BRS 403 Hops 3-3-0
Hops is the ingredient that contributes the characteristic bitterness of beer. It is also responsible for much of the flavours and aromas of beer, particularly those observed in heavily hopped beers such as India Pale Ale, American Pale Ale, and even hoppier double IPAs. The first section of this course will cover the farming, harvesting and processing of hops. The second section will cover hop chemistry, focusing on the resins (bittering agents) and essential oils (flavour and aroma contributors) of the hop cone and their transformations during the brewing process. Students cannot receive credit for both BRS 403 and BRS 503. If the student intends to enroll in the Graduate Certificate in Brewing Science, they should not take any of the BRS 40x courses because they cannot be counted for credit toward both a B.Sc. and a Graduate Certificate.

BRS 404 Microorganisms in the Brewery 3-3-0
The role of brewer's yeast in the brewing process, particularly its fermentation of sugars to produce alcohol, is fairly well known. However, yeast is also responsible for producing dozens, if not hundreds, of chemical compounds as it metabolizes the sugars, amino acids, and other components during fermentation. Many of these compounds contribute significantly to the flavour and aroma of beer. Other microorganisms, such as wild yeast and bacteria, are also potential contributors to the complex chemistry and biochemistry that occurs in the fermenter; sometimes to the benefit of the beer but more often to its detriment. This course will look at all of the microorganisms that are commonly found in the brewery and provide a detailed description of their chemistry and thus their impact on beer flavour and aroma.
Prerequisites: CHM 211 and BIO 201

BRS 405 Chemical Analysis of Beer and its Ingredients 3-3-0
As a food product, beer is rigorously controlled at both the federal and provincial levels of government. Part of this process is ensuring that a number of analytical parameters are accurately reported (e.g. alcohol by volume). Many other properties of beer are indicators of the efficacy of the brewing process and whether the brewer is producing a quality product. Analysis of the ingredients of beer (water, malt, hops, yeast) is essential to ensure that standards of quality necessary to produce good beer are met. This course will provide students with an in depth look at the chemical analyses commonly used to analyse beer and its precursors, using the methods database of the American Society of Brewing Chemists. Students will use what they learn to analyse the ingredients and the beer that they use / produce in the co-requisite practicum in brewing.
Prerequisites: CHM 141 and CHL 141

BRS 406 The Business of Brewing 3-3-0
There is a great deal of time and hard work that goes into planning, building, equipping, and running even a small microbrewery. When a microbrewery fails, it is generally because the ownership doesn't have a particular skill set, whether it be on the brewing side or on the business side. This course will take students through all of the steps necessary to get a microbrewery from the planning to the operation stage, and also introduce them to the business knowledge necessary for running a successful microbrewery.

BRS 498 Practicum in Brewing I 3-3-0
Ultimately, brewing is a hands-on activity. The brewer must pay careful attention at every step of the brewing process in order to ensure that they have the best chance of producing the desired final product. Even then, the beer, although well crafted, may not exhibit the characteristics of flavour, aroma, colour, bitterness, etc. that the brewer was attempting to produce. Recipe development is a wonderful example of the scientific method and this approach to brewing will be the main focus of this course. Upon completion of BRS 498, students will receive more than 90 hours of brewing experience, constantly comparing what they observe in the brewery with what they are learning in their BRS lecture courses. The aim is to produce a brewer who is proficient in the brewery but also understands the complex chemistry and biochemistry that is involved in producing the highest quality beers.
Prerequisites: BRS 401

BRS 499 Practicum in Brewing II 3-3-0
Ultimately, brewing is a hands-on activity. The brewer must pay careful attention at every step of the brewing process in order to ensure that they have the best chance of producing the desired final product. Even then, the beer, although well crafted, may not exhibit the characteristics of flavour, aroma, colour, bitterness, etc. that the brewer was attempting to produce. Recipe development is a wonderful example of the scientific method and this approach to brewing will be the main focus of this course. Upon completion of BRS 498 and BRS499, students will receive more than 180 hours of brewing experience, constantly comparing what they observe in the brewery with what they are learning in their BRS lecture courses. The aim is to produce a brewer who is proficient in the brewery but also understands the complex chemistry and biochemistry that is involved in producing the highest quality beers.
Prerequisites: BRS 401 and BRS 498

Computer Science

Faculty

Madjid Allili,
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Professor
Chair of the Department

Layachi Bentabet,
B.Sc.(Eng.National Polytechnic, Algeria), M.Sc.(Elec. Eng. Institut national des sciences appliquées, Lyon), Ph.D.(Sherbrooke); Professor

Stefan D. Bruda,
B.Sc.Eng., M.Sc., Ph.D. (Queen's); Professor

Russell Butler
B.Sc. (Bishop's), M.Sc., Ph.D. (Sherbrooke);Professor

Lin C. Jensen,
B.Sc. (Stanford), M. Sc. (Concordia); Senior Instructor

Program Overview

Computer science is a subject related to almost every contemporary intellectual discipline, the arts (computer-generated art, verification of historical documents, syntax study of languages including translation, etc.), social sciences (correlating experimental data, simulation, artificial intelligence studies), natural sciences (has always had application in this area), business and government (the largest single groups of users), education (computer-aided instruction, artificial intelligence), medicine, etc.

The department offers a wide selection of programs, ranging from broad to specialized:

1) Undergraduate B.Sc. Degree Programs

I. B.Sc, Honours in Computer Science

II. B.Sc, Major in Computer Science

2) A multidisciplinary B.A. with a Major in Information Technology (BAIT)

3) Minor in Computer Science

4) Certificate Program in Computer Science

Note: *A Co-op program is offered for all students in programs 2) and 3) above. Please refer to the Co-op section.*

5) Master's Degree Program (see *Graduate Programs* section)

I. Thesis Option

II. Project Option

Undergraduate B.Sc. Degree Programs

Honours in Computer Science (120 credits) HONCSC

A. Dissertation-based Honours

18 credits: Program prerequisites *(please refer to Table II in the Divisional section of the Calendar)*
57 CS credits: 39 required: CS 201, CS 211, CS 216, CS 304, CS 310, CS 311, CS 317, CS 321, CS 403, CS 409, CS 455, CS 499
18 electives: must include 12 credits from 400-level courses and above
12 MAT credits: 12 required: MAT 108, MAT 200, MAT 206, MAT 207
3 PHY credits: PHY 101
3 credits: Arts and Science requirement *(please refer to the Divisional section of the Calendar)*
27 credits of free electives

B. Course-based Honours

The course-based stream does not require a dissertation (i.e. CS 499) but requires 3 more CS courses. It is primarily designed for students wishing a specialization in Computer Science but are not interested in research and do not intend to pursue graduate studies:

18 credits: Program prerequisites *(please refer to Table II in the Divisional section of the Calendar)*
60 CS credits: 33 required: CS 201, CS 211, CS 216, CS 304, CS 310, CS 311, CS 317, CS 321, CS 403, CS 409, CS 455
27 electives: must include 15 credits from 400-level courses
12 MAT credits: 12 required: MAT 108, MAT 200, MAT 206, MAT 207
3 PHY credits: PHY 101
3 credits: Arts and Science requirement *(please refer to the Divisional section of the Calendar)*
27 credits of free electives

General Notes for Honours

- after a minimum of 1 semester, a student with a grade of at least 80% in required courses may request entry to the Honours program
- the dissertation stream requires, in addition, departmental permission.
- students must maintain an average of 80% in required courses to stay in the program

Major in Computer Science (120 credits) MAJCSC

18 credits: Program prerequisites (please refer to Table II in the Divisional section of the Calendar)
45 CS credits: 30 required: CS 201, CS 211, CS 216, CS 304, CS 310, CS 311, CS 317, CS 321, CS 403, CS409
15 electives
9 MAT credits: 6 required: MAT 108, MAT 200
3 elective (MAT 19X cannot count as MAT elective)
3 PHY credits: PHY 101
3 credits: Arts and Science requirement (please refer to the Divisional section of the Calendar)
42 credits of free electives

B.A. PROGRAM, MAJOR IN INFORMATION TECHNOLOGY

Information Technology MAJITC

Information Technology (IT) is defined by the Information Technology Association of America (ITAA), as the study, design, development, implementation, support or management of computer-based information systems, particularly software applications and computer hardware. IT deals with the use of electronic computers and computer software to convert, store, protect, manage, transmit and retrieve data, securely.

This program provides the necessary skills and knowledge to work/design/participate within organizations that manage large amount of data and provide services to a large number of users. Students will develop skills and knowledge in Information Technologies, Management practices and Organizations, with the required fundamentals of Computer Science

Note: Students following this degree program are not eligible to add a Business program.

Program prerequisites: (12 credits) *Please refer to Table II in the Divisional section of the Calendar.*

Core curriculum (30 credits):
CS 201, CS 211, CS214/CS 325, CS 304, CS 307
BCS 220, BHR 221, BMA 140, BMA 141, BMG 100

Secondary Core [1] (30 credits)

A minimum of 3 courses in Computer Science.
A minimum of 3 courses in Business, normally chosen from the following list:
BAC 121, BCS 210, BCS 212, BCS 216, BCS 313, BMG 214, BMK 211, BMK 214, BMK 291, BMK 323, BMK 371, BMS 231, BMS 303, BMS 332

[1] Students are advised to consult the Calendar for prerequisites

Arts and Science requirements (3 credits)
Please refer to the Divisional section of the Calendar

Free electives (45 credits)

Co-Operative Education Program

B.Sc. Coop

The co-operative Education Program combines a student's academic program with integrated work experiences through full-time work terms and regular academic sessions. The work terms are designed to present the students with the opportunity to blend theory and practice and to gain relevant work experience.

Each co-operative work term is between 12 and 16 weeks in length, and the student will be registered in a 3-credit Co-operative Placement course (CS 391, CS 392 or CS 393). These course credits count as free electives. Each is graded on a pass/fail basis and this grade is not included in the student's cumulative average. The evaluation is the responsibility of the Departmental Chair and will be based upon the submission of a work term report and a job performance report submitted by the employer. Normal academic regulations apply to the conduct and evaluation of the courses.

The number of work terms needed depends on the number of credits the students need to complete upon admission at Bishop's. Student who have been granted 30 advance credits (or more) will be required to complete two work terms (6 credits). Other students who have been admitted into a regular 120-credit degree program will be required to complete three work terms (9 credits). These credits will be added to the student's program and do not count as computer science courses, computer science electives, or free electives. All work terms must be completed before the student's final academic semester and a student's last semester before graduation cannot be a work term. While every effort will be made to find a suitable placement for all students in the program, no guarantee of placement can be made since the employment process is competitive and subject to market conditions.

Admission to the Co-operative Education Program

Students must submit an application to be admitted to the program. Full-time students in any Honours or Major program offered in the Computer Science Department who have completed the online application package, who have successfully completed BMG191 and who have a minimum cumulative average of 70% upon application are admissible into the Co-op Program. Students in the Co-op must maintain their 70% average and be full-time in order to stay in the program.

Work Term Registration

Once a student has signed the Co-operative Education Agreement, the student may not drop the course associated with the work placement, except for exceptional circumstances. A student who decides to do so will not be able to stay in the Co-operative Education program.

Tuition and Fees

Each work term placement is a 3-credit course and students will pay tuition based upon their fee paying status (Quebec resident, Canadian out-of-province, International).

Work Term Evaluation

Successful completion of the work term is based upon the following:

- The receipt of a satisfactory job performance report from the employer
- The submission of a satisfactory work term report by the student.

The job performance report will be completed by the employer, using guidelines supplied by the Computer Science Department. It is the student's responsibility to ensure that the employer sends the completed evaluation to the Co-op Coordinator on or before the established deadline. Employer evaluations are confidential and are not reported on the student's transcript.

MINOR IN COMPUTER SCIENCE (24 credits)

MINCSC

9 required: CS 201, CS 211, CS 304
15 electives from any CS course

CERTIFICATE PROGRAM (30 credits)

CONCSC

Description and objectives:

The Certificate Program in Computer Science is designed for individuals who need to acquire a basic understanding of computers and programming and knowledge of the field in order to expand their area of interest and professional expertise. Topics include: Programming, Software Engineering, Web Design, Networks, Graphics, Artificial Intelligence and others. This program will help students to take full advantage of the computer technology available in the workplace.

Prerequisites to programs:

Applicants with insufficient Math background might be required to take an additional 3-credit Math course in their first semester (Math 190 or equivalent).

Program Overview

Certificate in Computer Science

- 12 required credits: CS 201, CS 211, CS 304, CS 321
- 18 credits of CS electives

General Notes/Restrictions:

1. Only one of CS 404, CS 408 or CS 499 may be taken for credit, unless with a special departmental authorization
2. Computer Science courses that are double-listed in Math cannot be counted toward fulfilling the Math electives required for the Computer Science Honours/Major.
3. Students must fulfill their Arts and Science requirements and Humanities requirements outlined in the "Divisional" section of the Calendar.

List of Courses

CS 201 Foundations of Computer Science 3-3-0
An introduction to Computer Science and selected applications suitable for both majors and science non-majors who want a broad overview of the field. The course provides a layered introduction covering hardware, system software and applications packages. The course includes elementary programming. Topics include Algorithmic foundations of Computer Science; The hardware world: number systems, boolean logic, computer circuits, Von-Newmann architecture; System software: assembly language, operating systems, high level languages, language translation; Models of Computation; Applications and Social Issues
Note: Registration priority is given to Science and IT students. CS students must take this course in their first year.

CSL 201 Foundations of Computer Science Laboratory 1-0-3
This is the practical laboratory for CS 201

CS 203 Interactive Web Page Design 3-3-0
In this course, students will learn the basics of HTML, the language describing web pages, and CSS, another web page language. By constructing fill-in forms and employing short sections of script, students will learn how to enable users of the Internet to interact with their web pages: sending data to be stored, and receiving customized responses. The course will include simple database operations. Extensive laboratory work will result in students creating their own set of personal web pages on a publicly accessible server. The course is open to anyone interested in the subject.

CSL 203 Interactive Web Page Design Laboratory 1-0-3
This is the practical laboratory for CS 203

CS 211 Introduction to Programming 3-3-0
This course introduces algorithms, data structures and software engineering principles. The use of a high level language is the tool to develop these components. By the end of the course, a successful student should be 'fluent' in programming, and have a good base for simple data structures. The course provides the necessary programming skills needed for further studies in Computer Science.

CSL 211 Introduction to Programming Laboratory 1-0-3
This is the practical laboratory for CS 211

CS 214 Introduction to Networks 3-3-0
This course introduces and discusses the components and architectures of computer networks. Topics to be covered include: Resources Sharing (Network Interface Circuitry, Files Servers, Workstations, etc.), Network Protocols (TCP/IP, Apple Talk, Novel, etc.) and Network Infrastructure (Hubs, Routers, Gateways, Bridges, etc.).

CS 216 System Programming Languages 3-3-0
System programmers need to understand how a computer works at a low level. They program primarily in C, with some assembly language. This course covers number systems, the C programming language, and an assembly language for a representative processor architecture. Topics covered include addressing modes, the stack, function calls and argument passing.

CSL 216 System Programming Languages Laboratory 1-0-3
Practical work for CS 216 will consist of programming in C and MIPS assembly language.

CS 219 General Topics in Computer Applications 3-3-0
The course will present general Computer Science-related topics, of interest to both Computer Science as well as non-Computer Science students. The course content is expected to vary to reflect the interest of students and Faculty, as well as market innovations.

CSL 284 Unix System Administration Laboratory 1-0-0
This lab familiarizes students with the Linux and Unix environments covering system administration and user management. Students will start with isolated machines then learn how to interface a Unix system with a network. Advanced topics include the configuration and administration of email and Web servers, as well as techniques for the automation of system administrator tasks via scripting languages. All students will have root and console access to real machines, thus they will gain real networking experience.
Prerequisite: CS 211

CS 301 Computer Ethics 3-3-0
Ethics is a branch of philosophy. Computers introduce arguably unique ethical issues in the way their use affects society. Technically minded professionals often give little attention to ethical issues. This course explores the basis for ethical reasoning, and examines ethical issues such as invasion of privacy, mischief including viruses, piracy and liability of software. It also considers broader issues of impacts on the individual and society, control of the technology, and the question of the difference between human understanding and rule-base processing of data. Students will be expected to participate in class discussions and role-playing scenarios, and to write a term paper.

CS 304 Data Structures 3-3-0
An advanced course designed to expose the student to the latest programming theory and software engineering principles. Topics covered include modularization, data encapsulation, information hiding, data abstraction, and other object oriented software construction techniques will be discussed. Parallel design of algorithms and data structures, analysis of algorithms (including "big O" notation and software verification methods.) Standard data structures such as stacks, queues, trees and graphs will be examined. Programming examples are done in Java.
Prerequisite: CS 211

CS 306 Functional and Logic Programming 3-3-0
There is much more than imperative programming. This course introduces two other programming paradigms, functional and logic. Topics normally include: functional programming languages, such as Lisp and Haskell; higher order functions, lazy evaluation, abstract and recursive types, structural induction, symbolic expressions; logic programming languages, such as Prolog; operational interpretation of predicates and terms, proof search, unification, backtracking; typical applications.
Prerequisite: CS 304 Allow concurrent

CS 307 Using and Designing Data Bases 3-3-0
This course presents data modeling (Entity-Relationship model, UML, etc..), relational algebra, normalization, SQL language. Implementation of databases using the relational model is discussed. Object-oriented modeling and implementation is also introduced. Other topics include: Concurrency control, transaction processing, client-server systems, distributed databases, and web-based delivery of data.
Prerequisite: CS 304
Note: Students may not take this course for credit if they received credit for either BCS 214 (Jan 98 and onward) or CSC 274 (prior to 2003).

CSL 307 Using and Designing Data Bases Laboratory 1-0-3
This is the practical laboratory for CS 307

CS 308 Scientific Programming 3-3-0
Scientific Programming is a course for students who want to learn more about the computing that goes on behind computational science. Students will learn the basic mathematical tools and computational techniques including the design and analysis of algorithms for solving mathematical problems that arise in many fields, especially science and engineering. Emphasis is placed on both the actual implementation and on the numerical and algebraic methods. The programming projects assigned in this course will make substantial use of C and C++ for numerical computations and Maple for symbolic computations.
Prerequisite: CS 304, Math 191, Math 192
Note: See PHY 378. Students may not take this course for credit if they have received credit for Mat 279 or Phy 378.

CS 310 Introduction to Software Specifications 3-3-0
This course provides to all the students in CS degrees essential material on formal languages and automata, and also on program specification using logical predicates. The following topics will be addressed: introduction to techniques for specifying the behaviour of software, with applications of these techniques to design, verification, and construction of software; logic-based techniques such as loop invariants and class invariants; automata and grammar-based techniques, with applications to scanners, parsers, user-interface dialogs and embedded systems; computability issues in software specifications. These topics have been chosen because they are both theoretical and practical, and will be presented as such.
Prerequisite: CS 211
Prerequisite or Corequisite: MAT 200

CS 311 Computer Organization and Logic Design 3-3-0
This is a theoretical course on computer organization and architecture. Different computer components and how they function are studied in detail. By the end of the course, students should be able to build (in theory) a small computer without interface. Topics covered are: boolean algebra and gates, combinational circuits (decoders, multiplexers, PLAs), logic design (flip-flops, shirts registers, counters, sequential circuits), the ALU, memory (RAM,ROM, secondary storage), I/O Devices and the control unit (hardwired, microprogramed). For those interested students, a follow-up course, largely consisting of lab experiments, is CS 312
Prerequisite: CS 201, CS 211

CSL 311 Computer Organization and Logic Design Laboratory 1-0-3
This is the practical laboratory for CS 311

CS 312 Microcomputer Interfacing 3-3-0
This course and integrated laboratory introduces the techniques used to interface a microcomputer to the real world with a robot as the main interface. Students will complete projects of increasing difficulty as they build and program a robot to accomplish a given task and brief the class on their design and findings. Topics will include: interactive programming, analog and digital inputs, use of the bus and registers to control output signals, simple electronic sensors, multiplexing and decoding and practical problem solving.
Prerequisite: CS 311 or equivalent programming and electronic knowledge.

CSL 312 Microcomputer Interfacing Laboratory 1-0-3
This is the practical laboratory for CS 312

CS 315 Data Communications 3-3-0
This is a theoretical course on Data Communications. It covers the basic and physical aspects involved when data is transmitted from one point to another, such as analog vs. digital transmission, various forms of encoding analog and digital data into appropriate signals, error detection techniques, multiplexing, etc... As well as an introduction is given on networking techniques, differences between circuit and packet switching, routing techniques, and Local Area Networks. The course is of mathematical and physical nature.
Prerequisites: CS 211 or CS 216
Note: See PHY 365. Students may not take this course for credit if they have received credit for PHY 365.

CS 316 Artificial Intelligence 3-3-0
A course aiming to introduce students to the basic concepts and techniques of Artificial Intelligence. Topics will include: Search strategies; knowledge representation; AI languages; Rule-based inference systems, expert systems; computer vision; planning and problem solving; natural language understanding.
Prerequisite: CS 304, CS 306 or CS 403

CS 317 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 branch and bound algorithms. With every technique presented, examples from different domains are studied and their algorithms analyzed. At the end, students are briefly introduced to the vast area of "difficult" problems, or NP-complete.
Prerequisite: CS 304 and MAT 200

CS 318 Advanced C++ Programming 3-3-0
The C++ language has become an industry standard as an implementation language. The course aims at introducing the student to intermediate and advanced programming using C++, with particular emphasis on systems software and the use of the C++ object-oriented extensions in software engineering
C++ Programming basics (loops and decisions, arrays, structures, functions, pointers) Objects and Classes, Inheritance, Virtual functions, files and stream, I/O Structure and design of Class libraries, Standard Template Library, OOP Design basics.
Although no prior experience in C is required, it is assumed that the student is already fluent in some other programming language and in the programming of data structures.
Prerequisite: CS 304

CS 321 Advanced Programming Techniques 3-3-0
The course is intended to be a sequel to introductory programming with emphasis placed on the architecture of software. It will go in depth into object-oriented techniques, reusability, data abstraction, class design, and implementation, design and structure of class libraries. Topics to be covered include: polymorphism, encapsulation, overloading, inheritance and delegation, types of inheritance (Inheritance for Extension, Specialization and Specification), composition, aggregation and design of collections. Static and dynamic types, downcasting, exception handling. The second half of the course will be devoted to software design patterns, with particular emphasis on the observer, iterator, visitor and selected creational patterns. Course work will involve significant programming projects. The teaching language will be Java.
Prerequisite: CS 304 Allow concurrent

CSL 321 Advanced Programming Techniques Laboratory 1-0-3
This is the practical laboratory for CS 321

CS 325 Computer & Network Security 3-3-0
This course provides an introduction to security and privacy issues in various aspects of computing, including cryptography, software, operating systems, networks, databases, and Internet applications. It examines causes of security and privacy breaches, and gives methods to help prevent them.
Prerequisite: CS 216

CS 330 Programming Mobile Apps 3-3-0
This course will cover mobile application development for the Android operating system using Android Studio. The programming language is Java. Setting up and using Android Studio IDE will be covered in the introduction. Students will learn how to design and develop Android applications using best practices to account for the limited screen size and memory of mobile devices. Topics to be covered include layout design/management, communication between apps, Google Maps, 2D graphics, and mobile app specific software engineering patterns. The course concludes with monetization (ads, in-app purchases, etc) and app store optimization strategies. The goal is for each student to develop and release an app by the end of the course.
Prerequisite: CS 211

CSL 330 Advanced Programming for Mobile Apps Laboratory 1-0-3
This is a practical laboratory for CS 330
Co-requisite: CS 330

CS 375 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.
Prerequisite: CS 211, Mathematics 108 and 207.
Note: See Mat 325 and Phy 375. Students may not take this course for credit if they have received credit for MAT 325 or for PHY 375

CS 379 Electric Circuits and Electronics 3-3-3
Review of D.C. circuits, Kirchoff's laws, network theorems. Network analysis for A.C. circuits, phasors. Diode circuits and filters. The physical basis of semiconductor devices including semiconductor diodes, junction transistors, and field-effect transistors. The operation of transistor amplifiers, digital electronics and integrated circuits will also be covered.
Note: See PHY 319. Students may not take this course for credit if they have received credit for PHY 319

CS 391 Co-operative Placement I 3-0-0
Students will integrate theory and practice through a related work placement
Prerequisite: admission to the Co-op Education Program

CS 392 Co-operative Placement II 3-0-0
Students will integrate theory and practice through related work placement
Prerequisite: CS 391

CS 393 Co-operative Placement III 3-0-0
Students will integrate theory and practice through related work placement
Prerequisite: CS 392

CS 394 Stage in Bioinformatics 6-0-0
Students will integrate theory and practice through a related stage.
Prerequisite: CS 372 / BCH 342

CS 400 Independent Studies 3-0-0
Individual study and research under the guidance of an advisor and Department staff.
Prerequisite: Permission of the department

CS 401 Simulation Techniques 3-3-0
Computer simulation is defined and put into the context of other simulation methods. Two main techniques are studied, one involving automated spreadsheets (financial modelling) and the other queuing theory. A term project involving the simulation of an actual system is part of the course.
Prerequisite: CS 304, PHY 101 (or equivalent)
Note: Students may not take this course for credit if they received credit for BMS 343. This course will be offered in alternate years.

CS 402 Computer Graphics 3-3-0
This is an introductory course to the principles of interactive raster graphics. Topics include an introduction to basic graphics concepts, scan conversion techniques, 2-D and 3-D modeling and transformations, viewing transformations, projections, rendering techniques, graphical software packages and graphics systems. Students will use OpenGL graphics API to reinforce concepts and study fundamental computer graphics techniques.
Prerequisites: CS 304, MAT 108

CSL 402 Computer Graphics Laboratory 1-0-3
This is the practical laboratory for CS 402

CS 403 Principles of Programming Languages 3-3-0
The objective of this course is to introduce, analyze and evaluate, on a comparative basis, the concepts on which programming languages and their implementations are based. Topics to be covered: definition of languages, syntax and semantics; Compilation techniques, top-down parsing, creating a parser; variables and binding, expressions, statements; data types; procedures scope, and run-time considerations; coroutines; implementation of block-structured languages; modularity and abstractions; concurrency exception handling and program correctness; functional programming object-oriented programming languages; logic programming and constraint languages.
The languages ML, Eiffel, Lisp, Scheme, Prolog, Haskell, 02, Java and Smalltalk will be used to illustrate the above concepts.
Prerequisites: CS 304 and CS 310

CS 404 Project 3-0-3
This course is normally taken by CS students in their final year. The project must be approved in advance by the department. Students will be expected to submit a written report and to make a presentation.
Prerequisite: approval of the dept., 80% in CS courses

CS 405 Data Mining 3-3-0
Data is now created faster than humans are able to understand it and use it. There may be patterns hiding within this data with potentially useful information. This course will teach students, how to discover these patterns for the purpose of solving problems, gaining knowledge, and making predictions. Topics covered in this course include data preparation, clustering, classification, association rules for mining and models combination. This course includes assignments and a final project where the students are required to perform mining on real datasets.
Prerequisites: PHY 101 (or equivalent)
See PHY 374
Students may not take this course for credit if they have received credit for PHY 374.

CS 406 Compilers and Interpreters 3-3-0
This course is intended as an introduction to the fundamentals of language translation and compiler construction. Topics will include language theory and syntax; grammars, finite state machines, non-deterministic push-down automata; a thorough treatment of parsing methods covering top-down, bottom-up and precedence parsers; Syntax directed translation; Run-time environments; optimization and error recovery; code generation. Students will be required to construct a working interpreter of a Pascal-like language.
Prerequisite: CS 310
This course will be offered on alternate years.

CS 408 Project II 3-0-3
This course is normally taken in the final year of studies and may involve work on a theoretical topic or a practical implementation of a sizable software project. The topic must be approved in advance by the department. Students are expected to attend bi-weekly project meetings where they present and discuss their work. In addition, they will make a final presentation at the end of term and submit a report.
Prerequisite: approval of the dept. 80% in CS courses.

CS 409 Principles of Operating Systems 3-3-0
Basic concepts of computer hardware; program translation linking and loading; cooperating sequential processes; critical section problem, process synchronization primitives, parallel programming; introduction to multiprogramming; operating system nucleus; file systems; reliability and protection; system performance, measurement and evaluation. Memory Management. Paging and Virtual memory. Unix. Using and programming the Unix Shell, Unix implementation. Examination of the implementation of Unix clones Minix, Linux, Survey of state-of the-art operating systems. Distributed Systems, Communication and synchronization in distributed systems. Theoretical issues and implementation.
Prerequisites: CS 304

CS 410 Software Engineering 3-3-0
Software is an engineered product that requires planning, analysis, design, implementation, testing and maintenance. This course is a presentation of the techniques used in each step of the software product process. Topics: software requirements analysis and specifications; software design process, object oriented design; testing, reliability and maintenance. Students will be expected to work jointly on several large software projects.
Prerequisites: CS 304, CS 310, CS 321, CS 403 (allow concurrent)

CS 411 Advanced Computer Architecture 3-3-0
The focus in this course is on basic principles, current practice, and issues in computer architecture and organization. At the end of the course students will have gained an understanding of how a computing system is organized, as well as why it is organized this way. The relation between hardware and the software that runs on it is emphasized, leading to an intuitive understanding of how the behavior of applications influences computer organization and design. Topics covered typically include (but are not limited to): instruction set design, micro-programed versus hardwired processors, pipelining and superscalar processors, memory organization (cache, primary, virtual), I/O and interrupts, multiprocessors. Comparative critical and quantitative analyses of various systems that currently exist are presented.
Prerequisites: CS 311 or instructor's permission.

CS 412 Computer Games Design 3-3-0
This course will explore the theory and practice of video game design and programming. Students will learn the basic concepts and techniques for the design and development of digital games. The topics covered in this course will include the history and taxonomy of video games, the basic building blocks of a game, computer graphics and programming, use interface and interaction design, and the software architecture for video games. It is assumed that students have taken courses in programming (best if it includes C or C++) and data structures. A good background in algorithms and basic mathematics (matrix algebra, trigonometry, linear algebra, vector calculus) is an asset for this course.
Prerequisite: CS 304

CS 415 Special Topics in Communications 3-3-0
The course will present topics of current interest or research directions in Computer Communications Networking and network programming. The course content is expected to vary to reflect the current interests of students and faculty. It will be offered by arrangement with the department.
Prerequisite: CS 304

CS 416 Special Topics in Software 3-3-0
The course will present topics of current interest or research directions in Software Science. The course content is expected to vary to reflect the current interests of students and faculty. It will be offered by arrangement with the department.
Prerequisite: CS 304

CS 417 Special Topics in Computer Applications 3-3-0
The course will present topics of current interest or research directions in Computer Applications. The course content is expected to vary to reflect the current interests of students and faculty. It will be offered by arrangement with the department.
Prerequisite: CS 304

CS 418 Topics in Computer Science 3-3-0
The course will present topics of current interest or research directions in Computer Science. The course content is expected to vary reflecting the interests of the students and the faculty. It will be offered by arrangement with the department.
Prerequisite: CS 304

CS 426 Computer-Assisted Interventions 3-3-0
This course introduces students to the fundamentals of computer-aided intervention (CAI) in medicine. The use of computing technology before, during, and after interventions will be examined. Specifically, this course will teach students about tracking devices, coordinate systems, spatial transformations, rigid and non-rigid registrations (feature-based & intensity-based), calibration, digitization and imaging. Clinical applications will also be discussed. Basic knowledge of either C++, python or matlab is an asset.
Prerequisites: Instructor's permission
Students cannot receive credits for both CS426 and CS526.

CS 454 Complements in Data Structures and Algorithms 3-3-0
The aim of this course is to cover many concepts in Data Structures, Algorithms, and Programming to make up deficiencies in Computer Science background for entering graduate students.
This course cannot be taken for credits by undergraduate students

CS 455 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: CS 211, MAT 200

CS 457 Database Software Design 3-3-0
This course covers how one can implement a Database Management system. Major topics are storage management, Query processing, and Transaction management. As a basic assumption, data will not all fit in main memory, so algorithms and data structures appropriate for effective disk storage and quick access must be used. For example, one may use index structures such as B-trees or hash tables. We cover parsing of queries and optimizing of query plans. Finally, we cover durability of transactions using logging, and concurrency control for isolation of transactions. Additional topics in distributed databases are also presented.
Prerequisite: CS 307

CS 462 Image Processing 3-3-0
This course will introduce the area of Image Processing and present classical tools and algorithms in the field including: image perception, image acquisition and display, histogram techniques, image restoration, image enhancement, primitive operations for image analysis, segmentation, image transforms, and pattern and object recognition.
Some examples of industrial applications of image processing and some important developments in image processing research will be also addressed.
Prerequisites: CS 304, MAT 192, PHY 101 (or equivalent)

CS 463 Computer Vision 3-3-0
This course is concerned with the computer acquisition and analysis of image data. Computer vision is the construction of explicit, meaningful descriptions of a physical object from images. Emphasis will be placed on: camera models and calibration, image representation, pattern recognition concepts, filtering and enhancing, segmentation, texture, motion from image sequences, deformable models, matching, stereovision, perceiving 3D from 2D images and tracking with dynamic models. The programming projects assigned in this course will make substantial use of the C and C++ programming languages
Prerequisites: CS 304, CS 318, MAT 192, PHY 101 (or equivalent)

CS 464 Network Programming 3-3-0
This course presents computer networks at a functional level, with strong emphasis on programming distributed applications over a network. Discussion will be based on open networking and application standards such as the TCP/IP protocol suite and the Portable Operating System Interface (POSIX). Topics normally covered are TCP/ IP architecture and programming, the client-server model, network file systems, streaming, tunnelling. Programming distributed applications (in C or C++) is an integral part of the course.
Prerequisite: CS 216

CS 467 Special Topics in Algorithms 3-3-0
The course builds on the techniques covered in CS 317 to present some specialized algorithms in several areas, including Bioinformatics, Computational Geometry, and Network Flow.
Prerequisite: CS 317 or permission of the instructor

CS 469 Special Topics in Computer Science 3-3-0
The course will present topics of current interest or research directions in Computer Science. The course content is expected to vary from year to year to reflect the current interests of students and faculty. It will be offered by arrangement with the department.
Prerequisite: CS 304

CS 471 Graph Theory 3-3-0
An introduction to the combinatorial, algorithmic and algebraic aspects of graph theory.
Prerequisite: CS 304, MAT 200
Note: See MAT 421. Students may not take this course for credit if they have received credit for MAT 421.

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.,
Ph.D. (Zurich), Professor,
Maurice-Auslander Research Chair

François Huard,
B.Sc., M.Sc., Ph.D. (Sherbrooke); Professor,
Chair of the Department

Trevor H. Jones,
B.Sc.H. (Acadia), M.Sc. (Dalhousie),
Ph.D. (University of New Brunswick);
Senior Instructor

Scosha Merovitz,
B.Sc.(Bishop's), M.Sc.(Dalhousie); Coordinator, Math/Stats Help Centre

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Adjunct Professor

N. Brad Willms,
B.Math. M.M., Ph.D. (Waterloo);
Associate Professor

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, Society and Culture (courses coded CLA, ENG, HIS, LIB, PHI, or RSC).

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.

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 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 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 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.*

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 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. Vector spaces. 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 MAT111.

MAT 190 Precalculus Mathematics 3-3-0
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 may only receive credit for this course with consent of their Departmental Chair.

MAT 191 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 or MAT 198

MAT 192 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 MAT 198
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.

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 or 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.

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. 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.
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 521 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.
See CS 571. Credit will be given for only one of MAT421, MAT 521 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, 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. Credit will be given for only one of MAT424 and MAT 524..

MAT 529 Discrete Structures and Computational Statistics 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.
Credit will be given for only one of MAT529 or CS 561.

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

Physics & Astronomy

Faculty

Ariel Edery,
B.Sc. (McGill), M.Sc. (Queen's), Ph.D. (Montréal);
Professor
Chair of the Department

Valerio Faraoni,
B.Sc. (University of Pavia, Italy), M.Sc., Ph.D.
(International School for Advanced Studies, Italy); Professor

Faycal Hammad,
B.Sc., M.Sc., Ph.D. (A. Mira-Bejaia);
Adjunct Professor

Anca Nedelcescu,
B.Sc. (West University of Timisoara), M.Sc.,
Ph.D. (Sherbrooke); Adjunct Professor

Lorne Nelson,
B.Sc. (McGill), M.Sc., Ph.D. (Queen's); Professor

Jason Rowe,
B.Sc. (Toronto), M.Sc., Ph.D. (UBC); Associate Professor
Canada Research Chair (Tier II)

John Ruan,
B.Sc.(Columbia), M.Sc., Ph.D.(University of Washington)
Assistant Professor, Canada Research Chair (Tier II)

Sylvain Turcotte,
B.Sc., M.Sc., Ph.D. (Montreal); Adjunct Professor

Program Overview

Physics is often regarded as the cornerstone of the Natural Sciences. It encompasses a diverse range of disciplines including astronomy and astrophysics, photonics, electronics, classical and quantum mechanics, statistical mechanics, particle physics, and solid state physics. The BSc Major program provides students with a fundamental understanding of physics. The highest level of specialization at the undergraduate level is the BSc Honours program. It prepares students for direct entry into graduate work in physics (leading to an MSc or PhD degree). Students may be admitted into the Honours program after one year is completed in the Physics Major program.

The Master of Science (MSc) program is designed to give students a much deeper appreciation of physics while at the same time training them to become independent researchers and scientists. Graduate supervision is available in a wide variety of disciplines including astronomy, astrophysics, exoplanetary science, theoretical cosmology and gravitational theory, and particle physics.

First-year Science Core requirements

All Physics students are required to take six course credits of Introductory Physics (PHY 191, PHY 192), six course credits of Introductory Calculus (MAT 191, MAT 192), and six course credits of Introductory Chemistry (CHM 191, CHM 192), normally in their first year. Students with a Québec collegial diploma (DEC) shall be granted advanced credit for these courses if they have