

# Computer Science (COMP)

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## Computer Science (COMP) Courses

### COMP 5001 [0.5 credit] (CSI 5113)

#### Foundations of Programming Languages

Advanced study of programming paradigms from a practical perspective. Paradigms may include functional, imperative, concurrent, distributed, generative, aspect- and object-oriented, and logic programming. Emphasis on underlying principles. Topics may include: types, modules, inheritance, semantics, continuations, abstraction and reflection.

Prerequisite(s): COMP 3007 or the equivalent.

### COMP 5002 [0.5 credit] (CSI 5128)

#### Swarm Intelligence

Collective computation, collective action, and principles of self-organization in social agent systems. Algorithms for combinatorial optimization problems, division of labour, task allocation, task switching, and task sequencing with applications in security, routing, wireless and ad hoc networks and distributed manufacturing.

### COMP 5003 [0.5 credit] (CSI 5308)

#### Principles of Distributed Computing

Formal models; semantics of distributed computations; theoretical issues in design of distributed algorithms; computational complexity; reducibility and equivalence of distributed problems. Related topics: systolic systems and computations, oligarchical systems and control mechanisms.

### COMP 5004 [0.5 credit]

#### Fault Tolerance

### COMP 5005 [0.5 credit] (CSI 5390)

#### Learning Systems for Random Environments

Computerized adaptive learning for random environments and its applications. Topics include a mathematical review, learning automata which are deterministic/stochastic, with fixed/variable structures, of continuous/discretized design, with ergodic/absorbing properties and of estimator families.

Prerequisite(s): MATH 2600 or MATH 3500, or SYSC 5503 or equivalent.

### COMP 5007 [0.5 credit]

#### Graphic Models

### COMP 5008 [0.5 credit] (CSI 5164)

#### Computational Geometry

Study of design and analysis of algorithms to solve geometric problems; emphasis on applications such as robotics, graphics, and pattern recognition. Topics include: visibility problems, hidden line and surface removal, path planning amidst obstacles, convex hulls, polygon triangulation, point location.

Prerequisite(s): COMP 3804 or equivalent.

### COMP 5009 [0.5 credit] (CSI 5141)

#### Associative Data Structures and Advanced Databases

Concepts and advanced topics in the design, implementation and analysis of physical storage schemes with emphasis on their application to specialized database and information retrieval systems. Topics include: associative searching techniques; multidimensional storage structures; algorithms for spatial data modeling; formulation and optimization of database queries.

Prerequisite(s): COMP 3005 and COMP 3804, or the equivalent.

### COMP 5100 [0.5 credit] (CSI 5180, CSI 5580)

#### Topics in Artificial Intelligence

Areas in knowledge-based systems including recent approaches to machine learning and data mining, inference methods, knowledge-based and fuzzy systems, heuristic search, and natural language processing.

Precludes additional credit for COMP 4106.

Prerequisite(s): COMP 3007 or equivalent.

### COMP 5101 [0.5 credit] (CSI 5311)

#### Distributed Databases and Transaction Processing Systems

Principles in the design and implementation of distributed databases and distributed transaction processing systems. Topics include: distributed computing concepts, computing networks, distributed and multi-database system architectures and models, atomicity, synchronization and distributed concurrency control algorithms, data replication, recovery techniques, reliability in distributed databases.

Precludes additional credit for COMP 4101.

Prerequisite(s): COMP 3005, COMP 4001, and COMP 4003 or equivalent.

### COMP 5102 [0.5 credit] (CSI 5312)

#### Distributed Operating Systems

Design issues of advanced multiprocessor distributed operating systems: multiprocessor system architectures; process and object models; synchronization and message passing primitives; memory architectures and management; distributed file systems; protection and security; distributed concurrency control; deadlock; recovery; remote tasking; dynamic reconfiguration; performance measurement, modeling, and system tuning.

Prerequisite(s): COMP 3000 and COMP 3203 or equivalent.

### COMP 5103 [0.5 credit]

#### Wireless Ad Hoc Networking

### COMP 5104 [0.5 credit] (CSI 5314)

#### Object-Oriented Software Development

Issues in modeling and verifying quality and variability in object-oriented systems. Testable models in model-driven and test-driven approaches. System family engineering. Functional conformance: scenario modeling and verification, design by contract. Conformance to non functional requirements: goals, forces and tradeoffs, metrics.

Prerequisite(s): COMP 2004 or equivalent.

**COMP 5106 [0.5 credit] (CSI 5123)****Languages for Parallel Computing**

Survey of major language paradigms for parallel computing: sequential imperative, parallel imperative, logic, functional (reduction and dataflow), object and message-passing based languages; communicating sequential processes; and massive data-level parallelism. Topics include detection, determinism, data partitioning, task scheduling, task granularity, synchronization methods, resource management, and debugging. Prerequisite(s): COMP 5001.

**COMP 5107 [0.5 credit] (CSI 5185)****Statistical and Syntactic Pattern Recognition**

Topics include a mathematical review, Bayes decision theory, maximum likelihood and Bayesian learning for parametric pattern recognition, non-parametric methods including nearest neighbor and linear discriminants. Syntactic recognition of strings, substrings, subsequences and tree structures. Applications include speech, shape and character recognition. Prerequisite(s): permission of the School.

**COMP 5108 [0.5 credit]****Algorithms in Bioinformatics****COMP 5111 [0.5 credit]****Data Management for Business Intelligence**

Application of computational techniques to support business such as decision making, business understanding, data analysis, business process automation, learning from data, producing and using business models, data integration, data quality assessment and cleaning, use of contextual data. Also offered at the undergraduate level, with different requirements, as COMP 4111, for which additional credit is precluded.

**COMP 5112 [0.5 credit] (CSI 5104)****Algorithms for Data Science**

Algorithmic techniques to handle (massive/big) data arising from, for example, social media, mobile devices, sensors financial transactions. Algorithmic techniques may include locality-sensitive hashing, dimensionality reduction, streaming, clustering, VC-dimension, external memory, core sets, link analysis and recommendation systems.

**COMP 5201 [0.5 credit]****Computer Animation****COMP 5202 [0.5 credit]****Computer Graphics****COMP 5203 [0.5 credit] (CSI 5173)****Data Networks**

Mathematical and practical aspects of design and analysis of communication networks. Topics include: basic concepts, layering, delay models, multi-access communication, queuing theory, routing, fault-tolerance, and advanced topics on high-speed networks, ATM, mobile wireless networks, and optical networks. Prerequisite(s): COMP 4804 or permission of the School.

**COMP 5204 [0.5 credit] (CSI 5124)****Computational Aspects of Geographic Information Systems**

Computational perspective of geographic information systems (GIS). Data representations and their operations on raster and vector devices: e.g., quadtrees, grid files, digital elevation models, triangular irregular network models. Analysis and design of efficient algorithms for solving GIS problems: visibility queries, point location, facility location. Prerequisite(s): COMP 3804 or the equivalent.

**COMP 5205 [0.5 credit]****Virtual Environments****COMP 5206 [0.5 credit] (CSI 5183)****Evolutionary Computation and Artificial Life**

Study of algorithms based upon biological theories of evolution, applications to machine learning and optimization problems. Possible topics: Genetic Algorithms, Classifier Systems, and Genetic Programming. Recent work in the fields of Artificial Life (swarm intelligence, distributed agents, behavior-based AI) and of connectionism. Precludes additional credit for COMP 4107. Prerequisite(s): COMP 3007 or the equivalent.

**COMP 5207 [0.5 credit]****Software Engineering****COMP 5209 [0.5 credit] (CSI 5104)****Visual Analytics**

Principles, techniques, technology and applications of information visualization for data analysis. Topics include human visual perception, cognitive processes, static and dynamic models of image semantics, interaction paradigms, big data visual analysis case studies.

**COMP 5300 [0.5 credit]****Struct in Complexity Theory****COMP 5301 [0.5 credit]****Software Usability****COMP 5302 [0.5 credit]****Automated Verification & Valid****COMP 5304 [0.5 credit]****Wireless Netwks & Mobile**

**COMP 5305 [0.5 credit] (CSI 5129)****Advanced Database Systems**

In-depth study on developments in database systems shaping the future of information systems, including complex object, object-oriented, object-relational, and semi-structured databases. Data structures, query languages, implementation and applications.

Prerequisite(s): COMP 3005 or the equivalent.

**COMP 5306 [0.5 credit] (CSI 5100)****Data Integration**

Materialized and virtual approaches to integration of heterogeneous and independent data sources. Emphasis on data models, architectures, logic-based techniques for query processing, metadata and consistency management, the role of XML and ontologies in data integration; connections to schema mapping, data exchange, and P2P systems.

Precludes additional credit for COMP 5900 section 'G' offered fall term 2002 and 2004.

Prerequisite(s): COMP 3005 or equivalent.

**COMP 5307 [0.5 credit] (CSI 5101)****Knowledge Representation**

KR is concerned with representing knowledge and using it in computers. Emphasis on logic-based languages for KR, and automated reasoning techniques and systems; important applications of this traditional area of AI to ontologies and semantic web.

Precludes additional credit for COMP 5900 section 'X' offered in winter term from 2003-2004 to 2005-2006 inclusive.

Prerequisite(s): COMP 1805 and COMP 3005, or equivalents.

**COMP 5308 [0.5 credit] (CSI 5102)****Topics in Medical Computing**

Introductory course on data structures, algorithms, techniques, and software development related to medical computing (in particular spatial modeling). Topics may include: computational geometry algorithms for cancer treatment, medical imaging, spatial data compression algorithms, dynamic programming for DNA analysis.

Precludes additional credit for COMP 5900 section 'Y' offered 2001-2002 to 2005-2006 inclusive.

Prerequisite(s): COMP 3804 or equivalent.

**COMP 5309 [5.0 credits]****Digital Watermarking****COMP 5400 [0.5 credit] (CSI 5310)****Software Patterns**

Current developments in software patterns, three-part rules expressing relations between software contexts, problems and solutions. Pattern categories discussed include architectural, design, analysis, refactoring, general-purpose, anti-patterns, and idioms. Students are required to apply existing patterns and to develop and defend new ones.

Prerequisite(s): COMP 3004 or equivalent.

**COMP 5401 [0.5 credit] (CSI 5389, CSI 5789)****Electronic Commerce Technologies**

Introduction to business models and technologies. Search engines. Cryptography. Web services and agents. Secure electronic transactions. Value added e-commerce technologies. Advanced research questions.

Prerequisite(s): COMP 2005 and COMP 4104, or CSI 4128 and CSI 3140, or equivalent.

**COMP 5402 [0.5 credit] (CSI 5142)****Protocols for Mobile and Wireless Networks**

Link and network layer protocols of wireless networks; applications of wireless networks may be discussed. Topics may include: protocol implementation, mobile IP, resource discovery, wireless LANs/PANs, and Spreadpectrum.

Precludes additional credit for SYSC 5306.

Prerequisite(s): COMP 3203 or equivalent.

**COMP 5404 [0.5 credit] (CSI 5144)****Computer-Aided Program Verification**

Automatic verification techniques for concurrent, reactive, and real-time programs. Topics may include temporal logics, the basic model-checking algorithm, symbolic model checking, compositional techniques, exploiting abstraction and symmetry, models based on partial orders, model-checking for the mu-calculus, applications to communication protocols, computer security and digital circuits.

Prerequisite(s): COMP 4004 or equivalent.

**COMP 5405 [0.5 credit]****Syst & Archit for Elec Com****COMP 5406 [0.5 credit] (CSI 5105)****Network Security and Cryptography**

Advanced methodologies selected from symmetric and public key cryptography, network security protocols and infrastructure, identification, secret-sharing, anonymity, intrusion detection, firewalls, defending network attacks and performance in communication networks.

Prerequisite(s): COMP 3203 and COMP 4109, or equivalent, or permission of the instructor.

**COMP 5407 [0.5 credit] (CSI 5116)****Authentication and Software Security**

Specialized topics in security including advanced authentication techniques, user interface aspects, electronic and digital signatures, security infrastructures and protocols, software vulnerabilities affecting security, untrusted software and hosts, protecting software and digital content.

Prerequisite(s): COMP 3000 and COMP 4108, or equivalent; or permission of the instructor.

**COMP 5408 [0.5 credit] (CSI 5121)****Advanced Data Structures**

Simple methods of data structure design and analysis that lead to efficient data structures for several problems. Topics include randomized binary search trees, persistence, fractional cascading, self-adjusting data structures, van Emde Boas trees, tries, randomized heaps, and lowest common ancestor queries.  
Prerequisite(s): COMP 4804 or equivalent.

**COMP 5409 [0.5 credit] (CSI 5127)****Applied Computational Geometry**

Computer-based representation and manipulation of geometric objects. Design and analysis of efficient algorithms for solving geometric problems in applied fields such as Computer-Aided Design and Manufacturing, Cartography, Materials Science, and Geometric Network Design.  
Prerequisite(s): COMP 4804 or equivalent.

**COMP 5501 [0.5 credit]****Software Quality Engineering****COMP 5503 [0.5 credit]****Database Analysis & Design****COMP 5505 [0.5 credit]****Natural Language Processing****COMP 5604 [0.5 credit]****Validation Meth Distri Sys****COMP 5606 [0.5 credit]****Top in Syst Simul & Optim****COMP 5702 [0.5 credit]****Order****COMP 5703 [0.5 credit] (CSI 5163)****Algorithm Analysis and Design**

Topics of current interest in the analysis and design of sequential and parallel algorithms for non-numerical, algebraic and graph computations. Lower bounds on efficiency of algorithms. Complexity classes.  
Prerequisite(s): permission of the School.

**COMP 5704 [0.5 credit] (CSI 5131)****Parallel Algorithms and Applications in Bioinformatics**

Multiprocessor architectures from an application programmer's perspective: programming models, processor clusters and multi-core processors, algorithmic paradigms, efficient parallel problem solving, limits of parallelism, software scalability and portability. Projects with an emphasis on high performance computing in bioinformatics. Programming experience on parallel processing equipment.  
Prerequisite(s): COMP 3804 or the equivalent.

**COMP 5706 [0.5 credit]****Data Mining & Concept Learning****COMP 5707 [0.5 credit]****Prin Formal Software Devel****COMP 5709 [0.5 credit]****Combinatorial Algorithms****COMP 5800 [0.5 credit]****Distributed Data Proc****COMP 5801 [0.5 credit]****Topics in Machine Learning****COMP 5802 [0.5 credit] (CSI 5131)****Introduction to Information and Systems Science**

An introduction to the process of applying computers in problem solving. Emphasis is placed on the design and analysis of efficient computer algorithms for large, complex problems. Applications in a number of areas are presented: data manipulation, databases, computer networks, queuing systems, optimization.  
Also listed as MATH 5802, SYSC 5802, ISYS 5802.

**COMP 5805 [0.5 credit]****Appli. of Combinatorial Optim****COMP 5807 [0.5 credit] (CSI 5104)****Formal Language and Syntax Analysis**

Computability, unsolvable and NP-hard problems. Formal languages, classes of languages, automata. Principles of compiler design, syntax analysis, parsing (top-down, bottom-up), ambiguity, operator precedence, automatic construction of efficient parsers, LR, LR(O), LR(k), SLR, LL(k); syntax directed translation.  
Also listed as MATH 5807.

Prerequisite(s): COMP 3002, or MATH 4805 or MATH 5605, or the equivalent.

**COMP 5900 [0.5 credit] (CSI 5140)****Selected Topics in Computer Science**

Selected topics, not covered by other graduate courses. Details will be available from the School at the time of registration.

**COMP 5901 [0.5 credit] (CSI 5901)****Directed Studies (M.C.S.)**

A course of independent study under the supervision of a member of the School of Computer Science.

**COMP 5902 [0.5 credit]****Graduate Project (M.C.S./M.Sc. [ISS])****COMP 5903 [1.0 credit] (CSI 6900)****Intensive Graduate Project (M.C.S.)**

A one- or two-session course. For M.C.S. non-thesis option students only. Not to be combined for credit with COMP 5902.

**COMP 5904 [0.0 credit] (CSI 5902)****Master's Seminar**

To complete this course, the student must attend 5 graduate seminars at Carleton, and 5 at SITE within a year. The student must also make one presentation in the context of this graduate seminar.

**COMP 5905 [2.5 credits]****M.C.S. Thesis**

**COMP 5908 [1.5 credit] (CSI 6002)**  
**M.Sc. Thesis in Information and Systems Science**  
Also listed as MATH 5908, SYSC 5908.

**COMP 5913 [0.0 credit]**  
**Master's Co-operative Workterm**

**COMP 6100 [0.5 credit] (CSI 7131)**  
**Advanced Parallel and Systolic Algorithms**  
Continuation of COMP 5704.  
Prerequisite(s): COMP 5704.

**COMP 6104 [0.5 credit] (CSI 7314)**  
**Advanced Topics in Object-Oriented Systems**  
Advanced object-oriented software engineering, in particular the issues of reuse and testing. Sample topics include: interaction modeling; class and cluster testing; traceability; design patterns and testing; the C++ standard template library. Students will carry out research.  
Prerequisite(s): COMP 5104 or permission of instructor.

**COMP 6601 [0.5 credit]**  
**Advanced Topics in the Theory of Computing**

**COMP 6602 [0.5 credit]**  
**Advanced Topics in Distributed Computing**

**COMP 6603 [0.5 credit]**  
**Advanced Topics in Programming Systems and Languages**

**COMP 6604 [0.5 credit]**  
**Advanced Topics in Computer Applications**

**COMP 6605 [0.5 credit]**  
**Advanced Topics in Computer Systems**

**COMP 6901 [0.5 credit]**  
**Directed Studies (Ph.D.)**

**COMP 6902 [0.5 credit]**  
**Graduate Project (Ph.D.)**

**COMP 6907 [0.0 credit] (CSI 9998)**  
**Doctoral Comprehensive**  
A committee must be assembled and approve at least 3 topics for written examination: typically, a major and two minor areas. An oral examination occurs if the written exam is passed. Both elements must take place within the first 4 terms following initial registration in the program. The comprehensive may be failed, passed conditionally (i.e., with extra course requirements) or passed unconditionally. If failed this course may be retaken at most one time.

**COMP 6908 [0.0 credit] (CSI 9997)**  
**Doctoral Proposal**  
Within 8 terms following initial registration in the program, a document generally defining the problem addressed, relating it to the literature, and outlining the hypotheses, goals, research methodology, initial results and validation approach must be submitted to an examination committee and successfully defended.

**COMP 6909 [11.5 credits]**  
**Ph.D. Thesis**

**Summer session:** some of the courses listed in this Calendar are offered during the summer. Hours and scheduling for summer session courses will differ significantly from those reported in the fall/winter Calendar. To determine the scheduling and hours for summer session classes, consult the class schedule at [central.carleton.ca](http://central.carleton.ca)

Not all courses listed are offered in a given year. For an up-to-date statement of course offerings for the current session and to determine the term of offering, consult the class schedule at [central.carleton.ca](http://central.carleton.ca)