

# COMPUTING

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## Courses

### Computer and Information Science (CISC)

#### **CISC 101 Elements of Computing Science Units: 3.00**

Introduction to algorithms: their definition, design, coding, and execution on computers. Intended for students who have no programming experience. All or most assignment work will be completed during lab time.

NOTE Also offered online. Consult Arts and Science Online. Learning Hours may vary.

NOTE Sufficient preparation for CISC 121; alternative to CISC 110 and CISC 151.

LEARNING HOURS 120(36L;84P).

**Requirements:** Prerequisite None. Exclusion APSC 142; APSC 143; CISC 110; CISC 151. One-Way Exclusion May not be taken with or after CISC 121; CISC/CMPE/COCA/COGS/SOFT at the 200-level or above. Note This course is intended for students who have no programming experience.

**Offering Faculty:** Faculty of Arts and Science

#### **CISC 102 Discrete Mathematics for Computing I Units: 3.00**

Introduction to mathematical discourse and proof methods. Sets, functions, sequences, and relations. Properties of the integers. Induction. Equivalence relations. Linear and partial orderings.

NOTE Also offered online. Consult Arts and Science Online. Learning Hours may vary.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite None. One-Way Exclusion May not be taken with or after CISC 203.

**Offering Faculty:** Faculty of Arts and Science

#### **CISC 110 Creative Computing Units: 3.00**

Introduction to fundamental programming concepts in the context of visual, interactive media. Students may develop applications in any domain (e.g., fine art, education, commerce, physical or social sciences) while learning about algorithms, program design, logic, program control flow, functions, testing, etc.

NOTE Sufficient preparation for CISC 121; alternative to CISC 101 and CISC 151.

NOTE With permission of the School, students with programming experience may take this concurrently with CISC 121.

LEARNING HOURS 120 (36L;84P).

**Requirements:** Prerequisite None. Exclusion APSC 142; APSC 143; CISC 101; CISC 151. One-Way Exclusion May not be taken with or after CISC 121; CISC/CMPE/COCA/COGS/SOFT at the 200-level or above. Note No computing or art background required.

**Offering Faculty:** Faculty of Arts and Science

#### **CISC 121 Introduction to Computing Science I Units: 3.00**

Introduction to design, analysis, and implementation of algorithms. Recursion, backtracking, and exits. Sequences. Elementary searching and sorting. Order-of-magnitude complexity. Documentation, iterative program development, translating natural language to code, testing and debugging.

NOTE Also offered online. Consult Arts and Science Online. Learning Hours may vary.

LEARNING HOURS 120 (36L;84P).

**Requirements:** Prerequisite None. Corequisite (CISC 102 or MATH 110 or MATH 111 or MATH 112 or MATH 120 or MATH 121 or MATH 123 or MATH 124 or MATH 126 or APSC 171 or APSC 172 or APSC 174 or COMM 161 or COMM 162). Exclusion APSC 143. Recommended Some programming experience (such as high-school level programming or CISC 101 or CISC 110 or CISC 151).

**Offering Faculty:** Faculty of Arts and Science



**CISC 124 Introduction to Computing Science II Units: 3.00**

Introduction to object-oriented design, architecture, and programming. Use of packages, class libraries, and interfaces. Encapsulation and representational abstraction. Inheritance. Polymorphic programming. Exception handling. Iterators. Introduction to a class design notation. Numerical computation. Applications in various areas.  
LEARNING HOURS 120 (36L;24Lb;60P)

**Requirements:** Prerequisite A minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 121. Corequisite (CISC 102 or MATH 110 or MATH 111 or MATH 112 or MATH 120 or MATH 121 or MATH 123 or MATH 124 or MATH 126 or APSC 171 or APSC 172 or APSC 174 or COMM 161 or COMM 162).

**Offering Faculty:** Faculty of Arts and Science

**CISC 151 Elements of Computing with Data Analytics Units: 3.00**

Introduction to algorithms: their definition, design, coding, and execution on computers, with applications drawn from data analytics, including simple prediction and clustering. Intended for students who have no programming experience. All or most assignment work will be completed during lab time.

NOTE Sufficient preparation for CISC 121; alternative to CISC 101 and CISC 110.

LEARNING HOURS 120 (36L;84P).

**Requirements:** Prerequisite None. Exclusion APSC 142; APSC 143; CISC 101; CISC 110. One-Way Exclusion May not be taken with or after CISC 121; CISC/CMPE/COCA/COGS/SOFT at the 200-level or above.

**Offering Faculty:** Faculty of Arts and Science

**CISC 181 Digital Societies Units: 3.00**

This introductory course provides a broad overview and ethical implications of technological topics and trends in the digital world such as the Internet of Things (IoT), Social Networks, Security and Privacy, Data Analytics, and Artificial Intelligence (AI). No programming experience is required.  
LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite None. Equivalency CISC P81.

**Offering Faculty:** Faculty of Arts and Science

**CISC 203 Discrete Mathematics for Computing II Units: 3.00**

Proof methods. Combinatorics: permutations and combinations, discrete probability, recurrence relations. Graphs and trees. Boolean and abstract algebra.  
LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Level 2 or above and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 121 and [CISC 102 or MATH 110]).

**Offering Faculty:** Faculty of Arts and Science

**CISC 204 Logic for Computing Science Units: 3.00**

Elements of mathematical logic with computing applications. Formal proof systems for propositional and predicate logic. Interpretations, validity, and satisfiability. Introduction to soundness, completeness and decidability.  
LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Level 2 or above and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 121 and [CISC 102 or MATH 110]).

**Offering Faculty:** Faculty of Arts and Science

**CISC 220 System Level Programming Units: 3.00**

Basic concepts of Unix-like systems. Shells and scripting. System-level programming in the C language. Software development tools and techniques.  
LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Level 2 or above and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 121. Corequisite CISC 124.

**Offering Faculty:** Faculty of Arts and Science

**CISC 221 Computer Architecture Units: 3.00**

The descriptive levels of computer architecture. Instruction-set architectures. Assembly Language. Data representation. Support for operating-system management and high-level languages. Input/output and interrupts. Designing for performance. Digital Logic.

LEARNING HOURS 120 (12L;24G;84P)

RECOMMENDATION CISC 220/3.0.

**Requirements:** Prerequisite Level 2 or above and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 124. Recommended CISC 220.

**Offering Faculty:** Faculty of Arts and Science

**CISC 223 Software Specifications Units: 3.00**

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.  
LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Level 2 or above and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 124 and CISC 204).

**Offering Faculty:** Faculty of Arts and Science

**CISC 226 Game Design Units: 3.00**

An introduction to techniques for designing elementary computer games. Topics will include game development tools and processes, principles of game design, game prototyping and game evaluation.

LEARNING HOURS 120 (36L;60G;24P)

**Requirements:** Prerequisite Level 2 or above and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 124.

**Offering Faculty:** Faculty of Arts and Science

**CISC 235 Data Structures Units: 3.00**

Design and implementation of advanced data structures and related algorithms, including correctness and complexity analysis.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Level 2 or above and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 124 and CISC 203).

**Offering Faculty:** Faculty of Arts and Science

**CISC 251 Data Analytics Units: 3.00**

Introduction to data analytics; data preparation; assessing performance; prediction methods such as decision trees, random forests, support vector machines, neural networks and rules; ensemble methods such as bagging and boosting; clustering techniques such as expectation-maximization, matrix decompositions, and bi-clustering; attribute selection.

LEARNING HOURS 120 (36L;24Lb;60P).

**Requirements:** Prerequisite A cumulative GPA of a 1.70 or higher. Exclusion CISC 333; CMPE 333. Recommended Experience with problem solving in any discipline.

**Offering Faculty:** Faculty of Arts and Science

**CISC 271 Linear Data Analysis Units: 3.00**

Elements of linear algebra for data analysis, including: solution of linear equations; vector spaces; matrix decompositions; principal components analysis; linear regression; hyperplane classification of vectorial data.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Level 2 or above and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in {[CISC 101 or CISC 110 or CISC 151 or CISC 121] and [MATH 110 or MATH 111 or MATH 112] and [MATH 120 or MATH 121 or (MATH 123 and MATH 124) or MATH 126]}. Exclusion MATH 272.

**Offering Faculty:** Faculty of Arts and Science

**CISC 282 Fundamentals of Web Development Units: 3.00**

This course surveys current best practices for implementing attractive, usable, secure and maintainable web applications. Other issues considered include: accessibility, platform and browser independence, licensing of intellectual property, scalability, user privacy, and using web technologies in mobile development.

LEARNING HOURS 120 (36L;48O;36P)

**Requirements:** Prerequisite Level 2 or above and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 124. Equivalency CISC P82.

**Course Equivalencies:** cisc282; ciscP82

**Offering Faculty:** Faculty of Arts and Science

**CISC 320 Fundamentals of Software Development Units: 3.00**

Introduction to management of small and medium-scale software projects. Advanced programming methodology using the programming language C++. Includes a significant programming project.

LEARNING HOURS 120 (36L;24T;24G;36P)

**Requirements:** ASC Students: Prerequisite Registration in a School of Computing Plan a C- (any term) or a 'Pass' (Winter 2020) in CISC 235. Exclusion None. FEAS Students: Prerequisite Registration in a BAsC program (ELEC 276 or ELEC 278). Exclusion CISC 322.

**Offering Faculty:** Faculty of Arts and Science

**CISC 322 Software Architecture Units: 3.00**

Abstractions and patterns of interactions and relationships among modules. Design recovery; relationship of architecture to requirements and testing.

LEARNING HOURS 120 (36L;24T;36G;24P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 223 and CISC 235). Exclusion CISC 326.

**Offering Faculty:** Faculty of Arts and Science

**CISC 324 Operating Systems Units: 3.00**

Layered operating systems for conventional shared memory computers: concurrent processes. Synchronization and communication. Concurrent algorithms. Scheduling. Deadlock. Memory management. Protection. File systems. Device management. Typical layers.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 221 and CISC 235).

**Offering Faculty:** Faculty of Arts and Science

**CISC 325 Human-Computer Interaction Units: 3.00**

Developing usable software requires that human factors be considered throughout the design and development process. This course introduces a series of techniques for development and evaluating usable software, and shows how these techniques can be integrated into a process for software development.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite C- (or P in Winter 2020) in (CISC124 and CISC235) and registration in a School of Computing Plan. Exclusion SOFT325

**Offering Faculty:** Faculty of Arts and Science

**CISC 326 Game Architecture Units: 3.00**

An introduction to software architectural design through the application domain of game development. Abstractions and patterns of interactions and relationships among modules. Design recovery. Relationship to requirements and testing

LEARNING HOURS 120 (36L;24T;24G;36P).

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 223 and CISC 235). Exclusion CISC 322. Recommended CISC 226.

**Offering Faculty:** Faculty of Arts and Science

**CISC 327 Software Quality Assurance Units: 3.00**

Validation of software throughout the life cycle. Comparative effectiveness in defect removal of formal methods (proofs of correctness), inspection (walkthroughs and reviews), and testing (unit, integration, and system testing; white box versus black box).

LEARNING HOURS 120 (36L;84G)

**Requirements:** Prerequisite C- (or P in Winter 2020) in (CISC 220 and CISC 124) and registration in a School of Computing Plan. Exclusion SOFT 327

**Offering Faculty:** Faculty of Arts and Science

**CISC 330 Computer-Integrated Surgery Units: 3.00**

Concepts of computer-integrated surgery systems and underlying techniques such as medical-image computing, robotics, and virtual reality, learned through real-life applications and problems. Techniques learned in class will be applied in a hands-on surgery session where students perform minimally invasive surgery with virtual-reality navigation tools.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 121 and CISC 271). Exclusion COMP 329; COMP 230. Equivalency COMP 230.

**Course Equivalencies:** CISC330; COMP230

**Offering Faculty:** Faculty of Arts and Science

**CISC 332 Database Management Systems Units: 3.00**

Data models: relational, entity-relationship. Relational query languages: relational algebra and SQL. Relational database design. Application interfaces and embedded SQL. Storage and indexing.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Level 2 or above and registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 102 and CISC 124). Exclusion COMM 392.

**Offering Faculty:** Faculty of Arts and Science

**CISC 335 Computer Networks Units: 3.00**

Fundamental concepts in the design and implementation of computer communication networks, protocols, and applications. Overview of network architectures; applications; network programming interfaces (e.g., sockets); transport; congestion; routing and data link protocols; addressing; local area networks; wireless networks, mobility management; security.

LEARNING HOURS 120 (36L;84P).

**Requirements:** Prerequisite Registration in a School of Computing Plan and a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 324.

**Offering Faculty:** Faculty of Arts and Science

**CISC 340 Digital Systems Units: 3.00**

Combinational circuits; sequential circuits; digital systems design; micro-programming; bus structures; data communications; interface design; microprocessor systems.

LEARNING HOURS 120 (12L;24G;84P)

**Requirements:** ASC Students: Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 221. Exclusion None. FEAS Students: Exclusion ELEC 272; ELEC 373.

**Offering Faculty:** Faculty of Arts and Science

**CISC 351 Advanced Data Analytics Units: 3.00**

Design and implementation of complex analytics techniques; predictive algorithms at scale; deep learning; clustering at scale; advanced matrix decompositions, analytics in the Web, collaborative filtering; social network analysis; applications in specialized domains.

LEARNING HOURS 120 (36L;36Lb;84P)

**Requirements:** Prerequisite A minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 251 and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (3 units in STAT or 3 units from STAT\_Options). Exclusion CISC 371; CISC 372.

**Offering Faculty:** Faculty of Arts and Science



**CISC 352 Artificial Intelligence Units: 3.00**

An introduction to the basic principles and tools of artificial intelligence. Problem solving methods and knowledge representation techniques.

LEARNING HOURS 120 (36L;84P)

RECOMMENDATION CISC 360/3.0 or CISC 260/3.0.

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 235. Recommended CISC 360 or CISC 260.

**Offering Faculty:** Faculty of Arts and Science

**CISC 360 Programming Paradigms Units: 3.00**

Review of imperative programming features. Introduction to other widely used programming paradigms. 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.

LEARNING HOURS 120 (36L;84P)

EQUIVALENCY CISC 260/3.0.

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 124 and CISC 204). Equivalency CISC 260.

**Offering Faculty:** Faculty of Arts and Science

**CISC 365 Algorithms I Units: 3.00**

Principles of design, analysis and implementation of efficient algorithms. Case studies from a variety of areas illustrate divide and conquer methods, the greedy approach, branch and bound algorithms and dynamic programming.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 203 and CISC 204 and CISC 235).

**Offering Faculty:** Faculty of Arts and Science

**CISC 371 Nonlinear Data Analysis Units: 3.00**

Methods for nonlinear data analysis, particularly using numerical optimization. Applications may include: unconstrained data optimization; linear equality constraints; constrained data regression; constrained data classification; evaluating the effectiveness of analysis methods.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 271 and [STAT 263 or STAT\_Options]). Exclusion CISC 351.

**Offering Faculty:** Faculty of Arts and Science

**CISC 372 Advanced Data Analytics Units: 3.00**

Inductive modelling of data, especially counting models; ensemble approaches to modelling; maximum likelihood and density-based approaches to clustering, visualization. Applications to non-numeric datasets such as natural language, social networks, Internet search, recommender systems. Introduction to deep learning. Ethics of data analytics.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 271 and [3.0 units in STAT or STAT\_Options]).

**Offering Faculty:** Faculty of Arts and Science

**CISC 422 Formal Methods in Software Engineering Units: 3.00**

Mathematical methods for describing software behaviour and structure. Topics include (but are not limited to) the following: Requirements specification. Module specification: axiomatic, algebraic, and trace specifications. Abstract models. Verification. Specification-based validation.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 223.

**Offering Faculty:** Faculty of Arts and Science

**CISC 423 Software Requirements Units: 3.00**

An integrated approach to discovering and documenting software requirements. Identification of stakeholders; customer, operator, analyst, and developer perspectives. Requirements elicitation. Transition from initial (informal) requirements to semi-formal and formal representations. Requirements analysis process; analysis patterns. Requirements specification techniques. Relation to architecture and user interface design; traceability of requirements.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 223 and CISC 235). Corequisite (CISC 325 and [CISC 322 or CISC 326]).

**Offering Faculty:** Faculty of Arts and Science



**CISC 425 Advanced User Interface Design Units: 3.00**

Advanced user-interface styles such as eye-tracking input, digital desks, wearable computing, ubiquitous and context-aware computing, and tangible interfaces.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 325 or permission of the School.

**Offering Faculty:** Faculty of Arts and Science

**CISC 426 Real-Time Systems Units: 3.00**

Design and implementation of real-time embedded applications. Specifying timing properties: formal and semi-formal methods; soft real-time versus hard real-time. Design notations; language constructs. Real-time operating systems. Abstract device interfaces.

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 324 and CISC 327).

**Offering Faculty:** Faculty of Arts and Science

**CISC 432 Advanced Data Management Systems Units: 3.00**

Storage and representation of "big data", which are large, complex, structured or unstructured data sets. Provenance, curation, integration, indexing and querying of data.

LEARNING HOURS 120 (36L;84P).

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 235 and CISC 332).

**Offering Faculty:** Faculty of Arts and Science

**CISC 434 Distributed Systems Units: 3.00**

Distributed systems goals, characteristics, and architectures. Processes: models, inter-process communication and coordination. Name services. Consistency and replication. Fault tolerance: design for reliable communication and recovery. Security. Development paradigms based on data types: object, file, and web-based systems.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 324.

**Offering Faculty:** Faculty of Arts and Science

**CISC 437 Performance Analysis Units: 3.00**

Analytic and empirical evaluation of the performance of software systems. Performance modeling. Experimental design and statistical techniques for empirical performance analysis.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 324 and CISC 327).

**Offering Faculty:** Faculty of Arts and Science

**CISC 447 Introduction to Cybersecurity Units: 3.00**

An introduction to cybersecurity covering a wide range of vulnerabilities, attacks, and defense mechanisms in individual computers, networks, the Internet and the Web and applications that use them, and storage and computational clouds. The human side of cybersecurity, and the legal and ethical constraints on both attack and defense.

LEARNING HOURS 120(36L;84P)

**Requirements:** Prerequisite CISC 324 and CISC 335. Exclusion CISC 490 (Topic Title: Computer Security).

**Offering Faculty:** Faculty of Arts and Science

**CISC 448 Software Reliability and Security Units: 3.00**

Software dependability and other related concepts, software process models and methods for reliable software. Software reliability engineering process, software fault tolerance and run-time monitoring. Software security engineering process, secure software design, program security vulnerabilities and software security testing

LEARNING HOURS 120(36L;84P)

**Requirements:** Prerequisite CISC 327 or CMPE 327.

**Offering Faculty:** Faculty of Arts and Science

**CISC 451 Topics in Data Analytics Units: 3.00**

Content will vary from year to year; typical areas covered may include: tools for large scale data analytics (Hadoop, Spark), data analytics in the cloud, properties of large scale social networks, applications of data analytics in security.

LEARNING HOURS 120 (36L;36Lb;48P)

**Requirements:** Prerequisite A minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 333 or CISC 351 or CISC 372).

**Offering Faculty:** Faculty of Arts and Science

**CISC 452 Neural and Genetic Computing Units: 3.00**

Introduction to neural and genetic computing. Topics include associative memory systems, neural optimization strategies, supervised and unsupervised classification networks, genetic algorithms, genetic and evolutionary programming. Applications are examined, and the relation to biologic systems is discussed.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 235. Exclusion COGS 400.

**Offering Faculty:** Faculty of Arts and Science

**CISC 453 Topics in Artificial Intelligence Units: 3.00**

Investigation of selected areas of artificial intelligence research. Possible topics include natural language understanding, computational perception, planning, learning, and neurocomputing.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 352.

**Offering Faculty:** Faculty of Arts and Science

**CISC 454 Graphics (A) Units: 3.00**

Introduction to computer graphics, including a review of current hardware; modelling and transformations in two and three dimensions; visual realism: perspective, hidden surface elimination, and shading; colour models; applications in several fields. James Stewart.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Level 3 or above and registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 235 and [MATH 110 or MATH 111 or MATH 112]).

**Offering Faculty:** Faculty of Arts and Science

**CISC 455 Evolutionary Optimization and Learning Units: 3.00**

Building, applying and studying algorithms based on the Darwinian principles of natural evolution. A creative approach to AI able to create novel solutions. Genetic algorithms, evolution strategies, and genetic programming. Application to optimization and learning problems.

LEARNING HOURS 120 (36L;84P).

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 365 and STAT 263).

**Offering Faculty:** Faculty of Arts and Science

**CISC 457 Image Processing and Computer Units: 3.00**

Introduction to fundamental concepts and applications in image processing and computer vision. Topics include image acquisition, convolution, Discrete Fourier Transform, image enhancement, edge detection, segmentation, image registration, human contrast perception, colour perception and reproduction, stereo vision.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in ([MATH 110 or MATH 111 or MATH 112] and [MATH 120 or MATH 121 or MATH 123 or MATH 124 or MATH 126] and CISC 124).

**Offering Faculty:** Faculty of Arts and Science

**CISC 458 Programming Language Processors (S) Units: 3.00**

Introduction to the systematic construction of a compiler: grammars and languages, scanners, top-down and bottom-up parsing, runtime organization, symbol tables, internal representations; Polish notation, syntax trees, semantic routines, storage allocation, code generation, interpreters.

LEARNING HOURS 120 (36L;36Lb;48G)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 121 and CISC 221 and CISC 223).

**Offering Faculty:** Faculty of Arts and Science

**CISC 462 Computability and Complexity Units: 3.00**

Turing machines and other models of computability such as  $\mu$ -recursive functions and random-access machines. Undecidability. Recursive and recursively enumerable sets. Church-Turing thesis. Resource-bounded complexity. Complexity comparisons among computational models. Reductions. Complete problems for complexity classes.

LEARNING HOURS 120 (36L;84P)

RECOMMENDATION CISC 365/3.0.

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 223. Recommended CISC 365.

**Offering Faculty:** Faculty of Arts and Science



**CISC 465 Semantics of Programming Languages Units: 3.00**

Specifying syntax and semantics; operational and denotational semantics. Lambda calculi, type systems and logical foundations. Meta-theoretic properties. Semantics of imperative languages.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 204 and CISC 223 and [CISC 360 or CISC 260]).

**Offering Faculty:** Faculty of Arts and Science

**CISC 466 Algorithms II Units: 3.00**

A continuation of CISC 365/3.0. Lower bound theory. Average-case analysis of algorithms. Approximation algorithms. Probabilistic algorithms. Parallel algorithms.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 365.

**Offering Faculty:** Faculty of Arts and Science

**CISC 467 Fuzzy Logic Units: 3.00**

History of fuzzy theory; fundamental concepts of fuzzy theory: sets, relations, and logic operators. Approximate reasoning, fuzzy inference, possibility theory. Separation from probability. Fuzzy control systems. Fuzzy pattern recognition. Advanced topics may include fuzzy expert systems, financial systems, graph theory, optimization.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Level 4 or above and registration in a BCMP or COCA Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 204.

**Offering Faculty:** Faculty of Arts and Science

**CISC 468 Cryptography Units: 3.00**

Fundamentals of cryptographic algorithms: secure pseudorandom number generators, hash functions, symmetric-key cryptography (stream ciphers, block ciphers); public-key cryptography (encryption and decryption, digital signatures, key agreement). Applications of cryptography to secure communication protocols and systems.

LEARNING HOURS 120 (36L;84P).

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 235 and CISC 335).

**Offering Faculty:** Faculty of Arts and Science

**CISC 471 Computational Biology Units: 3.00**

Advanced computational approaches to the problems in molecular biology. Techniques and algorithms for sequence analysis and alignment; molecular databases; protein structure prediction and molecular data mining.

LEARNING HOURS 120 (36L;84P).

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 352 and CISC 365).

**Offering Faculty:** Faculty of Arts and Science

**CISC 472 Medical Informatics Units: 3.00**

Current topics in the application of information technology to medical image computing and its use in image-guided medical interventions.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 330.

**Offering Faculty:** Faculty of Arts and Science

**CISC 473 Deep Learning Units: 3.00**

Design of deep neural networks based on leading-edge algorithms such as Restricted Boltzmann Machines, Recurrent Neural Networks, Convolutional Neural Networks, Long-Short Term Machines. Autoencoding as a clustering technique. Applications to prediction problems in natural language and images.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 371 or [CISC 271 and CISC 352]).

**Offering Faculty:** Faculty of Arts and Science

**CISC 474 Reinforcement Learning Units: 3.00**

Formal and heuristic approaches to problem-solving, planning, knowledge representation and reasoning, Markov decision processes, dynamic programming, temporal-difference learning, Monte Carlo learning, function approximation, integration of learning and planning. Implementing simple examples of logical reasoning, clustering or classification.

LEARNING HOURS 120 (36L;12G;72P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 352.

**Offering Faculty:** Faculty of Arts and Science



**CISC 486 Game Development Units: 3.00**

An introduction to 'engines' used in networked 3-dimensional games. Topics include game-engine architecture and components providing 3-dimensional rendering, physics simulation, sound, artificial intelligence and networking services.

LEARNING HOURS 120 (36L;15G;69P)

**Requirements:** Prerequisite Registration in a School of Computing Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 226 and [CISC 322 or CISC 326] and CISC 324 and [MATH 110 or MATH 111 or MATH 112]).

**Offering Faculty:** Faculty of Arts and Science

**CISC 490 Topics in Computing Science I Units: 3.00**

Content varies. Not offered every year.

NOTE Learning Hours will vary.

**Requirements:** Prerequisite Registration in a School of Computing Plan and permission of the instructor.

**Offering Faculty:** Faculty of Arts and Science

**CISC 491 Topics in Computing Science II Units: 3.00**

Content varies. Not offered every year.

NOTE Learning Hours will vary.

**Requirements:** Prerequisite Registration in a School of Computing Plan and permission of the instructor.

**Offering Faculty:** Faculty of Arts and Science

**CISC 492 Topics in Computing III Units: 3.00**

Content varies. Not offered every year.

NOTE Learning Hours will vary.

**Requirements:** Prerequisite Registration in a School of Computing Plan and permission of the instructor.

**Offering Faculty:** Faculty of Arts and Science

**CISC 496 Game Development Project Units: 3.00**

Team-based project involving the development of a game using modern tools and software engineering techniques.

LEARNING HOURS 129 (9L;120G)

**Requirements:** Prerequisite: Registration in a Computing honours plan and (C- in CISC 486) and 30 units in CISC/SOFT/COGS/COCA and 2.6 GPA in all of CISC/SOFT/COGS/COCA Exclusion CISC 496; CISC 498; CISC 499; COGS 499; CISC 500.

**Offering Faculty:** Faculty of Arts and Science

**CISC 497 Social, Ethical and Legal Issues in Computing Units: 3.00**

A wide range of topics of current importance in computing, including technical issues, professional questions, and moral and ethical decisions. Students make presentations, deliver papers, and engage in discussion.

LEARNING HOURS 120 (12L;24S;84P)

**Requirements:** Prerequisite Level 4 or above and registration in a COMP Major or Specialization Plan and a cumulative GPA of 1.90 and a (GPA of 2.60 in CISC; COCA; COGS; SOFT) and (30.0 units of CISC; COCA; COGS; SOFT) and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 352 or CISC 365).

**Offering Faculty:** Faculty of Arts and Science

**CISC 498 Information Technology Project Units: 6.00**

Topic selected under the supervision of a faculty member.

Emphasis is on the application of software engineering techniques to the development of a substantial software system. Group work, oral presentation, participation in design and code review meetings, and delivery of complete software specification and design are required.

LEARNING HOURS 258 (18S;240G)

**Requirements:** Prerequisite Level 4 or above and registration in a SODE Specialization Plan and a cumulative GPA of 1.90 and a (GPA of 2.60 in CISC; COCA; COGS; SOFT) and (30.0 units in CISC; COCA; COGS; SOFT) and (a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in [CISC 322 or CISC 326] and [CISC 325 or CISC 327]). Exclusion CISC 496; CISC 499.

**Offering Faculty:** Faculty of Arts and Science

**CISC 499 Advanced Undergraduate Project Units: 3.00**

Topic selected under the supervision of a faculty member.

Emphasis may be on the development of a large program, or on more theoretical issues. Independent research, an oral presentation, and a written report are required.

LEARNING HOURS 120 (120P)

**Requirements:** Prerequisite Level 4 or above and registration in a COMP Major or BMCO or COMA or CSCI Specialization Plan and a cumulative GPA of 1.90 and a (GPA of 2.60 in CISC; COCA; COGS; SOFT) and (30.0 units in CISC; COCA; COGS; SOFT) and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in CISC 365. Exclusion CISC 496; CISC 498; COGS 499; CISC 500.

**Offering Faculty:** Faculty of Arts and Science



### **CISC 500 Undergraduate Thesis Units: 6.00**

Individual research project under the supervision of a School of Computing faculty member. Evaluation is based on an oral presentation and a written thesis. It is the responsibility of the student to make a research proposal and secure a supervisor prior to enrolling in the course.

LEARNING HOURS 240 (24I;216P)

**Requirements:** Prerequisite Permission of the School and a minimum cumulative GPA of 3.50 or higher and level 4 or above and registration in a COMP Major or BMCO, COGS, COMA, CSCI, or SODE Specialization Plan. Exclusion CISC 496; CISC 499; COGS 499.

**Offering Faculty:** Faculty of Arts and Science

### **CISC 594 Independent Study Units: 3.00**

**Offering Faculty:** Faculty of Arts and Science

### **CISC 595 Independent Study Units: 6.00**

**Offering Faculty:** Faculty of Arts and Science

### **CISC 596 Independent Study Units: 12.00**

**Offering Faculty:** Faculty of Arts and Science

## **Computing and the Creative Arts (COCA)**

### **COCA 201 Introduction to Computing and the Creative Arts Units: 3.00**

A multidisciplinary studio-oriented overview of computer-based applications in Art, Music, Drama and Film. History of human-computer interaction. Critical and philosophical issues. Animation. Virtual reality. Computer-aided design. Computer games. Enrollment is limited.

LEARNING HOURS 120 (36L;84P).

**Requirements:** Prerequisite Level 2 or above and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in 6.0 units in (ARTF or ARTH or DRAM or FILM or MUSC at the 100-level). Corequisite (CISC 101 or CISC 110 or CISC 121 or CISC 151 or APSC 142 or APSC 143) or permission of the School.

**Offering Faculty:** Faculty of Arts and Science

## **Cognitive Science (COGS)**

### **COGS 100 Introduction to Cognitive Science Units: 3.00**

A multidisciplinary approach to the study of the mind combining approached from philosophy, psychology, linguistics, neuroscience, anthropology, and artificial intelligence. Logic, rules, concepts, and other mental representations used to generate thought and behaviour. Implementation of computational and cognitive models of mental processes.

NOTE Also offered online. Consult Arts and Science Online. Learning Hours may vary.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite None.

**Offering Faculty:** Faculty of Arts and Science

### **COGS 201 Cognition and Computation Units: 3.00**

Introduction to the computational aspects of the mind. Implementation of computer programs for reasoning, decision making, and problem solving to understand these mental processes. Information theory and behaviourism; computational models of cognition, perception and memory processes demonstrating modeling approaches, and cognitive architectures.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Level 2 or above and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (COGS 100 or PSYC 100). Exclusion COGS 200; PSYC 220.

**Offering Faculty:** Faculty of Arts and Science

### **COGS 300 Programming Cognitive Models Units: 3.00**

Importance and challenges of building cognitive models; steps of model building, programming simple models using computational and statistical techniques and tools such as Matlab. Recent models from research publications.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite A minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in ([COGS 201 or PSYC 221] and [PSYC 202 or STAT\_Options]).

**Offering Faculty:** Faculty of Arts and Science

### **COGS 400 Neural and Genetic Cognitive Models Units: 3.00**

Artificial Neural Networks (ANN) and Genetic Algorithms (GA) for problem solving and prediction tasks such as classification, clustering, optimization and data reduction and modeling human cognition, with application to real world problems. Ongoing research in this area in various application domains.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Registration in a COGS Plan and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 235 or ELEC 278). Exclusion CISC 452; CMPE 452.

**Offering Faculty:** Faculty of Arts and Science

**COGS 499 Advanced Undergraduate Project Units: 3.00**

Topic selected under the supervision of a member of one of the faculties of CISC, LING, PHIL, PSYC. Emphasis may be on experimental, theoretical, or computer implementation topics. Independent research, an oral presentation, and a written report are required.

LEARNING HOURS 120 (24S;12I;84P)

**Requirements:** Prerequisite Level 4 or above and registration in a COGS Specialization Plan and a cumulative GPA of 1.90 or higher and a (GPA of 2.60 in CISC; COCA; COGS; SOFT) and (30.0 units in CISC; COCA; COGS; SOFT) and a minimum grade of a C- (obtained in any term) or a 'Pass' (obtained in Winter 2020) in (CISC 352 or CISC 365). Exclusion CISC 499; CISC 500.

**Offering Faculty:** Faculty of Arts and Science

**COGS 594 Independent Study Units: 3.00**

**Offering Faculty:** Faculty of Arts and Science

**Computing (COMP)****COMP 329 Introduction to Computer-Integrated Surgery Units: 3.00**

An introduction to concepts and novel technologies used in computer-integrated surgery, including image based navigation, medical robotics and virtual reality. Concepts and techniques learned in class will be applied in a hands-on surgery session where students perform minimally invasive surgery with virtual-reality navigation tools.

NOTE MATH P06/3.0 or one Mathematics 4U level courses is required.

NOTE Not available for credit towards a BCMP/BCMPH program. Computing students should take CISC 330/3.0.

LEARNING HOURS 120 (36L;84P)

**Requirements:** Prerequisite Level 2 or above. Exclusion CISC 330; COMP 230. Note Not available for credit towards a BCMP/BCMPH program. Computing students should take CISC 330.

**Offering Faculty:** Faculty of Arts and Science

**COMP 390 Computing Internship I Units: 6.00**

A Computing Internship involves spending twelve to sixteen months in a paid internship position in the private or public sectors. Students in a 12-month internship register in COMP 390/6.0 and either COMP 391/3.0 or COMP 392/3.0, or all of COMP 393/3.0, COMP 391/3.0 and COMP 392/3.0. Students in a 16-month internship register in COMP 390/6.0, COMP 391/3.0 and COMP 392/3.0. The Internship Coordinator must be satisfied that the work carried out has educational merit. Successful completion of the course requires submission of a satisfactory report on the experience within thirty days of completion of the work period. The Internship Coordinator is responsible for evaluating the report. The QUIP program includes prior workshops on interviewing, resumé preparation and work performance. Career Services manages the non-academic aspects of the program.

**Requirements:** Prerequisite A cumulative GPA of 1.90 or higher and level 2 or above and registration in a Bachelor of Computing Internship Plan (BMCO-I-BCH or COGS-I-BCH or COMA-I-BCH or COMP-I-BCH or CSCI-I-BCH or SODE-I-BCH).

**Offering Faculty:** Faculty of Arts and Science

**COMP 391 Computing Internship II Units: 3.00**

A Computing Internship involves spending twelve to sixteen months in a paid internship position in the private or public sectors. Students in a 12-month internship register in COMP 390/6.0 and either COMP 391/3.0 or COMP 392/3.0, or all of COMP 393/3.0, COMP 391/3.0 and COMP 392/3.0. Students in a 16-month internship register in COMP 390/6.0, COMP 391/3.0 and COMP 392/3.0. The Internship Coordinator must be satisfied that the work carried out has educational merit. Successful completion of the course requires submission of a satisfactory report on the experience within thirty days of completion of the work period. The Internship Coordinator is responsible for evaluating the report. The QUIP program includes prior workshops on interviewing, resumé preparation and work performance. Career Services manages the non-academic aspects of the program.

**Requirements:** Prerequisite A cumulative GPA of 1.90 or higher and level 2 or above and registration in a Bachelor of Computing Internship Plan (BMCO-I-BCH or COGS-I-BCH or COMA-I-BCH or COMP-I-BCH or CSCI-I-BCH or SODE-I-BCH).

**Offering Faculty:** Faculty of Arts and Science



### **COMP 392 Computing Internship III Units: 3.00**

A Computing Internship involves spending twelve to sixteen months in a paid internship position in the private or public sectors. Students in a 12-month internship register in COMP 390/6.0 and either COMP 391/3.0 or COMP 392/3.0, or all of COMP 393/3.0, COMP 391/3.0 and COMP 392/3.0. Students in a 16-month internship register in COMP 390/6.0, COMP 391/3.0 and COMP 392/3.0. The Internship Coordinator must be satisfied that the work carried out has educational merit. Successful completion of the course requires submission of a satisfactory report on the experience within thirty days of completion of the work period. The Internship Coordinator is responsible for evaluating the report. The QUIP program includes prior workshops on interviewing, resumé preparation and work performance. Career Services manages the non-academic aspects of the program.

**Requirements:** Prerequisite A cumulative GPA of 1.90 or higher and level 2 or above and registration in a Bachelor of Computing Internship Plan (BMCO-I-BCH or COGS-I-BCH or COMA-I-BCH or COMP-I-BCH or CSCI-I-BCH or SODE-I-BCH).

**Offering Faculty:** Faculty of Arts and Science

### **COMP 393 Computing Internship IV Units: 3.00**

A Computing Internship involves spending twelve to sixteen months in a paid internship position in the private or public sectors. Students in a 12-month internship register in COMP 390/6.0 and either COMP 391/3.0 or COMP 392/3.0, or all of COMP 393/3.0, COMP 391/3.0 and COMP 392/3.0. Students in a 16-month internship register in COMP 390/6.0, COMP 391/3.0 and COMP 392/3.0. The Internship Coordinator must be satisfied that the work carried out has educational merit. Successful completion of the course requires submission of a satisfactory report on the experience within thirty days of completion of the work period. The Internship Coordinator is responsible for evaluating the report. The QUIP program includes prior workshops on interviewing, resumé preparation and work performance. Career Services manages the non-academic aspects of the program.

**Requirements:** Prerequisite A cumulative GPA of 1.90 or higher and level 2 or above and registration in a Bachelor of Computing Internship Plan (BMCO-I-BCH or COGS-I-BCH or COMA-I-BCH or COMP-I-BCH or CSCI-I-BCH or SODE-I-BCH).

**Offering Faculty:** Faculty of Arts and Science