and Science	elective
Year 2	MAT 200	MAT 220
	MAT 206	MAT 207
	MAT 108	MAT 209
	CS 211	elective
	elective	elective
Year 3	MAT 1xx	MAT 1xx
	MAT 313	MAT 314
	MAT 322	MAT 323
	MAT 3xx	MAT 3xx
	elective	elective
Year 4	MAT 315	MAT 317
	MAT 310	MAT 3xx
	MAT 4xx	MAT 4xx
	MAT 46x	MAT 46x
	Elective	Elective

This schedule is provided as a recommendation only. The order in which the courses are taken is subject to change. Students are encouraged to consult the Chair of the department before registering for their courses. The code MAT nxx refers to any 3-credit MAT course at the n-hundred level or higher.

Mathematics Major (81 credits for B.Sc., 66 credits for B.A.)

MAJMAT

Requirements:

U1 (normally) : MAT 191, MAT 192, Humanities options (6 credits)*, PHY 191 & PHY 192 (for B.Sc. only)

MAT 108, MAT 200, MAT 206, MAT 207, MAT 209, CS 211, MAT 310, MAT 313, MAT 314, MAT 315, MAT 322

3 credits from the list {MAT 202, MAT 203 OR MAT 220}

6 optional credits of Mathematics courses at the 100 level or higher,

9 optional credits of Mathematics courses at the 300 level or higher.

3 credits to satisfy the Arts and Science requirement.

B.Sc. students must include at least 9 additional Science credits among their options.

**Students with a CEGEP DEC and mature students will be granted exemption for these courses.*

Total credits:

B.Sc.: 54 Mathematics, 3 Computer Science, 6 Physics, 6 Humanities, 9 Science options, 3 Arts and Science options, 39 credits of free electives.

B.A.: 54 Mathematics, 3 Computer Science, 6 Humanities, 3 Arts and Science options, 54 credits of free electives.

Recommended schedule:

	Fall	Winter
Year 1		
(for students in a four-year program or lacking some CEGEP requirements)		
	MAT 191	MAT 192
	PHY 191 (B.Sc. students)	PHY 192 (B.Sc. students)
	Humanities elective	elective
	elective (B.A. students)	elective (B.A. students)
	Humanities elective	elective
	Arts and Science elective	elective
Year 2	MAT 200	MAT {202 or 203 or 220}
	MAT 206	MAT 207
	MAT 108	MAT 209
	CS 211	elective
	elective	elective
Year 3	MAT 1xx	MAT 1xx
	MAT 313	MAT 314
	MAT 322	MAT 3xx
	elective	elective
	elective	elective
Year 4	MAT 315	MAT 3xx
	MAT 310	MAT 3xx
	elective	elective
	elective	elective
	elective	elective

This schedule is provided as a recommendation only. The order in which the courses are taken is subject to change. Students are encouraged to consult the Chair of the department before registering for their course. The code MAT nxx refers to any 3-credit MAT course at the n-hundred level or higher.

Mathematics Minor B.Sc., B.A. (30 credits) MINMAT

U1 (normally): MAT 191, MAT 192.

MAT 206, MAT 207, MAT 108, MAT 209 or MAT 200 plus 12 additional mathematics credits, including at least 6 credits at the 300 level or higher.

Mathematical Contexts Minor B.A. (30 credits) MINMAC

The ancient, rich, and universal endeavor which is mathematics underlies all of science and engineering. Increasingly however, mathematical contexts are entwined in the fabric of modern humanistic studies.

The mathematics of social choice is enlightening the study of politics, sociology, and anthropology. The modern mathematics of management science is essential not only in the world of Business and Economics, but also to the work of human geographers who rely on mathematical modeling. Mathematical contexts reach even to the creative arts. Here new geometries, elliptic, hyperbolic, and most recently, fractal, are providing fresh and exciting sources of pattern and inspiration, the raw materials of the visual artist.

Statistics are encountered daily in every media, while statistical analyses have invaded every facet of modern life. Indeed, if for no other reason, educated persons today must understand mathematical concepts for the critical evaluation of data. Such is required in order to avoid deception and bogus claims based on false or misleading representations of statistics. Finally, the information age has given new context to an ancient mathematics: coding theory. From data encryption to internet security, mathematics is the context of modern human communication.

Many students of the Liberal Arts and Humanities, Education, and the Social Sciences, come to the discipline of Mathematics relatively late. Recently convinced of the necessity of broadening the mathematical context of their education, they nevertheless now face a language barrier. Not having pursued mastery of the high-school "advanced math" curriculum, or having gone "rusty" from lack of recent use, they now find the language of mathematics, that of quantitative reasoning, unfamiliar, foreign, and even intimidating.

It is for such students that the Minor in Mathematical Contexts is intended. Here mathematical concepts are developed and analytical thinking is employed to systematically study patterns (the raw materials of mathematics) discovered in diverse fields of study. The emphasis will be on mathematical context and thinking; not on techniques, computations, and prerequisite skills. An adult willingness to think deeply, and academic admission to Bishop's University, are the only prerequisites. In no way should these courses be confused with the "remediation" courses of other institutions: rectifying shortcomings in algebraic skills is not the goal. Rather, developing analytical problem solving skills in mathematical contexts is the objective. Successful students will find, incidentally, that their Bishop's B.A. degree has been significantly enhanced by this innovative program of study for citizens of the 21st century.

The minor in Mathematical Contexts can be added to any degree program and consists of the following courses:

MAT 200	Discrete Mathematics
MAT 108	Matrix Algebra
PHY 101	Statistical Methods
MAT 191	Calculus I, *prerequisite: MAT 190 recommended*
MAT 192	Calculus II, *prerequisite: MAT 191*

** (Remedial Precalculus and Algebra courses are available)*

An additional 15 course lecture credits in Mathematics must be chosen from among:

MAT 100	Excursions in Modern Mathematics*
MAT 101	Further Excursions in Modern Mathematics**
MAT 103	Environmental Modeling
MAT 104	History of Mathematics
MAT 126	Problems, Puzzles and Games
MAT 202	Modern Geometry: Euclidean to Fractal, *prerequisite: MAT 200*
MAT 203	Number Theory
MAT 209	Linear Algebra, *prerequisite:* MAT 108
MAT 220	Further Discrete Mathematics, *prerequisite: MAT 200*
MAT 322	Introduction to Modern Algebra I, *prerequisite: MAT 200, MAT 209*
MAT 323	Introduction to Modern Algebra II, *prerequisite: MAT 322*

Notes: *The two courses, PMA 260 and PMA 360 may replace PHY 101 in the required list of courses. A student may not graduate with a double minor in mathematics.*

** The science version of this course, MAT 110 is also accepted.*

*** The science version of this course, MAT 111 is also accepted.*

List of Courses

Note: See also the list of cognate courses at the end of this section.

MAT 100 Excursions in Modern Mathematics 3-3-0
This is a mathematics class for everyone. The course will allow students to develop a sense of the applications of mathematics, and an appreciation of the role of mathematics in the modern world. Topics are chosen from: the mathematics of elections (the paradoxes of democracy), the distribution of power (weighted voting), mathematics of resource sharing (fair division games), routing problems (the Königsberg bridges problem and Euler circuits), the mathematics of touring (the traveling salesman problem and Hamilton circuits), networking problems (minimum spanning trees and the cost of being connected), scheduling problems (chasing the critical path), shape and form (the mathematics of symmetry), Fractal Geometry (the kinky nature of nature), Fibonacci numbers and the Golden Ratio (tales of rabbits and gnomes).
Note: Science and mathematics students must enrol in MAT 110 instead of this course. Students may only receive credit for one of MAT 100 or MAT 110.

MAT 101 Further Excursions in Mathematics 3-3-0
Further topics in modern applied mathematics. A continuation of the style and subjects in MAT 100, this course does not have any mathematical prerequisites. Topics may include growth models, game theory, linear programming, fractal geometry, coding theory, non-Euclidean geometry, percolating theory, mathematics of fraud detection, basic financial mathematics, the look and say sequence, and selected current readings.
Note: Science students must enrol in MAT 111 instead of this course. Students may only receive credit for one of MAT 101 and MAT 111.

MAT 103 Environmental Modeling 3-3-0
The course employs a problem solving approach to teach students modeling principles which apply to issues arising in the environmental sciences. Students will practice important skills: transforming realistic, qualitatively described problems into forms suitable for producing approximate, quantitative solutions, and interpreting the results obtained from their calculations. A variety of environmental problems are presented, on topics such as: units and conversions, geometric scaling, power-law scaling, steady-state box models, solar spectrum, npp and solar energy flow, black-body radiation, the greenhouse effect and the global climate (equilibrium) model, wind power and Betz's law, models for growth (e.g. population, peak oil, pandemics), transport of pollutants, diffusion, Darcy's law. The mathematics involved will be elementary, at a level suitable for a high-school graduate with credit for a university-preparatory mathematics course.

MAT 104 History of Mathematics 3-3-0
This course is designed to help history, philosophy, and education students come to a deeper understanding of the mathematical side of culture by means of writing short essays. Mathematics majors acquire a philosophical and cultural understanding of their subject by means of doing actual mathematics problems from different eras. Topics may include perfect numbers, Diophantine equations, Euclidean construction and proofs, the circle area formula, the Pell equation, cubic equations, the four square theorem, quaternions, and Cantor's set theory. The philosophical themes of infinity and Platonism recur repeatedly throughout the course.

MAT 108 Matrix Algebra 3-3-0
Operations on matrices, transpose and inverse. Systems of linear equations. Determinants. Linear transformations. Eigenvalue and eigenvectors. Bases and dimension. Rank and nullity. Applications (some of which may require basic Calculus knowledge)

MAT 110 Excursions in Modern Mathematics 3-3-0
This is the same course as MAT 100 but it is intended that science students would enrol in this course and complete assignments that are more appropriate to their needs.
Note: Students may only receive credit for one of MAT 100 or MAT 110.

MAT 111 Further Excursions in Mathematics 3-3-0
This is the same course as MAT 101 but it is intended that science students would enrol in this course and complete assignments that are more appropriate to their needs.
Note: See MAT 101. Students may only receive credit for one of MAT 101 and MAT 111.

MAT 126 Problems, Puzzles and Games 3-3-0
This course teaches creative problem solving, logic, and analytical thinking in the context of recreational mathematics. Various logic puzzles and geometry problems will be solved. Games such as Kenken and Calcrostic will be practiced. A variety of mathematical paradoxes will be examined. Other problems and puzzles will be selected from the publications of Martin Gardner (e.g. "The Monkey and the Coconuts"), John Conway (e.g. "The Angel Problem"), Ian Stewart, and others, including from the many on-line math problems and puzzles sites.

MAT 190 Precalculus Mathematics 3-3-1.5
Review of algebra (fractions, exponents, radicals, etc.). Sets, linear functions, quadratic functions, polynomial functions, rational functions and their graphs. Factorization and simplification. Exponential and logarithm functions with applications. Introduction to trigonometry.
Students who have received credit for an equivalent course may not receive credit for this course. Students who have received credit for any math class numbered MAT 19X or higher may not receive credit for this course. Students outside of Biology, Biochemistry, Chemistry, and Neuroscience may only receive credit for this course with consent of their Departmental Chair.

MAT 191 Calculus I 3-3-1.5
Elementary functions, limits, continuity. The derivative, differentiability, mean value theorem. Maxima and minima, Fermat's theorem, extreme value theorem, related rates, L'Hospital's rule. Applications. Emphasis is on conceptual understanding.
This course is for students who lack collegial MAT 103 or the equivalent.
This course is required for all students in B.Sc. programs (Biochemistry, Biology, Chemistry, Computer Science, Environmental Science, Mathematics, Physics and Neuroscience) as well as B.A. Mathematics students and some B. Ed. (CONEMT and CONSCT) students.
B.B.A. Finance students and B.A. (Information Technology) students are recommended to take MAT 197. Economics students should consult their Departmental Chair prior to registering in this course.
Students who have received credit for an equivalent course taken elsewhere may not register for this course.
Students may only receive credit for one of MAT 191 or MAT 197.

MAT 192 Calculus II 3-3-1.5
Riemann sums. Area. The definite integral. The Fundamental Theorem of Calculus. Techniques of integration. Volumes, centres of mass, moments of inertia, arc length and other applications of integration. Emphasis is on conceptual understanding.
Prerequisite: MAT 191 or MAT 197
This course is for students who lack Collegial Mathematics NYB or the equivalent.
This course is required for all students in Biochemistry, Chemistry, Mathematics, Physics, other B.Sc. programs (Biology, Computer Science, Environmental Science and Neuroscience) and B.Ed. Education (CONEMT and CONSCT).
Students who have received credit for an equivalent course taken elsewhere may not register for this course.

MAT 196 Finite Mathematics for Business Students 3-3-0
This course aims to familiarize business students with the fundamentals of linear algebra required by disciplines such as Statistics, Finance, Management, Economics, and others. Topics covered in this course include: review of high school algebra, arithmetic and geometric sequences, sums of sequences, inequalities in one and two variables, linear equations, introduction to matrices, matrix algebra: addition, multiplication, inverses, and Gaussian elimination.
Prerequisite: MAT 190 or equivalent or permission of instructor.

MAT 197 Calculus I 3-3-1.5
This course aims to familiarize business students with the fundamentals of calculus required by disciplines such as Statistics, Finance, Management, Economics, and others. Topics covered include: Elementary functions, limits, continuity. The derivative, differentiability, mean value theorem. Maxima and minima, Fermat's theorem, extreme value theorem, related rates, L'Hospital's rule. Applications. Emphasis is on conceptual understanding.
Prerequisite: MAT 196 or permission of Chair
This is a course for students in the B.B.A. Finance program and BAIT program. Economics students should consult their Departmental Chair prior to registering in this course.
Students who have received credit for an equivalent course taken elsewhere may not register for this course.
Students may only receive credit for one of MAT 191 or MAT 197.

MAT 200 Introduction to Discrete Mathematics 3-3-0
This course is an introduction to logic and proofs. Logic will be introduced through propositional logic and quantifiers. Concrete applications using topics drawn from the study of discrete mathematics, such as set, combinatorics, and recursion relations. These applications will form the basis for the introduction of proof techniques such as induction and proof by contradiction.

MAT 202 Modern Geometry: Euclidean to Fractal 3-3-0
Particularly recommended for elementary and high-school teachers. Geometry and the axiomatic method. Euclidean, elliptic and hyperbolic geometries. Constructability. Applications may include: modern graphics, fractal images and the work of analytical artists like M.C. Escher. Free geometry software (e.g., GeoGebra) projects will be used to enhance learning.
Prerequisite: MAT 200

MAT 203 Number Theory 3-3-0
A classical discipline, number theory has become the spectacularly successful language of modern cryptography and coding theory. This course is a gentle introduction to the classical theory and modern applications. Topics may include: unique factorization and congruences, group of integers modulo n and its units, Fermat's little theorem, Fermat's last theorem, Euler's function, Wilson's theorem, Chinese remainder theorem, quadratic reciprocity, Gaussian integers.

MAT 206 Advanced Calculus I 3-3-0
Parametric curves: rates of change, areas, arc-length, and polar coordinates. Vectors, dot-product, cross-product, equations on lines and planes. Functions of 2 and 3 variables. Partial derivatives, directional derivatives, differentials. Lagrange multipliers. Multiple integrals and applications. Change of variables and Jacobians.
Prerequisite: MAT 192
Co-requisite: MAT 108

MAT 207 Advanced Calculus II 3-3-0
Vector valued functions, curvature. Line integrals. Surface integrals. Green's theorem. Divergence theorem. Stoke's theorem. Differential operator. Sequences and series. Power Series. Taylor series and polynomials.
Prerequisite: MAT 206

MAT 209 Linear Algebra 3-3-0
Vector Spaces. Diagonalization. Inner product spaces. Gram-Schmidt process. Change of basis. Complex vector spaces. Applications may include systems of differential equations.
Prerequisite: MAT 108

MAT 220 Further Discrete Mathematics 3-3-0
Relations: functions, equivalence relations, partially ordered sets. Zorn's lemma. The axiom of choice. Cardinality and counting. Graph theory. Solving recurrence relations.
Prerequisite: MAT 200

MAT 310 Ordinary Differential Equations 3-3-0
Techniques for solving first order differential equations and second order linear differential equations. Systems of first order equations. Various applications of differential equations.
Prerequisite: MAT 192
Note: See PHY 270. Students may not take this course for credit if they have received credit for PHY 270

MAT 311 Mathematical Methods of Physics 3-3-0
Power series solutions for second order equations including the method of Frobenius. Discussion of series solutions in connection with the gamma function and Bessel, Legendre and hypergeometric functions. Elementary trigonometric Fourier series and boundary value problems. Certain partial differential equations of physics.
Prerequisites: MAT 207 and MAT 310 or PHY 270
Note: See PHY 371. Students may not take this course for credit if they have received credit for PHY 371

MAT 313 Introduction to Probability 3-3-0
Discrete and continuous distributions. Moments, mean and variance. Moment generating functions. Multivariate distributions. Laws of large numbers. Sampling distributions. Central Limit Theorem.
Prerequisite: MAT 206

MAT 314 Introduction to Mathematical Statistics 3-3-0
Further sampling distributions: Chi-square, t and F. Estimation, confidence intervals. Hypothesis testing, theory and practice. Regression and correlation.
Prerequisite: MAT 313

MAT 315 Real Analysis I 3-3-0
Real number system. Completeness theorem. Sequences of real numbers. Bolzano-Weierstrass Theorem. Cauchy sequences. Series of real numbers. Limits. Continuous functions. Infinite series.
Prerequisite: MAT 207

MAT 316 Real Analysis II 3-3-0
The generalized Riemann integral (improper integrals). Sequences and series of functions. Pointwise and uniform convergence. Power series. Taylor series. Classical theorems (integration, differentiation, Weierstrass M-test. Cauchy-Hadamard theorem). Equicontinuity. Ascoli-Arzela theorem. Stone-Weierstrass approximation theorem).
Prerequisite: MAT 315

MAT 317 Complex Analysis 3-3-0
Sequences and series of complex numbers. Functions. Limits. Continuous functions. Analytic functions. Cauchy-Riemann equations. Contour integration. Cauchy's theorem. Cauchy integral formula. Taylor and Laurent series. Singularities and residues. Conformal mappings.
Prerequisite: MAT 207

MAT 322 Introduction to Modern Algebra I 3-3-0
Introduction to the theory of groups. Symmetries of a square. The dihedral groups. Cyclic groups, permutation groups. Isomorphisms, external and internal direct sums. Cosets and Lagrange's theorem. Factor groups.
Prerequisites: MAT 200 and MAT 209

MAT 323 Introduction to Modern Algebra II 3-3-0
Additional topics from group theory. Introduction to Ring Theory. Integral Domains and Fields. Factorization of Polynomials. Finite Fields.
Prerequisite: MAT 322

MAT 324 Cryptography 3-3-0
Cryptography is a key technology in electronic security systems. The aim of this course is to explain the basic techniques of modern cryptography and to provide the necessary mathematical background. Topics may include: the classical encryption schemes, public-key encryption, RSA crypto system, prime number generation, and factoring.
Prerequisite: MAT 108
Note: Credit will only be given for only one of MAT 324 and MAT 524.

MAT 326 Mathematical Problem Solving 3-3-0
A course designed to foster problem solving abilities in mathematics. New mathematical concepts will be introduced to the student through solving specific problems. Problems may be taken from Putnam and Mathematics Olympiad competitions.
Prerequisites: MAT 200, MAT 207, MAT 108, or permission of instructor

MAT 401 Vector Analysis 3-3-0
Algebra of vectors. Vector-valued functions. Vector differential and integral calculus. Theorems of Gauss, Green and Stokes. Differential forms. Differentiability in Rn. Inverse function theorem.
Prerequisite: MAT 207

MAT 402 Tensor Analysis 3-3-0
General curvilinear coordinates. Differential forms. Bilinear forms and tensors of rank two. Tensor algebra and tensor calculus.
Prerequisite: MAT 401

MAT 405 Calculus of Variations 3-3-0
Euler-Lagrange equations for constrained and unconstrained single and double integral variational problems. Parameter-invariant single integrals. General variational formula. The canonical formalism. Hilbert's independent integral. Hamilton-Jacobi equation and the Caratheodory complete figure. Fields and the Legendre and Weierstrass sufficient conditions.
Prerequisites: MAT 207, MAT 310
Note: See PHY 376. Students may not take this course for credit if they have received credit for PHY 376

MAT 406 Differential Geometry 3-3-0
Curves in 3-space. Euclidean motions, surface theory. Introduction to differential manifold, Gaussian and mean curvature, imbedding conditions. Geodesics, parallel transport and the Gauss-Bonnet Theorem.
Prerequisites: MAT 207, MAT 310

MAT 414 Regression and Analysis of Variance 3-3-0
Topics in this course will include simple, multiple, polynomial and other nonlinear regression; Analysis of variance and covariance. The course may include data sets from case studies. Students will gain some facility with certain mathematics software packages.
Prerequisite: MAT 314

MAT 421 Graph Theory 3-3-0
This course provides an introduction to the combinatorial, algorithmic, and algebraic aspect of graph theory. There will be a brief refresher of mathematical proof techniques. Topics will include paths and circuits, graph trees, planar graphs, graph colourings, and the Max Flow-Min Cut Theorem. Programming assignments to implement graph algorithms (in Maple or Octave for example) may be required.
Prerequisite: MAT 200
Note: See CS 571. Credit will be given for only one of MAT 421, MAT 521, CS 471 and CS 571.

MAT 431 Metric Spaces and Topology 3-3-0
Sets, functions, images and preimages. Topological spaces, metric spaces. Open and closed sets, accumulation points, continuous functions, homeomorphisms. Some topological properties, particularly connectedness and compactness.
Prerequisite: MAT 315, or consent of the instructor.

MAT 446 Independent Study 3-3-0
This course aims to familiarize mathematics students with fundamental knowledge, skills and techniques in a chosen field of mathematics. A presentation will constitute a portion of the final grade.
Offered by arrangement

46x level courses are for Honours students only

MAT 460 Topics in Algebra I 3-3-0
A selection is made to suit the interests of students from such topics as: ring theory, introduction to homological algebra, introduction to group representations or commutative algebra.
Prerequisites: MAT 209, MAT 323 or consent of instructor.
Offered by arrangement.

MAT 461 Topics in Algebra II 3-3-0
A selection is made to suit the interests of students from such topics as: ring theory, introduction to homological algebra, introduction to group representations or commutative algebra.
Prerequisites: MAT 209, MAT 323 or consent of instructor.
Offered by arrangement.

MAT 462 Topics in Analysis I 3-3-0
Normed spaces, Banach and Hilbert spaces, Hilbert space operators, Normed algebras, Stone-Weierstrass theorem. Special function spaces.
Prerequisite: MAT 316

MAT 463 Topics in Analysis II 3-3-0
Theory of integration. Measurable functions, measures and integrable functions. Lebesque spaces. Models of convergence. Decomposition and generation of measures. Product measures.
Prerequisite: MAT 316
Offered by arrangement.

MAT 464 Topology 3-3-0
Offered by arrangement.

MAT 465 Topology 3-3-0
Offered by arrangement.

MAT 466 Independent Studies I 3-0-0
Open to final-year honours students by arrangement with the department. A presentation will constitute a portion of the final grade.

MAT 467 Independent Studies II 3-0-0
Open to final-year honours students by arrangement with the department. A presentation will constitute a portion of the final grade.
Note: See MAT 466.

MAT 480 Honours Research Dissertation 6-0-0
Each student is required to carry out an original research project under the supervision of a faculty member. A plan outlining the proposed research must be submitted for approval during the first four weeks of the course. Each student will present his/her results in the form of a seminar and a written dissertation.

MAT 521 Graph Theory 3-3-0
This course develops the theoretical foundations of graph theory with emphasis on combinatorial structures, algorithmic techniques, and algebraic properties of graphs. Topics include paths, cycles, trees, connectivity, planarity, graph colorings, and flow networks, including the Max-Flow–Min-Cut Theorem. The course emphasizes rigorous reasoning, proof techniques, and the formal analysis of graph algorithms. Assignments may involve the implementation and analysis of core graph algorithms to connect theory with computational practice.
Note: See CS 571. Credit will be given for only one of MAT 421, MAT 521, CS 471 and CS 571.

MAT 524 Cryptography 3-3-0
Cryptography is a key technology in electronic security systems. The aim of this course is to explain the basic techniques of modern cryptography and to provide the necessary mathematical background. Topics may include: the classical encryption schemes, public-key encryption, RSA crypto system, prime number generation, and factoring. Programming Assignments to implement certain encryption algorithms may be required.
Note: Credit will be given for only one of MAT 324 and MAT 524.

Cognate Courses:

The following courses may count as 200-level Mathematics options:

EMA 262 Mathematical Economics I
PHY 208 Introduction to Mechanics

The following courses may count as 300-level Mathematics options:

CS 308 Scientific Programming
CS 317 Design and Analysis of Algorithms
CS 455 Theoretical Aspects of Computer Science
EMA 361 Econometrics II
EMA 362 Mathematical Economic II
PHY 318 Advanced Mechanics