Faculty

Chair
LATA NARAYANAN, PhD *University of Rochester*, ing.; *Professor*

Associate Chair (Computer Science)
THOMAS FEVENS, PhD *Queen's University*; *Associate Professor*

Associate Chair (Software Engineering)
TODD EAVIS, PhD *Dalhousie University*; *Associate Professor*

Professors
SABINE BERGLER, PhD *Brandeis University*
GREGORY BUTLER, PhD *University of Sydney*
BIPIN C. DESAI, PhD *McGill University*
EUSEBIUS J. DOEDEL, PhD *University of British Columbia*
TERRILL FANCOTT, DSc *Université de Paris,* ing.
GOSTA GRAHNE, PhD *University of Helsinki*
YANN-GAEL GUÉHÉNEUC, PhD *University of Nantes*, ing.
VOLKER M. HAARSLEV, PhD *University of Hamburg*
HOVHANNES A. HARUTYUNYAN, PhD *Armenian Academy of Sciences*
BRIGITTE JAUMARD, PhD *École Nationale Supérieure des Télécommunications*
LEILA KOSSEIM, PhD *Université de Montréal*
ADAM KRZYZAK, PhD *University of Wroclaw*; *Provost's Distinction*
SUDHIR P. MUDUR, PhD *Bombay University*, PEng
JUERGEN RILLING, PhD *University of Illinois*
CHING Y. SUEN, PhD *University of British Columbia*; *Provost's Distinction*

Distinguished Professors Emeriti
J. WILLIAM ATWOOD, PhD *University of Illinois*
VACLAV CHVATAL, PhD *University of Waterloo*; *Provost's Distinction*
CLEMENT LAM, PhD *California Institute of Technology*
JOHN MCKAY, PhD *University of Edinburgh*; *Provost's Distinction*
JAROSLAV OPATRNY, PhD *University of Waterloo*

Professors Emeriti
V.S. ALAGAR, PhD *McGill University*
TIEN D. BUI, PhD *York University*, ing.
DAVID FORD, PhD *Ohio State University*
PETER GROGONO, PhD *Concordia University*, PEng
H.F. LI, PhD *University of California, Berkeley*
R. SHINGHAL, PhD *McGill University*

Associate Professors
CONSTANTINOS CONSTANTINIDES, PhD *Illinois Institute of Technology*, PEng
TRISTAN GLATARD, PhD *Université Nice Sophia Antipolis, France*
DHRUBAJYOTI GOSWAMI, PhD *University of Waterloo*, PEng
RAJAGOPALAN JAYAKUMAR, PhD *Concordia University*
OLGA ORMANDJIEVA, PhD *Concordia University*, ing.
JOEY PAQUET, PhD *Université Laval*
TIBERIU POPA, PhD *University of British Columbia*
CHARALAMBOS POULLIS, PhD *University of Southern California*
DAVID K. PROBST, DSc *Université de Bruxelles*
PETER RIGBY, PhD *University of Victoria*
EMAD SHIHAB, PhD *Queen's University*, PEng
NEMATOLLAAH SHIRI-VARNAAMKHAASTI, PhD *Concordia University*
NIKOLAOS TSANTALIS, PhD *University of Macedonia*, PEng
RENÉ WITTE, DrIng *University of Karlsruhe*, PEng
YUHONG YAN, PhD *Tsinghua University/Leipzig University*, PEng

Assistant Professors
TSE-HSUN (PETER) CHEN, PhD *Queen's University*
ANDREW DELONG, PhD *Western University*
MARTA KERSTEN-OERTEL, PhD *McGill University*
ESSAM MANSOUR, PhD *Dublin Institute of Technology*
DENIS PANKRATOV, PhD *University of Chicago*
WEIYI (IAN) SHANG, PhD *Queen's University*
JINQIU (ALICE) YANG, PhD *University of Waterloo*

Extended Term Appointments
AIMAN HANNA, PhD *Concordia University*, PEng
NORA HOUARI, PhD *University of Calgary*
RODRIGO MORALES, PhD *Polytechnique Montréal*

Affiliate Professors
L. LAM, PhD *University of Toronto*
ANDRZEJ PELC, PhD *University of Warsaw*

Affiliate Associate Professors
T. KENGATHARAM, PhD *Concordia University*
YASER KHAMAYSEH, PhD *University of Alberta*

Affiliate Assistant Professors
GILBERT HONNOUVO, PhD *McGill University*
FEHMI JAAFAR, PhD *Université de Montréal*
MUNA KHAYYAT, PhD *Concordia University*
MARIE-JEAN MEURS, PhD *University of Avignon*
SERGUEI MOKHOV, PhD *Concordia University*
MAMA NSANGOU MOUCHILI, PhD *Patrice Lumumba Peoples Friendship University*
K. PITULA, PhD *Concordia University*
MIAO SONG, PhD *Concordia University*
EMIL VASSEV, PhD *Concordia University*

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. Students

may choose either the General Program or one of eight options. 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 General Program and each option constitute 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 **General Program** is a major in Computer Science that emphasizes an exposure to a breadth of topics in Computer Science.

2. The **Computer Games option** is a major in Computer Science that deals with the design and implementation of computer games, and the tools and techniques that are useful in developing software for computer games.

3. The **Web Services and Applications option** is a major in Computer Science that deals with the analysis, design, and implementation of services and applications delivered over the web.

4. The **Computer Systems option** is a major in Computer Science that focuses on state-of-the-art hardware and software platforms and on the tools and techniques necessary to develop software on such platforms.

5. The **Software Systems option** is a major in Computer Science that gives a firm grounding in diverse tools and techniques required for a wide variety of software systems.

6. 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.

7. The **Computer Applications option** combines a major in Computer Science with a minor in a discipline of the student's choice.

8. The **Computation Arts option** combines a major in Computer Science with a major in Fine Arts specializing in the design of interactive multimedia.

9. 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 the General Program and each option (see §71.70.4). In addition, all programs 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 program 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 Gina Cody School 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 Gina Cody School of Engineering and Computer Science 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 transferring to the Gina Cody School 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 the General Program and eight options (see §71.70.1). All options consist of the Computer Science Core (33 credits), the Complementary Core (6 credits), Option-Specific Courses, Computer Science Electives, Mathematics Electives, and General Electives.

Computer Science Core (33 credits) *Credits*

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	3.50
COMP 249	Object-Oriented Programming II	3.50
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
		33.00

Complementary Core (6 credits) *Credits*

ENCS 282	Technical Writing and Communication	3.00
ENCS 393	Social and Ethical Dimensions of Information and Communication Technologies	3.00
		6.00

Computer Science Electives
Computer Science Electives must be chosen from the following list:
- All COMP courses with numbers 325 or higher.
- ENGR 490
- SOEN 287, 321, 331, 387, 422, 423, 487.
- COMP and SOEN 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:	*Credits*
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 234	Linear Algebra and Applications I	3.00
MAST 235	Linear Algebra and Applications II	3.00
MAST 324	Introduction to Optimization	3.00
MAST 332*	Techniques in Symbolic Computation	3.00
MAST 334*	Numerical Analysis	3.00
MATH 251	Linear Algebra I	3.00
MATH 252	Linear Algebra II	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 §71.110.
- Basic and Natural 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 GCS Student Request form, obtainable from the Office of Student Academic Services in the Gina Cody School of Engineering and Computer Science.

1. General Program

	Credits
Computer Science Core	33.00
Complementary Core	6.00
Computer Science Electives*	30.00
Mathematics Electives	6.00
General Electives	15.00
	90.00

*Note: Maximum of 12 credits from any one of Computer Games Electives, Web Services and Applications Electives, Computer Systems Electives, or Software Systems Core.

2. Computer Games Option

	Credits
Computer Science Core	33.00
Complementary Core	6.00
Computer Games Electives	24.00
Computer Science Electives	6.00
Mathematics Electives*	6.00
General Electives or Minor in Game Design**	15.00
	90.00

*Note: Students must take COMP 361 as part of their Mathematics Electives.
**Note: A maximum of 15 credits from the Minor in Game Design (see §81.90) may be counted towards the General Electives.

Computer Games Electives

Students must complete six courses (24 credits) from the following list of courses, including all the courses marked *.

		Credits
COMP 345*	Advanced Program Design with C++	4.00
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

3. Web Services and Applications Option

	Credits
Computer Science Core	33.00
Complementary Core	6.00
Web Services and Applications Electives	22.00
Computer Science Electives	8.00
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 *.

		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 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

4. Computer Systems Option

	Credits
Computer Science Core	33.00
Complementary Core	6.00
Computer Systems Electives	22.00
Computer Science Electives	8.00
Mathematics Electives	6.00
General Electives	15.00
	90.00

Computer Systems Electives

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

		Credits
COMP 326*	Computer Architecture	3.00
COMP 345*	Advanced Program Design with C++	4.00
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

5. Software Systems Option

	Credits
Computer Science Core	33.00
Complementary Core	6.00
Software Systems Core	20.00

Computer Science Electives	13.00
Mathematics Electives	6.00
General Electives	12.00
	90.00

Software Systems Core   *Credits*

COMP 326	Computer Architecture	3.00
COMP 339	Combinatorics	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
		20.00

6. Information Systems Option   *Credits*

Computer Science Core	33.00
Complementary Core	6.00
Information Systems Electives	31.00
Computer Science Electives	14.00
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 *.

Credits

ACCO 220*	Financial and Managerial Accounting	3.00
BSTA 445	Statistical Software for Data Management and Analysis	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
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

7. Computer Applications Option   *Credits*

Computer Science Core	33.00
Complementary Core	6.00
Computer Science Electives	18.00
Mathematics Electives	6.00
Minor*	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.
*Any credits beyond those required to complete the declared minor may be taken as General Electives.

8. Computation Arts Option
See §71.80 for details.

9. 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

9   MATH 203^3, 204^3, 205^3

6   Chosen from courses in Humanities or Social Sciences as noted in Section 71.110. ESL courses and courses that focus on the acquisition of a language may not be used to meet this requirement.

15   ECP elective credits chosen from the following lists, depending on the student's program:

a)   *General Program*, and *Computer Applications*, *Computer Games*, *Software Systems*, and *Web Services and Applications Options:*
15 elective credits chosen from outside the Gina Cody School of Engineering and Computer Science (see Note).

b)   *Computation Arts Option:*
15 elective credits chosen from outside the Gina Cody School of Engineering and Computer Science and the Department of Design and Computation Arts (see Note).

c)   *Information Systems Option:*
15 elective credits chosen from outside the John Molson School of Business and the Department of Computer Science and Software Engineering (see Note).

d)   *Mathematics and Statistics Option:*
15 elective credits chosen from outside the Gina Cody School of Engineering and Computer Science and the Department of Mathematics and Statistics (see Note).

e)   *Computer Systems Option:*
CHEM 205^3
PHYS 204^3, 205^3
and 6 elective credits chosen from outside the Gina Cody School of Engineering and Computer Science (see Note).

Note: ECP elective credits may be chosen as follows:
- General Education Electives found in §71.110.
- Basic and Natural Science Courses found in §71.70.9.
- Courses not included in the above lists may be taken with prior approval of the undergraduate program director.

71.70.4 Honours Program

Students should refer to §16.2.4 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.   Students who are required to withdraw from an honours program may continue in the regular program of their option or General Program 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.   Students must successfully complete the course COMP 490 as one of the Computer Science electives for their option.
3.   For students in the General Program, and the Computer Games, Computer Systems, and Web Services and Applications Options, at least six of the General Electives credits must be chosen from the list of Computer Science Electives with at least two of the following: COMP 339, COMP 465, and COMP or SOEN courses with a number between 6000 and 6951 not marked with (*).
4.   For students in the Software Systems Option, at least six of the General Electives credits must be chosen from the list of Computer Science Electives with at least one of the following: SOEN 331, and COMP or SOEN courses with a number between 6000 and 6951 not marked with (*).

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	3.50

COMP 249	Object-Oriented Programming II	3.50
COMP 352	Data Structures and Algorithms	3.00
	Computer Science Electives (see §71.70.2)	9.00
		———
		25.00

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 C.Edge (Career Edge) Option and Reflective Learning Courses

The C.Edge Option is administered through the Institute for Co-operative Education. See §24.
Students employed full-time in a computer science position during their non-study terms may have this C.Edge option listed on their official transcript and student record, provided they successfully complete the Reflective Learning course associated with this work term.
C.Edge 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 C.Edge terms COMP 107 and 207 carry no credit value and are used to indicate that the student is on a C.Edge term.
The COMP 108 and 208 C.Edge 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 C.Edge 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.

Extended Credit Program
The requirements of the Extended Credit Program (ECP) are set out in Section 71.20.2.

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. Students may choose either the **general program or one of 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, general program or an option, and electives.

Engineering Core (30.5 credits)
See §71.20.5

Software Engineering Core		*Credits*
SOEN 228	System Hardware	4.00
SOEN 287	Web Programming	3.00
SOEN 321	Information Systems Security	3.00
SOEN 331	Formal Methods for Software Engineering	3.00

SOEN 341	Software Process and Practices	3.00
SOEN 342	Software Requirements and Deployment	3.00
SOEN 343	Software Architecture and Design	3.00
SOEN 345	Software Testing, Verification and Quality Assurance	3.00
SOEN 357	User Interface Design	3.00
SOEN 363	Data Systems for Software Engineers	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	23.00
	Two Basic and Natural Science courses	6.00
		73.50

Computer Science Group *Credits*

COMP 232	Mathematics for Computer Science	3.00
COMP 248	Object-Oriented Programming I	3.50
COMP 249	Object-Oriented Programming II	3.50
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
		23.00

Basic and Natural Science Courses
Two Basic and Natural Science courses must be selected from the following, including at least one course marked *:

		Credits
BIOL 206*	Elementary Genetics	3.00
BIOL 261*	Molecular and General Genetics	3.00
CHEM 217*	Introductory Analytical Chemistry I	3.00
CHEM 221*	Introductory Organic Chemistry I	3.00
CIVI 231	Geology for Civil Engineers	3.00
ELEC 321	Introduction to Semiconductor Materials and Devices	3.50
ENGR 242	Statics	3.00
ENGR 243	Dynamics	3.00
ENGR 251	Thermodynamics I	3.00
ENGR 361	Fluid Mechanics I	3.00
MIAE 221*	Materials Science	3.00
PHYS 252*	Optics	3.00
PHYS 284*	Introduction to Astronomy	3.00
PHYS 385*	Astrophysics	3.00

General Program
Students must complete at least 16 credits chosen from the electives list.

Options
Students must complete at least 16 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++	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

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 387*	Web-Based Enterprise Application Design	3.00
SOEN 487**	Web Services and Applications	4.00

Real-Time, Embedded, and Avionics Software (REA) Option *Credits*

AERO 480**	Flight Control Systems	3.50
AERO 482**	Avionic Navigation Systems	3.00
COEN 320	Introduction to Real-Time Systems	3.00
COMP 345	Advanced Program Design with C++	4.00
COMP 444	System Software Design	4.00
SOEN 422*	Embedded Systems and Software	4.00
SOEN 423*	Distributed Systems	4.00

Electives *Credits*

COMP 345	Advanced Program Design with C++	4.00
COMP 353	Databases	4.00
COMP 371	Computer Graphics	4.00
COMP 425	Computer Vision	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 298	System Hardware Lab	1.00
SOEN 344	Advanced Software Architecture and Design	3.00
SOEN 422	Embedded Systems and Software	4.00
SOEN 423	Distributed Systems	4.00
SOEN 448	Management of Evolving Systems	3.00
SOEN 491	Software Engineering Project	1.00
SOEN 498	Topics in Software Engineering	3.00
SOEN 499	Topics in Software Engineering	4.00
ENGR 411	Special Technical Report	1.00

71.70.10   Course Descriptions

Students from outside the Gina Cody School 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 Gina Cody School 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 C.Edge Option Reflective Learning I* (3 credits)
Prerequisite: Permission of the GCS. This course is a reflective learning module for students in their related field which is based on their academic requirements and their first C.Edge term.

COMP 208   *Computer Science C.Edge Option Reflective Learning II* (3 credits)
Prerequisite: COMP 108 and permission of the GCS. This course expands on the students' second C.Edge 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 or COEN 243 may not take this course for credit.
NOTE: This course may not be taken for credit in the regular undergraduate programs in the Gina Cody School of Engineering and Computer Science.

COMP 228   *System Hardware* (3 credits)
Prerequisite: COMP 248; MATH 203 or Cegep Mathematics 103 or NYA previously or concurrently; MATH 204 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 232   *Mathematics for Computer Science* (3 credits)
Prerequisite: MATH 203 or Cegep Mathematics 103 or NYA; MATH 204 or Cegep Mathematics 105 or NYC. Sets. Propositional logic and predicate calculus. Functions and relations. Elements of number theory. Mathematical reasoning. 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: MATH 205 or Cegep Mathematics 203 or NYB. 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 248   *Object-Oriented Programming I* (3.5 credits)
Prerequisite: MATH 204 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. Laboratory: one hour per week.

COMP 249   *Object-Oriented Programming II* (3.5 credits)
Prerequisite: COMP 248; MATH 203 or Cegep Mathematics 103 or NYA; 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. Laboratory: one hour per week.

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 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++* (4 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 metaprogramming. Applications of C++: systems, engineering, games programming. Project. Lectures: three hours per week. Laboratory: two hours per week.

COMP 346   *Operating Systems* (4 credits)
Prerequisite: COMP 228 or SOEN 228; COMP 352. Fundamentals of operating system functionalities, design and implementation. Multiprogramming: processes and threads, context switching, queuing models and scheduling. Interprocess 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 232 or COEN 231; 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.

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 232 or COEN 231; 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.

COMP 376   *Introduction to Game Development* (4 credits)
Prerequisite: COMP 371. 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 425   *Computer Vision* (4 credits)
This course introduces basic techniques and concepts in computer vision including image formation, grouping and fitting, geometric vision, recognition, perceptual organization, and the state-of-the art software tools. Students learn fundamental algorithms and techniques, and gain experience in programming vision-based components; in particular, how to program in OpenCV, a powerful software interface used to process data captured from passive and active sensors. A project is required. Laboratory: two hours per week.
NOTE: Students who have received credit for this topic under a COMP 498 or 499 number may not take this course for credit.

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 or COEN 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 232 or COEN 231; COMP 339; 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. This course initially describes the scope and history of Artificial Intelligence. Then it covers knowledge representation, heuristic search, game playing and planning. Finally, it introduces the topics of machine learning, genetic algorithms and natural language processing. A project is required. 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 476   *Advanced Game Development* (4 credits)
Prerequisite: COMP 361 or ENGR 391; COMP 376. Introduction to advanced aspects of computer games. Game engine design. Artificial Intelligence (AI): non-player character movement, coordinated movement, pathfinding, world representations; decision making; tactical AI, strategic AI, learning in games. Physics-based techniques: collision detection and response. Networked gaming: multi-player games, networking and distributed game design, mobile gaming. Improving realism: cut scenes, 3D sound. 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.

COMP 499　　Topics in Computer Science with Lab (4 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. Laboratory: two hours per week.

SOFTWARE ENGINEERING

SOEN 228　　System Hardware (4 credits)
Prerequisite: MATH 203 or Cegep Mathematics 103, MATH 204 or Cegep Mathematics 105. This course covers the following topics: Boolean Algebra, Digital logic and the design of logic circuits; CPU design; addressing modes; instruction sets and sequencing; design of datapath and control units; memory systems and types; cache memory levels; I/O devices and their interconnection to the CPU; assembly language, and Interrupts. 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. This course covers the following topics: internet architecture and protocols; web applications through clients and servers; modern HTML and CSS; client-side programming using modern JavaScript and an overview of the advantages of some common modern JavaScript libraries; Regular Expressions; static website contents and dynamic page generation through server-side programming; preserving state (client-side) in web applications; deploying static and dynamic websites and content management systems vs. website deployment. Lectures: three hours per week. Tutorial: two hours per week.

SOEN 298   *System Hardware Lab* (1 credit)
Prerequisite: Permission of the undergraduate program director. Digital design exercises including assembly and testing corresponding to the SOEN 228 lab. Laboratory: two hours per week.

SOEN 321   *Information Systems Security* (3 credits)
Prerequisite: COMP 346 or COEN 346. This course covers the following topics: introduction to cryptography and cryptanalysis; threats, attacks, and vulnerabilities; security services (confidentiality, authentication, integrity); public key systems including Diffie-Hellman, RSA, Rabin; Digital Signature Schemes; Hash functions and MAC schemes; authentication protocols; network layers and security; protocols; Public Key Infrastructure (PKI); Transport Layer Security (TLS); firewalls; Intrusion Detection Systems; DNS security; Denial of Service Attacks; Penetration testing; Online Privacy and anonymity; Mix networks and Onion Routing; TOR; Malware; Botnets; Spam and Hot topics in Security and Privacy. Lectures: three hours per week. Tutorial: one hour per week.

SOEN 331   *Formal Methods for Software Engineering* (3 credits)
Prerequisite: COMP 232, 249. This course covers the following topics: property-based (axiomatic and algebraic) formalisms and model-based (abstract and visual) formalisms; axiomatic formalisms with temporal logic, assertions and contracts; algebraic formalisms through algebraic specifications; abstract formalisms through the Z and Object-Z specification languages; visual formalisms through automata (finite state machines and extended finite state machines). Lectures: three hours per week. Tutorial: two hours per week.

SOEN 341   *Software Process and Practices* (3 credits)
Prerequisite: COMP 352 or COEN 352; ENCS 282 previously or concurrently. This course covers the following topics: basic principles of software engineering; introduction to software process, including activities, phases, organization, roles, teamwork, and conflict resolution; notations used in software engineering; software development practices, including documentation, modern version control, review, testing, agile, and continuous integration. 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 Deployment* (3 credits)
Prerequisite: SOEN 341. This course covers the following topics: requirements engineering; eliciting and coping with changing and evolving requirements; deployment of a software system under real-life functional and non-functional requirements scenarios; understanding how requirements impact early-stage and deployed software systems through all phases of engineering, including design, implementation, test and verification, deployment, and evolution. A project is required. Lectures: three hours per week. Tutorial: one hour per week.

SOEN 343   *Software Architecture and Design* (3 credits)
Prerequisite: SOEN 341; SOEN 342 previously or concurrently. This course covers the following topics: 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; introduction to software architecture (styles and view models); design quality; architectural debt; design smells; refactoring Anti-Patterns to Patterns; design rationale. Lectures: three hours per week. Tutorial: one hour per week.

SOEN 344   *Advanced Software Architecture and Design* (3 credits)
Prerequisite: SOEN 343. This course covers the following topics: 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. This course covers the following topics: unit testing and test-driven development; characterization testing and legacy system testing; mocking, dependency injection, and breaking system dependencies; integration and system testing; test planning and management; test order, prioritization, redundancy, and flaky tests; advanced topics including static analysis, bisection, and fuzzing; data migration testing and verification; continuous integration and delivery; DevOps testing and validation including darklaunching, A/B testing, feature toggles, and logging. Lectures: three hours per week. Tutorial: one hour per week.

SOEN 357   *User Interface Design* (3 credits)
Prerequisite: SOEN 341. This course covers the following topics: principles, standards and guidelines for user interface design; usability principles and user experience; standards and design rationale for user-centred design; task-centred design; rationalized design; usability engineering; user models; interface design process, including interface requirement gathering, conceptual design and prototyping, and evaluation; usability testing and analytic evaluation; data gathering and analysis techniques for qualitative and quantitative data; interface design documentation; design approaches for touch, gesture-based, and haptic interfaces. Lectures: three hours per week. Tutorial: one hour per week.

SOEN 363   Data Systems for Software Engineers (3 credits)
Prerequisite: COMP 352. This course covers the following topics: introduction to the current data ecosystem; relational databases; key-value databases; document databases; column databases; graph databases; RDF stores; parallel and distributed file systems, data processing engines; data stream analytics; and data infrastructure. 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.

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 previously or concurrently; COMP 354 or SOEN 341; SOEN 287. This course covers the following topics: Hypertext Transfer Protocol (HTTP); client/server and layered architectures for Web-based Enterprise Applications (WEA); Application, Presentation, Domain and Data Source design patterns; Java servlets and Java Server Pages, and generating responses; authentication, security and transaction processing; system-level testing of web applications. Lectures: three hours per week. Tutorial: one hour per week.

SOEN 390   Software Engineering Team Design Project (3.5 credits)
Prerequisite: SOEN 345 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 the testing of the software, and prepare adequate documentation for it. In addition, each team will generate a report based on the process of development. 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. This course covers the following topics: embedded computer system architectures; programming of interface and peripheral control registers; analog to digital conversion and motor control using pulse width modulation; interrupts, communication methods and their application to interface control and multi-computer systems; architecture and operating systems of advanced embedded designs; design and testing of integrated systems; advanced topics. 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. This course covers the following topics: principles of distributed computing including scalability, transparency, concurrency, consistency, fault tolerance, high availability; client-server interaction technologies including interprocess communication, sockets, group communication, remote procedure call, remote method invocation, object request broker, web services; server design techniques including 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 448   Management of Evolving Systems (3 credits)
Prerequisite: SOEN 342, 343. This course covers the following topics: 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 existing software systems. Lectures: three hours per week.

SOEN 487   Web Services and Applications (4 credits)
Prerequisite: SOEN 387. This course covers the following topics: 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: 75 credits in the program; SOEN 390. Students work in teams of at least four 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 491   Software Engineering Project (1 credit)
Prerequisite: Permission of the undergraduate program director. Theoretical or practical project in an advanced topic in software engineering.

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.

SOEN 499   *Topics in Software Engineering with Lab* (4 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. Laboratory: two hours per week.