Mathematics

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 Economics, Hispanic Studies, the School of Education and the Williams School of Business.

Entrance Requirements

To enter a Mathematics program, a student will normally have completed either a Québec Collegial Diploma (DEC), or grade 12 in another Canadian province or the U.S.A., or the equivalent level of education internationally. Admitted students with a DEC will normally be registered in a three-year program of at least 94 credits, while students with a grade 12 diploma (or equivalent) will be registered in a four-year program of at least 124 course credits. A student's total credit requirement depends on the program and the type of degree chosen. However, all Bishop's students must complete the 3-credit, English Writing Proficiency (EWP) requirement which is included in the total credit requirement.

Students entering a Mathematics program at Bishop's from another Canadian University or College, or from accredited international post-secondary institutions, will have their transcripts of grades examined individually for possible transfer credit against a Bishop's program's requirements.

The Programs

The Department of Mathematics offers the following degree programs:

Name of Program	Code	Levels of Specialization Available	Degree Types Avai
Mathematics	MAT	Honours, Major or Minor	B.Sc. or B.A.
Mathematics Education	EDM	double Major with Education	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.
Applied Mathematics Economics	n/a B.C.S.	double Concentration with Business or	
Pure Mathematics Economics	n/a B.C.S.	double Concentration with Business and	
Mathematical Contexts	MAC	Minor	add to any

The requirements for Mathematics students differ depending on whether the degree being pursued is a B.Sc., a B.A. or a B.B.S., and whether the student entered Bishop's after completing CEGEP in

Québec, or after completing grade 12 (or the equivalent) in another province or elsewhere. Two or more Mathematics programs may not be combined in any Bishop's degree.

First-year Calculus requirement

All Mathematics students require six course credits of Calculus studies, normally in first year. Students with any Québec collegial diploma (DEC) are exempt from this requirement 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 the credits will be added to the total credit requirement. Students entering four-year programs in Mathematics with a grade 12 diploma (or equivalent) must register in Mathematics 191 and 192 in first year. These courses are included in the 124 (or higher) 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 193 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 199 (instead of Mat 191 and 192, although theses are acceptable), and do not need to do so in 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 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 the credits will be added to the total credit requirement. Students entering four-year B.Sc. programs in Mathematics with a grade 12 diploma (or equivalent) must register in Physics 191 and 192 in first year. These courses are included in the 124 (or higher) total credit requirement.

Humanities requirement

Students entering any four-year program in the Division of Natural Sciences and Mathematics, with a grade 12 diploma (or equivalent) from another Canadian province, the USA or elsewhere, must complete six course credits of humanities studies, normally in the 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 ELA 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). These credits are included in the 124 (or higher) total credit requirement.

Computer Science requirement

All Mathematics majors and honours students (except those in the Mathematics Education double major program) are required to complete the course CSC 111 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, 191, 192, 193, 195, 198, 199, as mathematics elective credits. Courses at the 400 level are only open to Honours students.

The courses Mathematics 190, 193, 195 are not accepted as credits for any Science or Mathematics degree. Mathematics 191, 192, 198, 199 are not accepted as credits in 90-credit Science programs. Mathematics courses 190, 191, 192, 193, 198, 199 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 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 Education double Major; B.Sc., B.A.

These students will find their program course list and additional program requirements listed in the School of Education's section of this Calendar.

Mathematics (Applied or Pure) double Concentration; B.B.S.

These students will find the Bachelor of Commerce and Science program description, their program course lists and additional program requirements listed at the beginning of the Division of Natural Science and Mathematics' section of this Calendar.

Mathematics Honours; B.Sc., B.A.

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:

MAT105, MAT106, MAT107, MAT108, MAT109, MAT115, CSC111, MAT210, MAT213, MAT214, MAT215, MAT217, MAT221, MAT222
6 optional credits of Mathematics courses at the 100 level or higher,
9 optional credits of Mathematics courses at the 200 level or higher,
6 optional credits of Mathematics courses at the 300 level or higher,
6 optional credits of Mathematics courses at the 400 level.

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

Total credits:

B.Sc.: 66 Mathematics, 4 Computer Science,
9 Science options, 12 options.
B.A. : 66 Mathematics, 4 Computer Science,
21 options.

Recommended schedule:

	Fall	Winter
Year 0		

(for students in a four-year program or lacking some CEGEP requirements)

	MAT191	MAT192
	PHY191 (B.Sc. students)	PHY192 (B.Sc. students)
	ELA116	Humanities electives
	elective (B.A. students)	elective (B.A. students)
	elective	elective
	elective	elective
Year 1	MAT105	MAT115
	MAT106	MAT107
	MAT108	MAT109
	CSC111	elective
	elective	elective
Year 2	MAT1xx	MAT1xx
	MAT213	MAT214
	MAT221	MAT222
	MAT2xx	MAT2xx
	elective	elective
Year 3	MAT215	MAT217
	MAT210	MAT2xx
	MAT3xx	MAT3xx
	MAT4xx	MAT4xx
	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 MATnxx refers to any 3-credit MAT course at the n-hundred level or higher.

Mathematics Major; B.Sc.,B.A.

Requirements:

MAT105, MAT106, MAT107, MAT108, MAT109, CSC111

3 credits from the list {MAT115, MAT114 OR MAT125}, MAT210, MAT213, MAT214, MAT215, MAT221,
6 optional credits of Mathematics courses at the 100 level or higher,
9 optional credits of Mathematics courses at the 200 level or higher.
B.Sc. students must include at least 9 additional Science credits among their options.

Total credits:

B.Sc.: 48 Mathematics, 4 Computer Science,
9 Science options, 30 options.
B.A.: 48 Mathematics, 4 Computer Science,
39 options.

Recommended schedule:

	Fall	Winter
Year 0		
(for students in a four-year program or lacking some CEGEP requirements)		
	MAT191	MAT192
	PHY191 (B.Sc. students)	PHY192 (B.Sc. students)
	ELA116	Humanities electives
	elective (B.A. students)	elective (B.A. students)

	elective	elective
	elective	elective
Year 1	MAT105	MAT{115 or 114 or 125}
	MAT106	MAT107
	MAT108	MAT109
	CSC111	elective
	elective	elective
Year 2	MAT1xx	MAT1xx
	MAT213	MAT214
	MAT221	MAT2xx
	elective	elective
	elective	elective
Year 3	MAT215	MAT2xx
	MAT210	MAT2xx
	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 MATnxx refers to any 3-credit MAT course at the n-hundred level or higher.

Mathematics Minor; B.Sc., B.A.

MAT 106a, 107b, 108a, 109b or 105b, plus 12 additional mathematics credits, not including MAT 191a or MAT 192b, including at least 6 credits at the 200 level or higher.

Minor in Mathematical Contexts; B.A.

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 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, of 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 (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 theses 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 105 Discrete Mathematics
Mat 108 Matrix Algebra
Phy 101 Statistical Methods
Mat 198* Calculus I (for Life Sciences) prereq: Precalculus
Mat 199* Calculus II (for Life Sciences) prereq: 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 109 Linear Algebra prereq: Mat 108
Mat 114 Modern Geometry: Euclidean to Fractal
prereq: Mat 105
Mat 115 Further Discrete Mathematics prereq: Mat 105
Mat 125 Number Theory
Mat 221 Introduction to Modern Algebra I
prereq: Mat 105, Mat 109
Mat 222 Introduction to Modern Algebra II prereq: Mat 221

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 100a 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 enroll in Mathematics 110 instead of this course. Students may only receive credit for one of MAT 100 or MAT 110.

Mathematics 101b Further Excursions in Mathematics 3-3-0

Further topics in modern applied mathematics. A continuation of the style and subjects in Mathematics 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 enroll in Mathematics 111b instead of this course. Students may only receive credit for one of MAT 101 and MAT 111.

Mathematics 104a 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.

Mathematics 105a Introduction to Discrete Mathematics 3-3-0
Combinatorics. Propositional logic. Induction. Sets. Quantifiers. Recursion relations.

Mathematics 106a Advanced Calculus I 3-3-0
Sequences and series. Taylor series and polynomials. Power Series. Functions of 2 and 3 variables. Partial Derivatives, directional derivatives, differentials. Lagrange multipliers. Multiple integrals and applications.
Prerequisite: Mathematics 192b or a grade of at least 80% in Mathematics 199b.

Mathematics 107b Advanced Calculus II 3-3-0
Vector-valued functions, parametric curves, arclength, curvature. Change of Variables and Jacobians. Line intergrals. Surface integrals. Green's theorem. Divergence theorem. Stoke's theorem. Differential operator.
Prerequisite: Mathematics 106a, Mathematics 108a

Mathematics 108a 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.

Mathematics 109b Linear Algebra 3-3-0
Diagonalization. Inner product spaces. Gram-Schmidt process. Change of basis. Complex vector spaces. Systems of differential equations. Applications.
Prerequisite: Mathematics 108a

Mathematics 110a Excursions in Modern Mathematics 3-3-0
This is the same course as Mathematics 100 but it is intended that science students would enroll 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.

Mathematics 111b Further Excursions in Mathematics 3-3-0
This is the same course as Mathematics 101b but it is intended that science students would enroll in this course and complete assignments that are more appropriate to their needs.
Note: See Mathematics 101b. Students may only receive credit for one of MAT 101 and MAT111.

Mathematics 114b 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 184b.
Prerequisite: Mat 105
Corequisite: Mat 184b

Mathematics 115b 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: Mathematics 105a

Mathematics 125a Number Theory 3-3-0
A classical discipline, number theory has become the spectacularly successful language of modern aryptography and coding theory. This course is a gently introduction to the classical theory and modern applications. Topics may include: unique factorization and congruences, group of integers module n and its units, Fermat's little theorem, Fermat's last theorem, Euler's function, Wilson's theorem, Chinese remainder theorem, quadratic repricocity, Gaussian integers.
Prerequisite: Mathematics 105

Mathematics 172a Mathematical Economics I 3-3-0
Application of matrix algebra and multivariate calculus to model-building and problem-solving in Economics
Prerequisites: Economics 102, 103
See EMA262A
Students may not take this course for credit if they have received credit for EMA262a.

Mathematics 177a Introduction to Mechanics 3-3-0
Statics: equilibrium of bodies subject to many forces. Kinematics; rectilinear, plane, circular and simple harmonic motion. Dynamics: conservation of mechanical energy and momentum; place and circular motion of particles; rotation of macroscopic bodies. Elasticity: elastic moduli. Hydrostatics and hydrodynamics.
Prerequisite: Physics 191a or equivalent
Corequisite: Mathematics 106a
See Physics 117a
Students may not take this course for credit if they have received credit for Physics 117a.

Mathematics 184b 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 114 which must be taken concurrently.
Corequisite: Mat 114b

Mathematics 190ab 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 taken elsewhere may not register for this course.

Mathematics 191a 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 Mathematics 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 Mathematics 191a, 193ab, and 198ab.

Mathematics 192b Enriched Calculus II 3-3-0
Area. The definite integral. The Fundamental Theorem of Calculus. Techniques of integration. Volumes, centers of mass, moments of inertia, arclength and other applications of integration. Mean value theorem for integrals. Emphasis is on analytical understanding.
Prerequisite: Mathematics 191a or a grade of at least 70% in Mathematics 198a or 80% in Mathematics 193ab.
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 Mathematics 191a, 193ab, and 198a.

Mathematics 193ab Calculus I (for Business and Economics students) 3-3-0
Functions. Limits and continuity. Slope of tangent line. Derivative of a function. Derivatives of polynomial, exponential and logarithmic functions. Rules for sums, products, quotients. Chain rule. Maxima and minima. Introduction to integration: antiderivatives and area.
Pre or Co-requisite: Mathematics 190a, CEGEP Math NYA or the equivalent
Credit will be given for only one of Mathematics 191a, 193ab and 198ab.
Students who have received credit for an equivalent course taken elsewhere may not register for this course.

Mathematics 195ab Calculus II (for Business and Economics Students) 3-3-0
Review and extension of differentiation and integration. Implicit differentiation. Integration by substitution and parts. Separable first order differential equations. Riemann sums. Applications to areas, finance, etc. Introduction to matrix algebra.
Prerequisite: Mathematics 193b or CEGEP Math NYA or the equivalent.
Credit will be given for only one of Mathematics 192b, 195ab and 199b.
Students who have received credit for an equivalent course taken elsewhere may not register for this course.

Mathematics 198a 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 Mathematics 191a, 193ab, and 198ab.

Mathematics 199b 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: Mathematics 198ab or 191a or the equivalent.
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 Mathematics 192b, 195ab, and 199b.

Mathematics 210a 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: Mathematics 106
See Physics 270
Students may not take this course for credit if they have received credit for Physics 270

Mathematics 211b 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: Mathematics 210a
See Physics 271

Students may not take this course for credit if they have received credit for Physics 271

Mathematics 213a 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: Mathematics 106a

Mathematics 214b 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: Mathematics 213a

Mathematics 215a 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: Mathematics 107b.

Mathematics 216b Real Analysis II 3-3-0
The generalized Riemann interal (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: Mathematics 215a
Offered alternately with Mathematics 217b

Mathematics 217b 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: Mathematics 215a.
Offered alternately with Mathematics 216b

Mathematics 221a 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: Mathematics 105ab, Mathematics 109b

Mathematics 222b 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: Mathematics 221a

Mathematics 224 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: Mathematics 105, 108
Professor Brüstle

Mathematics 225b 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: Computer Science 111ab. Mathematics 107, 108.
Note: See CSC 275 and Phy 275.
Students may not take this course for credit if they have received credit for Computer Science 275 or Physics 275.

Mathematics 226a 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: Mathematics 107, 108

Mathematics 271b Econometrics II 3-3-0
Ordinary least-square estimation and hypothesis testing using matrix algebra. The topics include: generalised least squares estimation, distributed (eg. models, two-stage) least squares estimation, and the Granger causality test.
See EMA 361b
Students may not take this course for credit if they have received credit for EMA 361b.

Mathematics 272b Mathematical Economics II 3-3-0

The application of differential and difference equations, and mathematical programming, to model building and problem solving in Economics.
See EMA 362b
Students may not take this course for credit if they have received credit for EMA 362b.

Mathematics 275b Theoretical Aspects of Computer Science 3-3-0
The course will include several of the following topics: Computational models; Computational complexity; Finite-state machines; Context-free languages; Pushdown automata; Turing machines; Undecidable problems.
Prerequisite: Math 105
See Computer Science 305b
Students may not take this course for credit if they have received credit for Computer Science 305b.

Mathematics 277a Design and Analysis of Algorithms 3-3-0
This course is intended to make students familiar with most of the existing techniques for problem solving. It starts with an introduction to algorithms efficiency, solving recurrence relations and basic data structures. Then different techniques for algorithms design are discussed; the divide-and-conquer technique, the greedy technique and its applications to graph algorithms, dynamic programming, backtracking and genetic algorithms. At the end, students are briefly introduced to the vase area of "difficult" problems, or NP-complete.
Prerequisite: Computer Science 204 and Mathematics 105.
See Computer Science 217a.
Students may not take this course for credit if they have received credit for Computer Science 217a.

Mathematics 278b Advanced Mechanics 3-3-0
Dynamics of macroscopic bodies. Newtonian gravitation: planetary orbits; tides. Elasticity; the flexure of elastic bodies. Relativistic dynamics of particles. The Lagrangian and Hamilton's Principle.
Prerequisite: Physics 117a, Mathematics 210a
Offered alternate years
See Physics 218b
Students may not take this course for credit if they have received credit for Physics 218b.

Mathematics 279b Scientific Programming 3-3-3
This course is designed as an introduction to programming languages and environments suitable for the numerically intensive applications in the natural sciences and mathematics. Examples will be given to illustrate the use of Fortran in numerical calculations. Other examples will be tackled using the Maple language initially developed to handle problems in symbolic computation.
Prerequisite: CSC 204, Math 191, Math 192
See Computer Science 208b, Physics 278B
Students may not take this course for credit if they have received credit for Computer Science 208b or Physics 278b.

Mathematics 301b 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: Mathematics 107b.

Mathematics 302b Tensor Analysis 3-3-0
General curvilinear coordinates. Differential forms. Bilinear forms and tensors of rank two. Tensor algebra and tensor calculus.
Prerequisite: Mathematics 301a.

Mathematics 305b 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 Cavatheodory complete figure. Fields and the Legendre and Weierstrass sufficient conditions.
Prerequisites: Mat 107, Mat210
See Physics 276
Students may not take this course for credit if they have received credit for Physics 276

Mathematics 306b Differential Geometry 3-3-0
Curves in 3-space. Euclidean motions, surface theory. Introduction to differential manifold, Guassian and mean curvature, imbedding conditions. Geodesics, parallel transport and the Gauss-Bonet Theorem.
Prerequisite: Mat 107, Mat 210

Mathematics 321a Graph Theory 3-3-0
An introduction to the combinatorial, algorithmic and algebraic aspects of graph theory.
Prerequisite: Mat 105
Note: See CSC371. Students may not take this course for credit if they have received credit for CSC371.

Mathematics 331b 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: Mathematics 215a, or consent of the instructor.

Mathematics 333b Infinite Abelian Groups 3-3-0
Structure of finite abelian groups, examples of infinite abelian groups, torsion and torsion-free groups, divisible groups, pure subgroups, algebraically compact groups, classification of torsion-free groups of rank 1. Generalizations of group concepts to modules over a principal ideal ring.
Prerequisite: Mathematics 221a, 222b

400 level courses are for Honours students only

Mathematics 450a, 451b Topics in Algebra I and 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: Mathematics 109b, 222b or consent of instructor.
Offered by arrangement.

Mathematics 452a 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: Mathematics 216b.

Mathematics 453b 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: Mathematics 216b.
Offered by arrangement.

Mathematics 454a, 455b Topology
Offered by arrangement.

Mathematics 456a Independent Studies I 3-0-0
Open to final-year honours students by arrangement with the department.

Mathematics 457b Independent Studies II 3-0-0
See Mathematics 456a.

Cognate Courses:

Philosophy 151 may count as a cognate for the Honours or Major program.