Mathematics

Faculty

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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. Students transferring into Mathematics programs may use credit for MAT 198 to replace MAT 191, and MAT 199 to replace MAT 192. Credit for MAT 197 with a grade of 80% or higher will also be accepted to replace MAT 191. Mathematical Contexts Minor program students normally complete MAT 198 and MAT 199 (instead of MAT 191 and MAT 192, although these are also acceptable), and do not need to do so in their first year.

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. The Humanities requirement must include ENG 116 Effective Writing, or another English course (coded 'ENG'), and one additional course selected from Humanities courses in Classical Studies, English, History, Liberal Arts, Philosophy or Religion (courses coded CLA, ENG, HIS, LIB, PHI, or REL).

Arts and Science requirement

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

Please refer to the Natural Sciences Division page for information on ***Divisional Requirements***.

The Programs			
The Department of Mathematics offers the following degree programs:			
Name of Program	**Code**	**Levels of Specialization Available**	**Degree Types Available**
Mathematics	MAT	Honours, Major or Minor	B.Sc. or B.A.
Matemáticas en Español	n/a	Major in Mathematics combined with a Minor in Hispanic Studies	B.Sc. or B.A.
Mathematical Contexts	MAC	Minor	B.A.

Computer Science requirement

All Mathematics majors and honours students (except those in the Mathematics Education double major program) 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, MAT 198, MAT 199, as mathematics elective credits. Courses at the 460 level are only open to Honours students.

The courses MAT 190, MAT 196, MAT 197 are not accepted as credits for any Science or Mathematics degree. Mathematics courses MAT 190, MAT 191, MAT 192, MAT 196, MAT 197, MAT 198, MAT 199 may not be taken for credit by students who have already passed equivalent course(s) elsewhere. The course MAT 190 may not be taken for credit by any student without permission from their department chair. Students in Science programs, including Mathematics B.A., may receive a maximum of three credits in elementary statistics 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, ENG 116*, Humanities 1xx option*, 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)
	ENG 116	Humanities electives
	elective (B.A. students)	elective (B.A. students)
	elective	elective
	elective	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, ENG 116*, Humanities 1xx option*, 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)
	ENG 116	Humanities elective
	elective (B.A. students)	elective (B.A. students)
	elective	elective
	elective	elecive
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.

Minor in Mathematical Contexts; 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 198*	Calculus I (for Life Sciences), prerequisite: MAT 190 recommended
MAT 199*	Calculus II (for Life Sciences), prerequisite: MAT 198

** (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 104	History of Mathematics
MAT 209	Linear Algebra, prerequisite: MAT 108
MAT 202	Modern Geometry: Euclidean to Fractal, prerequisite: MAT 200
MAT 220	Further Discrete Mathematics, prerequisite: MAT 200
MAT 203	Number Theory
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 160 and PMA 260 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.*

Mathematics Electives

Mathematics students (in any program) may not include courses from the list: MAT 190, MAT 191, MAT 192, MAT 196, MAT 197, MAT 198, MAT 199, as mathematics elective credits. Courses at the 460 level are only open to Honours students.

The courses MAT 190, MAT 196, MAT 197 are not accepted as credits for any Science or Mathematics degree. Mathematics courses MAT 190, MAT 191, MAT 192, MAT 196, MAT 197, MAT 198, MAT 199 may not be taken for credit by students who have already passed equivalent course(s) elsewhere. The course MAT 190 may not be taken for credit by any student without permission from their department chair. Students in Science programs, including Mathematics B.A., may receive a maximum of three credits in elementary statistics courses.

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

An introduction to modern applied mathematics: social choice, management science, growth, symmetry, and descriptive statistics. Not intended as a numeracy course, nor for the remediation of algebraic shortcomings: computational complexity is minimal, and math prerequisites are absent. Instead, the methodology of mathematics is addressed: the use of unambiguous language and simplification to model practical problems, the types of answers the discipline can provide, and the notions of generalization and "open" problems. The course will allow the student to develop a sense of the nature of mathematics as a discipline, and an appreciation of its role in the modern world.

Note: Science 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 is also not intended to redress deficiencies in numeracy, nor does it have any mathematical prerequisites. Topics may include growth models, game theory, linear programming, fractal geometry, coding theory, non-Euclidean geometry 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 will teach students to apply mathematical modeling principles and techniques to problems arising in the environmental sciences. Students will gain some understanding of basic mathematical models and techniques employed in the environmental sciences, and will practice the important skill of interpreting the results obtained from these models. The course will consist of a topics based, interdisciplinary approach to basic mathematical modeling. Topics covered may include ground water transport, air pollution such as modeling of ground-level ozone, hazardous materials disposal modeling, mathematical models for population growth, environmental economics, oil spill mitigation and avoidance, micro-climate weather predication, or others. The mathematics involved will be largely elementary, at a level suitable for a high-school graduate with credit for a university-preparatory level 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. Vector spaces. Bases and dimension. Rank and nullity. Applications.

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 MAT111.

MAT 190 Precalculus Mathematics 3-3-0
Review of algebra. Sets, Functions, graphs. Slope and equation of a straight line. Equation of a circle. Exponential and logarithm functions with applications. Arithmetic and geometric progressions. Permutations and Combinations.
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 may only receive credit for this course with consent of their Departmental Chair.

MAT 191 Enriched Calculus I 3-3-0
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. Riemann sums, definite integral. Emphasis is on an analytical understanding.
This course is for students who lack collegial MAT 103 or the equivalent.
This course is required for all students in Mathematics, Physics and Computer Science.
Students who have received credit for an equivalent course taken elsewhere may not register for this course.
Credit will be given for only one of MAT 191, MAT 197, and MAT 198

MAT 192 Enriched Calculus II 3-3-0
Area. The definite integral. The Fundamental Theorem of Calculus. Techniques of integration. Volumes, centres of mass, moments of inertia, arclength and other applications of integration. Mean value theorem for integrals. Emphasis is on analytical understanding.
Prerequisite: MAT 191 or a grade of at least 70% in MAT 198 or 80% in MAT 197
This course is for students who lack Collegial Mathematics NYB or the equivalent.
This course is required for all students in Mathematics, Physics and Computer Science.
Students who have received credit for an equivalent course taken elsewhere may not register for this course.
Credit will be given for only one of MAT 192 and MAT 199

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 for Business Students 3-3-0
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: introduction to limits, differential calculus with one variable with applications, functions with several variables, partial derivatives, area under a curve.
Prerequisite: MAT 196 or the equivalent or consent of the instructor.

MAT 198 Calculus I (for Life Sciences) 3-3-0
Elementary functions, limits, tangent line approximations. The derivative, and differentiation rules. Continuous optimization in one variable. Applications to Biology, Chemistry, Medicine and Environmental Science. The emphasis is on conceptual understanding and computational competency.
This course is intended for students who lack collegial Mathematics NYA or the equivalent.
Students who have received credit for an equivalent course taken elsewhere may not register for this course.
Credit will be given for only one of MAT 191, MAT 197, and MAT 198

MAT 199 Calculus II (for Life Sciences) 3-3-0
The definite integral, area, integration by substitution and parts. Applications to Biology, Chemistry, Medicine and Environment Science. Separable and linear differential equations. The emphasis is on conceptual understanding and computational competency.
Prerequisite: MAT 198 or MAT 191 or the equivalent, or a grade of at least 80% in MAT 197
This course is intended for students who lack collegial Mathematics NYB or the equivalent.
Students who have received credit for an equivalent course taken elsewhere may not register for this course.
Credit will be given for only one of MAT 192 and MAT 199

MAT 200 Introduction to Discrete Mathematics 3-3-0
Combinatorics. Propositional logic. Induction. Sets. Quantifiers. Recursion relations.

MAT 202 Modern Geometry: Euclidean to Fractal 3-3-0
Particularly recommended for elementary and high-school teachers. Euclidean, elliptic and hyperbolic geometries, and applications: modern graphics, fractal images and the work of analytical artists like M.C. Escher.
This course must be taken concurrently with Mathematics laboratory 202 (MAL 202)
Prerequisite: MAT 200
Corequisite: MAL 202

MAL 202 Mathematics Lab:
Modern Geometry by Laboratory Explorations 1-0-3
Geometry explorations using Geometer's Sketchpad software. Projects will enhance the learning of the curriculum of the course MAT 202 which must be taken concurrently.
Corequisite: MAT 202

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.
Prerequisite: MAT 200

MAT 206 Advanced Calculus I 3-3-0
Vector-valued functions,parametric curves, arc-length, curvature. .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 or a grade of at least 80% in MAT 199
Corequisite: MAT 108

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

MAT 209 Linear Algebra 3-3-0
Diagonalization. Inner product spaces. Gram-Schmidt process. Change of basis. Complex vector spaces. Systems of differential equations. Applications.
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 and second order linear differential equations. Systems of first order equations. Power series solutions for second order equations including the method of Frobenius. Various applications of differential equations.
Prerequisite: MAT 192 or a grade of at least 80% in MAT 199
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
Discussion of series solutions in connection with the gamma function and Bessel, Legendre and hypergeometric functions. Laplace transform with applications. Elementary trigonometric Fourier series and boundary value problems. Certain partial differential equations of physics.
Prerequisites: MAT 207 and MAT 310
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. Analysis of Variance. Nonparametric methods.
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. Differentiation. Mean-Value Theorem. L'Hospital's rule. Riemann integration. Fundamental Theorem of Calculus.
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.
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.
Prerequisite: 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. Introduction to Algebraic Coding Theory.
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, perfect secrecy, DES, prime number generation, public-key encryption, factoring, digital signatures, quantum computing.
Prerequisites: MAT 200, MAT 108

MAT 325 Numerical Methods 3-3-0
Numerical techniques for problem solving in Mathematics, Computer Science and Physics. Error analysis, roots of equations, QR-algorithm, interpolation, Numerical approaches to differentiation, integration and solutions of differential equations.
Prerequisites: CS 211, MAT 207, MAT 108.
Note: See CS 375 and PHY 375
Students may not take this course for credit if they have received credit for CS 375 or PHY 375.

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 will be taken from Putnam and Mathematics Olympiad competitions and from actuarial examinations.
Prerequisites: MAT 200, MAT 207, MAT 108

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
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.
Prerequisite: 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, algoritmic 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 Floss-Min Cut Theorem. Programming Assignments to implement graph algorithms (in Maple or Octave for example) will be required. An introduction to the combinatorial, algorithmic and algebraic aspects of graph theory.
Prerequisite: MAT 200
See CS 571. Credit will be given for only one of MAT 421 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.
Pre-requisite: 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.
Prerequisite: 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.
Prerequisite: 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.
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 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, perfect secrecy, DES, prime number generation, public-key encryption, factoring, digital signatures, and quantum computing. Programming Assignments to implement certain encryption algorithms (in Maple or Octave, for example) may be required.
Prerequisite: MAT 108, MAT 200 and CS 211 or equivalent from elsewhere, or the permission of the instructor.
See MAT 324

MAT 529 Mathematical Methods for Computer Science 3-3-0
This course will provide opportunity for graduate students with weaker mathematical backgrounds to upgrade their skills in the mathematical techniques and concepts required in graduate courses in Computer Science such as: CS 502 Digital Toplogy & Mathematical Morphology, CS 503 Data Visualization, CS 504 Programming Languages for Data Analysis, CS 505 Data Mining, CS 506 Parallel Models and Algorithms, CS 507 Statistical Learning, CS 509 Pattern Recognition, CS 512 Computer Games Design, CS 516 Volumetric Image Analysis & Visualization, CS 562 Mathematical Models in Image Processing, CS 563 Image Analysis.
Prerequisite: MAT 108, MAT 192, and MAT 200 or equivalent from elsewhere, or the permission of the instructor.

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