
71.70

DEPARTMENT OF COMPUTER SCIENCE AND SOFTWARE ENGINEERING

Faculty

<i>Chair</i> SUDHIR P. MUDUR, PhD <i>Bom.</i> , PEng, <i>Professor</i>	PhD <i>Ill. Tech.</i> , PEng TODD EAVIS, PhD <i>Dal.</i> DHRUBAJYOTI GOSWAMI, PhD <i>Wat.</i> , PEng GOSTA GRAHNE, PhD <i>Helsinki</i> RAJAGOPALAN JAYAKUMAR, PhD <i>C'dia.</i> S.L. KLASA, PhD <i>Geneva</i> LEILA KOSSEIM, PhD <i>Montr.</i> LATA NARAYANAN, PhD <i>Roch.</i> , ing. OLGA ORMANDJIEVA, PhD <i>C'dia.</i> , ing. JOEY PAQUET, PhD <i>Laval</i> DAVID K. PROBST, DSc <i>Bruxelles</i> JUERGEN RILLING, PhD <i>Ill.</i> NEMATOLLAH SHIRI-VARNAAMKHAASTI, PhD <i>C'dia.</i>
<i>Associate Chair</i> THOMAS FEVENS, PhD <i>Qu.</i> , <i>Associate Professor</i>	<i>Assistant Professors</i> RENÉ WITTE, Drlng <i>Karlsruhe</i> YUHONG YAN, PhD <i>Tsinghua/Leip.</i> , PEng
<i>Professors</i> TIEN D. BUI, PhD <i>York (Can.)</i> , ing. GREGORY BUTLER, PhD <i>Syd.</i> VACLAV CHVATAL, PhD <i>Wat.</i> , <i>Provost's Distinction</i> BIPIN C. DESAI, PhD <i>McG.</i> EUSEBIUS J. DOEDEL, PhD <i>Br.Col.</i> TERRILL FANCOTT, DSc <i>Paris</i> , ing. PETER GROGONO, PhD <i>C'dia.</i> , PEng VOLKER M. HAARSLEV, PhD <i>Hamburg</i> HOVHANNES A. HARUTYUNYAN, PhD <i>A.A.O.S.</i> BRIGITTE JAUMARD, PhD <i>Nat'l Sup.</i> <i>Telecommunications</i> ADAM KRZYZAK, PhD <i>Wroclaw, Poland</i> THIRUVENGADAM RADHAKRISHNAN, PhD <i>I.I.T.Kanpur</i> , PEng CHING Y. SUEN, PhD <i>Br.Col.</i> , <i>Provost's Distinction</i>	<i>Extended Term Appointment</i> AIMAN HANNA, MCompSc <i>C'dia.</i> , PEng
<i>Distinguished Professors Emeriti</i> J. WILLIAM ATWOOD, PhD <i>Ill.</i> JOHN MCKAY, PhD <i>Edin.</i> , <i>Provost's Distinction</i>	<i>Affiliate Professors</i> P. DINI, PhD <i>Montr.</i> T. KASVAND, PhD <i>Br.Col.</i> L. LAM, PhD <i>Tor.</i>
<i>Professors Emeriti</i> V.S. ALAGAR, PhD <i>McG.</i> DAVID FORD, PhD <i>Ohio State</i> CLEMENT LAM, PhD <i>Cal. Tech.</i> H.F. LI, PhD <i>Calif. (Berkeley)</i> G. MARTIN, MSc <i>New Br.</i> JAROSLAV OPATRNY, PhD <i>Wat.</i> R. SHINGHAL, PhD <i>McG.</i>	<i>Affiliate Associate Professor</i> P. CHALIN, PhD <i>C'dia.</i> , ing. <i>Affiliate Assistant Professors</i> M. KASSAB, PhD <i>C'dia.</i> M. MOHAMMAD, PhD <i>C'dia.</i> E. YURASOVSKAYA, PhD <i>Br. Col.</i>
<i>Associate Professors</i> SABINE BERGLER, PhD <i>Brandeis</i> CONSTANTINOS CONSTANTINIDES,	

For the complete list of faculty members, please consult the Department website.

Location

Sir George Williams Campus
Engineering, Computer Science and Visual Arts Complex, Room: EV 003.139
514-848-2424, ext. 3000

Objectives

Computer Science is the study and design of computer systems: hardware and software. Computer scientists are primarily concerned with the design of algorithms, languages, hardware architecture, systems software, applications software and tools. Applications range from simple game playing to the control of space vehicles, power plants and factories, from banking machines to intelligent fault and medical diagnosis. Computer professionals, in short, are concerned with the creation of computer and information systems for the benefit of society.

Software Engineering applies the principles and practices of engineering to the creation of reliable, efficient, and economical software. Software Engineering has its roots in the theory and mathematics of computer science, but carries this knowledge further towards creative applications such as software control systems for vehicles, aircraft, industrial processes; animation, interactive video, virtual reality, commercial systems for banking and financial analysis; health systems for the analysis of biological systems and the control of therapeutic devices.

It shares with engineering the rigorous methodology of analysis and design in the search for economical, reliable, and efficient solutions. Software engineers are trained in all aspects of the software life cycle, from specification through analysis and design, to testing, maintenance and evaluation of the product. They are concerned with safety and reliability of the product as well as cost and schedule of the development process. The discipline is particularly applicable to very large software projects, as well as the re-engineering of existing products.

71.70.1
*Curriculum for the
Degree of Bachelor
of/Baccalaureate in
Computer Science*

The Computer Science program emphasizes fundamentals and techniques that remain relevant and useful for many years after graduation. The program consists of a combination of core courses in computer science, elective courses in computer science and mathematics, and some free electives. The Computer Science Core provides a basic and broad study of theory, mathematical basics, programming methodology, computer architecture, data structures, operating systems, and software engineering. The option courses are designed to provide an integrated yet specialized training in particular application areas of the discipline. Each option involves the study of selected advanced elective courses in computer science to provide further depth in computer science and the particular application area.

The Department offers eight options. Each option constitutes a 90-credit program that consists of courses in the following groups: Computer Science Core, Complementary Core, Option-Specific Courses, Computer Science Electives, Mathematics Electives, and General Electives.

1. The **Computer Games option** deals with the design and implementation of computer games, and the tools and techniques that are useful in developing software for computer games.
2. The **Web Services and Applications option** deals with the analysis, design, and implementation of services and applications delivered over the web.
3. The **Computer Systems option** focuses on state-of-the-art hardware and software platforms and on the tools and techniques necessary to develop software on such platforms.
4. The **Software Systems option** gives a firm grounding in diverse tools and techniques required for a wide variety of software systems.
5. The **Information Systems option** combines a major in Computer Science with approximately a third of the credits from the John Molson School of Business to create a program focusing on business applications of computer systems.
6. The **Computer Applications option** combines a major in Computer Science with a minor in a discipline of the student's choice.
7. The **Computation Arts option** combines a major in Computer Science with a major in Fine Arts specializing in the design of interactive multimedia.
8. The **Mathematics and Statistics option** combines a major in Computer Science with a major in Mathematics and Statistics.

There is an honours program corresponding to each option (see §71.70.4). In addition, all options are offered in the co-operative format, with alternating study and work terms, for a limited number of students with suitable qualifications (see §24).

71.70.2
Degree Requirements

To be recommended for the degree of BCompSc, students must satisfactorily complete an approved program of at least 90 credits comprising the courses of the Computer Science Core and those courses specified for their particular option in accordance with the graduation requirements of §71.10.5.

Students may not register for a 400-level course before completing all of the 200-level Computer Science Core courses of their program.

The Faculty of Engineering and Computer Science is committed to ensuring that its students possess good writing skills. Hence, every student in an undergraduate degree program is required to demonstrate competence in writing English or French prior to graduation.

All students admitted to the Faculty of Engineering and Computer Science as of September 2001 must meet the writing skills requirement as outlined in §71.20.7 (Writing Skills Requirement).

If a student has satisfied the writing skills requirement prior to September 2001, or prior to transferring to the Faculty of Engineering and Computer Science, that student is deemed to have satisfied the writing skills requirement.

Newly admitted students are strongly encouraged to meet the requirement very early in their program (fall term of first year for students starting in September or winter term of first year for students starting in January) to avoid the risk of delayed graduation should remedial work prove necessary. Students who are required to take ESL courses should meet the Faculty writing skills requirements in the term following completion of their ESL courses.

Students registered in the Computer Science program must complete a minimum of 90 credits.

The program offers eight options (see §71.70.1). All options consist of the Computer Science Core (32 credits), the Complementary Core (6 credits), Option-Specific Courses, Computer Science Electives, Mathematics Electives, and General Electives.

Computer Science Core (32 credits)		<i>Credits</i>
COMP 228	System Hardware	3.00
COMP 232	Mathematics for Computer Science	3.00
COMP 233	Probability and Statistics for Computer Science	3.00
COMP 248	Object-Oriented Programming I	3.00
COMP 249	Object-Oriented Programming II	3.00
COMP 335	Introduction to Theoretical Computer Science	3.00
COMP 346	Operating Systems	4.00
COMP 348	Principles of Programming Languages	3.00
COMP 352	Data Structures and Algorithms	3.00
COMP 354	Introduction to Software Engineering	4.00
		<hr/> 32.00

Complementary Core (6 credits)		<i>Credits</i>
ENCS 282	Technical Writing and Communication	3.00
ENCS 393	Social and Ethical Dimensions of Information and Communication Technologies	3.00
		<hr/> 6.00

Computer Science Electives

Computer Science Electives must be chosen from the following list:

- All COMP courses with numbers 325 or higher.
- SOEN 287, 321, 387, 422, 423, 487.
- COMP courses with numbers between 6000 and 6951 (maximum of eight credits, and with permission from the Department).

In every option, any credits exceeding the required number of Computer Science Elective credits will accrue towards the General Elective credits.

Mathematics Electives

Mathematics Electives must be chosen from the following list:

		<i>Credits</i>
COMP 339*	Combinatorics	3.00
COMP 361*	Elementary Numerical Methods	3.00
COMP 367*	Techniques in Symbolic Computation	3.00
ENGR 213	Applied Ordinary Differential Equations	3.00
ENGR 233	Applied Advanced Calculus	3.00
MAST 218	Multivariable Calculus I	3.00
MAST 219	Multivariable Calculus II	3.00
MAST 224	Introduction to Optimization	3.00
MAST 234	Linear Algebra and Applications I	3.00
MAST 235	Linear Algebra and Applications II	3.00
MAST 332*	Techniques in Symbolic Computation	3.00
MAST 334*	Numerical Analysis	3.00
MATH 339*	Combinatorics	3.00
MATH 392	Elementary Number Theory	3.00

In every option, any credits exceeding the required number of Mathematics Elective credits will accrue towards the General Elective credits.

*Students cannot receive credit for both COMP 339 and MATH 339; COMP 361 and MAST 334; COMP 367 and MAST 332.

General Electives

General Electives must be chosen from the following list:

- Computer Science Electives as mentioned above.
- Mathematics Electives as mentioned above.
- General Education Electives found in §71.20.2 and §71.20.6.
- Basic Science Courses list found in §71.70.9.

A course outside this list may qualify as a General Elective only with prior written permission on an ENCS Student Request form, obtainable from the Office of Student Academic Services in the Faculty of Engineering and Computer Science.

1. Computer Games Option		<i>Credits</i>
Computer Science Core		32.00
Complementary Core		6.00
Computer Games Electives		23.00
Computer Science Electives		8.00
Mathematics Electives*		6.00
General Electives		15.00
		90.00

*Note: Students must take COMP 361 as part of their Mathematics Electives.

Computer Games Electives

Students must complete six courses (23 credits) from the following list of courses, including all the courses marked *.

		<i>Credits</i>
COMP 345*	Advanced Program Design with C++	3.00
COMP 353	Databases	4.00
COMP 371*	Computer Graphics	4.00
COMP 376*	Introduction to Game Development	4.00
COMP 472	Artificial Intelligence	4.00
COMP 476	Advanced Game Development	4.00
COMP 477	Animation for Computer Games	4.00

2. Web Services and Applications Option		<i>Credits</i>
Computer Science Core		32.00
Complementary Core		6.00
Web Services and Applications Electives		22.00
Computer Science Electives		9.00
Mathematics Electives		6.00
General Electives		15.00
		90.00

Web Services and Applications Electives

Students must complete six courses (22 credits) from the following list of courses, including all the courses marked *.

		<i>Credits</i>
COMP 353*	Databases	4.00
COMP 445	Data Communication and Computer Networks	4.00
COMP 479	Information Retrieval and Web Search	4.00
SOEN 287*	Web Programming	3.00
SOEN 387*	Web-Based Enterprise Application Design	3.00
SOEN 423	Distributed Systems	4.00
SOEN 487	Web Services and Applications	4.00

3. Computer Systems Option		<i>Credits</i>
Computer Science Core		32.00
Complementary Core		6.00
Computer Systems Electives		21.00
Computer Science Electives		10.00
Mathematics Electives		6.00
General Electives		15.00
		90.00

Computer Systems Electives

Students must complete six courses (21 credits) from the following list of courses, including all the courses marked *.

		<i>Credits</i>
COMP 326*	Computer Architecture	3.00
COMP 345*	Advanced Program Design with C++	3.00
COMP 426	Multicore Programming	4.00

COMP 428	Parallel Programming	4.00
COMP 445	Data Communication and Computer Networks	4.00
SOEN 422*	Embedded Systems and Software	4.00
SOEN 423	Distributed Systems	4.00

4. Software Systems Option *Credits*

Computer Science Core	32.00
Complementary Core	6.00
Software Systems Core	17.00
Computer Science Electives	14.00
Mathematics Electives	6.00
General Electives	15.00
	90.00

Software Systems Core *Credits*

COMP 326	Computer Architecture	3.00
COMP 353	Databases	4.00
COMP 361	Elementary Numerical Methods	3.00
COMP 445	Data Communication and Computer Networks	4.00
COMP 465	Design and Analysis of Algorithms	3.00
	17.00	

5. Information Systems Option *Credits*

Computer Science Core	32.00
Complementary Core	6.00
Information Systems Electives	31.00
Computer Science Electives	15.00
Mathematics Electives	6.00
	90.00

Information Systems Electives

Students must complete 10 courses (31 credits) from the following list of courses, including all the courses marked *.

		<i>Credits</i>
ACCO 220*	Financial and Managerial Accounting	3.00
BTM 387	E-Business	3.00
BTM 430	Enterprise Resource Planning and Information Technology Integration	3.00
COMM 210*	Contemporary Business Thinking	3.00
COMM 222*	Organizational Behaviour and Theory	3.00
COMM 223*	Marketing Management I	3.00
COMM 225*	Production and Operations Management	3.00
COMM 308*	Introduction to Finance	3.00
COMP 353*	Databases	4.00
DESC 445	Statistical Software for Data Management and Analysis	3.00
ECON 201*	Introduction to Microeconomics	3.00
SCOM 361	Management Science Models for Operations Management	3.00
SCOM 372	Supply Chain Planning and Control	3.00

6. Computer Applications Option *Credits*

Computer Science Core	32.00
Complementary Core	6.00
Computer Science Electives	19.00
Mathematics Electives	6.00
Minor and General Electives	27.00
	90.00

Students must satisfy the requirements for a minor program in any other department in the University. Students must declare their minor by the end of their first year.

7. Computation Arts Option

See §71.80 for details.

8. Mathematics and Statistics Option

See §71.85 for details.

71.70.3 Extended Credit Program

Students admitted to an Extended Credit Program (ECP) under the provisions of Sections 13.3.2 or 13.8.1 must successfully complete a minimum of 120 credits including:

- 90 Program requirements as set out in Section 71.70.2
- 12 MATH 202³, 203³, 204³, 205³
- 6 Chosen from courses in Humanities or Social Sciences in Section 71.20.2
- 3 COMP 201³
- 9 ECP elective credits chosen from the following lists, depending on the student's option:
 - a) *Computer Applications Option:*
9 elective credits chosen from outside the Faculty of Engineering and Computer Science, in consultation with the undergraduate program director.
 - b) *Computation Arts Option:*
9 elective credits chosen from outside the Faculty of Engineering and Computer Science and the Department of Design and Computation Arts, in consultation with the undergraduate program director.
 - c) *Information Systems Option:*
9 elective credits chosen from outside the John Molson School of Business and the Department of Computer Science and Software Engineering, in consultation with the undergraduate program director.
 - d) *Mathematics and Statistics Option:*
9 elective credits chosen from outside the Faculty of Engineering and Computer Science and the Department of Mathematics and Statistics, in consultation with the undergraduate program director.
 - e) *Other Options (Computer Games, Computer Systems, Software Systems, and Web Services and Applications Options):*
CHEM 205³
PHYS 204³, 205³

71.70.4 Honours Program

Students should refer to §16.2.3 of the Calendar for academic regulations for the honours program.

The following regulations are additional requirements for the Honours BCompSc program.

1. Applications to enter an honours program must be submitted to the Office of the Associate Dean (Student Academic Services) at least three months before the start of the term in which the student wishes to enter an honours program.
2. Students must complete at least 30 credits towards their degree before entering an honours program.
3. Each student in an honours program must have an honours advisor who approves the student's choice of courses prior to each registration.
4. Students who are required to withdraw from an honours program may continue in the regular program of their option provided they are in acceptable or conditional standing according to the academic regulations in §71.10.3.

Course Requirements for Honours Programs

Honours students must fulfill the requirements of their option. In addition, to receive an honours degree:

1. The student must have a final graduation GPA of at least 3.30.
2. The student must successfully complete the course COMP 490.
3. For students in the Computer Games, Computer Systems, Web Services and Applications, and Software Systems Options, at least six of the General Electives credits must be chosen from the list of Computer Science Electives.

71.70.5 Minor in Computer Science

NOTE: Admission profile is 10.12.

Minor in Computer Science		Credits
COMP 228	System Hardware	3.00
COMP 232	Mathematics for Computer Science	3.00
COMP 248	Object-Oriented Programming I	3.00

COMP 249	Object-Oriented Programming II	3.00
COMP 352	Data Structures and Algorithms	3.00
	Computer Science Electives (see §71.70.2)	9.00
		24.00

Students who require any of the above courses as part of their major should replace these courses with elective courses chosen from the list of Computer Science Electives.

71.70.6
Programs Related to Computer Science

Both major and minor programs in Management Information Systems can be found in the John Molson School of Business Section of the Undergraduate Calendar, §61. The Faculty of Fine Arts and the Department of Computer Science and Software Engineering offer complementary major programs. Students who take the Computer Applications Option (see §71.70.2 above) can also take the Major in Computation Arts and Computer Science (see §71.80, and the Fine Arts Section, §81) or the Joint Major in Mathematics and Statistics and Computer Applications (see §71.85, and the Mathematics and Statistics Section, §31.200).

71.70.7
Industrial Experience and Reflective Learning Courses

Students employed full-time in a computer science position during their non-study terms may have this Industrial Experience listed on their record, provided they successfully complete the Reflective Learning course associated with this work term. Industrial Experience work terms will be coded as COMP 107 and 207, and the associated Reflective Learning courses will be coded as COMP 108 and 208 respectively. Students may only register for these courses with the permission of the Faculty. The Industrial Experience terms COMP 107 and 207 carry no credit value and are used to indicate that the student is on an Industrial Experience term. The COMP 108 and 208 Industrial Experience Reflective Learning courses are worth three credits and are marked on a pass/fail basis. They are above and beyond the credit requirements of the student's program and are not transferable nor are they included in the full- or part-time assessment status. Students studying for a co-op work term or CIADI term should not register for these Industrial Experience and Reflective Learning courses.

71.70.8
Curriculum for the Degree of BEng in Software Engineering

The Software Engineering program is built on the fundamentals of computer science, an engineering core, and a discipline core in Software Engineering to cover the engineering approach to all phases of the software process and related topics. The curriculum builds on the traditional computer science core topics of computer mathematics, theory, programming methodology, and mainstream applications to provide the computing theory and practice which underlie the discipline. The engineering core covers basic science, professional topics, and introduces the engineering approach to problem solving. The program core in Software Engineering includes advanced programming techniques, software specification, design, architecture, as well as metrics, security, project management, and quality control. The options cover a broad range of advanced topics, from formal methods to distributed systems.

71.70.9
Degree Requirements for the BEng in Software Engineering

Students registered in the Software Engineering program must complete a minimum of 120 credits during four years of full-time study. The program offers three options: Computer Games; Web Services and Applications; and Real-Time, Embedded, and Avionics Software. The program consists of the Engineering Core, Software Engineering Core, an option, and electives.

Engineering Core (30.5 credits)
See §71.20.5

Software Engineering Core		<i>Credits</i>
SOEN 228	System Hardware	4.00
SOEN 287	Web Programming	3.00
SOEN 331	Introduction to Formal Methods for Software Engineering	3.00
SOEN 341	Software Process	3.00
SOEN 342	Software Requirements and Specifications	3.00
SOEN 343	Software Architecture and Design I	3.00
SOEN 344	Software Architecture and Design II	3.00
SOEN 345	Software Testing, Verification and Quality Assurance	3.00
SOEN 357	User Interface Design	3.00
SOEN 384	Management, Measurement and Quality Control	3.00

SOEN 385	Control Systems and Applications	3.00
SOEN 390	Software Engineering Team Design Project	3.50
SOEN 490	Capstone Software Engineering Design Project	4.00
	Computer Science Group	22.00
	Two Basic Science courses	6.00
		<hr/> 69.50

Computer Science Group *Credits*

COMP 232	Mathematics for Computer Science	3.00
COMP 248	Object-Oriented Programming I	3.00
COMP 249	Object-Oriented Programming II	3.00
COMP 335	Introduction to Theoretical Computer Science	3.00
COMP 346	Operating Systems	4.00
COMP 348	Principles of Programming Languages	3.00
COMP 352	Data Structures and Algorithms	3.00
		<hr/> 22.00

Basic Science Courses

Two Basic Science courses must be selected from the following:

		<i>Credits</i>
BIOL 206	Elementary Genetics	3.00
BIOL 208	Environmental Biology	3.00
BIOL 226	Biodiversity and Ecology	3.00
BIOL 261	Molecular and General Genetics	3.00
CHEM 209	Discovering Biotechnology	3.00
CHEM 217	Introductory Analytical Chemistry I	3.00
CHEM 221	Introductory Organic Chemistry I	3.00
CHEM 234	Physical Chemistry I: Thermodynamics	3.00
GEOL 206	Earthquakes, Drifting Continents and Volcanoes	3.00
GEOL 208	The Earth, Moon and the Planets	3.00
PHYS 252	Optics	3.00
PHYS 253	Electricity and Magnetism I	3.00
PHYS 273	Energy and Environment	3.00
PHYS 334	Thermodynamics	3.00
PHYS 354	Electricity and Magnetism II	3.00
PHYS 384	Introduction to Astronomy	3.00
PHYS 385	Astrophysics	3.00

Options

Students must complete at least 20 credits with a minimum of 15 credits from one of the options listed below, including all the courses marked *, and at least one course marked **, and the remainder chosen from the electives list.

Computer Games (CG) Option *Credits*

COMP 345	Advanced Program Design with C++	3.00
COMP 371*	Computer Graphics	4.00
COMP 376*	Introduction to Game Development	4.00
COMP 472	Artificial Intelligence	4.00
COMP 476**	Advanced Game Development	4.00
COMP 477**	Animation for Computer Games	4.00

Web Services and Applications (WSA) Option *Credits*

COMP 353*	Databases	4.00
COMP 445	Data Communication and Computer Networks	4.00
COMP 479**	Information Retrieval and Web Search	4.00
SOEN 321	Information Systems Security	3.00
SOEN 387*	Web-Based Enterprise Application Design	3.00
SOEN 487**	Web Services and Applications	4.00

Real-Time, Embedded, and Avionics Software (REA) Option		<i>Credits</i>
COEN 320	Introduction to Real-Time Systems	3.00
COMP 345	Advanced Program Design with C++	3.00
COMP 444	System Software Design	4.00
SOEN 422*	Embedded Systems and Software	4.00
SOEN 423*	Distributed Systems	4.00
MECH 480**	Flight Control Systems	3.50
MECH 482**	Avionic Navigation Systems	3.00

Electives		<i>Credits</i>
COMP 345	Advanced Program Design with C++	3.00
COMP 353	Databases	4.00
COMP 371	Computer Graphics	4.00
COMP 426	Multicore Programming	4.00
COMP 428	Parallel Programming	4.00
COMP 442	Compiler Design	4.00
COMP 445	Data Communication and Computer Networks	4.00
COMP 451	Database Design	4.00
COMP 465	Design and Analysis of Algorithms	3.00
COMP 472	Artificial Intelligence	4.00
COMP 473	Pattern Recognition	4.00
COMP 474	Intelligent Systems	4.00
COMP 478	Image Processing	4.00
COMP 479	Information Retrieval and Web Search	4.00
SOEN 422	Embedded Systems and Software	4.00
SOEN 423	Distributed Systems	4.00
SOEN 431	Formal Methods	3.00
SOEN 448	Management of Evolving Systems	3.00
ENGR 411	Special Technical Report	1.00

71.70.10
Course Descriptions

Please note that new course numbers have been implemented. For equivalent course numbers under the old system, please consult §200.6.

Students from outside the Faculty of Engineering and Computer Science who are not registered in a Computer Science program may not take more than five COMP courses numbered higher than 212. Students from outside the Faculty of Engineering and Computer Science who are registered for the Minor in Computer Science may not take more than 30 credits of COMP courses numbered higher than 212.

COMPUTER SCIENCE

COMP 108 *Computer Science Industrial Experience Reflective Learning I* (3 credits)

Prerequisite: Permission of the Faculty. This course is a reflective learning module for students in their related field which is based on their academic requirements and their first industrial experience.

COMP 201 *Introduction to Computing* (3 credits)

Prerequisite: MATH 201 or equivalent. Overview of computing systems. Problem solving and algorithms. Introduction to computer programming. Hardware, software and data storage, programming languages, data organization, program design and development. Lectures: three hours per week. Tutorial: one hour per week.

NOTES: 1. Students who have received credit for COMP 218, COMP 248, or COEN 243 may not take this course for credit.

2. This course may not be taken for credit in the regular undergraduate programs in Engineering and Computer Science.

COMP 208 *Computer Science Industrial Experience Reflective Learning II* (3 credits)

Prerequisite: COMP 108 and permission of the Faculty. This course expands on the students' second industrial experience term in their related field of study to further develop their knowledge and work-related skills.

COMP 218 *Fundamentals of Programming* (3 credits)

Prerequisite: MATH 201 or equivalent (no prior experience with computers is assumed). Computers and computing: problem solving with computers, basic data types, expressions, assignments, control structures, simple library functions, programmer-defined functions, arrays of basic types. Basic elements of object-oriented programming: classes, objects and methods. Lectures: three hours per week. Tutorial: one hour per week. *NOTE: Students who have received credit for COMP 248 may not take this course for credit.*

COMP 228 *System Hardware* (3 credits)

Prerequisite: COMP 248; MATH 203 or 209 or Cegep Mathematics 103 or NYA previously or

concurrently; MATH 204 or 208 or Cegep Mathematics 105 or NYC previously or concurrently. Levels of system abstraction and von Neumann model. Basics of digital logic design. Data representation and manipulation. Instruction set architecture. Processor internals. Assembly language programming. Memory subsystem and cache management. I/O subsystem. Introduction to network organization and architecture. Lectures: three hours per week. Tutorial: two hours per week. *NOTE: Students who have received credit for SOEN 228 may not take this course for credit.*

COMP 229 System Software (3 credits)
Prerequisite: COMP 228; COMP 248; MATH 203 or 209 or Cegep Mathematics 103 or NYA; MATH 204 or 208 or Cegep Mathematics 105 or NYC. Hardware-software interface, system kernel, system services, system evolution. Assemblers, compilers, linkers, and loaders. System component interfaces. User-level view of operating systems. Lectures: three hours per week. Tutorial: two hours per week. *NOTE: Students who have received credit for SOEN 229 or COEN 311 may not take this course for credit.*

COMP 232 Mathematics for Computer Science (3 credits)
Prerequisite: MATH 203 or 209 or Cegep Mathematics 103 or NYA previously or concurrently; MATH 204 or 208 or Cegep Mathematics 105 or NYC previously or concurrently. Sets. Propositional logic and predicate calculus. Functions and relations. Elements of number theory. Proof techniques: direct proof, indirect proof, proof by contradiction, proof by induction. Lectures: three hours per week. Tutorial: two hours per week. *NOTE: Students who have received credit for COMP 238 or COEN 231 may not take this course for credit.*

COMP 233 Probability and Statistics for Computer Science (3 credits)
Prerequisite: COMP 232. Combinatorics. Axioms of probability. Conditional probability. Discrete and continuous probability distributions. Expectation and moments. Hypothesis testing. Parameter estimation. Correlation and linear regression. Applications to computer science. Lectures: three hours per week. Tutorial: two hours per week. *NOTE: Students who have received credit for ENGR 371, STAT 249, STAT 250, COMM 215, MAST 221, MAST 333 may not take this course for credit.*

COMP 239 Mathematics for Computer Science II (3 credits)
Prerequisite: COMP 232; MATH 203 or 209 or Cegep Mathematics 103 or NYA; MATH 204 or 208 or Cegep Mathematics 105 or NYC; MATH 205 or Cegep Mathematics 203 or NYB previously or concurrently. Counting and number theory. Permutations and combinations. Recurrence relations. Graphs and trees. Lectures: three hours per week. Tutorial: two hours per week.

COMP 248 Object-Oriented Programming I (3 credits)
Prerequisite: MATH 204 or 208 or Cegep Mathematics 105 or NYC previously or concurrently. Introduction to programming. Basic data types, variables, expressions, assignments, control flow. Classes, objects, methods. Information hiding, public vs. private visibility, data abstraction and encapsulation. References. Arrays. Lectures: three hours per week. Tutorial: two hours per week. *NOTE: Students who have received credit for COMP 218 may not take this course for credit.*

COMP 249 Object-Oriented Programming II (3 credits)
Prerequisite: COMP 232; COMP 248; MATH 203 or 209 or Cegep Mathematics 103 or NYA; MATH 204 or 208 or Cegep Mathematics 105 or NYC; MATH 205 or Cegep Mathematics 203 or NYB previously or concurrently. Design of classes. Inheritance. Polymorphism. Static and dynamic binding. Abstract classes. Exception handling. File I/O. Recursion. Interfaces and inner classes. Graphical user interfaces. Generics. Collections and iterators. Lectures: three hours per week. Tutorial: two hours per week.

COMP 318 Introduction to Database Applications (4 credits)
Prerequisite: COMP 218 or COMP 248, or a course in C, C++, or Java. This is a hands-on course on database technology intended for non-computer science students in engineering, science, business, or arts. It emphasizes practical issues in application development while introducing the fundamentals of databases with a focus on the relational data model and the Structured Query Language (SQL). Upon completion of this course, students will be able to design and implement databases, and develop user interfaces to access, search, and update the database through the Internet using the web technology. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week. *NOTE: Students who have received credit for COMP 353 may not take this course for credit. NOTE: Students in the BCompSc program may not take this course for credit.*

COMP 326 Computer Architecture (3 credits)
Prerequisite: COMP 346. Computer architecture models: control-flow and data-flow. Concurrency and locality, data dependency theory. Instruction level parallelism. Instruction scheduling. Pipelined processors. Vector processors. Thread level parallelism. Multiprocessors. Shared memory models. Coherence protocols. Interconnection networks. Performance issues. Advanced topics in contemporary computer architectures. Lectures: three hours per week. Tutorial: one hour per week.

COMP 327 Digital System Design (4 credits)
Prerequisite: COMP 228 or SOEN 228. Basic theory and techniques related to the design of

digital systems: design specifications, manipulation of Boolean expressions and its relation to logic circuit design. Sequential circuit design. Design with SSI and MSI circuits. Interfacing with devices. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week.

COMP 335 Introduction to Theoretical Computer Science (3 credits)

Prerequisite: COMP 232 or COEN 231; COMP 249 or COEN 244. Finite state automata and regular languages. Push-down automata and context-free languages. Pumping lemmas. Applications to parsing. Turing machines. Undecidability and decidability. Lectures: three hours per week. Tutorial: one hour per week.

COMP 339 Combinatorics (3 credits)

Prerequisite: COMP 232 or 18 credits in post-Cegep Mathematics. General principles of counting, permutations, combinations, identities, partitions, generating functions, Fibonacci numbers, Stirling numbers, Catalan numbers, principle of inclusion-exclusion. Graphs, subgraphs, isomorphism, Euler graphs, Hamilton paths and cycles, planar graphs, Kuratowski's Theorem, trees, colouring, 5-colour theorem, matching, Hall's theorem.

NOTE: Students who have received credit for MATH 339 may not take this course for credit.

COMP 345 Advanced Program Design with C++ (3 credits)

Prerequisite: COMP 352 previously or concurrently. Introduction to C++. I/O with stream classes. Pointers and their uses. The Standard Template Library (STL): containers, algorithms, iterators, adaptors, function objects. Class design: constructors, destructors, operator overloading, inheritance, virtual functions, exception handling, memory management. Advanced topics: libraries, locales, STL conventions, concurrency, template meta-programming. Applications of C++: systems, engineering, games programming. Project. Lectures: three hours per week.

NOTE: Students who have received credit for COMP 446 may not take this course for credit.

COMP 346 Operating Systems (4 credits)

Prerequisite: COMP 228 or SOEN 228; COMP 352. Fundamentals of operating system functionalities, design and implementation. Multi-programming: processes and threads, context switching, queuing models and scheduling. Inter-process communication and synchronization. Principles of concurrency. Synchronization primitives. Deadlock detection and recovery, prevention and avoidance schemes. Memory management. Device management. File systems. Protection models and schemes. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week.

NOTE: Students who have received credit for COEN 346 may not take this course for credit.

COMP 348 Principles of Programming Languages (3 credits)

Prerequisite: COMP 249. Survey of programming paradigms: Imperative, functional, and logic programming. Issues in the design and implementation of programming languages. Declaration models: binding, visibility, and scope. Type systems, including static and dynamic typing. Parameter passing mechanisms. Hybrid language design. Lectures: three hours per week. Tutorial: one hour per week.

COMP 352 Data Structures and Algorithms (3 credits)

Prerequisite: COMP 232 previously or concurrently; COMP 249. Abstract data types: stacks and queues, trees, priority queues, dictionaries. Data structures: arrays, linked lists, heaps, hash tables, search trees. Design and analysis of algorithms: asymptotic notation, recursive algorithms, searching and sorting, tree traversal, graph algorithms. Lectures: three hours per week. Tutorial: one hour per week.

NOTE: Students who have received credit for COEN 352 may not take this course for credit.

COMP 353 Databases (4 credits)

Prerequisite: COMP 352 or COEN 352. Introduction to database management systems. Conceptual database design: the entity-relationship model. The relational data model and relational algebra: functional dependencies and normalization. The SQL language and its application in defining, querying, and updating databases; integrity constraints; triggers. Developing database applications. Other data models: Datalog. Object-oriented data model and ODL. Semi-structured data. Project. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week.

NOTE: Students who have received credit for COMP 318 may not take this course for credit.

COMP 354 Introduction to Software Engineering (4 credits)

Prerequisite: COMP 352; ENCS 282. Software development process models (e.g. linear vs. iterative). Project management; roles, activities and deliverables for each software life cycle phase. Requirements management: analysis, elicitation, and scope. Architecture, design and the mapping of requirements to design and design to implementation. Traceability. Software quality assurance: verification, validation and the role of testing. Maintenance and evolution. Project. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week.

NOTES: 1. Students who have received credit for SOEN 341 may not take this course for credit. 2. Students in the BEng in Software Engineering program may not take this course for credit.

COMP 361 Elementary Numerical Methods (3 credits)

Prerequisite: COMP 232, 249. Vector and matrix norms. Numerical methods for solving linear

systems, Gaussian elimination, LU decomposition, error analysis. Numerical solution of nonlinear equations, Newton's method, fixed point iterations. Interpolation and approximation, Taylor, Lagrange, Chebyshev and Legendre polynomials. Cubic spline interpolation. Numerical differentiation, numerical integration, Gauss quadrature. Discrete least-squares approximation. Initial value problems in ordinary differential equations, stiff differential equations. Boundary value problems in ordinary differential equations. Lectures: three hours per week. Tutorial: one hour per week.

NOTE: Students who have received credit for ENGR 391 or MAST 334 may not take this course for credit.

COMP 367 *Techniques in Symbolic Computation* (3 credits)

Prerequisite: COMP 232 or MAST 217; COMP 248 or MAST 234. Symbolic computation and its use in pure and applied mathematics, in particular in algebra, number theory, cryptography, coding theory, and combinatorics. Programming in a symbolic computing system (e.g. MAPLE).

NOTE: Students who have received credit for MAST 332 may not take this course for credit.

COMP 371 *Computer Graphics* (4 credits)

Prerequisite: COMP 352 or COEN 352. Introduction to computer graphics and graphics hardware. Introduction to graphics API and graphics systems architecture. Mathematics of 2D and 3D transformations, and 2D and 3D viewing. Colour and basic rendering algorithms. Visual realism and visibility. Illumination and shading, global illumination techniques, and textures. Introduction to curves and surfaces, and 3D object modelling. Introduction to computer animation. Project. Lectures: three hours per week. Laboratory: two hours per week.

NOTE: Students who have received credit for COMP 471 may not take this course for credit.

COMP 376 *Introduction to Game Development* (4 credits)

Prerequisite: COMP 371 previously or concurrently. Introduction to design and implementation aspects of computer gaming: basic game design, storytelling and narratives, and game genres. Virtual environments, 2D and 3D game engines, and game development tools. Character development, gameplay strategies, level design in games, and user interfaces. Architecture of game consoles, analog and digital controllers, and the incorporation of graphics, sound, and music in game implementations. Project. Lectures: three hours per week. Laboratory: two hours per week.

COMP 426 *Multicore Programming* (4 credits)

Prerequisite: COMP 346 or COEN 346. Fundamental concepts of computer architecture. Architecture of the selected multicore platform. Review of shared-memory parallel programming. The difficulties inherent to parallel programming. Scalability of programming models. The stream

programming model for multicore. Implicit and explicit threading. Implicit and explicit orchestration of data movement, both on chip and off. Adapting standard algorithms to multicore. Critical assessment of the available system-software support. Project. Lectures: three hours per week. Laboratory: two hours per week.

COMP 428 *Parallel Programming* (4 credits)

Prerequisite: COMP 346. Parallel programming techniques as a natural extension to sequential programming. Overview of parallel programming architectures and models. Parallel programming issues: locality, granularity, scheduling, data decomposition and distribution, load balancing, communication and synchronization, determinacy and non-determinacy, cost and performance. Techniques and tools for message-passing parallel programming. Case studies. Project. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week.

COMP 442 *Compiler Design* (4 credits)

Prerequisite: COMP 228 or SOEN 228 or COEN 311; COMP 335; COMP 352 or COEN 352. Compiler organization and implementation: lexical analysis and parsing, syntax-directed translation, code optimization. Run-time systems. Project. Lectures: three hours per week. Laboratory: two hours per week.

COMP 444 *System Software Design* (4 credits)

Prerequisite: COMP 346. Detailed examination of the design, implementation and system call interface of a contemporary operating system: its kernel, file system, process and thread management including scheduling, file system design and implementation, memory management, device management, I/O management, interprocess communication and synchronization mechanisms, system call interface, interrupt handling, and other advanced issues. Project. Lectures: three hours per week. Laboratory: two hours per week.

COMP 445 *Data Communication and Computer Networks* (4 credits)

Prerequisite: COMP 346. Network architectures: OSI and Internet models. Link layer: error detection, multiple access protocols, addressing. Local area networks: Ethernet, ATM, switches and hubs. Network layer: forwarding and routing, IP, routing algorithms, multicast. Transport layer: connectionless and connection-oriented transport, reliable data transport, congestion control, QoS, UDP and TCP. Application layer: DNS, the web and http, file transfer, and email. Introduction to network security, multimedia protocols and wireless networking. Lectures: three hours per week. Laboratory: two hours per week.

COMP 451 *Database Design* (4 credits)

Prerequisite: COMP 353. Storage management. Buffer management. Data organization. Index structures. Query optimization and execution.

Transaction management. Recovery. Concurrency control. Database performance analysis and tuning. New trends in database technology. Project. Lectures: three hours per week. Laboratory: two hours per week.

COMP 465 *Design and Analysis of Algorithms* (3 credits)

Prerequisite: COMP 335; COMP 352 or COEN 352. Order statistics: worst-case, average-case and amortized analysis. Algorithm design techniques: greedy algorithms, dynamic programming. Selected algorithms from graph theory, linear programming, number theory, string matching, and computational geometry. A survey of hard problems, NP-completeness, and approximation algorithms. Lectures: three hours per week.

COMP 472 *Artificial Intelligence* (4 credits)

Prerequisite: COMP 352 or COEN 352. Scope of AI. First-order logic. Automated reasoning. Search and heuristic search. Game-playing. Planning. Knowledge representation. Probabilistic reasoning. Introduction to machine learning. Introduction to natural language processing. Project. Lectures: three hours per week. Laboratory: two hours per week.

COMP 473 *Pattern Recognition* (4 credits)

Prerequisite: COMP 352. Preprocessing. Feature extraction and selection. Similarity between patterns and distance measurements. Syntactic and statistical approaches. Clustering analysis. Bayesian decision theory and discriminant functions. Neural networks and machine learning. Applications. Project. Lectures: three hours per week. Laboratory: two hours per week.

COMP 474 *Intelligent Systems* (4 credits)

Prerequisite: COMP 352 or COEN 352. Rule-based expert systems, blackboard architecture, and agent-based. Knowledge acquisition and representation. Uncertainty and conflict resolution. Reasoning and explanation. Design of intelligent systems. Project. Lectures: three hours per week. Laboratory: two hours per week.

COMP 475 *Human-Computer Interaction* (3 credits)

Prerequisite: COMP 352. Importance of human-computer interactions in modern computer applications: desktop, hand-held, and embedded computers. Empirical nature of user interface testing and evaluation. Input and output: devices, methods and media. Human cognition and user modelling. Relating task models and dialog models to user interface (UI) design. Principles of graphical UI design and user-centred design. Usability definitions and usability testing. Relevant ISO standards. Case studies. Lectures: three hours per week.

COMP 476 *Advanced Game Development* (4 credits)

Prerequisite: COMP 361 or ENGR 391; COMP 376. Introduction to advanced aspects of computer games. Artificial Intelligence: acting,

game state, perception, reacting, searching, and learning. Group behaviour, non-player characters and bots, opponent modelling, and strategy. Physics-based techniques: path-finding and collision detection and response. Networked gaming: multi-player games, networking and distributed game design, massively multi-player online games (MMOGs). Improving realism: advanced rendering techniques such as ray-tracing, GPU programming, 3D scene management, level-of-detail, terrains, and 3D sound. Testing for games. Project. Lectures: three hours per week. Laboratory: two hours per week.

COMP 477 *Animation for Computer Games* (4 credits)

Prerequisite: COMP 361 or ENGR 391; COMP 371. Introduction to the algorithms, data structures, and techniques used in modelling and rendering dynamic scenes. Topics include principles of traditional animation, production pipeline, animation hardware and software, orientation representation and interpolation, modelling physical and articulated objects, forward and inverse kinematics, motion control and capture, key-frame, procedural, and behavioural animation, camera animation, scripting system, and free-form deformation. Project. Lectures: three hours per week. Laboratory: two hours per week.

COMP 478 *Image Processing* (4 credits)

Prerequisite: COMP 352. Digital image fundamentals, image transforms (Fourier, Walsh, Haar, Hotelling, wavelet), image enhancement (histogram processing, spatial filtering, high- and low-pass filtering), image restoration, image compression (elements of information theory, image compression models, error-free compression, lossy compression, image compression standards), image segmentation (line detection, Hough transform, edge detection and linking, thresholding, region splitting and merging), representation and description (chain codes, signatures, skeletons, shape descriptors, moments, texture). Project. Lectures: three hours per week. Laboratory: two hours per week.

COMP 479 *Information Retrieval and Web Search* (4 credits)

Prerequisite: COMP 233 or ENGR 371; COMP 352. Basics of information retrieval (IR): boolean, vector space and probabilistic models. Tokenization and creation of inverted files. Weighting schemes. Evaluation of IR systems: precision, recall, F-measure. Relevance feedback and query expansion. Application of IR to web search engines: XML, link analysis, PageRank algorithm. Text categorization and clustering techniques as used in spam filtering. Project. Lectures: three hours per week. Laboratory: two hours per week.

COMP 490 *Computer Science Project I* (3 credits)

Prerequisite: ENCS 282; completion of 60 credits; permission of the Department. Students work on a computer science project under the supervision of a faculty member and submit a suitable written

report on the work carried out. Students planning to register for this course should consult with the Department prior to registration in the final year of study.

NOTE: Students can register for COMP 490 by itself or, with the permission of the Department, students can register for COMP 490 and 492 concurrently and carry out a major project.

COMP 492 Computer Science Project II
(3 credits)

Prerequisite: COMP 490 previously or concurrently; permission of the Department. Students work on a computer science project under the supervision of a faculty member and submit a suitable written report on the work carried out. Students planning to register for this course should consult with the Department prior to registration in their final year of study.

NOTE: Students can register for COMP 492 by itself or, with the permission of the Department, students can register for COMP 490 and 492 concurrently and carry out a major project.

COMP 495 Honours Seminar (1 credit)

Prerequisite: ENCS 282; registration in the final year of the honours program. Students are required to attend a number of departmental seminars and submit a written report on them.

COMP 498 Topics in Computer Science
(3 credits)

Prerequisite: Permission of the Department. This course may be offered in a given year upon the authorization of the Department. The content may vary from offering to offering and will be chosen to complement the available elective courses. Lectures: three hours per week.

SOFTWARE ENGINEERING

SOEN 228 System Hardware (4 credits)

Prerequisite: MATH 203 or 209 or Cegep Mathematics 103, MATH 204 or 208 or Cegep Mathematics 105. Processor structure, Data and Instructions, Instruction Set Processor (ISP) level view of computer hardware, assembly language level use. Memory systems — RAM and disks, hierarchy of memories. I/O organization, I/O devices and their diversity, their interconnection to CPU and Memory. Communication between computers at the physical level. Networks and computers. Lectures: three hours per week.

Tutorial: two hours per week. Laboratory: two hours per week.

NOTE: Students who have received credit for COMP 228 may not take this course for credit.

SOEN 287 Web Programming (3 credits)

Prerequisite: COMP 248. Internet architecture and protocols. Web applications through clients and servers. Markup languages. Client-side programming using scripting languages. Static website contents and dynamic page generation through server-side programming. Preserving state (client-side) in web applications. Lectures: three hours per week. Tutorial: two hours per week.

SOEN 321 Information Systems Security
(3 credits)

Prerequisite: COMP 346. Protocol layers and security protocols. Intranets and extranets. Mobile computing. Electronic commerce. Security architectures in open-network environments. Cryptographic security protocols. Threats, attacks, and vulnerabilities. Security services: confidentiality; authentication; integrity; access control; non-repudiation; and availability. Security mechanisms: encryption; data-integrity mechanisms; digital signatures; keyed hashes; access-control mechanisms; challenge-response authentication; traffic padding; routing control; and notarization. Key-management principles. Distributed and embedded firewalls. Security zones. Lectures: three hours per week. Tutorial: one hour per week.

SOEN 331 Introduction to Formal Methods for Software Engineering
(3 credits)

Prerequisite: COMP 232, 249. Assertions. Static and dynamic checking. Method specification using preconditions and postconditions. Strengthening and weakening. Design by contract. Hoare logic. Invariants. Class specification using invariants. Software tools for assertion checking and verification. Reliable software development. Lectures: three hours per week. Tutorial: two hours per week.

SOEN 341 Software Process (3 credits)

Prerequisite: COMP 228 or SOEN 228 or COEN 311; COMP 352 or COEN 352; ENCS 282 previously or concurrently. Basic principles of software engineering. Introduction to software process models. Activities in each phase, including review activities. Working in teams: organization; stages of formation; roles; conflict resolution. Notations used in software documentation. How to review, revise, and improve software documentation. Lectures: three hours per week. Tutorial: one hour per week.
NOTE: Students who have received credit for COMP 354 may not take this course for credit.

SOEN 342 Software Requirements and Specifications (3 credits)

Prerequisite: SOEN 341. Requirements engineering. Functional and non-functional requirements. Traceability. Test generation. Formal and informal specifications. Formal specification languages. Reasoning with specifications. Correctness issues. Verification. Lectures: three hours per week. Tutorial: one hour per week.

SOEN 343 Software Architecture and Design I (3 credits)

Prerequisite: SOEN 341; SOEN 342 previously or concurrently. From requirements to design to implementation. Planned vs. evolutionary design and refactoring. Model-driven design and Unified Modelling Language (UML). Structural and behavioural design descriptions and specifications. General and domain-specific design principles, patterns and idioms. Object-oriented design

concepts such as interfaces vs. abstract types, polymorphism, generics, and delegation vs. subclassing. Introduction to software architecture (styles and view models). Design quality. Design rationale. Design methodologies (e.g. based on responsibility assignment). Test-driven development. Lectures: three hours per week. Tutorial: one hour per week.

SOEN 344 *Software Architecture and Design II* (3 credits)

Prerequisite: SOEN 343. Architectural activities, roles, and deliverables. Architectural view models. Architectural styles (including client-server, layered, pipes-and-filters, event-based, process control) and frameworks. Architectural analysis and the interplay with requirements elicitation. Notations for expressing architectural designs, structural and behavioural specifications. From architectural design to detailed design. Domain specific architectures and design patterns. Evaluation and performance estimation of designs. Advanced object-oriented design patterns and idioms. Lectures: three hours per week. Tutorial: one hour per week.

SOEN 345 *Software Testing, Verification and Quality Assurance* (3 credits)

Prerequisite: SOEN 343 previously or concurrently. Testing strategies. Specification-based vs. code-based, black-box vs. white-box, functional vs. structural testing; unit, integration, system, acceptance, and regression testing. Verification vs. validation. Test planning, design and artifacts. Introduction to software reliability and quality assurance. Formal verification methods, oracles; static and dynamic program verification. Lectures: three hours per week. Tutorial: one hour per week.

SOEN 357 *User Interface Design* (3 credits)

Prerequisite: SOEN 342. The human side: I/O; memory; and information processing. Interaction: mental models; human error; interaction frameworks and paradigms. Direct manipulation. User interface design: principles; standards; and guidelines. User-centred design: standards and design rationale; heuristic evaluation; iterative design; and prototyping. Task-centred design. Rationalized design: usability engineering; dialogue notations; user models; diagrammatic notations; and textual notations. Evaluation: with the user; without the user; quantitative; and qualitative. Implementation support. Help and documentation. Lectures: three hours per week. Tutorial: one hour per week.

SOEN 384 *Management, Measurement and Quality Control* (3 credits)

Prerequisite: ENCS 282; SOEN 341. Organization of large software development. Roles of team members, leaders, managers, stakeholders, and users. Tools for monitoring and controlling a schedule. Financial, organizational, human, and computational resources allocation and control. Project and quality reviews, inspections, and walkthroughs. Risk management. Communication and collaboration. Cause and effects of project

failure. Project management via the Internet. Quality assurance and control. Lectures: three hours per week. Tutorial: one hour per week. *NOTE: Students who have received credit for SOEN 383 may not take this course for credit.*

SOEN 385 *Control Systems and Applications* (3 credits)

Prerequisite: ENGR 213, 233. Mathematical modelling of dynamical systems; block diagrams; feedback; open and closed loops. Linear differential equations; time domain analysis; free, forced, and total response; steady state and transient response. Laplace transform and inverse transform; second order systems. Transfer functions and stability. Control system design: PID and root locus techniques. Computer simulation of control systems. Applications. Lectures: three hours per week. Tutorial: one hour per week.

SOEN 387 *Web-Based Enterprise Application Design* (3 credits)

Prerequisite: COMP 353; COMP 354 or SOEN 341; SOEN 287. Hypertext Transfer Protocol (HTTP), web mark-up languages and encodings. Document Object Models (DOM). Client/server and layered architectures for Web-based Enterprise Applications (WEA). Presentation, Domain and Data Source design patterns. Client-side programming. Java servlets and Java Server Pages. Authentication, security and transaction processing. Lectures: three hours per week. Tutorial: one hour per week.

SOEN 390 *Software Engineering Team Design Project* (3.5 credits)

Prerequisite: SOEN 344 and 357 previously or concurrently. Students work in teams to design and implement a software project from requirements provided by the coordinator. Each team will demonstrate the software and prepare adequate documentation for it. In addition, each student will write an individual report. Lectures: two hours per week. Tutorial: one hour per week. Laboratory: three hours per week.

SOEN 422 *Embedded Systems and Software* (4 credits)

Prerequisite: COMP 346. Characteristics of embedded systems. Microcontroller architecture and typical target systems. Programming issues related to mixed languages. Real-time kernel services: task management; intertask communication and synchronization; memory management; time management; interrupt support; configuration; and initialization. Development methods: state machines and fuzzy logic. Debugging methods for interrupts. Testing and simulation methods. Lectures: three hours per week. Tutorial one hour per week. Laboratory: two hours per week. *NOTE: Students who have received credit for COEN 421 may not take this course for credit.*

SOEN 423 *Distributed Systems* (4 credits)

Prerequisite: COMP 346. Principles of distributed computing: scalability, transparency, concurrency, consistency, fault tolerance, high availability.

Client-server interaction technologies: interprocess communication, sockets, group communication, remote procedure call, remote method invocation, object request broker, CORBA, web services. Server design techniques: process replication, fault tolerance through passive replication, high availability through active replication, coordination and agreement, transactions and concurrency control. Lectures: three hours per week. Tutorial one hour per week. Laboratory: two hours per week.

SOEN 431 Formal Methods (3 credits)

Prerequisite: SOEN 342, 343. Components of formal systems. Formal methods; levels of formalism. Integrating formal methods into the existing software life-cycle process model for a given project. Attributes of a formal specification language. Formal notations based on extended finite state machines; case studies involving the design of user interfaces, reactive systems, and concurrent systems. Software development using formal methods, including tools for type checking; debugging; verifying checkable properties; validation of refinements; and code generation from refinements. Lectures: three hours per week.

SOEN 448 Management of Evolving Systems (3 credits)

Prerequisite: SOEN 342, 343, 344. Software maintenance: corrective; perfective; and adaptive. Software reuse; construction of reusable software. Techniques for reverse engineering and re-engineering software. Software development as "growing" software. Long-term evolution of software systems. Legacy systems. Lectures: three hours per week.

SOEN 449 Component Engineering (3 credits)

Prerequisite: SOEN 344. Review of high-level language concepts and abstraction mechanisms. Programming with functional and logical languages. Typed vs. untyped languages. The use of scripting languages and other language-based techniques to assemble systems from high-level components. Lectures: three hours per week.

SOEN 487 Web Services and Applications (4 credits)

Prerequisite: SOEN 387 previously or concurrently. Analysis and design of web services and applications. Advanced architectures for the design, deployment, and testing of large multi-server web services and applications. Service Oriented Architecture (SOA). Electronic Commerce. Security. Load balancing. Stress testing. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week.

SOEN 490 Capstone Software Engineering Design Project (4 credits)

Prerequisite: SOEN 390. Students work in teams of between six and nine members to construct a significant software application. The class meets at regular intervals. Team members will give a presentation of their contribution to the project. Lectures: one hour per week. Laboratory: two hours per week. Two terms.

SOEN 498 Topics in Software Engineering (3 credits)

Prerequisite: Permission of the Department. This course may be offered in a given year upon the authorization of the Department. The content may vary from offering to offering and will be chosen to complement the available elective courses. Lectures: three hours per week.