Faculty of Engineering and Computer Science

Section 71

FACULTY OF ENGINEERING AND COMPUTER SCIENCE

Section 71

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Location

Sir George Williams Campus
Engineering, Computer Science and Visual Arts Complex, Room: EV 002.139; 514-848-2424, ext. 3109
Student Academic Services, Room: EV 002.125; 514-848-2424, ext. 3055

Mission Statement

The Faculty of Engineering and Computer Science is dedicated to providing high-quality and comprehensive undergraduate and graduate curricula, to promoting high-calibre research, and to the development of the profession of engineering and computer science in an ethical and socially responsible manner. We strive to prepare graduates to solve real world problems with excellent professional skills leading to superior career opportunities.

71.10 FACULTY OF ENGINEERING AND COMPUTER SCIENCE

71.10.1 Programs Offered

The following programs are offered in the Faculty of Engineering and Computer Science:

1. BEng degrees in Aerospace, Building, Civil, Computer, Electrical, Industrial, Mechanical, and Software Engineering.
2. BCompSc degree.
3. Minor in Computer Science.

The requirements for the programs are different, and the appropriate section in the following pages must be consulted for each.

71.10.2 Admission Requirements

General admission requirements are listed in §13
In addition, the following specific requirements exist for the various programs. Applicants should specify their choice of program on their application.
Students entering the Faculty of Engineering and Computer Science are presumed to have acquired some familiarity with computers and programming, either through a course or through time spent working with a personal or other computer.

APPLICANTS FROM QUEBEC INSTITUTIONS
Successful completion of a two-year pre-university Cegep program is required, including the specific courses in the appropriate profile, as follows:

1. **BEng (all programs)**
   BCompSc (Computer Systems Option)

   Cegep Profile
   Mathematics 201 —
   103 or NYA, 105 or NYC, 203 or NYB
   Physics 203 —
   101 or NYA, 201 or NYB
   Chemistry 202 —
   101 or NYA

2. **BCompSc (Computer Applications, Computation Arts, Computer Games, Information Systems, Mathematics and Statistics, Software Systems, and Web Services and Applications Options; and Minor in Computer Science)**

   Cegep Profile 10.12
   Mathematics 201 —
   103 or NYA, 105 or NYC, 203 or NYB

Applications from graduates of Cegep technology programs will also be considered. Program requirements for successful applicants will be determined on an individual basis.

APPLICANTS FROM OUTSIDE QUEBEC
Academic qualifications presented by students applying from institutions outside Quebec should be comparable to those expected of students applying from within Quebec.
Where the pre-university education is shorter than in Quebec, students may be considered for admission to the first year of the Extended Credit Program. (See §13.3.2 to 13.3.6, §71.20.2, and 71.70.3)

MATURE ENTRY
Admission requirements are listed in §14.

71.10.3 Academic Regulations

Students should refer to the Academic Regulations of the University in §16.

Definitions
Assessable courses: *all record entries of courses* listed in this Concordia Calendar for which a grade point value is specified in §16.3.3. However, any course which is a requirement for admission to a program offered by the Faculty of Engineering and Computer Science will not be counted unless specifically listed on the student's admission letter.
Dean's Office: appropriate member of the Dean's Office, normally the Associate Dean, Student Academic Services.
Program of Study: course requirements in effect at the time of the latest admission or readmission to a program, for example, BEng (Civil) or BCompSc (Information Systems), including modifications on an individual basis as specified or approved in writing by the Dean's Office, or the Student Request Committee of Faculty Council.
Grade Points: as defined in §16.3.3 of this Calendar.
Weighted Grade Point Average (WGPA): as defined in §16.3.11 of this Calendar.
Academic Year: a period which begins with a summer session followed by a regular session (fall and winter).

Objectives
The objectives of these regulations are:
a) to ensure that the Faculty can certify that all of its graduates are qualified to enter their profession, and
b) to ensure that students can, with the assistance or intervention of the Faculty, assess themselves objectively and plan programs of study designed to meet their individual needs.

Grading System
See §16.3.3 for the Concordia grading system.
NOTE: Although a "C-" grade is designated as satisfactory, a weighted grade point average of at least 2.00 for the assessment period is required for acceptable standing in the Faculty of Engineering and Computer Science.

Regulations
1. Students' standings are assessed at the end of each academic year providing they have registered for at least 12 credits subsequent to their previous assessment, or in the case of a first assessment, subsequent to their admission to a program of study.
   Standings of students who have attempted less than 12 credits since their last assessment are assessed as follows:
a) The standings of potential graduates are determined on the basis that these credits constitute an extension of the last assessment period.
b) The standings of other students are determined at the end of the academic year in which they have attempted a total of at least 12 credits since their last assessment.
2. Students' standings are determined according to the following criteria.

Acceptable Standing:
A WGPA of at least 2.00 for the assessment period.
Students in acceptable standing may proceed subject to the following conditions: any failing grade must be cleared by repeating and passing the failed course; or in the case of an elective, by replacing the failed course by an alternative within the same group of electives and passing this course. Any variation must be approved by the Dean's Office.

Conditional Standing:
A WGPA of at least 1.50 but less than 2.00 for the assessment period.
Students in conditional standing may proceed subject to the following conditions.
a) They must successfully repeat all courses in which failing grades were obtained, or replace them by alternatives approved by the appropriate member of the Dean's Office in consultation with the student's department.
b) They must repeat or replace by approved alternatives at least one-half of those courses in which they obtained grades in the "D" range. The specific courses to be repeated will be determined by the Dean's Office in consultation with the student's department.
c) Courses to be taken may be specified by the Dean's Office. In no case will the number exceed five per term for full-time students and two per term for part-time students.
d) They must obtain acceptable standing at the time of their next assessment.

Failed Standing:
Failure to meet the criteria for acceptable or conditional standing, or remaining in conditional standing over two consecutive assessments.
Failed students may apply for readmission through the Dean's Office – Student Academic Services. If readmitted, they will be placed on academic probation. The Application for Readmission form is available in the Student Academic Services Office or can be obtained from the Student Academic Services website located at: encs.concordia.ca.
Failed students should consider the following deadline when they submit their application. Full consideration will be given to all applications that have been received by the Student Academic Services Office before July 15 of each year. Every attempt will be made to inform students regarding the status of their application by August 1 of each year.
Students who are in failed standing and have been absent from their program for 30 consecutive months should refer to §71.10.4 since a new application for admission is required.
No students will be readmitted in the January or summer sessions.

Readmitted students are subject to the following regulations:
a) They must successfully repeat all courses in which failing grades were obtained, or replace them by alternative courses approved by the appropriate member of the Dean's Office in consultation with the relevant Department.
b) They must repeat or replace, by approved alternatives, all of the courses in which they obtained grades in the "D" range for the academic year in which they were assessed as failed, and any previous outstanding repeats. The specific courses to be repeated will be determined by the Dean's Office.
c) They must successfully complete all courses they are required to repeat prior to further registration in other courses.
d) They must return to acceptable standing at the time of their next assessment.
e) Other conditions may be applied as deemed appropriate by the Dean's Office.

Availability of Supplemental Examinations
Supplemental examinations are not offered in the Faculty of Engineering and Computer Science other than in the courses COMP 201 and COMP 218.

71.10.4 Registration Regulations

1. Students in the Faculty of Engineering and Computer Science who have been absent from their program for six consecutive terms or more will be officially withdrawn from their program by the Faculty and must submit a new application for admission through the Office of the Registrar.
2. Except for students registered for the co-operative format, the maximum load in the summer sessions is 14 credits, with no more than eight credits in either of its terms.

Prerequisites

1. Students are responsible for ensuring that they have successfully completed all prerequisites to a course before attempting to register for the course.
2. Students must complete all 200-level courses required for their program before registering for any 400-level courses.
3. All 200-level courses within the program which are prerequisites for other courses must be completed with a C- or higher. A 200-level course in which a student has obtained a D+ or lower must be repeated before attempting a course for which it is a prerequisite.
4. A student who has registered for a course without satisfactorily completing all prerequisites may be withdrawn from the course.

71.10.5 Graduation Regulations

Students must satisfy all program requirements, be in acceptable standing, and have a minimum final graduation GPA of 2.00. The standings of potential graduates who have attempted less than 12 credits since their last assessment are determined on the basis that these credits constitute an extension of the last assessment period.

Students who fail to meet acceptable standing but meet conditional standing will have the following options:

a) register for 12 credits and meet the criteria for acceptable standing;
b) register for fewer than 12 credits. In this case, standing will be determined on the basis that these credits constitute an extension of the last assessment period.

The maximum number of credits obtained as an Independent student which may be transferred into programs offered by the Faculty of Engineering and Computer Science is as follows:

BEng and BCompSc: 30

71.10.6 Availability of Programs

Full-time students in the Engineering program normally follow an eight-term sequence. In general, introductory level courses are offered in both day and evening. Subject to the Registration Regulations in §71.10.4 above, a student may register on a part-time basis. Further information on sequencing may be found in the Undergraduate Program Guide issued by the Dean's Office.

71.10.7 Curriculum Requirements and Course Sequences

All students in Engineering programs are required to meet the Canadian Engineering Accreditation Board (CEAB) standards. Students are required to graduate having met the substantial equivalent of the curriculum in force in the winter term prior to degree conferral. It is the student's responsibility to ensure that their course selection meets the program requirements for their graduation. To accommodate this requirement, students are provided with course equivalencies and course sequences on the Student Academic Services website at encs.concordia.ca/scs.

Engineering students should follow the outlined cohort sequence for their program. Failure to do so may result in scheduling problems, the unavailability of courses, or ultimately an extension in the time period to complete their program.

71.10.8 The Co-operative Format

A limited number of high ranking students entering the first year of the regular program leading to the BCompSc degree and the BEng degree are permitted to undertake their studies in the co-operative format in conjunction with the Institute for Co-operative Education. See §24.

The academic content is identical to that of the regular programs; however, in order to continue their studies in the co-operative format in the Faculty of Engineering and Computer Science, or to graduate from one of its programs as members of the Institute for Co-operative Education, students must satisfy the following conditions:

(i) maintain an annual grade point average (WGPA)* of at least 2.50 in their program;
(ii) be assigned a grade of pass or pass with distinction for each of the three work-term courses (CWTE or CWTC). Under certain conditions, a student may be placed on co-op probation status. For details, refer to §24;
(iii) remain in their designated work-study sequence. Any deviations must have prior approval by the director of the Institute for Co-operative Education in consultation with Student Academic Services. For additional information, please refer to §24.

*The WGPA is calculated over all courses in the program in the manner described in §16.3.11.

Regulations for Work Terms

1. Successful completion of the work terms shown in the Co-op Schedule indicated in §24 is a prerequisite for graduation as a member of the Institute for Co-operative Education.
2. Work-term job descriptions are screened by the co-op coordinator. Only jobs approved by the Institute for Co-operative Education will be accepted as being suitable for the work-term requirements.
3. Work-term jobs are full-time employment normally for a minimum of 12 consecutive weeks (14 to 16 weeks preferably).
4. A work-term report must be submitted each work term on a subject related to the student's employment. This report must be submitted to the Institute for Co-operative Education on or before the deadline shown in §24. Grammar and content of work-term reports are evaluated by the Institute for Co-operative Education and the technical aspects are evaluated by the co-op program director responsible. Evidence of the student's ability to gather material relating to the job, analyze it effectively, and present it in a clear, logical, and concise form is required in the report.

5. The required communication component consists of an oral presentation on a technical subject or engineering task taken from the student's work environment. The presentation will be given on campus in a formal setting after students have returned to their study term. A written summary is also required. Guidelines for the preparation of this oral presentation are provided in the Co-op Student Handbook.
6. Work terms will be evaluated for satisfactory completion. Assessment is based upon the employer evaluation of performance, the work-term report and communication component which together constitute the job performance as related to the whole work term. Students must pass all required components. The grade of pass with distinction, pass, or failure will be assigned to each of the work-term courses. A failing grade will result in the student's withdrawal from the Institute for Co-operative Education.

71.10.9 Concordia Institute for Aerospace Design and Innovation (CIADI)

The Concordia Institute for Aerospace Design and Innovation (CIADI) promotes awareness and provides leading-edge know-how among Engineering students and practising engineers in design and innovation, particularly in the field of aerospace, with emphasis on its multidisciplinary nature. While some members of the Institute may enter their field upon completion of their degree, the initiation into research provided to CIADI members is helpful to students who wish to pursue graduate studies in the field of aerospace.

Membership
Students accepted to the Institute are selected from among the top second- and third-year undergraduate students in the Faculty of Engineering and Computer Science, and work on collaborative design and research projects over several terms of Engineering studies. Students are supervised by Concordia faculty members and receive mentoring from industry representatives working in the field. Eligible projects are credited by the Faculty as capstone design projects.

Registration
Students accepted to the Institute register in one or two zero-credit courses, IADI 301 and 401, in order to remain affiliated with CIADI. A pass or fail is awarded for these courses. Students who receive a pass for IADI 301 may continue in CIADI. Students who successfully complete one or both courses, IADI 301 and 401, will be recognized as full members of the Institute and this recognition will also appear on their University transcript. Students who successfully complete both IADI 301 and 401 will also have this recognition appear on their diploma. Students who fail IADI 301 will not be allowed to continue with CIADI and shall receive no acknowledgement of this activity on their transcript.

71.20 BENG

71.20.1 Curriculum for the Degree of BEng

The University offers programs leading to the degree of BEng in the fields of Aerospace, Building, Civil, Computer, Electrical, Industrial, Mechanical, and Software Engineering.
The BEng degrees in Aerospace, Computer, Electrical, Industrial, Mechanical and Software Engineering require completion of a minimum of 120 credits. The BEng degrees in Building and Civil Engineering consist of 119 credits. Program requirements comprise a group of required courses with a group of elective courses which allow students to select part of their program to provide some depth in an area of specialization (their "option") according to their particular interests, or breadth in the general field of their chosen discipline.
Students in Engineering programs may not combine their program with a minor or cluster from another field of study. Any exception to this policy must be approved by the Faculty's Student Request Committee.
In their final undergraduate year, students with high standing may apply for permission through the Dean's Office to register for a limited number of graduate courses offered by the Faculty in lieu of some courses in the undergraduate program.
Successful completion of a BEng program requires hard work and considerable dedication on the part of each student. Courses are presented with the expectation of an average of about two hours of "outside" work for each lecture hour and about one-half hour of "outside" work for each hour spent in the laboratory for all programs of study.

71.20.2 Extended Credit Program

Students admitted to an Extended Credit Program under the provisions of §13.3.2 or 13.8.1 must successfully complete the requirements of a specific program, as set out in §71.30 to 71.50, plus the following courses:

MATH 202[3], 203[3], 204[3], 205[3]
PHYS 204[3], 205[3]
CHEM 205[3]
Six credits chosen from courses in the humanities and social sciences. ESL courses and courses that focus on the acquisition of a language may not be used to meet this requirement.

Students in the Extended Credit Program (ECP) or the Mature Entry Program (MEP) (see §14.2.3) or any other students who have been assigned credits in Humanities and Social Sciences must select those credits from the two lists below.

Social Sciences

AHSC 242	Recreation and Leisure in Canada
ANTH 202	Introduction to Culture
ECON 201	Introduction to Microeconomics
ECON 203	Introduction to Macroeconomics
EDUC 230	Introduction to Philosophy of Education
ENCS 483	Creativity, Innovation and Critical Thinking in Science and Technology
GEOG 203	Canadian Environmental Issues
GEOG 204	Global Environmental Issues
GEOG 210	Geography of Global Change
GEOG 220	The Human Environment: Place, Space, and Identity
INST 250	Introduction to Library Research Practices
LING 222	Language and Mind: The Chomskyan Program
LING 300	Sociolinguistics
POLI 202	Introduction to Political Science
POLI 213	Contemporary Issues in Global Politics
POLI 390	Ethics and Competing Political Perspectives
RELI 214	Religions of the West
RELI 215	Religions of Asia
RELI 216	Encountering Religions
RELI 218	Wisdom, Traditions, and Enlightenment
RELI 310	Self and Other: Exploring Value Choices in Personal and Interpersonal Relations
RELI 312	Justice and Social Conflict in a Globalized World
RELI 374	Religion and Science
SCPA 201	Introduction to Public Policy and the Public Interest
SCPA 215	Economics for Public Policy and Community Development
SOCI 203	Introduction to Society
WSDB 290	Introduction to Women's Studies I
WSDB 291	Introduction to Women's Studies II

Humanities

ARTH 353	Technology and Contemorary Art
ARTH 354	Studies in Interdisciplinarity in the Visual Arts
CLAS 266	An Introduction to Classical Archaeology
COMS 360	Mass Communication
ENGL 224	The Creative Process
ENGL 233	Critical Reading
FLIT 230	Introduction à la culture francophone
FLIT 240	Introduction à la littérature francophone
FMST 214	English-Canadian Film
FMST 215	Le cinéma québécois
HIST 201	Introduction to European History to 1789
HIST 202	Introduction to European History, from 1789 to the Present
HIST 205	History of Canada, Post-Confederation
HIST 281	Film in History
HIST 283	The 20th Century: A Global History
LBCL 201	Great Books: Western History and Thought from Antiquity through the Renaissance
LBCL 202	Great Books: Western Culture and Expression from Antiquity through the Renaissance
LBCL 203	Great Books: Western History and Thought from the Reformation through Modernity
LBCL 204	Great Books: Western Culture and Expression from the Reformation through Modernity
PHIL 201	Problems of Philosophy
PHIL 210	Critical Thinking
PHIL 232	Introduction to Ethics
PHIL 233	Applied Ethics: Moral Sensitivity and Human Well-Being
PHIL 235	Biomedical Ethics
PHIL 275	From Modern to Postmodern: Philosophical Thought and Cultural Critique
PHIL 330	Contemporary Ethical Theory
THEO 202	Introduction to Biblical Studies
THEO 204	Introduction to Christian Ethics
THEO 233	Religious Pluralism in a Secular Culture

71.20.3 Accreditation by the Canadian Council of Professional Engineers

All Engineering programs in the Faculty have been designed to meet the criteria of the Canadian Engineering Accreditation Board. These programs are assessed at regular intervals according to the rules and procedures of the Board. Graduates of accredited programs are qualified for membership in the Ordre des ingénieurs du Québec, or its equivalent in any other provincial jurisdiction.

71.20.4 Membership in the Ordre des ingénieurs du Québec

The Ordre des ingénieurs du Québec (oiq.qc.ca) currently admits graduates of the BEng curricula in Building, Civil, Computer, Electrical, Industrial, Mechanical, and Software Engineering, as members.Quebec law requires that candidates seeking admission to provincially recognized Quebec professional corporations (such as the Ordre des ingénieurs du Québec) possess an appropriate knowledge of the French language.
A person is deemed to have that knowledge who:
(1) has taken at least three years of full-time instruction given in French at the secondary or post-secondary level;
(2) has passed the French mother tongue examinations in the fourth or fifth grade of the secondary level;
(3) has obtained in Quebec, a secondary-school certificate for the 1985-86 school year or later.
In all other cases, a person must obtain a certificate delivered by the Office québécois de la langue française (oqlf.gouv.qc.ca) or hold a certificate defined as equivalent by regulation of the Government.

71.20.5 Degree Requirements

To be recommended for the degree of BEng, students must satisfactorily complete the courses of the Engineering Core as well as those specified for their particular program in subsequent sections in accordance with the graduation requirements in §71.10.5.

Engineering Core		*Credits*
ELEC 275	Principles of Electrical Engineering	3.50 (2)
ENCS 282	Technical Writing and Communication	3.00
ENGR 201	Professional Practice and Responsibility	1.50
ENGR 202	Sustainable Development and Environmental Stewardship	1.50 (1)
ENGR 213	Applied Ordinary Differential Equations	3.00
ENGR 233	Applied Advanced Calculus	3.00
ENGR 301	Engineering Management Principles and Economics	3.00
ENGR 371	Probability and Statistics in Engineering	3.00
ENGR 391	Numerical Methods in Engineering	3.00 (3)
ENGR 392	Impact of Technology on Society	3.00 (4)
	General Education elective	3.00 (5)
		30.50

NOTES:
(1) The Engineering Core credits for students in the Building Engineering program are reduced from 30.5 credits to 29 credits since Building Engineering students are not required to take this course in their program.
(2) The Engineering Core credits for students in the Mechanical, Industrial and Aerospace Engineering programs are reduced from 30.5 credits to 27 credits since Mechanical, Industrial and Aerospace Engineering students are not required to take this course in their program. Students in Electrical and Computer Engineering shall replace ELEC 275 with ELEC 273.
(3) Students in Software Engineering may replace ENGR 391 with COMP 361.
(4) Students in Building Engineering shall replace ENGR 392 with BLDG 482.
(5) Students must select three General Education elective credits from one of the lists in §71.20.2 and §71.20.6. Students in Industrial Engineering shall take ACCO 220 as their General Education elective.

71.20.6 General Education Elective

All Engineering students must complete three credits of General Education. This course may be chosen from courses in the Social Sciences and Humanities listed in §71.20.2 or the list below.

ADMI 201	Introduction to Administration
ADMI 202	Perspective on Canadian Business
ENCS 484	Development and Global Engineering
MANA 201	Introduction to Business and Management
MANA 202	Human Behaviour in Organizations
MANA 300	Entrepreneurship: Launching Your Business
MARK 201	Introduction to Marketing
URBS 230	Urban Development

Please note the following:
1) Prior to registering, students who do not have any specified prerequisites for a General Education elective course must obtain permission of the relevant Department.

2) An ESL course or an introductory course that deals with the acquisition of a language will not be considered as a General Education elective.
3) Should students wish to take a General Education elective course not listed above, they must receive written permission from the Student Academic Services Office of the Faculty of Engineering and Computer Science prior to taking the course.

71.20.7 Writing Skills Requirement

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. To do this, students can write the Engineering Writing Test, or take ENCS 272 and earn a grade of C- or better.
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) in order to avoid the risk of delayed graduation should remedial work prove necessary. The Engineering Writing Test is especially designed to address the writing skills typically demanded of engineers. Students who are required to take ESL courses should meet the writing skills requirements in the term following completion of their ESL courses.
All ESL and English/French language courses taken to satisfy this requirement are in addition to Engineering program requirements.

71.20.8 Industrial Experience and Reflective Learning Courses

Students employed full-time in an engineering position during their non-study terms may have this Industrial Experience recorded on their record, provided they successfully complete the Reflective Learning course associated with this work term.
Industrial Experience work terms will be coded as ENGR 107, 207, and 307, and the associated Reflective Learning courses will be coded as ENGR 108, 208, and 308 respectively.
Students may only register for these courses with the permission of the Faculty.
The Industrial Experience terms ENGR 107, 207, and 307 carry no credit value and are used to indicate that the student is on an Industrial Experience term.
The ENGR 108, 208, and 308 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.

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Section 71.30

Faculty

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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 005.139
514-848-2424, ext. 3100

Department Objectives

Electrical Engineering is concerned primarily with energy and information, their conversion and transmission in the most efficient and reliable manner. This vast field of endeavour includes many specialties and electrical engineers may be involved in one or more of these throughout their careers. A partial list includes electronics, integrated circuit design, very large scale integrated (VLSI) circuit design, layout and testing, controls, robotics, system simulation, telecommunications, signal processing, computer hardware design, software design, power devices, power and control systems, electromechanical systems, microelectromechanical devices, electromagnetics, antennas, wave guides, lasers, and optoelectronics.
Computer Engineering is the driving force of the information revolution and its transformation of society. Over the course of their careers, computer engineers will be called upon to meet a number of challenges, most of which cannot be imagined today. A partial list of current specialties includes computer architecture, digital electronics, digital circuits, very large scale integrated (VLSI) circuit design, layout and testing, digital circuit testing and reliability, software design, software engineering, digital communication and computer networks.
The four-year programs consist of the Engineering Core, taken by all Engineering students, program cores and electives. The Electrical Engineering Core provides a solid introduction to all aspects of the discipline, to programming methodology and to the design of large software systems. Technical electives are scheduled to enable students to register for sets of related technical courses. Current sets of electives include: Communications and Signal Processing, Computer Systems, Electronics and VLSI, Power, Control Systems and Avionics, and Waves and Electromagnetics. The Computer Engineering Core provides a thorough grounding in all aspects of computer hardware and software. Technical electives allow students to acquire further knowledge in various aspects of hardware or software. A mandatory final-year design project gives students in both programs the opportunity to apply the knowledge they have acquired to the design and testing of a working prototype.
Six Quebec universities have joined together with Hydro-Québec to create the Institute for Electrical Power Engineering whose primary mission is to meet the anticipated shortfall in this area. Students accepted by the Institute are expected to complete six courses offered by participating universities. Some of these courses are offered in English and others in French. Students register for courses at their home universities.

71.30.1 Course Requirements (BEng in Electrical Engineering)

The program in Electrical Engineering consists of the Engineering Core, the Electrical Engineering Core, and one of five choices as set out below. The normal length of the program is 120 credits.

Engineering Core (30.5 credits)
See §71.20.5.

Electrical Engineering Core		*Credits*
COEN 212	Digital Systems Design I	3.50
COEN 231	Introduction to Discrete Mathematics	3.00
COEN 243	Programming Methodology I	3.00
COEN 244	Programming Methodology II	3.00
COEN 311	Computer Organization and Software	3.50
ELEC 251	Fundamentals of Applied Electromagnetics	3.00
ELEC 264	Signals and Systems I	3.00
ELEC 311	Electronics I	4.00
ELEC 321	Introduction to Semiconductor Materials and Devices	3.50
ELEC 331	Fundamentals of Electrical Power Engineering	3.50
ELEC 351	Electromagnetic Waves and Guiding Structures	3.00
ELEC 363	Fundamentals of Telecommunications Systems	3.50
ELEC 364	Signals and Systems II	3.50
ELEC 365	Complex Variables and Partial Differential Equations	3.00
ELEC 372	Fundamentals of Control Systems	3.50
ELEC 390	Electrical Engineering Product Design Project	3.00
ELEC 490	Capstone Electrical Engineering Design Project	4.00
ENGR 290	Introductory Engineering Team Design Project	3.00
		59.50

Students may choose one of the following options:
I. Electronics/VLSI Option
II. Telecommunications Option
III. Power and Renewable Energy Option
IV. Avionics and Control Option

Otherwise, students must follow V.

I. Electronics/VLSI Option		*Credits*
COEN 315	Digital Electronics	3.50
COEN 451	VLSI Circuit Design	4.00
ELEC 312	Electronics II	4.00
	Minimum number of Elective credits: at least 3.5 of these 18.5 credits must be taken from the Electronics/VLSI Option Electives list. The rest may be chosen from the Electrical Engineering Electives list.	18.50
		30.00

Electronics/VLSI Option Electives		*Credits*
COEN 313	Digital Systems Design II	3.50
COEN 413	Hardware Functional Verification	3.00
ELEC 421	Solid State Devices	3.50
ELEC 422	Design of Integrated Circuit Components	3.50
ELEC 423	Introduction to Analog VLSI	4.00
ELEC 424	VLSI Process Technology	3.50
ELEC 425	Optical Devices for High-Speed Communications	3.50
ELEC 433	Power Electronics	3.50
ELEC 441	Modern Analog Filter Design	3.50
ELEC 442	Digital Signal Processing	3.50

II. Telecommunications Option *Credits*

ELEC 442	Digital Signal Processing	3.50
ELEC 462	Introduction to Digital Communications	3.50
ELEC 463	Telecommunication Networks	3.00
	Minimum number of Elective credits: at least 6 of these 20 credits must be taken from the Telecommunications Option Electives list. The rest may be chosen from the Electrical Engineering Electives list.	20.00
		30.00

Telecommunications Option Electives *Credits*

ELEC 425	Optical Devices for High-Speed Communications	3.50
ELEC 453	Microwave Engineering	3.50
ELEC 456	Antennas	3.50
ELEC 457	Design of Wireless RF Systems	3.00
ELEC 464	Wireless Communications	3.00
ELEC 465	Networks Security and Management	3.50
ELEC 466	Introduction to Optical Communication Systems	3.50
ELEC 472	Advanced Telecommunication Networks	3.50

III. Power and Renewable Energy Option *Credits*

ELEC 433	Power Electronics	3.50
ELEC 437	Renewable Energy Systems	3.00
ELEC 440	Controlled Electric Drives	3.50
ELEC 481	Linear Systems	3.50
	Minimum number of Elective credits: at least 3 of these 16.5 credits must be taken from the Power and Renewable Energy Option Electives list. The rest may be chosen from the Electrical Engineering Electives list.	16.50
		30.00

Power and Renewable Energy Option Electives *Credits*

ELEC 430	Electrical Power Equipment*	3.50
ELEC 431	Electrical Power Systems	3.50
ELEC 432	Control of Electrical Power Conversion Systems*	3.50
ELEC 434	Behaviour of Power Systems*	3.50
ELEC 435	Electromechanical Energy Conversion Systems	3.50
ELEC 436	Protection of Power Systems*	3.50
ELEC 438	Industrial Electrical Systems*	3.50
ELEC 439	Hybrid Electric Vehicle Power System Design and Control	3.00
ELEC 442	Digital Signal Processing	3.50
ELEC 482	System Optimization	3.50
ELEC 483	Real-Time Computer Control Systems	3.50

*Note: ELEC 430, 432, 434, 436, and 438 are usually offered in the French language.

IV. Avionics and Control Option *Credits*

AERO 417	Standards, Regulations and Certification	3.00
AERO 480	Flight Control Systems	3.50
AERO 482	Avionic Navigation Systems	3.00
AERO 483	Integration of Avionics Systems	3.00
ELEC 483	Real-Time Computer Control Systems	3.50
	Minimum number of Elective credits: Electives must be chosen from the Electrical Engineering Electives list.	14.00
		30.00

V. For students NOT selecting an option
A minimum of 29.5 credits must be chosen from the Electrical Engineering Electives list.

Electrical Engineering Electives
Courses are listed in groups to facilitate course selection.

A. Communications and Signal Processing		*Credits*
ELEC 441	Modern Analog Filter Design	3.50
ELEC 442	Digital Signal Processing	3.50
ELEC 462	Introduction to Digital Communications	3.50
ELEC 463	Telecommunication Networks	3.00
ELEC 464	Wireless Communications	3.00
ELEC 465	Networks Security and Management	3.50
ELEC 466	Introduction to Optical Communication Systems	3.50
ELEC 472	Advanced Telecommunication Networks	3.50

B. Computer Systems		*Credits*
COEN 313	Digital Systems Design II	3.50
COEN 316	Computer Architecture and Design	3.00
COEN 317	Microprocessor Systems	4.00
COEN 320	Introduction to Real-Time Systems	3.00
COEN 345	Software Testing and Validation	4.00
COEN 346	Operating Systems	4.00
COEN 352	Data Structures and Algorithms	3.00
COEN 421	Embedded Systems and Software Design	4.00
COEN 432	Applied Genetic and Evolutionary Systems	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

C. Electronics/VLSI		*Credits*
COEN 315	Digital Electronics	3.50
COEN 413	Hardware Functional Verification	3.00
COEN 451	VLSI Circuit Design	4.00
ELEC 312	Electronics II	4.00
ELEC 421	Solid State Devices	3.50
ELEC 422	Design of Integrated Circuit Components	3.50
ELEC 423	Introduction to Analog VLSI	4.00
ELEC 424	VLSI Process Technology	3.50
ELEC 425	Optical Devices for High-Speed Communications	3.50

D. Power		*Credits*
ELEC 430	Electrical Power Equipment*	3.50
ELEC 431	Electrical Power Systems	3.50
ELEC 432	Control of Electrical Power Conversion Systems*	3.50
ELEC 433	Power Electronics	3.50
ELEC 434	Behaviour of Power Systems*	3.50
ELEC 435	Electromechanical Energy Conversion Systems	3.50
ELEC 436	Protection of Power Systems*	3.50
ELEC 437	Renewable Energy Systems	3.00
ELEC 438	Industrial Electrical Systems*	3.50
ELEC 439	Hybrid Electric Vehicle Power System Design and Control	3.00
ELEC 440	Controlled Electric Drives	3.50

*Note: ELEC 430, 432, 434, 436, and 438 are usually offered in the French language.

E. Control Systems and Avionics		*Credits*
AERO 417	Standards, Regulations, and Certification	3.00
AERO 480	Flight Control Systems	3.50
AERO 482	Avionic Navigation Systems	3.00

AERO 483	Integration of Avionics Systems	3.00
ELEC 481	Linear Systems	3.50
ELEC 482	System Optimization	3.50
ELEC 483	Real-Time Computer Control Systems	3.50
ENGR 472	Robot Manipulators	3.50

F. Waves and Electromagnetics *Credits*

ELEC 453	Microwave Engineering	3.50
ELEC 455	Acoustics	3.00
ELEC 456	Antennas	3.50
ELEC 457	Design of Wireless RF Systems	3.00
ELEC 458	Techniques in Electromagnetic Compatibility	3.00

G. Other *Credits*

ELEC 498	Topics in Electrical Engineering	3.00
ENGR 411	Special Technical Report	1.00

71.30.2 Course Requirements (BEng in Computer Engineering)

The program in Computer Engineering consists of the Engineering Core, the Computer Engineering Core, and one of the two choices as set out below. The normal length of the program is 120 credits.

Engineering Core: (30.5 credits)
See §71.20.5.

Computer Engineering Core *Credits*

COEN 212	Digital Systems Design I	3.50
COEN 231	Introduction to Discrete Mathematics	3.00
COEN 243	Programming Methodology I	3.00
COEN 244	Programming Methodology II	3.00
COEN 311	Computer Organization and Software	3.50
COEN 316	Computer Architecture and Design	3.00
COEN 317	Microprocessor Systems	4.00
COEN 346	Operating Systems	4.00
COEN 352	Data Structures and Algorithms	3.00
COEN 390	Computer Engineering Product Design Project	3.00
COEN 490	Capstone Computer Engineering Design Project	4.00
ELEC 264	Signals and Systems I	3.00
ELEC 311	Electronics I	4.00
ELEC 321	Introduction to Semiconductor Materials and Devices	3.50
ELEC 353	Transmission Lines, Waves and Signal Integrity	3.00
ELEC 364	Signals and Systems II	3.50
ELEC 372	Fundamentals of Control Systems	3.50
ENGR 290	Introductory Engineering Team Design Project	3.00
SOEN 341	Software Process	3.00
		63.50

Students may choose the Avionics and Embedded Systems option; otherwise, students must follow II.

I. Avionics and Embedded Systems Option Core *Credits*

AERO 480	Flight Control Systems	3.50
AERO 482	Avionic Navigation Systems	3.00
AERO 483	Integration of Avionics Systems	3.00
COEN 320	Introduction to Real-Time Systems	3.00
COEN 421	Embedded Systems and Software Design	4.00
	Minimum number of Elective credits must be chosen from the Computer Engineering Electives list	9.50
		26.00

II. For Students NOT Selecting an Option:
A minimum of 26 credits must be chosen from the Computer Engineering Electives list. No more than 16 of these credits may be chosen from topic area C – Computer Science and Software Engineering.

Computer Engineering Electives
Courses are listed in groups to facilitate course selection.

A. Hardware/Electronics/VLSI		*Credits*
COEN 313	Digital Systems Design II	3.50
COEN 315	Digital Electronics	3.50
COEN 413	Hardware Functional Verification	3.00
COEN 451	VLSI Circuit Design	4.00
ELEC 312	Electronics II	4.00
ELEC 423	Introduction to Analog VLSI	4.00
ELEC 458	Techniques in Electromagnetic Compatibility	3.00

B. Real-Time and Software Systems		*Credits*
COEN 320	Introduction to Real-Time Systems	3.00
COEN 345	Software Testing and Validation	4.00
COEN 421	Embedded Systems and Software Design	4.00
COEN 432	Applied Genetic and Evolutionary Systems	3.00

C. Computer Science and Software Engineering		*Credits*
COMP 335	Introduction to Theoretical Computer Science	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 451	Database Design	4.00
COMP 465	Design and Analysis of Algorithms	3.00
COMP 472	Artificial Intelligence	4.00
COMP 474	Intelligent Systems	4.00
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 357	User Interface Design	3.00
SOEN 431	Formal Methods	3.00
SOEN 448	Management of Evolving Systems	3.00

D. Telecommunications, Networks and Signal Processing		*Credits*
COEN 445	Communication Networks and Protocols	4.00
ELEC 363	Fundamentals of Telecommunications Systems	3.50
ELEC 442	Digital Signal Processing	3.50
ELEC 462	Introduction to Digital Communications	3.50
ELEC 465	Networks Security and Management	3.50
ELEC 472	Advanced Telecommunication Networks	3.50

E. Control Systems		*Credits*
ELEC 481	Linear Systems	3.50
ELEC 482	System Optimization	3.50
ELEC 483	Real-Time Computer Control Systems	3.50
ENGR 472	Robot Manipulators	3.50

F. Avionics		*Credits*
AERO 417	Standards, Regulations and Certification	3.00
AERO 480	Flight Control Systems	3.50
AERO 482	Avionic Navigation Systems	3.00
AERO 483	Integration of Avionics Systems	3.00

G. Other		*Credits*
COEN 498	Topics in Computer Engineering	3.00
ENGR 411	Special Technical Report	1.00

DEPARTMENT OF MECHANICAL AND INDUSTRIAL ENGINEERING

Section 71.40

Faculty

Chair
MARTIN D. PUGH, PhD *University of Leeds*, PEng; *Professor*, *Provost's Distinction*

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Professors
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JAVAD DARGAHI, PhD *Caledonian University (U.K.)*, PEng
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CAMILLE-ALAIN RABBATH, PhD *McGill 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 004.139
514-848-2424, ext. 3125

Department Objectives

The Department of Mechanical and Industrial Engineering offers three distinct undergraduate programs: BEng in **Mechanical Engineering**, BEng in **Industrial Engineering** and BEng in **Aerospace Engineering**.
Mechanical Engineering is concerned with all forms of power generation (hydro-electric, steam, internal combustion, nuclear, jet rocket, and fuel cells), the design of mechanisms and machines, transportation systems, controls and automation, vibration analysis, environmental control (heating, ventilation, and refrigeration), materials handling, and precision measurement. The Mechanical Engineering curriculum consists of a combination of core courses with a series of technical electives that allow students to obtain some specialization in a particular area of the field depending on their interests and expected future professional activity. Three options are available: Aerospace and Propulsion Engineering; Design and Manufacturing Engineering; and Systems and Mechatronics.
Industrial Engineering is concerned with the design, organization, analysis, and integration of people and industrial systems components in order to achieve or enhance effectiveness. These components include whole machines, transportation and conveyance elements, physical plant, organizational frameworks, schedules, and budgets. The Industrial Engineering curriculum is therefore designed to give students the background needed to define and solve problems related to the conception, improvement, integration, and implementation of industrial systems.
The Aerospace Engineering program is offered jointly with the Department of Electrical and Computer Engineering. The detailed description of this program can be found in §71.55.

71.40.1 Course Requirements (BEng in Mechanical Engineering)

The program in Mechanical Engineering consists of the Engineering Core, the Mechanical Engineering Core, and option requirements as shown below. The minimum length of the program is 120 credits.

Engineering Core (27 credits)
See §71.20.5.

Mechanical Engineering Core		*Credits*
ENGR 242	Statics	3.00
ENGR 243	Dynamics	3.00
ENGR 244	Mechanics of Materials	3.75
ENGR 251	Thermodynamics I	3.00

ENGR 311	Transform Calculus and Partial Differential Equations	3.00
ENGR 361	Fluid Mechanics I	3.00
MECH 211	Mechanical Engineering Drawing	3.50
MECH 215	Programming for Mechanical and Industrial Engineers	3.50
MECH 221	Materials Science	3.00
MECH 311	Manufacturing Processes	3.75
MECH 313	Machine Drawing and Design	3.00
MECH 321	Properties and Failure of Materials	3.50
MECH 343	Theory of Machines	3.50
MECH 344	Machine Element Design	3.00
MECH 351	Thermodynamics II	3.50
MECH 352	Heat Transfer I	3.50
MECH 361	Fluid Mechanics II	3.50
MECH 368	Electronics for Mechanical Engineers	3.50
MECH 370	Modelling, Simulation and Control Systems	3.50
MECH 371	Analysis and Design of Control Systems	3.75
MECH 375	Mechanical Vibrations	3.50
MECH 390	Mechanical Engineering Design Project	3.00
		73.25

Option Requirements
Students in the Mechanical Engineering program must complete at least 19.75 elective credits from within one of options A, B, or C. Prior to registration for elective courses, students indicate their choice of option on a form available from the Department, which must be submitted to the Chair's office for approval *prior to March 30.* With permission of the Department, students may take one technical elective course from another option. Students work in the area of their option within their MECH 490 project.

1. Option A — Aerospace and Propulsion
Students must complete the following compulsory courses from the Option Core and at least 12.75 credits from the Option Electives.

Option A Core		*Credits*
AERO 464	Aerodynamics	3.00
MECH 490A	Capstone Mechanical Engineering Design Project	4.00

Option A Electives		*Credits*
AERO 417	Standards, Regulations and Certification	3.00
AERO 431	Principles of Aeroelasticity	3.00
AERO 462	Turbomachinery and Propulsion	3.00
AERO 465	Gas Turbine Design	3.50
AERO 480	Flight Control Systems	3.50
AERO 482	Avionic Navigation Systems	3.00
AERO 483	Integration of Avionics Systems	3.00
AERO 485	Introduction to Space Systems	3.00
AERO 486	Aircraft Stress Analysis	3.00
AERO 487	Design of Aircraft Structures	3.00
ENGR 411	Special Technical Report	1.00
ENGR 412	Honours Research Project	3.00
MECH 452	Heat Transfer II	3.50
MECH 453	Heating, Ventilation and Air Conditioning Systems	3.00
MECH 460	Finite Element Analysis	3.75
MECH 461	Gas Dynamics	3.50
MECH 498	Topics in Mechanical Engineering	3.00

2. Option B — Design and Manufacturing
Students must complete the following compulsory courses from the Option Core and at least 12.25 credits from the Option Electives.

Option B Core		*Credits*
MECH 412	Computer-Aided Mechanical Design	3.50
MECH 490B	Capstone Mechanical Engineering Design Project	4.00

Option B Electives		*Credits*
ENGR 411	Special Technical Report	1.00
ENGR 412	Honours Research Project	3.00
INDU 372	Quality Control and Reliability	3.00

INDU 410	Safety Engineering	3.50
INDU 411	Computer Integrated Manufacturing	3.50
INDU 440	Product Design and Development	3.00
MECH 411	Instrumentation and Measurements	3.50
MECH 414	Computer Numerically Controlled Machining	3.50
MECH 415	Advanced Programming for Mechanical and Industrial Engineers	3.00
MECH 421	Mechanical Shaping of Metals and Plastics	3.50
MECH 422	Mechanical Behaviour of Polymer Composite Materials	3.00
MECH 423	Casting, Welding, Heat Treating, and Non-Destructive Testing	3.50
MECH 424	MEMS — Design and Fabrication	3.50
MECH 425	Manufacturing of Composites	3.50
MECH 426	Stress and Failure Analysis of Machinery	3.00
MECH 460	Finite Element Analysis	3.75
MECH 498	Topics in Mechanical Engineering	3.00

3. Option C — Systems and Mechatronics
Students must complete the following compulsory course from the Option Core and at least 15.75 credits from the Option Electives.

Option C Core		*Credits*
MECH 490C	Capstone Mechanical Engineering Design Project	4.00

Option C Electives		*Credits*
AERO 480	Flight Control Systems	3.50
AERO 482	Avionic Navigation Systems	3.00
ENGR 411	Special Technical Report	1.00
ENGR 412	Honours Research Project	3.00
ENGR 472	Robot Manipulators	3.50
MECH 411	Instrumentation and Measurements	3.50
MECH 415	Advanced Programming for Mechanical and Industrial Engineers	3.00
MECH 444	Guided Vehicle Systems	3.00
MECH 447	Fundamentals of Vehicle System Design	3.50
MECH 448	Vehicle Dynamics	3.00
MECH 454	Vehicular Internal Combustion Engines	3.00
MECH 463	Fluid Power Control	3.50
MECH 471	Microcontrollers for Mechatronics	3.50
MECH 472	Mechatronics and Automation	3.50
MECH 473	Control System Design	3.50
MECH 474	Mechatronics	3.75
MECH 498	Topics in Mechanical Engineering	3.00

71.40.2 Course Requirements (BEng in Industrial Engineering)

The program in Industrial Engineering consists of the Engineering Core, the Industrial Engineering Core, and elective credits as shown below. The minimum length of the program is 120 credits.

Engineering Core (27 credits)
See §71.20.5.

Industrial Engineering Core		*Credits*
ENGR 244	Mechanics of Materials	3.75
ENGR 245	Mechanical Analysis	3.00
ENGR 251	Thermodynamics I	3.00
ENGR 311	Transform Calculus and Partial Differential Equations	3.00
INDU 211	Introduction to Production and Manufacturing Systems	3.00
INDU 311	Simulation of Industrial Systems	3.50
INDU 320	Production Engineering	3.00
INDU 321	Lean Manufacturing	3.00
INDU 323	Operations Research I	3.00
INDU 324	Operations Research II	3.00
INDU 330	Engineering Management	3.00
INDU 371	Stochastic Models in Industrial Engineering	3.00
INDU 372	Quality Control and Reliability	3.00
INDU 411	Computer Integrated Manufacturing	3.50

INDU 412	Human Factors Engineering	3.50
INDU 421	Facilities Design and Material Handling Systems	3.50
INDU 423	Inventory Control	3.50
INDU 490	Capstone Industrial Engineering Design Project	4.00
MECH 211	Mechanical Engineering Drawing	3.50
MECH 215	Programming for Mechanical and Industrial Engineers	3.50
MECH 221	Materials Science	3.00
MECH 311	Manufacturing Processes	3.75
MECH 313	Machine Drawing and Design	3.00
		75.00

Electives

Students must complete a minimum of 18 credits from the following courses, with no more than two of the courses marked *.

		Credits
BSTA 478*	Data Mining Techniques	3.00
BTM 430*	Enterprise Resource Planning and Information Technology Integration	3.00
BTM 480*	Project Management	3.00
ENGR 361	Fluid Mechanics I	3.00
ENGR 411	Special Technical Report	1.00
ENGR 412	Honours Research Project	3.00
INDU 410	Safety Engineering	3.50
INDU 440	Product Design and Development	3.00
INDU 441	Introduction to Six Sigma	3.00
INDU 442	Logistics Network Models	3.00
INDU 466	Decision Models in Service Sector	3.00
INDU 475	Advanced Concepts in Quality Improvement	3.00
INDU 498	Topics in Industrial Engineering	3.00
MANA 300*	Entrepreneurship: Launching Your Business	3.00
MECH 370	Modelling, Simulation and Control Systems	3.50
MECH 371	Analysis and Design of Control Systems	3.75
MECH 415	Advanced Programming for Mechanical and Industrial Engineers	3.00

DEPARTMENT OF BUILDING, CIVIL AND ENVIRONMENTAL ENGINEERING

Section 71.50

Faculty

Chair
MOHAMMED ZAHEERUDDIN, PhD *University of Alberta*, PEng; *Professor*

Associate Chair
ZHI CHEN, PhD *University of Regina*, APEGS; *Associate Professor*

Professors
HASHEM AKBARI, PhD *University of California, Berkeley*
ANDREAS K. ATHIENITIS, PhD *University of Waterloo,* ing.; *Provost's Distinction*
MARIA ELEKTOROWICZ, PhD *Warsaw Technical University*, ing.; *Provost's Distinction*
PAUL P. FAZIO, PhD *University of Windsor,* ing.; *Provost's Distinction*
KINH H. HA, DEng *Sir George Williams University*, ing.
FARIBORZ HAGHIGHAT, PhD *University of Waterloo*, PEng; *Provost's Distinction*
ADEL M. HANNA, PhD *Technical University of Nova Scotia*, ing.; *Provost's Distinction*
OSAMA MOSELHI, PhD *Concordia University*, ing.; *Provost's Distinction*
CATHERINE MULLIGAN, PhD *McGill University*, ing.
OSCAR A. PEKAU, PhD *University of Waterloo,* ing.; *Provost's Distinction*
AMRUTHUR S. RAMAMURTHY, PhD *Purdue University*, ing.; *Provost's Distinction*
THEODORE STATHOPOULOS, PhD *University of Western Ontario,* ing.; *Provost's Distinction*
TAREK ZAYED, PhD *Purdue University*, PEng
RADU G. ZMEUREANU, PhD *Concordia University*, ing.

Distinguished Professors Emeriti
DOREL FELDMAN, PhD *University of Iasi*
RICHARD W. GUY, PhD *University of Liverpool*, PEng
ZENON A. ZIELINSKI, DTechSc *Warsaw University of Technology*

Professors Emeriti
SABAH TOMA ALKASS, PhD *Loughborough University*, PEng; *Provost's Distinction*
BALA ASHTAKALA, PhD *University of Waterloo*
HORMOZ B. POOROOSHASB, PhD *University of Cambridge*

Associate Professors
CIPRIAN ALECSANDRU, PhD *Louisiana State University*, PEng
ASHUTOSH BAGCHI, PhD *Carleton University*, PEng
KHALED GALAL, PhD *McMaster University*, PEng
SAMUEL LI, PhD *Norwegian Institute of Technology*, APEG (B.C.)
MICHELLE NOKKEN, PhD *University of Toronto*, PEng
ATTILA M. ZSAKI, PhD *University of Toronto*, PEng

Assistant Professors
LUIS AMADOR, PhD *University of New Brunswick*, PEng
ANJAN BHOWMICK, PhD *University of Alberta*, APPEGA
HUA GE, PhD *Concordia University*, APEG (B.C.)
LAN LIN, PhD *University of Ottawa*
MD. SAIFUR RAHAMAN, PhD *University of British Columbia*
LUCIA TIRCA, PhD *Technical University of Civil Engineering, Bucharest*, ing.
LIANGZHU WANG, PhD *Purdue University*
ZHENHUA ZHU, PhD *Georgia Institute of Technology*

Extended Term Appointments
JASSIM HASSAN, PhD *University of Calgary*
CHRISTOPHER WILLIS, PhD *University of New Brunswick*, PEng

Affiliate Professors
SUZELLE BARRINGTON, PhD *McGill University*, ing., Agr.
KENNETH LEE, PhD *University of Toronto*
ROBERT REIMERS, PhD *Vanderbilt University*

Affiliate Associate Professors
ALI BAHLOUL, PhD *Université du Havre*
LALEH YERUSHALMI, PhD *McGill 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 006.139
514-848-2424, ext. 3200
514-848-2424, ext. 7800

Objectives

Building Engineering, as a discipline, encompasses the body of knowledge which pertains to all phases in the life-cycle of a constructed facility, namely conception, planning, design, construction, operation, and disposal.
Concordia has a unique undergraduate program leading to a BEng in Building Engineering designed to meet the needs of the construction industry for engineers familiar with the overall design of built facilities.
In addition to the basic engineering sciences, the program emphasizes the fundamentals of building materials, structural analysis and design, building services (acoustical, heating, lighting, air conditioning), economics, and project management. The student also has available certain electives which will be of use in the design of various phases of a building.
Students who complete all but one of their 200- and 300-level courses with a sufficiently high standing may apply through the Associate Dean, Student Academic Services to enter a combined program leading to the joint award of both a BEng and an MEng degree in Building Engineering. It is expected that those who aspire to leadership roles within the building industry will enter such a combined program. The combined program requires a further 12 months of full-time study, after which graduates will not only have obtained further grounding in the basics, but will also have specialized in one of four branches: Building Science, Building Environment, Building Structures, Construction Management. For details of the graduate component, refer to the School of Graduate Studies Calendar.

71.50.1 Course Requirements (BEng in Building Engineering)

The program in Building Engineering consists of the Engineering Core, the Building Engineering Core, and at least nine elective credits chosen from the elective courses listed below. The normal length of the program is 119 credits.

Engineering Core for Building Engineering (29 credits)*
See §71.20.5. Students in BEng (Bldg) must successfully complete BLDG 482 instead of ENGR 392.
*Note: The Engineering Core credits for students in the Building Engineering program are reduced from 30.5 credits to 29 credits since Building Engineering students are not required to take ENGR 202 (1.5 credits) in their program.

Building Engineering Core		*Credits*
BCEE 231	Structured Programming and Applications for Building and Civil Engineers	3.00
BCEE 342	Structural Analysis I	3.00
BCEE 343	Structural Analysis II	3.00
BCEE 344	Structural Design I	3.00
BCEE 345	Structural Design II	3.00
BCEE 371*	Surveying	3.00
BCEE 451	Construction Engineering	3.00
BLDG 212	Building Engineering Drawing and Introduction to Design	3.00
BLDG 341	Building Engineering Systems	3.00
BLDG 365	Building Science	3.50
BLDG 366	Acoustics and Lighting	3.50
BLDG 371	Building Service Systems	3.50
BLDG 390	Building Engineering Design Project	3.50
BLDG 463	Building Envelope Design	3.00
BLDG 471	HVAC System Design	4.00
BLDG 476	Thermal Analysis of Buildings	3.00
BLDG 490	Capstone Building Engineering Design Project	4.00
CIVI 321	Engineering Materials	3.75
CIVI 432	Soil Mechanics	3.50

ENGR 242	Statics	3.00
ENGR 243	Dynamics	3.00
ENGR 244	Mechanics of Materials	3.75
ENGR 251	Thermodynamics I	3.00
ENGR 311	Transform Calculus and Partial Differential Equations	3.00
ENGR 361	Fluid Mechanics I	3.00
		81.00

*Summer course to be taken before entering second year of BEng program.

Elective Courses
A student must choose a minimum of nine credits from the following list of elective courses.

		Credits
BCEE 452	Matrix Analysis of Structures	3.00
BCEE 455	Introduction to Structural Dynamics	3.00
BLDG 462	Modern Building Materials	3.00
BLDG 465	Fire and Smoke Control in Buildings	3.00
BLDG 472	Building Energy Conservation Technologies	3.00
BLDG 473	Building Acoustics	3.00
BLDG 474	Building Illumination and Daylighting	3.00
BLDG 475	Indoor Air Quality	3.00
BLDG 477	Control Systems in Buildings	3.00
BLDG 478	Project Management for Construction	3.00
BLDG 491	Labour and Industrial Relations in Construction	3.00
BLDG 492	Construction Processes	3.00
BLDG 493	Legal Issues in Construction	3.00
BLDG 498	Topics in Building Engineering	3.00
CIVI 435	Foundation Design	3.00
CIVI 453	Design of Reinforced Concrete Structures	3.50
CIVI 454	Design of Steel Structures	3.50
ENGR 411	Special Technical Report	1.00
ENGR 412	Honours Research Project	3.00

Objectives

Civil Engineering is concerned with the creation of systems of constructed facilities which play an important role in sound economic growth of society. It is also concerned with the development of technologies to combat pollution of air, water, and soil. Civil engineers are responsible for the design of foundations and superstructures of common structures such as buildings, bridges, dams, tunnels, wharves, as well as many unusual structures such as rocket installations, containment vessels for nuclear reactors, supports for radio telescopes, frameworks for aircraft. In addition, they are concerned with the engineering aspects of water resources; transportation facilities; planning metropolitan areas, and conducting and managing their public facilities. In dealing with environmental problems, civil engineers perform vital functions such as monitoring and controlling air, water, and soil quality, assessing the impact of technological changes on the environment, and developing innovative waste reduction technologies.

71.50.2 Course Requirements (BEng in Civil Engineering)

The program in Civil Engineering consists of the Engineering Core, the Civil Engineering Core, and one of the options listed below. The normal length of the program is 119 credits.

Engineering Core (30.5 credits)

Civil Engineering Core		*Credits*
BCEE 231	Structured Programming and Applications for Building and Civil Engineers	3.00
BCEE 342	Structural Analysis I	3.00
BCEE 343	Structural Analysis II	3.00
BCEE 344	Structural Design I	3.00
BCEE 345	Structural Design II	3.00
BCEE 371*	Surveying	3.00
BCEE 451	Construction Engineering	3.00
CIVI 212	Civil Engineering Drawing and Introduction to Design	3.00
CIVI 231	Geology for Civil Engineers	3.00
CIVI 321	Engineering Materials	3.75

CIVI 341	Civil Engineering Systems	3.00
CIVI 361	Introduction to Environmental Engineering	3.50
CIVI 372	Transportation Engineering	3.00
CIVI 381	Hydraulics	3.50
CIVI 390	Civil Engineering Design Project	3.50
CIVI 432	Soil Mechanics	3.50
CIVI 490	Capstone Civil Engineering Design Project	4.00
ENGR 242	Statics	3.00
ENGR 243	Dynamics	3.00
ENGR 244	Mechanics of Materials	3.75
ENGR 251	Thermodynamics I	3.00
ENGR 311	Transform Calculus and Partial Differential Equations	3.00
ENGR 361	Fluid Mechanics I	3.00
		73.50

*Summer course to be taken before entering second year of BEng program.

Option Course Requirements
Students must complete a minimum of 15 credits from one of the following options: A, B or C. Option A is designed for students interested in careers in structural, geotechnical, and transportation engineering. Option B is tailored for students wishing to pursue careers in environmental engineering. Option C is designed for students interested in construction engineering and management.

	Option A – Civil Infrastructure	*Credits*
BCEE 452	Matrix Analysis of Structures	3.00
BCEE 455	Introduction to Structural Dynamics	3.00
CIVI 435	Foundation Design	3.00
CIVI 437*	Advanced Geotechnical Engineering	3.00
CIVI 453	Design of Reinforced Concrete Structures	3.50
CIVI 454	Design of Steel Structures	3.50
CIVI 471	Highway and Pavement Design	3.00
CIVI 474*	Transportation Planning and Design	3.00
CIVI 498	Topics in Civil Engineering	3.00
ENGR 411	Special Technical Report	1.00
ENGR 412	Honours Research Project	3.00

Note: Students may choose one course marked with * from Option B or C.

	Option B – Environmental	*Credits*
CIVI 382*	Water Resources Engineering	3.50
CIVI 464*	Environmental Impact Assessment	3.00
CIVI 465	Water Pollution and Control	3.50
CIVI 466	Engineering Aspects of Chemical and Biological Processes	3.00
CIVI 467*	Air Pollution and Emission Control	3.00
CIVI 468	Waste Management	3.00
CIVI 469*	Geo-Environmental Engineering	3.50
CIVI 483*	Hydrology	3.00
CIVI 484*	Hydraulic Engineering	3.50
CIVI 498	Topics in Civil Engineering	3.00
ENGR 411	Special Technical Report	1.00
ENGR 412	Honours Research Project	3.00

Note: Students may choose one course marked with * from Option A or C.

	Option C – Construction Engineering and Management (CEM)	*Credits*
BCEE 464	Project Cost Estimating	3.00
BCEE 465	Construction Planning and Control	3.00
BCEE 466	Simulations and Design of Construction Operations	3.00
BLDG 478*	Project Management for Construction	3.00
BLDG 491	Labour and Industrial Relations in Construction	3.00
BLDG 492	Construction Processes	3.00
BLDG 493	Legal Issues in Construction	3.00
CIVI 440*	Computer Applications in Civil Engineering Practice	3.00
CIVI 498	Topics in Civil Engineering	3.00
ENGR 411	Special Technical Report	1.00
ENGR 412	Honours Research Project	3.00

Note: Students may choose one course marked with * from Option A or B.

AEROSPACE ENGINEERING

Section 71.55

Faculty

Undergraduate Program Director
T.B.A.

The Aerospace Engineering program is offered jointly by the Department of Mechanical and Industrial Engineering and the Department of Electrical and Computer Engineering. For a complete list of faculty members, please consult the Departments' websites.

Location

Sir George Williams Campus
Engineering, Computer Science and Visual Arts Complex, Room: EV 004.139
514-848-2424, ext. 3125

Program Objectives

Aerospace Engineering is concerned with the engineering science governing flight and the design and construction of aircraft and spacecraft. This includes the mechanisms behind flight and propulsion in the atmosphere and space including aerodynamics, lift and drag as well as the design and control of aircraft such as airplanes, helicopters, unmanned aerial vehicles (UAVs) and rockets. The Aerospace Engineering curriculum comprises fundamental engineering courses followed by technical electives which allow students to obtain some specialization in a particular area of the field depending on their interests and expected future professional activity. Three options are available: Aerodynamics and Propulsion; Aerospace Structures and Materials; and Avionics and Aerospace Systems.
Aerodynamics and Propulsion is strongly related to the "flying" aspect of aircraft and includes topics such as aerodynamics, gas dynamics, aerospace vehicle performance, turbo-machinery and propulsion. Aerospace Structures and Materials is related to the design and manufacture of aircraft and spacecraft and includes topics such as aircraft stress analysis, aeroelasticity and vibrations, composite materials and aircraft design. Avionics and Aerospace Systems has significant electrical and computer engineering content in order to provide the necessary background for the avionics and systems engineering required to control modern aircraft and includes topics such as avionic navigation systems, communication networks, spacecraft mission design and flight control systems.

Course Requirements (BEng in Aerospace Engineering)

The program in Aerospace Engineering consists of the Engineering Core, the Aerospace Engineering Core, and option requirements as shown below. The minimum length of the program is 120 credits.

Engineering Core (27 credits)
See §71.20.5.

Aerospace Engineering Core		*Credits*
AERO 201	Introduction to Flight and Aerospace Systems	3.50
AERO 371	Modelling and Control Systems	3.50
AERO 390	Aerospace Engineering Design Project	3.00
AERO 417	Standards, Regulations and Certification	3.00
AERO 490	Capstone Aerospace Engineering Design Project	4.00
ENGR 242	Statics	3.00
ENGR 243	Dynamics	3.00
ENGR 244	Mechanics of Materials	3.75
ENGR 251	Thermodynamics I	3.00
ENGR 361	Fluid Mechanics I	3.00
		32.75

Option Requirements
Students in the Aerospace Engineering program must complete at least 60.25 elective credits from within one of options A, B, or C. Prior to registration for elective courses, students indicate their choice of option on a form available from the Department, which must be submitted to the Chair's office for approval *prior to March 30.*

1. Option A — Aerodynamics and Propulsion

Students must complete the following compulsory courses from the Option Core and at least 10 credits from the Option Electives, with no more than one of the courses marked *. Students having a GPA of 3.0 or more may submit a request to take a graduate course as an elective.

Option A Core		*Credits*
AERO 446	Aerospace Vehicle Performance	3.00
AERO 455	Computational Fluid Dynamics for Aerospace Applications	3.75
AERO 462	Turbomachinery and Propulsion	3.00
AERO 464	Aerodynamics	3.00
AERO 465	Gas Turbine Design	3.50
AERO 481	Materials Engineering for Aerospace	3.50
ENGR 311	Transform Calculus and Partial Differential Equations	3.00
MECH 211	Mechanical Engineering Drawing	3.50
MECH 215	Programming for Mechanical and Industrial Engineers	3.50
MECH 221	Materials Science	3.00
MECH 343	Theory of Machines	3.50
MECH 351	Thermodynamics II	3.50
MECH 352	Heat Transfer I	3.50
MECH 361	Fluid Mechanics II	3.50
MECH 461	Gas Dynamics	3.50
		50.25

Option A Electives		*Credits*
AERO 431	Principles of Aeroelasticity	3.00
AERO 444	Concurrent Engineering in Aerospace Systems	3.00
AERO 480	Flight Control Systems	3.50
AERO 482	Avionic Navigation Systems	3.00
AERO 485	Introduction to Space Systems	3.00
AERO 486*	Aircraft Stress Analysis	3.00
ENGR 412	Honours Research Project	3.00
INDU 372	Quality Control and Reliability	3.00
MECH 368	Electronics for Mechanical Engineers	3.50
MECH 375*	Mechanical Vibrations	3.50
MECH 411	Instrumentation and Measurements	3.50
MECH 426*	Stress and Failure Analysis of Machinery	3.00
MECH 452	Heat Transfer II	3.50
MECH 453	Heating, Ventilation and Air Conditioning Systems	3.00
MECH 460*	Finite Element Analysis	3.75
MECH 463	Fluid Power Control	3.50
MECH 498	Topics in Mechanical Engineering	3.00

2. Option B — Aerospace Structures and Materials

Students must complete the following compulsory courses from the Option Core and at least 6.75 credits from the Option Electives, with no more than one of the courses marked *. Students having a GPA of 3.0 or more may submit a request to take a graduate course as an elective.

Option B Core		*Credits*
AERO 431	Principles of Aeroelasticity	3.00
AERO 481	Materials Engineering for Aerospace	3.50
AERO 486	Aircraft Stress Analysis	3.00
AERO 487	Design of Aircraft Structures	3.00
ENGR 311	Transform Calculus and Partial Differential Equations	3.00
MECH 211	Mechanical Engineering Drawing	3.50
MECH 215	Programming for Mechanical and Industrial Engineers	3.50
MECH 221	Materials Science	3.00
MECH 311	Manufacturing Processes	3.75
MECH 313	Machine Drawing and Design	3.00
MECH 343	Theory of Machines	3.50
MECH 352	Heat Transfer I	3.50
MECH 375	Mechanical Vibrations	3.50
MECH 411	Instrumentation and Measurements	3.50
MECH 412	Computer-Aided Mechanical Design	3.50
MECH 460	Finite Element Analysis	3.75
		53.50

Option B Electives *Credits*

AERO 444	Concurrent Engineering in Aerospace Systems	3.00
AERO 446*	Aerospace Vehicle Performance	3.00
AERO 455*	Computational Fluid Dynamics for Aerospace Applications	3.75
AERO 480*	Flight Control Systems	3.50
AERO 482*	Avionic Navigation Systems	3.00
AERO 485	Introduction to Space Systems	3.00
ENGR 412	Honours Research Project	3.00
INDU 372	Quality Control and Reliability	3.00
MECH 344	Machine Element Design	3.00
MECH 351*	Thermodynamics II	3.50
MECH 361*	Fluid Mechanics II	3.50
MECH 368	Electronics for Mechanical Engineers	3.50
MECH 422	Mechanical Behaviour of Polymer Composite Materials	3.00
MECH 425	Manufacturing of Composites	3.50
MECH 498	Topics in Mechanical Engineering	3.00

3. Option C — Avionics and Aerospace Systems

Students must complete the following compulsory courses from the Option Core and at least 11.75 credits from the Option Electives. Students having a GPA of 3.0 or more may submit a request to take a graduate course as an elective.

Option C Core *Credits*

AERO 482	Avionics Navigation Systems	3.00
AERO 483	Integration of Avionics Systems	3.00
COEN 212	Digital Systems Design I	3.50
COEN 231	Introduction to Discrete Mathematics	3.00
COEN 243	Programming Methodology I	3.00
COEN 244	Programming Methodology II	3.00
COEN 311	Computer Organization and Software	3.50
COEN 352	Data Structures and Algorithms	3.00
ELEC 251	Fundamentals of Applied Electromagnetics	3.00
ELEC 264	Signals and Systems I	3.00
ELEC 273	Basic Circuit Analysis	3.50
ELEC 311	Electronics I	4.00
ELEC 364	Signals and Systems II	3.50
ELEC 483	Real-Time Computer Control Systems	3.50
SOEN 341	Software Process	3.00
		48.50

Option C Electives *Credits*

AERO 480	Flight Control Systems	3.50
COEN 313	Digital Systems Design II	3.50
COEN 317	Microprocessor Systems	4.00
COEN 320	Introduction to Real-Time Systems	3.00
COEN 346	Operating Systems	4.00
COEN 413	Hardware Functional Verification	3.00
COEN 421	Embedded Systems and Software Design	4.00
COEN 445	Communication Networks and Protocols	4.00
COEN 498	Topics in Computer Engineering	3.00
ELEC 331	Fundamentals of Electrical Power Engineering	3.50
ELEC 351	Electromagnetic Waves and Guiding Structures	3.00
ELEC 363	Fundamentals of Telecommunications Systems	3.50
ELEC 433	Power Electronics	3.50
ELEC 442	Digital Signal Processing	3.50
ELEC 458	Techniques in Electromagnetic Compatibility	3.00
ELEC 462	Introduction to Digital Communications	3.50
ELEC 464	Wireless Communications	3.00
ELEC 481	Linear Systems	3.50
ELEC 482	System Optimization	3.50
ELEC 498	Topics in Electrical Engineering	3.00
SOEN 342	Software Requirements and Specifications	3.00
SOEN 343	Software Architecture and Design I	3.00

ENGINEERING COURSE DESCRIPTIONS *Section 71.60*

ENGINEERING AND COMPUTER SCIENCE

ENCS 272 ***Composition and Argumentation for Engineers*** (3 credits)
Prerequisite: Completion of all ESL courses required on admission. Fundamentals of English composition and argumentation: grammar; reasoning and persuasion; persuasive proofs; argumentation; structuring and outlining; the problem statement; the body; and the conclusions. Language and persuasion for effective communication in professional engineering. Cultivation of a writing style firmly based on clear and critical thinking skills. Lectures: three hours per week. Tutorial: one hour per week.
NOTE: Students who pass this course with C- or higher will fulfill the Faculty writing skills requirement, and will be eligible to enrol in ENCS 282.

ENCS 282 ***Technical Writing and Communication*** (3 credits)
Prerequisite: Students must have satisfied the requirements in §71.20.7 by passing the Engineering Writing Test (EWT), or by passing ENCS 272 with a grade of C- or higher. Technical writing form and style. Technical and scientific papers, abstracts, reports. Library research and referencing methods for engineers and computer scientists. Technical communication using information technology: document processing software, computer-assisted presentation, analysis and design of web presentation, choice and use of appropriate tools. Students will prepare an individual major report and make an oral presentation. Lectures: three hours per week. Tutorial: two hours per week.

ENCS 393 ***Social and Ethical Dimensions of Information and Communication Technologies*** (3 credits)
Prerequisite: ENCS 282; 40 credits in BCompSc program. Ethics in an information society; surveillance and privacy; economic globalization and intellectual property in a digital world: the digital divide; computer-based profiling and hacking; electronic democracy; computer-mediated experience; and information productivity and the work/life balance. Lectures: three hours per week.

ENCS 483 ***Creativity, Innovation and Critical Thinking in Science and Technology*** (3 credits)
Prerequisite: Minimum of 60 credits in an engineering program or minimum of 45 credits in a non-engineering program. Understanding, thinking, arguing, and creativity in science and technology; analyzing and critiquing complex problems using multidisciplinary theories of creativity; exploring the processes of invention and innovation and their impact on economics, popular media, and social and cultural structures; case studies of why some inventions fail and others succeed. Students will be evaluated on case studies, assignments, and a project. Lectures: three hours per week.
NOTE: Students who have received credit for ENCS 283 may not take this course for credit.

ENCS 484 ***Development and Global Engineering*** (3 credits)
Prerequisite: Minimum of 60 credits in an engineering program or minimum of 45 credits in a non-engineering program. International development and global engineering: globalization; development projects; planning and analysis; and participatory data gathering. A project. Lectures: three hours per week.
NOTE: Students who have received credit for this topic under an ENCS 498 number may not take this course for credit.

ENCS 498 ***Topics in Engineering and Computer Science*** (3 credits)
Prerequisite: Permission of the Faculty. This course may be offered in a given year upon the authorization of the Faculty. The course content may vary from offering to offering.

ENGINEERING

ENGR 108 ***Engineering 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.

ENGR 201 ***Professional Practice and Responsibility*** (1.5 credits)
Health and safety issues for engineering projects: Quebec and Canadian legislation; safe work practices; general laboratory safety common to all engineering disciplines, and specific laboratory safety pertaining to particular engineering disciplines. Review of the legal framework in Quebec, particularly the Professional Code and the Engineers Act, as well as professional ethics. Lectures: one and a half hours per week. Tutorial: one hour per week, alternate weeks.

ENGR 202 ***Sustainable Development and Environmental Stewardship*** (1.5 credits)
Introduction to the concept of sustainable development and the approaches for achieving it. Relationships with economic, social, and technological development. Methods for evaluating sustainability of engineering projects, including utilization of relevant databases and software. Impact of engineering design and industrial development on the environment. Case studies. Lectures: one and a half hours per week.

ENGR 208 ***Engineering Industrial Experience Reflective Learning II*** (3 credits)
Prerequisite: ENGR 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.

ENGR 213 ***Applied Ordinary Differential Equations*** (3 credits)
Prerequisite: MATH 204 (Cegep Mathematics 105) previously or concurrently; MATH 205 (Cegep Mathematics 203). This course introduces Engineering students to the theory and application of ordinary differential equations. Definition and terminology, initial-value problems, separable differential equations, linear equations, exact equations, solutions by substitution, linear models, orthogonal trajectories, complex numbers, form of complex numbers: powers and roots, theory: linear equations, homogeneous linear equations with constant coefficients, undetermined coefficients, variation of parameters, Cauchy-Euler equation, reduction of order, linear models: initial value, review of power series, power series solutions, theory, homogeneous linear systems, solution by diagonalisation, non-homogeneous linear systems. Eigenvalues and eigenvectors. Lectures: three hours per week. Tutorial: two hours per week.

ENGR 233 ***Applied Advanced Calculus*** (3 credits)
Prerequisite: MATH 204 (Cegep Mathematics 105); MATH 205 (Cegep Mathematics 203). This course introduces Engineering students to the theory and application of advanced calculus. Functions of several variables, partial derivatives, total and exact differentials, approximations with differentials. Tangent plane and normal line to a surface, directional derivatives, gradient. Double and triple integrals. Polar, cylindrical, and spherical coordinates. Change of variables in double and triple integrals. Vector differential calculus; divergence, curl, curvature, line integrals, Green's theorem, surface integrals, divergence theorem, applications of divergence theorem, Stokes' theorem. Lectures: three hours per week. Tutorial: two hours per week.

ENGR 242 ***Statics*** (3 credits)
Prerequisite: ENGR 213 previously or concurrently; PHYS 204; MATH 204. Resultant of force systems; equilibrium of particles and rigid bodies; distributed forces; statically determinate systems; trusses; friction; moments of inertia; virtual work. Shear and bending moment diagrams. Lectures: three hours per week. Tutorial: two hours per week.

ENGR 243 ***Dynamics*** (3 credits)
Prerequisite: ENGR 213, 242. Kinematics of a particle and rigid body; forces and accelerations; work and energy; impulse and momentum; dynamics of a system of particles and rigid bodies, introduction to vibrations. Lectures: three hours per week. Tutorial: two hours per week.

ENGR 244 ***Mechanics of Materials*** (3.75 credits)
Prerequisite: ENGR 213; ENGR 242 or 245; ENGR 233 previously or concurrently. Mechanical behaviour of materials; stress; strain; shear and bending moment diagrams; introduction to inelastic action. Analysis and design of structural and machine elements subjected to axial, torsional, and flexural loadings. Combined stresses and stress transformation. Deflections. Introduction to elastic stability. Lectures: three hours per week. Tutorial: two hours per week. Laboratory: three hours per week, alternate weeks.

ENGR 245 ***Mechanical Analysis*** (3 credits)
Prerequisite: PHYS 204; ENGR 213 previously or concurrently. Forces in a plane and in space, moments of forces, Varignon's theorem, rigid bodies in equilibrium, free-body diagram. Centroids, centres of gravity. Distributed forces, moments of inertia. Principle of virtual work. Kinematics of particles and rigid bodies. Forces and accelerations; work and energy; impulse and momentum. Kinetics of particles and rigid bodies. Lectures: three hours per week. Tutorial: one hour per week.

ENGR 251 ***Thermodynamics I*** (3 credits)
Prerequisite: MATH 203 (Cegep Mathematics 103). Basic principles of thermodynamics and their application to various systems composed of pure substances and their homogeneous non-reactive mixtures. Simple power production and utilization cycles. Lectures: three hours per week. Tutorial: two hours per week.

ENGR 290 ***Introductory Engineering Team Design Project*** (3 credits)
Prerequisite: ENCS 282; ENGR 213, 233. The introductory team design project introduces students to teamwork, project management, engineering design for a complex problem, technical writing and technical presentation in a team environment. Students work in teams and each team designs and builds a prototype defined by the Department. Students present their design and demonstrate that their design works in a competition at the end of the term. The students are also introduced to the basic principles of mechanics including the description of translational motion, rotational motion, forces and moments, work and energy, and they build a mechanical prototype to which the electronics and software are then added. A significant team project is required in this course. Lectures: three hours per week. Tutorial: two hours per week.
NOTE: All written documentation must follow the Concordia Form and Style guide. Students are responsible for obtaining this document before beginning the project.

ENGR 301 ***Engineering Management Principles and Economics*** (3 credits)
Introduction to project delivery systems. Principles of project management; role and activity of a manager; enterprise organizational charts; cost estimating; planning and control. Company finances; interest and time value of money; discounted cash flow; evaluation of projects in private and public sectors; depreciation methods; business tax regulations; decision tree; sensitivity analysis. Lectures: three hours per week. Tutorial: one hour per week.

ENGR 308 ***Engineering Industrial Experience Reflective Learning III*** (3 credits)
Prerequisite: ENGR 208 and permission of the Faculty. This course further expands on the students' third industrial experience in their related field of study to further develop their knowledge and work-related skills.

ENGR 311 ***Transform Calculus and Partial Differential Equations*** (3 credits)
Prerequisite: ENGR 233. Elements of complex variables. The Laplace transform: Laplace transforms and their properties, solution of linear differential equations with constant coefficients. Further theorems and their applications. The Fourier transform: orthogonal functions, expansion of a function in orthogonal functions, the Fourier series, the Fourier integral, the Fourier transform, the convolution theorem. Partial differential equations: physical foundations of partial differential equations, introduction to boundary value problems. Lectures: three hours per week. Tutorial: two hours per week.

ENGR 361 ***Fluid Mechanics I*** (3 credits)
Prerequisite: ENGR 213, 233, 251. Basic concepts and principles of fluid mechanics. Classification of fluid flow. Hydrostatic forces on plane and curved surfaces, buoyancy and stability, fluids in rigid body motion. Mass, momentum, and energy conservation integral equations. Bernoulli equation. Basic concepts of pipe and duct flow. Introduction to Navier-Stokes equations. Similarity and model studies. Lectures: three hours per week. Tutorial: one hour per week.

ENGR 371 ***Probability and Statistics in Engineering*** (3 credits)
Prerequisite: ENGR 213, 233. Axioms of probability theory. Events. Conditional probability. Bayes theorem. Random variables. Mathematical expectation. Discrete and continuous probability density functions. Transformation of variables. Probabilistic models, statistics, and elements of hypothesis testing (sampling distributions and interval estimation). Introduction to statistical quality control. Applications to engineering problems. Lectures: three hours per week. Tutorial: one hour per week.

ENGR 391 ***Numerical Methods in Engineering*** (3 credits)
Prerequisite: ENGR 213, 233; COMP 248 or COEN 243 or MECH 215 or BCEE 231. Roots of algebraic and transcendental equations; function approximation; numerical differentiation; numerical integration; solution of simultaneous algebraic equations; numerical integration of ordinary differential equations. Lectures: three hours per week. Tutorial: one hour per week.

ENGR 392 ***Impact of Technology on Society*** (3 credits)
Prerequisite: ENCS 282; ENGR 201, 202. Social history of technology and of science including the industrial revolution and modern times. Engineering and scientific creativity, social and environmental problems created by uncontrolled technology, appropriate technology. Lectures: three hours per week.

ENGR 411 ***Special Technical Report*** (1 credit)
Prerequisite: ENCS 282; permission of the Department. Students must submit a report on a topic related to the students' discipline and approved by the Department. The report must present a review of a current engineering problem, a proposal for a design project, or a current engineering practice.
NOTE: Students who have received credit for ENGR 410 may not take this course for credit.

ENGR 412 ***Honours Research Project*** (3 credits)
Prerequisite: ENCS 282; minimum 75 credits in the BEng program with a CGPA of 3.00 or better; permission of the Department. Students work on a research project in their area of concentration, selected in consultation with and conducted under the supervision of a faculty member of the Department. The student's work must culminate in a final report, as well as an oral presentation. Students planning to register for this course should consult with the Department prior to term of planned registration. Intended for students with potential interest in graduate programs.
NOTE: Must be approved by the Department prior to registration.

ENGR 472 ***Robot Manipulators*** (3.5 credits)
Prerequisite: ELEC 372 or MECH 371. Spatial descriptions and transformations. Manipulator forward and inverse kinematics. Jacobians: velocities and static forces. Manipulator dynamics. Trajectory generation. Position control of manipulators. Force control of manipulators. Robot programming languages. Lectures: three hours per week. Laboratory: 15 hours total.

ENGR 498 ***Topics in Engineering*** (3 credits)
Prerequisite: Permission of the Faculty. This course may be offered in a given year upon the authorization of the Faculty. The course content may vary from offering to offering.

AEROSPACE ENGINEERING

AERO 201 ***Introduction to Flight and Aerospace Systems*** (3.5 credits)
Prerequisite: ENGR 213; ENGR 233 previously or concurrently. Introduction to flight vehicles in the atmosphere and in space; elements of aerodynamics, airfoils and wings; aerospace technologies including structures, materials and propulsion systems; elements of aircraft performance; basic principles of flight stability, control and systems integration; aspects of aircraft conceptual design. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

AERO 371 ***Modelling and Control Systems*** (3.5 credits)
Prerequisite: PHYS 205; ENGR 213, 243; ENGR 311 or ELEC 364 previously or concurrently. Definition and classification of dynamic systems and components. Modelling of system components using ordinary differential equations: mechanical, electrical, electromechanical, and electrohydraulic subsystems in an airplane. Modelling of systems using transfer function models, block

diagrams and signal flow graphs. Linearization of non-linear systems. Transient and steady-state characteristics of dynamic systems. Systems analyses using time domain methods, root-locus methods, and frequency response methods. Characteristics and performance of linear feedback control systems. System stability. Proportional, integral and derivative controllers. Simulation technique using Matlab/Simulink. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.
NOTE: Students who have received credit for ELEC 372 or MECH 371 may not take this course for credit.

AERO 390 ***Aerospace Engineering Design Project*** (3 credits)
Prerequisite: AERO 201, 371. General design philosophy and the design process. Design factors such as product safety, reliability, life cycle costs and manufacturability. Design in the aerospace context: vehicle and system design with regard to mission requirements, configuration, sizing, loads, etc. Mathematical modelling, analysis, and validation. Introduction to Computer-Aided Design and Engineering (CAD and CAE). Design documentation. A team-based project in which an aerospace system/subsystem is designed, implemented, documented and presented is an intrinsic part of this course. Lectures: three hours per week. Tutorial: two hours per week.

AERO 417 ***Standards, Regulations and Certification*** (3 credits)
Overview of DoT and other international aviation standards (e.g. FAA), regulations and certification procedures; regulatory areas, namely, pilot training/testing, air traffic procedures, aircraft systems design and airworthiness; development process for new regulations and criteria for certification. Lectures: three hours per week.
NOTE: Students who have received credit for ENGR 417 or for this topic under an ENGR 498 number may not take this course for credit.

AERO 431 ***Principles of Aeroelasticity*** (3 credits)
Prerequisite: ENGR 243, 311. Aerodynamic loading of elastic airfoils. Phenomenon of divergence. Effect of flexible control surface on divergence of main structure. Divergence of one- and two-dimensional wing models. Phenomenon of flutter. Flutter of two- and three-dimensional wings. Flutter prevention and control. Panel flutter in high speed vehicles, flutter of turbomachine bladings, galloping vortex-induced oscillations, bridge buffeting. Lectures: three hours per week.
NOTE: Students who have received credit for MECH 431 may not take this course for credit.

AERO 444 ***Concurrent Engineering in Aerospace Systems*** (3 credits)
Prerequisite: AERO 390. Introduction: objectives, definitions, impact on product development; process modelling and optimization; forming of engineering team; selection of techniques, methodology and tools; market design focus vs. quality design focus; development time management; process integration; aerospace case studies/projects, future trends. Lectures: three hours per week.

AERO 446 ***Aerospace Vehicle Performance*** (3 credits)
Prerequisite: AERO 464. Introduction to fixed-wing aircraft operation. Flying environment and its measurement by aircraft instrumentation. Computation of lift and drag, effects of viscosity and compressibility. Review of piston, turboprop, turbojet and turbofan power plants. Operational performance of aircraft in climb, cruise, descent and on ground. Advanced aircraft systems. Operational considerations in aircraft design. Projects on selected topics. Lectures: three hours per week. Tutorial: one hour per week.

AERO 455 ***Computational Fluid Dynamics for Aerospace Applications*** (3.75 credits)
Prerequisite: ENGR 311, 391; MECH 361. Introduction to computational methods in fluid dynamics using commercial CFD codes; aspects of geometry modelling, structured and unstructured grid generation, solution strategy, and post-processing; conversion of CAD to CFD models; an overview of basic numerical methods for the Navier-Stokes equations with emphasis on accuracy evaluation and efficiency. Elements of turbulence closure modelling. User-defined function for customized physical models into commercial CFD codes. Lectures: three hours per week. Laboratory: three hours per week, alternate weeks.

AERO 462 ***Turbomachinery and Propulsion*** (3 credits)
Prerequisite: MECH 351, 361. Aircraft design process, preliminary sizing and thrust requirements. Rotary and fixed wing aerodynamics and stability. Helicopter configurations. Structure and fatigue design considerations. Review of the gas turbine cycle and components arrangement. Turbo-propulsion: turboprop, turbofan, turbojet and turboshafts. Energy transfer in turbomachines: Euler equation, velocity triangles. Dimensional analysis of turbomachines. Flow in turbomachines. Three-dimensional flow in turbomachines. Mechanisms of losses in turbomachines. Axial-flow turbines and compressors. Centrifugal compressors. Compressor and turbine performance maps; surge and stall. Lectures: three hours per week. Tutorial: one hour per week.
NOTE: Students who have received credit for MECH 462 may not take this course for credit.

AERO 464 ***Aerodynamics*** (3 credits)
Prerequisite: MECH 361. Flow conservation equations, incompressible Navier-Stokes equations, inviscid irrotational and rotational flows: the Euler equations, the potential and stream function equations. Dynamics of an incompressible inviscid flow field: the Kelvin, Stokes, and Helmholtz theorems. Elementary flows and their superposition, panel method for non-lifting bodies. Airfoil and wing characteristics, aerodynamic forces and moments coefficients. Incompressible flows around thin airfoils, Biot-Savart law, vortex sheets. Incompressible flow around thick airfoils, the panel method for lifting bodies. Incompressible flow around wings, Prandtl's lifting line theory, induced angle and down-wash, unswept wings, swept wings. Compressible subsonic flow: linearized theory, Prandlt-Glauert equation and other compressibility correction rules, the area rule. Transonic flow: Von Karman's ransonic small disturbance equation, transonic full potential equation, super-critical airfoils. Lectures: three hours per week. Tutorial: one hour per week.
NOTE: Students who have received credit for MECH 464 may not take this course for credit.

AERO 465 ***Gas Turbine Design*** (3.5 credits)
Prerequisite: AERO 462. Review of turbo-propulsion types and energy transfer in turbomachines. Two- and three-dimensional flow. Lift and drag for airfoils. Cascade tests and correlations. Aerodynamic losses: physics, mechanisms, control of viscous effects. Preliminary and detailed design of turbines and compressors. Structural and thermal design requirements. Failure considerations: creep, fatigue and corrosion. Performance matching. Combustion and gearbox design. Air and oil systems design requirements. Installations and acoustics. Evolution of design. Recent trends in technologies. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.
NOTE: Students who have received credit for MECH 465 may not take this course for credit.

AERO 480 ***Flight Control Systems*** (3.5 credits)
Prerequisite: AERO 371 or ELEC 372 or MECH 371 or SOEN 385. Basic flight control and flight dynamics principles. Aircraft dynamic equations and performance data. Implementation of aircraft control: control surfaces and their operations, development of thrust and its control; autopilot systems, their algorithms, dynamics and interaction problems. Flight instruments, principles of operation and dynamics. Cockpit layouts — basic configuration, ergonomic design, control field forces; advanced concepts in instruments, avionics and displays; HUD; flight management systems, and communication equipment. Introduction to flight simulation: overview of visual, audio and motion simulator systems; advanced concepts in flight simulators. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.
NOTE: Students who have received credit for ELEC 415 or MECH 480 may not take this course for credit.

AERO 481 ***Materials Engineering for Aerospace*** (3.5 credits)
Prerequisite: MECH 221. Different types of materials used in aerospace. Metals, composites, ceramics, polymers. Failure prediction and prevention. Modes of material failure, fracture, fatigue, creep, corrosion, impact. Effect of high temperature and multiaxial loadings. High temperature materials. Cumulative damage in fatigue and creep. Materials selection. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.
NOTE: Students who have received credit for MECH 321 or 481 may not take this course for credit.

AERO 482 ***Avionic Navigation Systems*** (3 credits)
Prerequisite: ENGR 371 or COMP 233; AERO 371 or ELEC 372 or MECH 370 or SOEN 385. Basics of modern electronic navigation systems, history of air navigation, earth coordinate and mapping systems; basic theory and analysis of modern electronic navigation instrumentation, communication and radar systems, approach aids, airborne systems, transmitters and antenna coverage; noise and losses, target detection, digital processing, display systems and technology; demonstration of avionic systems using flight simulator. Lectures: three hours per week. Tutorial: one hour per week.
NOTE: Students who have received credit for ELEC 416 or MECH 482 may not take this course for credit.

AERO 483 ***Integration of Avionics Systems*** (3 credits)
Prerequisite: AERO 482. Introduction to the basic principles of integration of avionics systems; review of Earth's geometry and Newton's laws; inertial navigation sensors and systems (INS); errors and uncertainty in navigation; Global Positioning System (GPS); differential and carrier tracking GPS applications; terrestrial radio navigation systems; Kalman filtering; integration of navigation systems using Kalman filtering; integration of GPS and INS using Kalman filtering. Lectures: three hours per week.
NOTE: Students who have received credit for ENGR 418 may not take this course for credit.

AERO 485 ***Introduction to Space Systems*** (3 credits)
Prerequisite: MECH 351, 361. Classification of space propulsion systems; Tsiolkovskj's equation; ideal rocket and nozzle design; flight performance; basic orbital mechanics; chemical propellant rocket performance analysis; fundamentals of liquid and solid propellant rocket motors; electric, solar, fusion thruster. Lectures: three hours per week.
NOTE: Students who have received credit for MECH 485 or for this topic under a MECH 498 number may not take this course for credit.

AERO 486 ***Aircraft Stress Analysis*** (3 credits)
Prerequisite: ENGR 243, 244. Definition of load paths in typical aircraft structures. Derivation of analysis procedures to enable the designer to size preliminary designs. Internal shear flow distributions that balance external loads. Stress analysis of open and closed cell beams; statically indeterminate beams and frames; single and multi cell torque boxes; symmetric heavy fuselage frames. Structural instability of columns, beams, plates and flanges in compression and shear. Centres of twist and flexure; structural warping; margins of safety; concepts of optimum design; lug analysis and mechanical joints; matrix analysis methods leading to the Finite Element method. Stress analysis of thin-walled metallic structures. Lectures: three hours per week.
NOTE: Students who have received credit for MECH 486 may not take this course for credit.

AERO 487 ***Design of Aircraft Structures*** (3 credits)
Prerequisite: AERO 486. Design process for aircraft structures. Aero/performance aspects of aircraft structures. Airworthiness and design considerations. Materials. Static, vibratory and aeroelastic loadings. Propulsion-induced loadings. Functions and fabrication of structural components. Design for buckling of aircraft structures: local buckling, instability of stiffened panels, flexural torsional buckling. Design for fracture and fatigue failures. Stress analysis and design of wings, fuselages, stringers, fuselage frames, wing ribs, cut-outs in wings and fuselages, and laminated structures. Design using Finite Element Method. Concept of Optimum Design of Aircraft Structures. Design case studies. Lectures: three hours per week.
NOTE: Students who have received credit for MECH 487 may not take this course for credit.

AERO 490 ***Capstone Aerospace Engineering Design Project*** (4 credits)
Prerequisite: 75 credits in the program; AERO 390; ENCS 282; ENGR 301. A supervised design, simulation or experimental capstone design project including a preliminary project proposal with complete project plan and a technical report at the end of the fall term; a final report by the group and presentation at the end of the winter term. Lectures: one hour per week, one term. Equivalent laboratory time: three hours per week, two terms.
NOTE: Students will work in groups under direct supervision of a faculty member.
NOTE: Students who have received credit for COEN 490 or ELEC 490 or MECH 490 may not take this course for credit.

BUILDING, CIVIL AND ENVIRONMENTAL ENGINEERING

BCEE 231 ***Structured Programming and Applications for Building and Civil Engineers*** (3 credits)
Prerequisite: MATH 204; ENGR 242 previously or concurrently. Elements of procedural programming: variables, primitive data types, scope, operators and expressions, control structures, functions, derived data types and basic data structures. Program structure and development: specifications, analysis of requirements, flow charting, incremental development, testing, validation and program documenting. Application of procedural programming, graphics and numerical tool box to mathematics and building, civil and environmental engineering. Lectures: three hours per week. Tutorial: two hours per week.

BCEE 342 ***Structural Analysis I*** (3 credits)
Prerequisite: ENGR 244. Analysis of statically determinate structures: deflections, strain energy concepts, virtual work principles. Mueller Breslau principle, influence lines. Approximate methods for statically indeterminate structures. Collapse load analysis. Cables and Arches. Computer applications. Lectures: three hours per week. Tutorial: two hours per week.

BCEE 343 ***Structural Analysis II*** (3 credits)
Prerequisite: BCEE 342. Analysis of statically indeterminate structures: the methods of consistent deformations, slope deflection, and moment distribution. Application of virtual work principles. Introduction to matrix methods. Computer applications. Lectures: three hours per week. Tutorial: one hour per week.

BCEE 344 ***Structural Design I*** (3 credits)
Prerequisite: BCEE 342. Basis for limit states design. Code requirements. Structural steel design: tension and compression members, beams and beam-columns. Connections. Introduction to the design of timber members. Lectures: three hours per week. Tutorial: two hours per week.

BCEE 345 ***Structural Design II*** (3 credits)
Prerequisite: BCEE 342. Behaviour of reinforced concrete elements in flexure, compression, shear and bond. Limit states design of reinforced concrete beams, one-way slabs, columns, and footings. Serviceability limits states. Introduction to prestressed concrete and masonry structures. Design examples. Lectures: three hours per week. Tutorial: two hours per week.

BCEE 371 ***Surveying*** (3 credits)
Prerequisite: BLDG 212 or CIVI 212. Elementary operations employed in engineering surveying; use, care, and adjustment of instruments; linear and angular measurements; traversing; earthwork calculations; theory of errors; horizontal and vertical curves and curve layout; slope stakes and grades, application of surveying methods to city, topographic surveying, and introduction to advanced surveying techniques; use of digital computers in surveying calculations. Summer school taken before entering second year of study in the BEng program. Lectures and fieldwork: eight hours per day; six days per week for three weeks.

BCEE 451 ***Construction Engineering*** (3 credits)
Prerequisite: BLDG 341 or CIVI 341. The nature of construction and the environment in which the industry works; organizational structures for project delivery; construction contracts and documents; introduction to construction processes: excavation and site works, foundation layout, concrete form design, concrete, steel, timber, and masonry construction; project planning, scheduling, and control; construction safety. Lectures: three hours per week.

BCEE 452 ***Matrix Analysis of Structures*** (3 credits)
Prerequisite: ENGR 213, 233; BCEE 343. Classical and matrix methods of structural analysis; influence coefficients, transformation matrices. Matrix formulation of the force and of the displacement methods of analysis. Direct stiffness approach; sub-structure technique. Introduction to finite-element method. Computer applications. Lectures: three hours per week.

BCEE 455 ***Introduction to Structural Dynamics*** (3 credits)
Prerequisite: ENGR 243, 391; BCEE 342. Theory of vibration. Dynamic response of simple structural systems. Effects of blast, wind, traffic, and machinery vibrations. Basic concepts in earthquake resistant design. Computer applications. Lectures: three hours per week.

BCEE 464 ***Project Cost Estimating*** (3 credits)
Prerequisite: ENGR 301. Techniques and procedures used for estimating cost of construction projects. Cost estimation process; elements of project cost; conceptual and detailed cost estimation methods; risk assessment and range estimating; case studies; computer-aided estimating.

BCEE 465 ***Construction Planning and Control*** (3 credits)
Prerequisite: BLDG 478. Methods of delivering construction. Contractual relationships and organizational structures. Phases of project development. Estimating resource requirements; costs and durations. Bidding strategies. Network analysis using CPM

and PERT, time-cost trade-off, resource allocation. Cash flow analysis. Earned-value concept for integrated time and cost control. Quality control. Value engineering. Lectures: three hours per week.

BCEE 466 ***Simulations and Design of Construction Operations*** (3 credits)
Prerequisite: BCEE 451. Principles of modelling and simulation. Classification and validation of simulation models. Analysis of input data and outputs. Object Oriented Simulation (OOS). Simulation languages. Application of discrete event simulation in construction operations including earthmoving operations, building construction operations, and tunnelling operations.

BUILDING ENGINEERING

BLDG 212 ***Building Engineering Drawing and Introduction to Design*** (3 credits)
Fundamentals of technical drawing, dimensioning practices, orthographic projections, auxiliary and sectional views of buildings. Theory and applications of descriptive geometry in building design. Computer-aided building drawing. Building sub-systems and related graphics standards; architectural and building engineering drawing at preliminary and final stages. Introduction to the design of light-frame buildings. Project: representation of a building and its sub-systems. Introduction to conceptual design. Lectures: three hours per week. Tutorial: two hours per week.

BLDG 341 ***Building Engineering Systems*** (3 credits)
Prerequisite: BCEE 231 previously or concurrently. Introduction to systematic solution of building engineering problems. Techniques treated include linear programming, network analysis, nonlinear programming. Introduction to decision analysis and simulation. Application of optimization methods for solution of design problems in building science, building environment, building structures, and construction management, taking into account sustainability issues. Lectures: three hours per week.

BLDG 365 ***Building Science*** (3.5 credits)
Prerequisite: ENGR 251. General introduction to the thermal environment and sustainable development issues. Topics include heat, temperature, one-dimensional steady-state processes. Convection: natural and forced. Radiation. Combined radiative and convective surface transfer. Psychrometrics. Thermal comfort. Air quality. Condensation: surface and interstitial. Introduction to compressible viscous flow, friction, and flow in pipes; boundary layer and wind effects. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.

BLDG 366 ***Acoustics and Lighting*** (3.5 credits)
Prerequisite: ENGR 243. General introduction to the aural and visual environment. Psychological impact of environment. Subjective and objective scales of measurement. Introduction to vibration. The hearing mechanism. Transmission of sound, passive control of noise in buildings, transmission loss, absorption and reverberation time. Room acoustic assessment. Active control of the aural environment. Visual perception. Photometry, brightness, luminance, and illumination. Concept of natural lighting in building. Artificial lighting; light sources; luminaries. Calorimetry. Calculation methods for artificial lighting. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.

BLDG 371 ***Building Service Systems*** (3.5 credits)
Prerequisite: BLDG 365 previously or concurrently. Principles of building service systems, including electrical, gas, communications, service-water supply and distribution; introduction to plans, codes, and standards for utility distribution systems. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

BLDG 390 ***Building Engineering Design Project*** (3.5 credits)
Prerequisite: BLDG 341; ENCS 282; BCEE 344 previously or concurrently. The project of each team will encompass the conceptual and preliminary design of a new medium-size building. Students learn building engineering design process, methodology, identification of objectives, building codes, formulation of design problems. Development and evaluation of sustainable building design alternatives. Conceptual building design: spatial requirements, design of space layout. Preliminary building design: synthesis and design of structures, enclosure systems, and services (HVAC, lighting, electrical distribution) using computer-aided design tools. Performance evaluation using modelling, sensitivity analysis and cost estimation. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

BLDG 462 ***Modern Building Materials*** (3 credits)
Prerequisite: CIVI 321. Engineering properties of building materials such as: plastics, synthetic fibres, adhesives, sealants, caulking compounds, foams, sandwich panels, composites, polymer concrete systems, fibre-reinforced concretes, plastic mortars, polymers for flooring, roofing, synthetic wall papers. Their structural, thermal, and acoustical properties. Consideration of corrosion, bio- and thermal-degradation, stability to ultraviolet and solar radiation. Laboratory sessions to illustrate synthesis, application, testing, deterioration, and protection. Lectures: three hours per week.

BLDG 463 ***Building Envelope Design*** (3 credits)
Prerequisite: BLDG 365; CIVI 321. Technical influences in the design of building envelope, including the control of heat flow, air and moisture penetration, building movements, and deterioration. Application of air/vapour barrier and rain-screen systems. Performance assessment and building codes through case studies and design projects. Sustainable design principles. Design of walls, roofs, joints and assemblies. Cause of deterioration and preventive measures, on-site investigation. Relevant building codes and standards. Lectures: three hours per week.

BLDG 465 ***Fire and Smoke Control in Buildings*** (3 credits)
Prerequisite: BLDG 365. Topics treated include fire and smoke control; failure mechanisms of building enclosure illustrated by case studies; code requirements for enclosure systems; systems approach for fire safety. Lectures: three hours per week.

BLDG 471 ***HVAC System Design*** (4 credits)
Prerequisite: BLDG 371; BLDG 476 previously or concurrently. Principles of HVAC system design and analysis; sustainable design issues and impact on environment; component and system selection criteria including room air distribution, fans and air circulation, humidifying and dehumidifying processes, piping and ducting design. Air quality standards. Control systems and techniques; operational economics; computer applications. Lectures: three hours per week. Laboratory: two hours per week.

BLDG 472 ***Building Energy Conservation Technologies*** (3 credits)
Prerequisite: BLDG 471 previously or concurrently. Standards of energy efficiency in buildings.Trends in energy consumption. Energy audit: evaluation of energy performance of existing buildings, weather normalization methods, measurements, disaggregation of total energy consumption, use of computer models, impact of people behaviour. Energy efficiency measures in buildings: approaches, materials and equipments, operating strategies, evaluation methods of energy savings. Renewable energy sources: passive or active solar systems, geothermal systems, free-cooling. Optimum selection of energy sources. Impact of emerging technologies. Case studies. Lectures: three hours per week.

BLDG 473 ***Building Acoustics*** (3 credits)
Prerequisite: BLDG 366. Noise control criteria and regulations, instrumentation, noise sources, room acoustics, walls, barriers and enclosures, acoustical materials and structures, vibration and noise control systems for buildings. Lectures: three hours per week.

BLDG 474 ***Building Illumination and Daylighting*** (3 credits)
Prerequisite: BLDG 366. Production, measurement and control of light. Photometric quantities, visual perception and colour theory. Daylight and artificial illumination systems. Radiative transfer, fixture and lamp characteristics, control devices and energy conservation techniques. Design of lighting systems. Solar energy utilization and daylighting. Integration of lighting systems with mechanical systems for energy conservation and sustainable development. Lectures: three hours per week.

BLDG 475 ***Indoor Air Quality*** (3 credits)
Prerequisite: BLDG 371 previously or concurrently. Elements of indoor air quality, physical/ chemical characteristics of contaminants, health effects, standard requirements. Estimation of the levels of indoor air contaminants in buildings. Design of ventilation systems for pollutant control. Air pollution due to outdoor air supply through ventilation systems. Effect of outdoor air pollution on indoor air quality. Lectures: three hours per week.

BLDG 476 ***Thermal Analysis of Buildings*** (3 credits)
Prerequisite: BLDG 365; ENGR 361. Two- and three-dimensional steady-state and transient conductive heat transfer together with convection and radiation as applied to building materials and geometries. Heating and cooling load analysis, including building shapes, construction type, solar radiation, infiltration, occupancy effects, and daily load variations. Computer applications for thermal load analysis. Introduction to heat exchangers. Lectures: three hours per week. Tutorial: one hour per week.

BLDG 477 ***Control Systems in Buildings*** (3 credits)
Prerequisite: BLDG 371 previously or concurrently. Introduction to automatic control systems. Control issues related to energy conservation, indoor air quality and thermal comfort in buildings. Classification of HVAC control systems. Control system hardware: selection and sizing of sensors, actuators and controllers. Practical HVAC control systems; elementary local loop and complete control systems. Designing and tuning of controllers. Building automation systems. Case studies. Lectures: three hours per week.

BLDG 478 ***Project Management for Construction*** (3 credits)
Prerequisite: BLDG 341 or CIVI 341. Introduction to project management techniques in construction, including project delivery methods, construction contracts, cost estimating and bidding planning and scheduling, cash flow analysis, project tracking and control, computer applications. Lectures: three hours per week.

BLDG 482 ***Impact of Technology on Society and Architecture*** (3 credits)
Prerequisite: 20 courses in the BEng program. History of architecture as the confluence of social and technological evolution. Methodology and thought processes in the theory and design of cities and the human habitat. Impact of technology on society. Energy conservation, environmental constraints and sustainability issues. Lectures: three hours per week.

BLDG 490 ***Capstone Building Engineering Design Project*** (4 credits)
Prerequisite: Minimum of 75 credits in the BEng (Bldg) program including ENCS 282; BCEE 344, 345; BLDG 371, 390; ENGR 301. The project of each team will encompass the integrated design of at least three sub-systems of a new or retro-fitted building to achieve high performance and efficiency at reasonable cost; sustainable design issues and environmental impact be addressed in all projects. In the process, students learn, through case studies and literature survey, the information gathering and decision/design process, problem-resolution as well as aspects related to management, teamwork and communication. Students registering for this course must contact the course coordinator for the detailed procedure. Lectures: two hours per week, two terms.

BLDG 491 ***Labour and Industrial Relations in Construction*** (3 credits)
Prerequisite: ENGR 301. The study of labour legislation with special emphasis on the construction industry, union organization, the theory and practice of negotiations, mediation, contract administration, and arbitration. Review of actual contracts, discussion of future trends. Lectures: three hours per week.

BLDG 492 ***Construction Processes*** (3 credits)
Prerequisite: BCEE 451 or ENGR 451. A study of current construction methods and techniques. The subjects include site preparation and earth-work, wood framing, masonry, concrete forming, slip forming, precast construction, industrialized building, deep excavation shoring and underpinning. Design, erection, and removal of temporary construction work. Current field practice and safety considerations. Site visits. Lectures: three hours per week.

BLDG 493 ***Legal Issues in Construction*** (3 credits)
Prerequisite: ENGR 301. Legal concepts and processes applicable to the development of constructed facilities and to the operation of the construction firm. Emphasis on Quebec law and institutions. Lectures: three hours per week.

BLDG 498 ***Topics in Building Engineering*** (3 credits)
Prerequisite: Permission of the Department. This course may be offered in a given year upon the authorization of the Department. The course content may vary from offering to offering and will be chosen to complement the available elective courses. Lectures: three hours per week.

CIVIL ENGINEERING

CIVI 212 ***Civil Engineering Drawing and Introduction to Design*** (3 credits)
Fundamentals of technical drawing, orthographic projections, sectional views. Computer-aided drawing; slabs, beams, and columns; steel structures; building trusses and bridges, wood and masonry structures. Working drawing and dimensioning practice. Introduction to the design process. Lectures: three hours per week. Tutorial: two hours per week.

CIVI 231 ***Geology for Civil Engineers*** (3 credits)
Basic principles of physical and structural geology with emphasis on topics related to civil engineering, study of minerals, rocks and soil types, load formation, techniques of air-photo interpretations, and geological mapping. Geological site investigation. Preparation and interpretation of engineering geology reports. Lectures: three hours per week. Tutorial: one hour per week.

CIVI 321 ***Engineering Materials*** (3.75 credits)
Prerequisite: CHEM 205 or equivalent. Linear and nonlinear material behaviour, time-dependent behaviour; structural and engineering properties of structural metals; behaviour of wood; production and properties of concrete; bituminous materials, ceramics, plastics; introduction to composite materials. Lectures: three hours per week. Laboratory: three hours per week, alternate weeks.

CIVI 341 ***Civil Engineering Systems*** (3 credits)
Prerequisite: BCEE 231 previously or concurrently. Development of concepts and techniques commonly associated with systems engineering which are applicable to design and operation of systems that concern civil engineers. Design and planning process; problem formulation, optimization concepts, linear programming, decision analysis; system simulation; network planning and project scheduling; computer applications. The techniques developed are used to solve problems in transportation, water resources, structures, and construction management. Lectures: three hours per week.

CIVI 361 ***Introduction to Environmental Engineering*** (3.5 credits)
Prerequisite: ENGR 361. Ecosystems considerations, food chain, natural decomposition, and recycling; environmental problems and impact of engineering activities. Various modes of pollution, water, air, and soil contamination, noise pollution; pollution measurement and quantification. Water and waste-water physical, chemical and biological characteristics; turbidity and colour, dissolved oxygen, hardness, pH, alkalinity, organic content, sampling and analysis, chemical and biochemical oxygen demand. Basic processes of treatment: flocculation and coagulation, sedimentation, filtration. Lectures: three hours per week. Tutorial: two hours per week, alternate weeks. Laboratory: two hours per week, alternate weeks.

CIVI 372 ***Transportation Engineering*** (3 credits)
Prerequisite: BCEE 371; CIVI 341. Fields of transportation engineering; transportation's roles in society; planning and design of road, rail, air, and water-way system components: terminals, right-of-way; control systems: evaluation of alternative modes and decision-making process; introduction to computer-aided design and management of systems. Lectures: three hours per week. Tutorial: one hour per week.

CIVI 381 ***Hydraulics*** (3.5 credits)
Prerequisite: ENGR 361, 391. Basic hydrodynamics; boundary layer theory, principle of energy losses. Steady flow in open channel; uniform flow, specific energy and critical flow, transition; gradually varied flow in channels and conduits, water surface profiles, computer applications. Flow measurement in open channel, weirs, overflow spillways. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.

CIVI 382 ***Water Resources Engineering*** (3.5 credits)
Prerequisite: CIVI 381; ENGR 391 or EMAT 391. Sources of water: surface water, groundwater, water quantities and requirements. Water use cycle. Characteristics of water and wastewater. Demand forecast, water use prediction and planning. Groundwater withdrawal and well hydraulics. Water supply network analysis, design of distribution systems, storage, pumping. Sanitary and storm water quantities, urban hydrology. Design of sewer systems, interceptors, gravity sewer, computer applications. Sustainable use of water resources. Design case studies. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.

CIVI 390 ***Civil Engineering Design Project*** (3.5 credits)
Prerequisite: CIVI 361; ENCS 282; BCEE 344 previously or concurrently. The project of each team will encompass the conceptual and preliminary design of a medium-size civil engineering project. Students learn civil engineering design process, methodology, identification of objectives, codes, formulation of design problems. Development and evaluation of sustainable design alternatives. Computer-aided design tools. Performance evaluation using modelling, sensitivity analysis, and cost estimation. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

CIVI 432 ***Soil Mechanics*** (3.5 credits)
Prerequisite: ENGR 244. Index properties and classification of soils. Weight-volume relationships. Soil structures. Moisture-density relationships. Permeability, deformation, and strength of soils. Principle of total and effective stresses. Steady stage seepage through isotropic soil media. Stress distribution due to external loads and analysis of total settlements. Outline of theory of consolidation. Fundamentals of stability of earth retaining walls, slopes, and footings. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.

CIVI 435 ***Foundation Design*** (3 credits)
Prerequisite: CIVI 432. Site investigation. Shallow and deep foundations. Bearing capacity and settlement of foundations. Earth-retaining structures, sheet piles, cofferdams, anchors. Foundations subjected to dynamic loading. Foundations on difficult soils, soil improvement and underpinning. Lectures: three hours per week. Tutorial: two hours per week.

CIVI 437 ***Advanced Geotechnical Engineering*** (3 credits)
Prerequisite: CIVI 432. Mechanical properties of rocks and rock formations. Underground openings in rocks. Slope stability of stratified formations. Foundations on rocks. Rock bolting. Introduction of soil dynamics. Wave propagation in one and two dimensions in elastic media. Seismic waves. Foundations subjected to dynamic loading. Theory of liquefaction. Lectures: three hours per week.

CIVI 440 ***Computer Applications in Civil Engineering Practice*** (3 credits)
Prerequisite: BCEE 231; 75 credits in the program. General purpose IT tools for civil engineering applications: database programming and web-based tools. Introduction to remote sensing and GIS. Application of major software packages in selected areas of civil engineering practice with emphasis on modelling, data integration, and work-flow. Case studies in structural design, geotechnical engineering, transportation, and environmental engineering. Lectures: two hours per week. Laboratory: two hours per week.

CIVI 453 ***Design of Reinforced Concrete Structures*** (3.5 credits)
Prerequisite: BCEE 342, 345. Two-way slab systems: flat plate, flat slab and slab-on-beams. Slender columns; columns subjected to biaxial bending. Calculation of lateral loads: wind and seismic. Lateral loads resisting systems: moment-resisting frames, shear walls and coupled shear walls. Prestressed concrete: losses, design requirements for flexure, shear, bond, anchorage and deflections. Design project. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.

CIVI 454 ***Design of Steel Structures*** (3.5 credits)
Prerequisite: BCEE 342, 344. Trends and developments in structural-steel design. Framing systems. Floor systems; composite construction; plate girders. Braced frames; moment-resisting frames. Connections. P-Delta effects. Introduction to steel-bridge design. Design project. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.

CIVI 464 ***Environmental Impact Assessment*** (3 credits)
Prerequisite: CIVI 361. Engineering activities and the environment; environmental ethics. Prediction and estimation of impact on air, water, soil quality, and biological, socio-economic, cultural environments. Water and air pollution laws, solid and hazardous waste laws. Environmental inventories, assessment preparation, and review. Federal and provincial laws and regulations on environmental assessment. Strategies for environmental compliance, resolution of environmental conflicts. Case studies. Lectures: three hours per week.

CIVI 465 ***Water Pollution and Control*** (3.5 credits)
Prerequisite: CIVI 361. Physical, chemical, and biological characteristics of water, water quality standards, reaction kinetics and material balances, eutrophication. Containment of reactive contaminants. Natural purification processes in water systems, adsorption, absorption; diffusion and dispersion, oxidation. Large-scale transport of contaminants, single and multiple source models; modelling of transport processes, computer simulation. Introduction to ground-water pollution, sea-water intrusion. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

CIVI 466 ***Engineering Aspects of Chemical and Biological Processes*** (3 credits)
Prerequisite: CIVI 361. Introduction to water purification, chemical treatment, coagulation, disinfection, special purification methods. Primary and secondary waste-water treatment, solution and surface chemistry, microbiological consideration; reaction kinetics, diffusion processes, membrane processes, re-aeration. Biological treatment, activated sludge process, treatment and disposal; biological reactors; aerated lagoons; trickling filter; biological nutrient removal. Tertiary waste-water treatment. Lectures: three hours per week.

CIVI 467 ***Air Pollution and Emission Control*** (3 credits)
Prerequisite: CIVI 361. Types of air pollutants. Sources of air pollutants, effects of air pollutants on health, vegetation, materials, and the atmosphere; emission standards. Meteorological considerations, dispersion of pollutants in the atmosphere, distribution

and cleansing of particle matter, atmospheric photochemical reactions. Particulate pollutant control, source correction, cooling treatment; control of gaseous pollutant, point sources, odour control; measurement techniques; computer applications. Lectures: three hours per week.

CIVI 468 ***Waste Management*** (3 credits)
Prerequisite: CIVI 361. Solid waste; source and generation, sampling and analysis, collection, transport, and storage. Waste recycling, physical and chemical reduction; drying; energy recovery; disposal of solid waste. Sanitary and secure landfill planning, site selection, design and operation; chemical and biological reactions. Hazardous waste, chemical and physical characteristics, handling, processing, transportation, and disposal. Resource recovery alternatives, material exchanges, hazardous waste management facilities, incinerators, landfills. Lectures: three hours per week.

CIVI 469 ***Geo-Environmental Engineering*** (3.5 credits)
Prerequisite: CIVI 361. Structure and surface chemistry of soil, ion exchange, hydrolysis equilibrium, adsorption. Biochemical degradation, toxic contaminants. Mechanical and thermodynamic equilibrium in soil. Geotechnical considerations in environmental design; soil decontamination. Barrier technologies and soil interaction. Landfill covers and leachate collection systems; subsurface investigation, soil-gas survey. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

CIVI 471 ***Highway and Pavement Design*** (3 credits)
Prerequisite: BCEE 371; CIVI 372. Design criteria, including capacity and level of service; route alignment and right-of-way considerations; geometric design; earthworks and construction practices. Pavement materials and tests. Flexible and rigid pavement design procedures; subgrade, base, and surfacing characteristics; loads; stresses in pavement systems; material characterization; pavement response models; effects of natural forces, and construction practices. Pavement management. Computer applications. Geometric and pavement design projects. Lectures: three hours per week. Tutorial: two hours per week.

CIVI 474 ***Transportation Planning and Design*** (3 credits)
Prerequisite: CIVI 372. Transportation planning process; data collection and demand analysis; trip generation, trip distribution, modal split and route assignment; forecasting travel patterns. Design of transportation facilities: street sections, intersections, and parking areas. Computer applications and design projects. Lectures: three hours per week. Tutorial: two hours per week, alternate weeks.

CIVI 483 ***Hydrology*** (3 credits)
Prerequisite: CIVI 381. Weather elements; precipitation, stage-discharge relations; evapo-transpiration; ground-water flow; stream-flow hydrography, unit hydrography, synthetic hydrographs; laminar flow; hydrologic routing; instantaneous hydrograph; hydraulic routing, method of characteristics, kinematic routing; statistical analysis, confidence intervals, stochastic generator, autoregressive model; applications of hydrology. Lectures: three hours per week. Tutorial: two hours per week.

CIVI 484 ***Hydraulic Engineering*** (3.5 credits)
Prerequisite: CIVI 381. Development of surface water resource; basic measurements in hydraulic engineering; storage reservoirs; practical problems; run-off characteristics of natural steams; probabilistic models; control structures; economic analysis; production function; project optimization; energy dissipators; sediment transportation; elements of river engineering; navigation; control of floods; computer modelling application. Design examples. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.

CIVI 490 ***Capstone Civil Engineering Design Project*** (4 credits)
Prerequisite: Minimum of 75 credits in BEng (Civil) including ENGR 301; CIVI 361, 390; BCEE 344, 345. The project of each team will encompass the integrated design of at least two sub-disciplines of civil engineering to achieve high performance at reasonable cost. Through case studies and literature survey, students learn the information gathering and decision/design process, problem resolution, and aspects related to management, teamwork, and communication. Students registering for this course must contact the course coordinator for the detailed procedure. Lectures: two hours per week, two terms.
NOTE: Students will work in groups under direct supervision of a faculty member.

CIVI 498 ***Topics in Civil Engineering*** (3 credits)
Prerequisite: Permission of the Department. This course may be offered in a given year upon the recommendation of the Department and approval of ENCS Council. The course content may vary from offering to offering and will be chosen to complement the available elective courses. Lectures: three hours per week.

COMPUTER ENGINEERING

COEN 212 ***Digital Systems Design I*** (3.5 credits)
Prerequisite: COEN 231. Logic gates and their use in the realization of Boolean algebra statements; logic minimization, multiple output circuits. Designing with MSI and LSI chips, decoders, multiplexers, adders, multipliers, programmable logic devices. Introduction to sequential circuits; flip-flops. Completely specified sequential machines. Machine equivalence and minimization. Implementation of clock mode sequential circuits. Lectures: three hours per week. Tutorial: two hours per week. Laboratory: 15 hours total.
NOTE: Students who have received credit for COEN 312 may not take this course for credit.

COEN 231 ***Introduction to Discrete Mathematics*** (3 credits)
Prerequisite: MATH 204 (Cegep Mathematics 105). Fundamental principles of counting: rules of sum and product; permutations, arrangements and combinations, the binomial theorem; combinations with repetition; distributions. Fundamentals of logic: basic

connectives and truth tables; logical equivalence; the laws of logic; logical implication; rules of inference; the use of quantifiers; proofs of theorems. Sets: the laws of set theory. Boolean algebra. Relation of Boolean algebra to logical and set theoretic operations. Modulo arithmetic: representations of numbers in binary, octal and hexadecimal formats; binary arithmetic. Induction and recursion: induction on natural numbers; recursive definitions. Functions and relations: cartesian products and relations; functions; function composition and inverse functions; computational complexity. Elements of graph theory: basic definitions of graph theory; paths, reachability and connectedness; computing paths from their matrix representation; traversing graphs represented as adjacency lists; trees and spanning trees. Lectures: three hours per week. Tutorial: one hour per week.

COEN 243 ***Programming Methodology I*** (3 credits)
Prerequisite: COEN 231 previously or concurrently. Introduction to computer hardware and software, programming and programming paradigms; including low-level programming. Overview of procedural programming languages: key elements; reserved words and identifiers; data types and declarations; statements; arithmetic expressions; different modes of execution. Top-down modular design using functions (and native classes). Flow control using If-Else and Switch statements. Repetition using loops and recursive functions. Simple data types: native and user-defined. Static data structures: arrays and structures. Overview of object-oriented programming languages. User-defined classes. Class attributes and methods. Object creation, use and destruction. Pointers and an introduction to dynamic data structures. Introduction to streams and files. Lectures: three hours per week. Tutorial: two hours per week.
NOTE: Students who have received credit for COMP 248 may not take this course for credit.

COEN 244 ***Programming Methodology II*** (3 credits)
Prerequisite: COEN 243. Review of object-oriented programming and further concepts. More on classes. Revisiting pointers. Operator overloading: regular and advanced usage. Fundamentals of file and stream processing. Class composition and inheritance: regular and advanced usage. Virtual functions. Polymorphism. Static and dynamic binding. Abstract classes. Case study of a small-scale object-oriented project: simplified analysis, design, and implementation. Introduction to templates, the standard template library, and exception handling. Introduction to dynamic data types. Namespaces. Lectures: three hours per week. Tutorial: two hours per week.
NOTE: Students who have received credit for COMP 249 may not take this course for credit.

COEN 311 ***Computer Organization and Software*** (3.5 credits)
Prerequisite: COEN 212, 243, previously or concurrently. Introduction and terminology. Overview of the functional units and the operation of a computer. Machine programming fundamentals: instruction structure, addressing modes, the assembly process, examples of architectures. Case study of a microprocessor architecture: programming model, assembler and addressing modes, instruction set and formats; programming examples. Stacks, subroutines, macros, exceptions, interrupts. Program and interrupt driven I/O. Memory management. Introduction to system software: system kernel, system services, assemblers, compilers, linkers and loaders, user-level view of operating systems. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: 15 hours total.

COEN 313 ***Digital Systems Design II*** (3.5 credits)
Prerequisite: COEN 212. Two-level and multi-level logic optimization techniques. Hardware description languages (VHDL) for synthesis and simulation. Asynchronous design. Algorithmic state machines. Clocking and clock skew. Metastability. Self-timed concepts. Finite state machine (FSM) optimization. State reduction. FSM partitioning. Programmable logic devices and field programmable gate arrays. Data path and control design for processors. Testing issues. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: 15 hours total.

COEN 315 ***Digital Electronics*** (3.5 credits)
Prerequisite: ELEC 311. Analysis and simulation of basic digital circuit blocks, in particular, CMOS, BiCMOS and ECL technologies. The focus is on the electronics aspect of digital circuits. Combinational and sequential circuit units, including logic gates, flip-flops, signal generators, static and dynamic memories, and interconnections. Performance analysis in terms of switching speeds, power dissipation, noise immunity, fan-in and fan-out. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: 15 hours total.

COEN 316 ***Computer Architecture and Design*** (3 credits)
Prerequisite: COEN 212, 311. Review of basic computer architecture designs. Fundamentals of computer design and performance. Cost issues. Instruction set design principles. Memory hierarchies: registers, caches, and virtual memories. Basic processor implementation issues. High performance computing issues such as pipelining, superscalar, and vector processing. Input/output subsystem designs. Lectures: three hours per week. Tutorial: one hour per week.

COEN 317 ***Microprocessor Systems*** (4 credits)
Prerequisite: COEN 311 or COMP 228 or SOEN 228; COEN 212. Introduction to microprocessor interfacing. Bus functions, bus interconnections, synchronous and asynchronous bus. Signal flow and data transfer, decoding for I/O and memory, memory organization and structures. Interfacing examples; parallel interfacing, serial interfacing, the interrupt system; bus arbitration and DMA. Analog-to-digital and digital-to-analog structures and interfacing. Floppy disk and CRT controllers; bus standards; local area networks. Benchmarking and comparative study of recent microprocessors. Lectures: three hours per week. Laboratory: 30 hours total.
NOTE: Students who have received credit for COEN 417 may not take this course for credit.

COEN 320 ***Introduction to Real-Time Systems*** (3 credits)
Prerequisite: COEN 346 or COMP 346. Fundamentals of real-time systems: definitions, requirements, design issues and applications. Real-time operating systems (RTOS) feature: multi-tasking, process management, scheduling, interprocess communication

and synchronization, real-time memory management, clocks and timers, interrupt and exception handling, message queues, asynchronous input/output. Concurrent programming languages: design issues and examples, POSIX threads and semaphores. Introduction to real-time uniprocessor scheduling policies: static vs. dynamic, pre-emptive vs. non-pre-emptive, specific techniques — rate-monotonic algorithm, earliest-deadline-first, deadline monotonic, least-laxity-time-first; clock-driven scheduling. Design and specification techniques — Finite state machine based State-chart, Dataflow diagram, Petri nets. Reliability and fault-tolerance. Case studies of RTOS — QNX, VxWorks, and research prototypes. Lectures: three hours per week. Tutorial: one hour per week.

COEN 345 ***Software Testing and Validation*** (4 credits)
Prerequisite: SOEN 341. Overview of the three phases and deliverables of a project. Validation vs. verification, reviews, walkthrough. Testing: acceptance testing, integration testing, module testing. Writing stubs. Performance testing. Role of formal methods. Code inspection. Defect tracking. Causality analysis. Software Metrics and quality management. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: 30 hours total.

COEN 346 ***Operating Systems*** (4 credits)
Prerequisite: COEN 311; COMP 352 or COEN 352. The evolution, architecture, and use of modern operating systems (OS). Multi-tasking, concurrency and synchronization, IPC, deadlock, resource allocation, scheduling, multi-threaded programming, memory and storage managements, file systems, I/O techniques, buffering, protection and security, the client/server paradigm and communications. Introduction to real time operating systems. Students write substantial programs dealing with concurrency and synchronization in a multi-tasking environment. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: 30 hours total.
NOTE: Students who have received credit for COMP 346 may not take this course for credit.

COEN 352 ***Data Structures and Algorithms*** (3 credits)
Prerequisite: COEN 244. Mathematical introduction: mathematical induction, program analysis, and algorithm complexity. Fundamental data structures: lists, stacks, queues, and trees. Fundamental algorithms: hashing and sorting. Graph structures and algorithms. Overview of algorithm design techniques, including greedy algorithms, divide and conquer strategies, recursive and backtracking algorithms, and heuristics. Application of data structures and algorithms to engineering. Lectures: three hours per week. Tutorial: one hour per week.
NOTE: Students who have received credit for COMP 352 may not take this course for credit.

COEN 390 ***Computer Engineering Product Design Project*** (3 credits)
Prerequisite: Minimum of 45 credits in BEng (Computer); COEN 244, 311; ENGR 290, 301. The Product Design Project reinforces skills introduced in ENGR 290, which include teamwork, project management, engineering design for a complex problem, technical writing, and technical presentation in a team environment. It also introduces students to product development. Students are assigned to teams and each team develops, defines, designs and builds a system and/or device under broad constraints set by the Department. Students present their product definition and design, and demonstrate that their system/device works at the end of the term. Tutorial: two hours per week. Equivalent laboratory time: six hours per week.
NOTE: All written documentation must follow the Concordia Form and Style guide. Students are responsible for obtaining this document before beginning the project.

COEN 413 ***Hardware Functional Verification*** (3 credits)
Prerequisite: COEN 313. Review of hardware design languages. Introduction to functional verification. Design for verification. Writing test benches, simulation engines, and coverage metrics. Introduction to verification languages. Verification plan: strategies, test cases, test benches. Modelling verification environments. Modelling input relations, intervals, events. Introduction to formal verification tools. Lectures: three hours per week.

COEN 421 ***Embedded Systems and Software Design*** (4 credits)
Prerequisite: COEN 317, 320; SOEN 341. Introduction to real-time modelling languages. Introduction to embedded systems design using a unified view of software and hardware. Processor technologies: general purpose, single purpose, application-specific. Memory. Interfacing. Design technologies: hardware-software co-design/co-synthesis/co-simulation. Real-time debugging and monitoring techniques. Real-time communication protocols. Introduction to clock synchronization and group communication techniques. A multi-component project provides a hands-on experience in designing, implementing, and testing a real-time embedded system. Lectures: three hours per week. Laboratory: 30 hours total.

COEN 432 ***Applied Genetic and Evolutionary Systems*** (3 credits)
Prerequisite: COEN 352 or COMP 352. Motivation for the use of Genetic Algorithms (GAs). Theory: the Schema Theorem, the K-armed Bandit, the Building Block Hypothesis, the Idealized GA and comparison of GAs. Methodology: representation, fitness and selection, crossover and mutation, parameterization and constraints, implementation. Applications: function optimization, evolving computer programs, optimizing a pattern recognizer, system modelling. Identification of classes of problems suitable for the use of GAs. Lectures: three hours per week.

COEN 445 ***Communication Networks and Protocols*** (4 credits)
Prerequisite: COEN 346. Network topologies. Communications protocols basics. Local Area Networks (LANs). Wide Area Networks (WANs). Layered architecture standards (OSI and TCP/IP) and protocols. Internetworking. Lectures: three hours per week. Laboratory: 30 hours total.
NOTE: Students who have received credit for ELEC 463 may not take this course for credit.

COEN 451 ***VLSI Circuit Design*** (4 credits)
Prerequisite: COEN 212; ELEC 311. Analysis and design of electronic circuits using Very Large Scale Integration (VLSI) technologies. Physical design of MOS digital circuits. CMOS circuit schematic and layout. CMOS processing technology, design

rules and CAD issues. Physical layers and parasitic elements of CMOS circuits. Characterization and performance evaluation. Constraints on speed, power dissipation and silicon space consumption. Design and implementation of CMOS logic structures, interconnections and I/O structures. Circuit design project using a specified CMOS technology. Lectures: three hours per week. Laboratory: 30 hours total.

COEN 490 ***Capstone Computer Engineering Design Project*** (4 credits)
Prerequisite: Minimum of 75 credits in BEng (Computer) or permission of the Department; ENGR 371; COEN 352, 390; ELEC 311 or SOEN 341. Students are assigned to groups, and work together under faculty supervision to solve a complex interdisciplinary design problem — typically involving communications, control systems, electromagnetics, power electronics, software design, and/or hardware design. The project fosters teamwork between group members and allows students to develop their project management, technical writing, and technical presentation skills. Tutorial: one hour per week, two terms. Equivalent laboratory time: four hours per week, two terms.
NOTE: All written documentation must follow the Concordia Form and Style guide. Students are responsible for obtaining this document before beginning the project.

COEN 498 ***Topics in Computer Engineering*** (3 credits)
Prerequisite: Permission of the Department. The course, when offered, will include topics which complement elective courses in computer engineering and computer science. Lectures: three hours per week.

ELECTRICAL ENGINEERING

ELEC 251 ***Fundamentals of Applied Electromagnetics*** (3 credits)
Prerequisite: ELEC 273 or ENGR 273; ENGR 233 previously or concurrently. Electric charge, Coulomb's law, electrostatic forces, electric field, Gauss' law, electric potential, stored energy. Dielectrics, properties of materials in electric fields. Electric current, conduction in a vacuum and in material media, displacement current, magnetic field of a current, force on a current-carrying wire, magnetic induction, electromotive force, energy stored in a magnetic field. Magnetism in material media, magnetic circuits. Time-varying fields. Capacitance, resistance, inductance, elements of electric circuits. Lectures: three hours per week. Tutorial: one hour per week.

ELEC 264 ***Signals and Systems I*** (3 credits)
Prerequisite: ELEC 273; ENGR 213. Continuous-time and discrete-time signals and systems. Linear Time Invariant (LTI) systems. Convolution-sum and convolution-integral representation of systems. Causal LTI systems. Fourier series representation of continuous-time and discrete-time periodic signals. Filters described by differential or difference equations. The continuous-time Fourier transform. Systems based on linear constant-coefficient differential equations. The discrete-time Fourier transform. Systems based on linear constant-coefficient difference equations. Lectures: three hours per week. Tutorials: two hours per week.
NOTE: Students who have received credit for ELEC 361 may not take this course for credit.

ELEC 273 ***Basic Circuit Analysis*** (3.5 credits)
Prerequisite: ENGR 213 previously or concurrently; PHYS 205. Units: current, voltage, power, and energy. Elementary wave-forms. Time averages. Ohm's law. KVL and KCL. Ideal sources. Mesh and node analysis of resistive circuits. Network theorems. Inductors and capacitors and their response to the application of elementary waveforms. Transient response of simple circuits. Natural frequency and damping. Initial conditions. Steady state AC analysis: resonance, impedance, power factor. Introduction to three phase power, delta and Y connections. Ideal operational amplifiers. Ideal transformers. Lectures: three hours per week. Tutorial: two hours per week. Laboratory: 15 hours total.
NOTE: Students who have received credit for ENGR 273 may not take this course for credit.

ELEC 275 ***Principles of Electrical Engineering*** (3.5 credits)
Prerequisite: ENGR 213 previously or concurrently; PHYS 205. Fundamentals of electric circuits: Kirchoff's laws, voltage and current sources, Ohm's law, series and parallel circuits. Nodal and mesh analysis of DC circuits. Superposition theorem, Thevenin and Norton Equivalents. Use of operational amplifiers. Transient analysis of simple RC, RL and RLC circuits. Steady state analysis: Phasors and impedances, power and power factor. Single and three phase circuits. Magnetic circuits and transformers. Power generation and distribution. Lectures: three hours per week. Tutorial: two hours per week. Laboratory: 15 hours total.

ELEC 311 ***Electronics I*** (4 credits)
Prerequisite: ELEC 273 or ENGR 273. Diodes: the ideal diode; terminal characteristics of junction diodes; analysis of diode circuits; the small signal model and its application; operation in the reverse-breakdown region — Zener diodes; rectifier circuits; limiting and clamping circuits. Bipolar junction transistors: structure and physical operation; DC analysis: biasing considerations: small signal analysis and parameters; hybrid π model, T model; common base, common emitter, common collector configurations. Field-effect transistors: structure and physical operation; DC analysis; biasing considerations; small signal analysis and parameters; hybrid π model, T model; common gate, common source, common collector configurations. Lectures: three hours per week. Tutorial: two hours per week. Laboratory: 30 hours total.

ELEC 312 ***Electronics II*** (4 credits)
Prerequisite: ELEC 311, 364. Differential and multi-stage amplifiers: differential pair; differential gain; common-mode gain and common-mode rejection ratio (CMRR) current mirrors. High frequency models: s-domain analysis, transfer functions; hybrid $\eth$ model at high frequency; common base, common emitter, common drain configurations; common gate, common source, common collector configurations; differential BJT pairs at high frequency; MOS differential pair at high frequency. Feedback: general feedback structure;

properties of negative feedback; the four basic feedback configurations: series-shunt, series-series, shunt-series; loop gain and stability problems; effect of feedback on amplifier poles; bode plots and frequency compensation. Power amplifiers: classification and output stages; class A, B, C, and AB amplifiers; biasing the class AB amplifier; variations on the class AB configuration; IC power amplifiers and MOS power transistors. Introduction to filters and oscillators. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: 30 hours total.

ELEC 321 ***Introduction to Semiconductor Materials and Devices*** (3.5 credits)
Prerequisite: CHEM 205; ENGR 213. Fundamentals underlying optical and electronic devices. The structure and growth of crystals. The energy band model for elemental and compound semiconductors. Electronic and optical properties of semiconductors. Electroluminescence and photoluminescence. The semiconductor in equilibrium. Carrier transport and non-equilibrium phenomena. Introductions to junctions and devices. The laboratory demonstrates the basic electrical and optical properties of semiconductor materials. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: 15 hours total.

ELEC 331 ***Fundamentals of Electrical Power Engineering*** (3.5 credits)
Prerequisite: ELEC 251, 273. Review of fundamentals of AC circuit analysis. Overview of power systems. Three-phase circuits: balanced three-phase circuits with star and delta connected loads, power measurements. Magnetic circuits. Transformers. Power conversion techniques: single phase AC/DC rectifiers, DC/DC choppers and DC/AC converters. DC machines: Operating principle, separately excited DC motor, torque speed characteristics and control methods using rectifiers and choppers. Induction machines: Theory of three-phase induction machines, equivalent circuit parameters, efficiency, torque speed characteristics and control methods using inverters. Overview of power distribution systems. Safety codes. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: 15 hours total.

ELEC 351 ***Electromagnetic Waves and Guiding Structures*** (3 credits)
Prerequisite: ELEC 251, 365. Maxwell's equations. Differential forms of the laws of electromagnetism. Boundary conditions. Power and energy. Uniform plane waves. Transmission line theory. Rectangular waveguides. Antennas. Lectures: three hours per week. Tutorial: one hour per week.

ELEC 353 ***Transmission Lines, Waves and Signal Integrity*** (3 credits)
Prerequisite: ELEC 264; ENGR 233. Transmission lines and high-speed logic design. Intersymbol interference and eye patterns. Transmission line circuits in the frequency domain, rise time and bandwidth of digital signals. Maxwell's equations, plane waves, and antennas. Wireless communications and indoor propagation. Lectures: three hours per week. Tutorial: one hour per week.

ELEC 363 ***Fundamentals of Telecommunications Systems*** (3.5 credits)
Prerequisite: ELEC 364; ENGR 371. Introduction to basic telecommunications concepts and systems. Analog communications: AM and FM, system level consideration of noise-bandwidth tradeoffs. Digital communications: sampling and quantization, digital modulation techniques, the matched filter. Redundancy encoding. Lectures: three hours per week. Laboratory: 15 hours total.
NOTE: Students who have received credit for ELEC 461 may not take this course for credit.

ELEC 364 ***Signals and Systems II*** (3.5 credits)
Prerequisite: ELEC 264. Sampling of continuous-time signals. Reconstruction of a signal from its samples using interpolation. Laplace Transform. Inverse Laplace Transform. Analysis of systems using Laplace Transform. Unilateral Laplace Transform. Continuous-time filters and their design. The Z-Transform and inverse Z-Transform. Analysis of systems using Z-Transform. Unilateral Z-Transform. Discrete-time filters and their design. Computer-based MATLAB simulation. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: 15 hours total.
NOTE: Students who have received credit for ELEC 361 may not take this course for credit.

ELEC 365 ***Complex Variables and Partial Differential Equations*** (3 credits)
Prerequisite: ENGR 213, 233. Review of complex arithmetic. Analytic functions. Taylor and Laurent series. Residue theory. Fourier series. Partial differential equations. Applications to Laplace, heat, and wave equations. Bessel and Legendre functions. Lectures: three hours per week. Tutorial: one hour per week.
NOTE: Students who have received credit for ELEC 261 or 362 may not take this course for credit.

ELEC 372 ***Fundamentals of Control Systems*** (3.5 credits)
Prerequisite: ELEC 364. Mathematical models of control systems. Characteristics, performance, and stability of linear feedback control systems. Root-locus methods. Frequency response methods. Stability in the frequency domain. Design and compensation of feedback control systems. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: 15 hours total.
NOTE: Students who have received credit for ENGR 372 or MECH 371 may not take this course for credit.

ELEC 390 ***Electrical Engineering Product Design Project*** (3 credits)
Prerequisite: Minimum of 45 credits in BEng (Electrical); COEN 244; ELEC 311; ENGR 290, 301. The Product Design Project reinforces skills introduced in ENGR 290, which include teamwork, project management, engineering design for a complex problem, technical writing, and technical presentation in a team environment. It also introduces students to product development. Students are assigned to teams and each team develops, defines, designs and builds a system and/or device under broad constraints set by the Department. Students present their product definition and design, and demonstrate that their system/device works at the end of the term. Tutorial: two hours per week. Equivalent laboratory time: six hours per week.
NOTE: All written documentation must follow the Concordia Form and Style guide. Students are responsible for obtaining this document before beginning the project.

ELEC 421 ***Solid State Devices*** (3.5 credits)
Prerequisite: ELEC 321. Junction theory (PN junctions, Schottky and ohmic contacts, hetero-junctions). Diodes and bipolar transistors. Light-emitting diodes, photodetectors, solar cells, and fibre optics. Lasers: operating principles and applications in optoelectronic devices. Planar silicon junctions and transistors will be designed, fabricated and evaluated in the laboratory, including resistivity measurements, semiconductor cleaning, oxidation, diffusion, photolithography, etching, metallization, and comparison of design with experimental results. Lectures: three hours per week. Laboratory: 15 hours total.

ELEC 422 ***Design of Integrated Circuit Components*** (3.5 credits)
Prerequisite: ELEC 421. Structures, characteristics and design of MOS capacitors and MOSFETs. Structures, characteristics and design of laser diodes. Optoelectronic devices and integrated circuits. Planar MOS devices, including capacitors and MOSFETs will be designed, fabricated, and evaluated in the laboratory. Lectures: three hours per week. Laboratory: 15 hours total.

ELEC 423 ***Introduction to Analog VLSI*** (4 credits)
Prerequisite: ELEC 311. CMOS transistor layout considerations, design rules, circuit extraction. MOSFET modelling, I-V equations, AC equivalent circuits for high-frequency operation, computer-based simulation. Analysis and design of small-scale integrated circuit building blocks including MOS switch, active resistor, current source, current mirror, voltage amplifiers, voltage-reference circuits, multipliers. Analysis and design of medium-scale integrated circuit building blocks including op-amps, fully-differential op-amp and common mode feedback circuits, transconductance amplifiers, transimpedance amplifiers, comparators. Noise analysis. Mismatch analysis and modelling, offset removal techniques. Analog VLSI system examples. Lectures: three hours per week. Laboratory: 30 hours total.

ELEC 424 ***VLSI Process Technology*** (3.5 credits)
Prerequisite: ELEC 311, 321. Introduction to basic VLSI technologies; crystal growth, thermal oxidation, diffusion, ion implantation, chemical vapour deposition, wet and dry etching, and lithography. Layout, yield, and VLSI process integration. The lab demonstrates a semiconductor device fabrication process. Lectures: three hours per week. Laboratory: 15 hours total.

ELEC 425 ***Optical Devices for High-Speed Communications*** (3.5 credits)
Prerequisite: ELEC 321, 351. Optical properties of semiconductors. Fundamental principles for understanding and applying optical fibre technology. Fundamental behaviour of the individual optical components and their interactions with other devices. Lasers, LEDs, optical fibres, light detectors, optical switches. Concepts of WDM and DWDM. Components required for WDM and DWDM. A comprehensive treatment of the underlying physics: noise and distortion in optical communications, light polarization, modulation and attenuation. Lectures: three hours per week. Laboratory: 15 hours total.

ELEC 430 ***Electrical Power Equipment*** (3.5 credits)
Prerequisite : ELEC 331. Components of a transmission system. Transmission line; modelling and parameters. Transformers: equivalent circuits, losses, connections and protection. Breakers: operation and design. Compensation equipment: capacitors, inductors, series and shunt connections. Insulation coordination. Lectures: three hours per week. Laboratory: 15 hours total.
NOTE: This course is usually offered in the French language.

ELEC 431 ***Electrical Power Systems*** (3.5 credits)
Prerequisite: ELEC 331. Inductance, capacitance, resistance of polyphase transmission lines; current and voltage relations of transmission lines; load flow studies; symmetrical and unsymmetrical faults; power system stability. Lectures: three hours per week. Laboratory: 15 hours total.

ELEC 432 ***Control of Electrical Power Conversion Systems*** (3.5 credits)
Prerequisite: ELEC 331, 372. Basic considerations and control requirements. Control system principles and structures. Controller characteristics and operation. Static power conversion systems. Electromechanical systems and electrical machine modelling. Control system design. Applications to electric motor drives and typical power conversion systems. Lectures: three hours per week. Laboratory: 15 hours total.
NOTE: This course is usually offered in the French language.

ELEC 433 ***Power Electronics*** (3.5 credits)
Prerequisite: ELEC 311, 331. Review of basic electrical concepts. Power electronic systems. Power semiconductor switches. AC controllers. Line frequency AC-DC converters: diodes and thyristor circuits. DC-DC converters. DC-AC converters. Utility applications: STATCOM and power electronic interfaces. Industrial and utility applications. Lectures: three hours per week. Laboratory: 15 hours total.

ELEC 434 ***Behaviour of Power Systems*** (3.5 credits)
Prerequisite: ELEC 331. Introduction: classification of phenomena, structure of power systems. Review of component models: lines, transformers, electrical machines and load. Excitation systems of machines. Steady-state operation. Transient stability, voltage stability and small signal stability. Compensation methods: stabilizer, series and shunt compensators. Sub-synchronous resonances. Transient electromagnetic phenomena. Methods and tools for numerical simulation. Lectures: three hours per week. Laboratory: 15 hours total.
NOTE: This course is usually offered in the French language.

ELEC 435 ***Electromechanical Energy Conversion Systems*** (3.5 credits)
Prerequisite: ELEC 331. Lumped parameter concepts of electromechanics. Energy, co-energy in the derivation of torques and forces. Examples of electric machines: dc, synchronous and induction types. Steady-state, transient and stability analysis. Power electronic controllers. Lectures: three hours per week. Laboratory: 15 hours total.

ELEC 436 ***Protection of Power Systems*** (3.5 credits)
Prerequisite: ELEC 331. General aspects of protection systems. Measurement transformers. Grounding. Overcurrent and ground fault protection. Protection of transformers, shunt capacitors and buses. Protection of transmission lines. Telecommunication for protection and automation systems. Protection of inverters. Protection of distribution networks. Lectures: three hours per week. Laboratory: 15 hours total.
NOTE: This course is usually offered in the French language.

ELEC 437 ***Renewable Energy Systems*** (3 credits)
Prerequisite: COEN or ELEC 390 or equivalent. Electrical basics and models of solar energy (photo-voltaics), electrical power from wind energy, electrical power from water, including wave energy, tidal energy, micro-hydro. Case studies, for example the application of solar PV to street lighting. Electrical engineering design implications. Design assignments. Lectures: three hours per week.
NOTE: Students who have received credit for this topic under an ELEC 498 number may not take this course for credit.

ELEC 438 ***Industrial Electrical Systems*** (3.5 credits)
Prerequisite: ELEC 331. Structures of industrial power systems. Voltage levels. Electric installations, codes and standards. Short-circuits, protection and coordination. Grounding. Power quality. Power factor, tariffs and energy management. Lectures: three hours per week. Laboratory: 15 hours total.
NOTE: This course is usually offered in the French language.

ELEC 439 ***Hybrid Electric Vehicle Power System Design and Control*** (3 credits)
Prerequisite: ELEC 331. Introduction to Electric Vehicles (EV), Hybrid Electric Vehicles (HEV). Vehicle design fundamentals. Traction motors for EV/HEV propulsion. On-board energy sources and storage devices: high-voltage traction batteries, fuel cells, ultra-capacitors, flywheels. Power electronic converters and control. Various EV/HEV/Fuel Cell Vehicle topologies and modelling. Energy management strategies. Practical design considerations. Engineering impact of electric, hybrid electric, and fuel cell vehicles. Lectures: three hours per week.

ELEC 440 ***Controlled Electric Drives*** (3.5 credits)
Prerequisite: ELEC 331. Elements of a drive system, characteristics of common mechanical systems, drive characteristics, operation in one, two, or four quadrants. Fully controlled rectifier drives, braking of DC motors, control of DC motors using DC/DC converters. Control of polyphase induction motors, voltage-source and current-source inverter drives, frequency-controlled induction motor drives, introduction to vector control of induction motor drives, field oriented control, sensor-less operation. Control of synchronous motors, permanent magnet motors. Switched reluctance motor drives, stepper motors. Brushless DC motor drives, low-power electronic motor drives. Lectures: three hours per week. Laboratory: 15 hours total.
NOTE: Students who have received credit for this topic under an ELEC 498 number may not take this course for credit.

ELEC 441 ***Modern Analog Filter Design*** (3.5 credits)
Prerequisite: ELEC 364. Review of network analysis. Magnitude and frequency scaling. Magnitude and phase approximation in synthesis of filter functions. Second-order active RC filters. Synthesis of all-pole LC ladder filters. Second-order switched-capacitor filters. Realization of high-order active filters. Current mode filters. Switched-current filters. Integrated circuit filters. Lectures: three hours per week. Laboratory: 15 hours total.

ELEC 442 ***Digital Signal Processing*** (3.5 credits)
Prerequisite: ELEC 364; ENGR 371. Review of Z-transform; linear phase and non-linear phase systems; all-pass and minimum phase systems, recursive and non-recursive digital filters; common digital filter structures, common design approaches for digital filters; description of typical Digital Signal Processor chips; Review of sampling, reconstruction, interpolation and decimation; changing the sampling rate by integer and non-integer factor; multirate signal processing, polyphase decomposition, multirate filter banks; digital processing of analog signals, A/D and D/A converters; discrete Fourier transform; random signals, Least-Mean-Square (LMS) filters. Lectures: three hours per week. Laboratory: 15 hours total.

ELEC 453 ***Microwave Engineering*** (3.5 credits)
Prerequisite: ELEC 351. Properties of waveguides, striplines, and microstrips. Scattering parameters. Butterworth and Chebyshev impedance transformers. Microwave couplers, cavities, and Fabry-Perot resonators. Periodic structures. Microwave filter design. Faraday rotation and non-reciprocal devices. Lectures: three hours per week. Laboratory: 15 hours total.

ELEC 455 ***Acoustics*** (3 credits)
Prerequisite: ELEC 351. Sound generation and propagation in elastic media; conversion between acoustical, electrical, and mechanical energy. Lumped-parameter approximations, sound in rooms, underwater acoustics, microphones; loudspeakers and audio communications problems; noise and vibration control problems. Lectures: three hours per week.

ELEC 456 ***Antennas*** (3.5 credits)
Prerequisite: ELEC 351. Antenna fundamentals and definitions. Radiation integrals. Dipoles and loops. Arrays. Antenna self and mutual impedance. Matching techniques. Travelling wave antennas. Broadband antennas. Equivalence principle. Aperture antennas. Antenna measurement techniques. Lectures: three hours per week. Laboratory: 15 hours total.

ELEC 457 ***Design of Wireless RF Systems*** (3 credits)
Prerequisite: ELEC 453. Introduction to wireless systems. Noise and distortion in microwave systems. Antennas and propagation. Amplifiers. Mixers. Transistor oscillators and frequency synthesizers. Modulation techniques. Receiver design. Use of RF CAD tools. Lectures: three hours per week.

ELEC 458 ***Techniques in Electromagnetic Compatibility*** (3 credits)
Prerequisite: ELEC 351 or 353. Introduction to EMC procedures, control plans, and specifications. Radiated and conducted susceptibility and emission testing. Introduction to EMC antennas, antenna concepts, electric and magnetic dipoles, biconical dipoles, conical log spiral antennas, setting up fields for susceptibility testing, measuring radiation from equipment. Coupled transmission lines, pulse propagation, closely spaced parallel transmission lines, capacitive coupling, inductive coupling, shielding against magnetic fields. Shielding and enclosures, electric and magnetic field screening mechanisms, shielding effectiveness, grounding considerations. EMC test facilities, screened rooms, TEM cells, signals and spectra, intermodulation, cross-modulation, the spectrum analyzer. Noise and pseudo-random noise, noise performance of measurement/receiving systems, noise equivalent bandwidth, noise figure, antenna noise temperature and S/N ratio. Lectures: three hours per week.

ELEC 462 ***Introduction to Digital Communications*** (3.5 credits)
Prerequisite: ELEC 363. Noise in communication systems, additive white Gaussian noise; modulation, demodulation and detection; maximum likelihood receiver, matched filter, error probability; intersymbol interference, pulse shaping filter; bandpass modulation and demodulation techniques such as PAM, PSK, DPSK, FSK, QAM; error control coding, linear block codes, cyclic codes, convolutional codes, Viterbi decoder; coding in system design considerations, bit error rates and coding gain, trade-offs in power, bandwidth, data rate and system reliability; codulation. Lectures: three hours per week. Laboratory: 15 hours total.

ELEC 463 ***Telecommunication Networks*** (3 credits)
Prerequisite: ELEC 363. Communication networks and services; introduction to layered network architectures; transmission systems and the telephone network: multiplexing, circuit switches, routing and signalling; peer-to-peer protocols: ARQ protocols, data-link controls, packet multiplexing; multiple access communications: Aloha, CSMA, reservation schemes, polling, token-passing ring, LAN standards, LAN bridges; packet-switching networks: datagrams and virtual circuits; TCP/IP architecture: Internet protocol, transmission control protocol. Lectures: three hours per week.
NOTE: Students who have received credit for COEN 445 may not take this course for credit.

ELEC 464 ***Wireless Communications*** (3 credits)
Prerequisite: ELEC 462. Review of modulation and error control coding. Modulation vs. coding trade-off, communications link analysis. Introduction to cellular systems: frequency reuse, trunking and grade of services, sectoring and cell splitting, coverage and capacity. Modulation techniques for mobile communications. Mobile radio channels. Spread-spectrum techniques. Multiplexing and multiple access techniques. Wireless and cordless standards. Lectures: three hours per week.

ELEC 465 ***Networks Security and Management*** (3.5 credits)
Prerequisite: COEN 445 or ELEC 463. Network security threats. Importance of security policy. Principles and techniques of encryption and authentication. Network security protocols: X509, IPSEC (Internet Protocol Security Architecture). Network management: issues, architectures, and protocols. Fault management, configuration management, security management, performance management, and accounting management. Management Information Bases (MIBs). SNMP and its evolution. Lectures: three hours per week. Laboratory: 15 hours total.

ELEC 466 ***Introduction to Optical Communication Systems*** (3.5 credits)
Prerequisite: ELEC 351, 363. Overview of optical fibres and optical fibre communications. Signal propagation in optical fibres: attenuation, chromatic dispersion, mode coupling, and nonlinearities. Optical transmitters' characteristics and requirements for optical networks. Power launching and coupling: optical transmitter-to-fibre coupling, fibre-to-fibre joints, and optical fibre connectors. Optical receivers: basic structures, noise analysis, characteristics and requirements for optical networks. Digital/analog transmissions: link power budget, rise-time budget, line coding, error correction, and noise effects on transmissions. WDM concepts: operation principle of WDM. Optical amplifiers: characteristics and requirements for optical networks, amplifier noise, system applications, and wavelength conversion. Optical networks: basic topologies, SONET/SDH, broadcast-and-select WDM networks, wavelength-routed networks. Optical measurements: test equipments, attenuation/dispersion measurements, OTDR, eye pattern and OSA. Lectures: three hours per week. Laboratory: 15 hours total.

ELEC 472 ***Advanced Telecommunication Networks*** (3.5 credits)
Prerequisite: ELEC 463 or COEN 445. Routing in packet networks, shortest-path algorithms, Internet routing protocols, ATM networks: ATM and ATM adaptation layers, traffic management and QoS, congestion control, ATM signalling, advanced network architectures: classical IP over ATM, MPLS, integrated and differentiated services, mobile communications: wireless transmission, medium access control, GSM system, mobile IP, mobile transport layer and support for mobility. Lectures: three hours per week. Laboratory: 15 hours total.

ELEC 481 ***Linear Systems*** (3.5 credits)
Prerequisite: ELEC 372 or MECH 371. Review of matrix algebra. State-space description of dynamic systems: linearity, causality, time-invariance, linearization. Solution of state-space equations. Transfer function representation. Discrete-time models. Controllability and observability. Canonical forms and minimal-order realizations. Stability. Stabilizability and pole placement. Linear quadratic optimal control. Observer design. Lectures: three hours per week. Laboratory: 15 hours total.
NOTE: Students who have received credit for ENGR 471 may not take this course for credit.

ELEC 482 ***System Optimization*** (3.5 credits)
Prerequisite: ENGR 391 or EMAT 391. Linear least squares. Properties of quadratic functions with applications to steepest descent method, Newton's method and Quasi-Newton methods for nonlinear optimization. One-dimensional optimization. Introduction to

constrained optimization, including the elements of Kuhn-Tucker conditions for optimality. Least p^{th} and mini-max optimization. Application of optimization techniques to engineering problems. Lectures: three hours per week. Laboratory: 15 hours total.
NOTE: Students who have received credit for ENGR 472 may not take this course for credit.

ELEC 483 ***Real-Time Computer Control Systems*** (3.5 credits)
Prerequisite: ELEC 372. Introduction to real-time computer control systems; a review of discrete-time signals and systems, difference equations, z-transform; sampled-data systems, sample and hold, discrete models; discrete equivalents of continuous-time systems; stability analysis; design specifications; design using root locus and frequency response methods; implementation issues including bumpless transfer, integral windup, sample rate selection, pre-filtering, quantization effects and computational delay; scheduling theory and priority assignment to control processes, timing of control loops, effects of missed deadlines; principles and characteristics of sensors and devices, embedded processors, processor/device interface. Lectures: three hours per week. Laboratory: 15 hours total.

ELEC 490 ***Capstone Electrical Engineering Design Project*** (4 credits)
Prerequisite: Minimum of 75 credits in BEng (Electrical) or permission of the Department; ENGR 371; COEN 311; ELEC 364, 390. Students are assigned to groups, and work together under faculty supervision to solve a complex interdisciplinary design problem — typically involving communications, control systems, electromagnetics, power electronics, software design, and/or hardware design. The project fosters teamwork between group members and allows students to develop their project management, technical writing, and technical presentation skills. Tutorial: one hour per week, two terms. Equivalent laboratory time: four hours per week, two terms.
NOTE: All written documentation must follow the Concordia Form and Style guide. Students are responsible for obtaining this document before beginning the project.

ELEC 498 ***Topics in Electrical Engineering*** (3 credits)
Prerequisite: Permission of the Department. This course may be offered in a given year upon the authorization of the Electrical and Computer Engineering Department. The course content may vary from offering to offering and will be chosen to complement elective courses available in a given year.

CONCORDIA INSTITUTE FOR AEROSPACE DESIGN AND INNOVATION

IADI 301 ***Undergraduate Aerospace Industry Project I*** (0 credit)
Prerequisite: Acceptance into CIADI. The activities associated with this course include participation in regular meetings at the Institute and with faculty and industry members, attendance at training sessions (as applicable), industry training and tours. A project is assigned to the students. Students are also required to prepare and present progress reports on their project. A final report of their project must be submitted to the director of CIADI. A grade of pass or fail will be awarded based on the evaluation of the above activities. All students accepted to CIADI are required to register for this non-credit course activity.

IADI 401 ***Undergraduate Aerospace Industry Project II*** (0 credit)
Prerequisite: Pass in IADI 301. The activities associated with this course deal with participation in regular meetings at the Institute and with faculty and industry members, attendance at training sessions (as applicable), industry training and tours. A project is assigned to the students. Students are also required to prepare and present progress reports on their project. A final report of their project must be submitted to the director of CIADI. A grade of pass or fail will be awarded based on the evaluation of the above activities. Students wishing to use their research and design project for their capstone project (e.g. MECH 490, COEN 490) must receive written approval from the Capstone Design Project coordinator in their respective department at the commencement of their CIADI project, and meet all requirements set out by both CIADI and their individual department.

INDUSTRIAL ENGINEERING

INDU 211 ***Introduction to Production and Manufacturing Systems*** (3 credits)
History of industrial engineering. Role of industrial engineers. Types of manufacturing and production systems. Material flow systems. Job design and work measurement. Introduction to solution methodologies for problems which relate to the design and operation of integrated production systems of humans, machines, information, and materials. Lectures: three hours per week. Tutorial: one hour per week.

INDU 311 ***Simulation of Industrial Systems*** (3.5 credits)
Prerequisite: ENGR 371. Modelling techniques in simulation; application of discrete simulation techniques to model industrial systems; random number generation and testing; design of simulation experiments using different simulation languages; output data analysis. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks. Tutorial: one hour per week.

INDU 320 ***Production Engineering*** (3 credits)
Prerequisite: INDU 323. The systems approach to production. Interrelationships among the component blocks of the system: forecasting, aggregate planning, production, material and capacity planning, operations scheduling. An overview of integrated production planning and control including MRP II, Just in Time manufacturing (JIT). Lectures: three hours per week. Tutorial: one hour per week.

INDU 321 ***Lean Manufacturing*** (3 credits)
Prerequisite: INDU 320. Lean fundamentals; lean manufacturing; lean engineering; lean principles, tools and techniques, practices, and implementation; five S's, process analysis/spaghetti charts, value engineering; value stream mapping; standardized work/

standard times; set-up reduction/line balancing; unit manufacturing; cell layout/cellular manufacturing; total productive maintenance; kanban; lean supply chain management; transition-to-lean roadmap; people/organizational issues in the lean enterprise; Six Sigma; TOM; agile manufacturing. Lectures: three hours per week. Tutorial: one hour per week.
NOTE: Students who have received credit for INDU 420 may not take this course for credit.

INDU 323 ***Operations Research I*** (3 credits)
Prerequisite: ENGR 213, 233. An introduction to deterministic mathematical models with emphasis on linear programming. Applications to production, logistics, and service systems. Computer solution of optimization problems. Lectures: three hours per week. Tutorial: one hour per week.

INDU 324 ***Operations Research II*** (3 credits)
Prerequisite: INDU 323. Integer programming (IP), including modelling and enumerative algorithms for solving IP problems; post-optimality analysis. Network flows, dynamic programming and non-linear programming. Applications in the design and operation of industrial systems. Lectures: three hours per week. Tutorial: one hour per week.
NOTE: Students who have received credit for INDU 430 may not take this course for credit.

INDU 330 ***Engineering Management*** (3 credits)
Organizational structures, their growth and change. Motivation, leadership, and group behaviour. Design of alternatives for improving organizational performance and effectiveness. Planning, organization and management of engineering projects. Management for total quality. Lectures: three hours per week.

INDU 371 ***Stochastic Models in Industrial Engineering*** (3 credits)
Prerequisite: ENGR 371. Overview of probability theory; probability distributions; exponential model and Poisson process; discrete-time and continuous-time Markov chains; classification of states; birth and death processes; queuing theory. Application to industrial engineering problems. Lectures: three hours per week. Tutorial: one hour per week.

INDU 372 ***Quality Control and Reliability*** (3 credits)
Prerequisite: ENGR 371. Importance of quality; total quality management; statistical concepts relevant to process control; control charts for variables and attributes; sampling plans. Introduction to reliability models and acceptance testing; issues of standardization. Lectures: three hours per week. Tutorial: one hour per week.

INDU 410 ***Safety Engineering*** (3.5 credits)
Prerequisite: MECH 311. Engineering design for the control of workplace hazards. Occupational injuries and diseases. Codes and standards. Workplace Hazardous Materials Information Systems (WHMIS). Hazard evaluation and control. Design criteria. Risk assessment. Safety in the manufacturing environment. Applications in ventilation, air cleaning, noise and vibration. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

INDU 411 ***Computer Integrated Manufacturing*** (3.5 credits)
Prerequisite: MECH 311. Concepts and benefits of computer integrated manufacturing (CIM). Design for manufacturing. Computer-aided design, process planning, manufacturing (computer numerical control parts programming), and inspection. Robots in CIM. Production planning and scheduling in CIM. System integration. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

INDU 412 ***Human Factors Engineering*** (3.5 credits)
Prerequisite: ENGR 371. Elements of anatomy, physiology, and psychology; engineering anthropometry; human capacities and limitations; manual material handling; design of workplaces; human-machines system design; design of controls and displays; shift work. Applications to a manufacturing environment. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

INDU 421 ***Facilities Design and Material Handling Systems*** (3.5 credits)
Prerequisite: INDU 311, 320. An introduction to planning and design of production and manufacturing. Facility layout and location. Material handling systems and equipment specifications. Computer-aided facilities planning. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.

INDU 423 ***Inventory Control*** (3.5 credits)
Prerequisite: INDU 320. Inventory analysis and control systems; the role of forecasting in controlling inventories; the role of inventories in physical distribution; supply chain management; work in process inventories; inventory in just-in-time manufacturing systems. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.

INDU 440 ***Product Design and Development*** (3 credits)
Prerequisite: MECH 311. Development processes and organizations, product planning, identifying customer needs, product specifications, concept generation, concept selection, concept testing, product architecture, industrial design, design for manufacturing, prototyping robust design, patents and intellectual property. Lectures: three hours per week.

INDU 441 ***Introduction to Six Sigma*** (3 credits)
Prerequisite: INDU 372. Overview of the Six Sigma concepts and tools. Six Sigma deployment practices: Define, Measure, Analyze, Improve and Control phases (DMAIC). Project development, and the DMAIC problem-solving approach. Project. Lectures: three hours per week.

INDU 442 ***Logistics Network Models*** (3 credits)
Prerequisite: INDU 324. Overview of transportation systems; airlines, railways, ocean liners, cargo, energy transportation and pipelines. Supply chain characterization. Site location. Distribution planning. Vehicle routing. Fleet scheduling. Crew scheduling. Demand management. Replenishment management. Revenue management. Geographic information systems. Real-time network control issues. Project. Lectures: three hours per week.

INDU 466 ***Decision Models in Service Sector*** (3 credits)
Prerequisite: ENGR 371; INDU 320. Introduction to service strategy and operations. Service demand forecasting and development of new services. Service facility location and layout planning. Applications of decision models in service operations and service quality control. Cost analysis, queuing models, risk management and resource allocation models for service decisions. Service outsourcing and supply chain issues. Efficiency and effectiveness issues in different service sectors such as emergency force deployment, municipal resource allocation and health care. Case studies using operations research, operations management, and statistical techniques. Lectures: three hours per week.

INDU 475 ***Advanced Concepts in Quality Improvement*** (3 credits)
Prerequisite: INDU 372. Statistical experimental design issues such as randomized blocks, factorial designs at two levels, applications on factorial designs, building models, Taguchi methods. Lectures: three hours per week.

INDU 490 ***Capstone Industrial Engineering Design Project*** (4 credits)
Prerequisite: 75 credits in the program; ENCS 282; ENGR 301; INDU 421 previously or concurrently. A supervised design, simulation or experimental capstone design project including a preliminary project proposal with complete project plan and a technical report at the end of the fall term; a final report by the group and individual oral presentation at the end of the winter term. Lectures: one hour per week, one term. Equivalent laboratory time: three hours per week, two terms.
NOTE: Students will work in groups under direct supervision of a faculty member.

INDU 498 ***Topics in Industrial Engineering*** (3 credits)
Prerequisite: Permission of the Department Chair. This course may be offered in a given year upon the authorization of the Mechanical and Industrial Engineering Department. The course content may vary from offering to offering and will be chosen to complement the elective courses available in the Industrial Engineering program. Lectures: three hours per week.

MECHANICAL ENGINEERING

MECH 211 ***Mechanical Engineering Drawing*** (3.5 credits)
Introduction to graphic language and design — means and techniques. The third and the first angle projections. Orthographic projection of points, lines, planes and solids. Principal and auxiliary views. Views in a given direction. Sectional views. Intersection of lines, planes and solids. Development of surfaces. Drafting practices. Dimensioning, fits and tolerancing. Computer-aided drawing and solid modelling. Working drawings — detail and assembly drawing. Design practice. Machine elements representation. Lectures: three hours per week. Tutorial: two hours per week — includes learning of a CAD software. Laboratory: two hours per week, alternate weeks.

MECH 215 ***Programming for Mechanical and Industrial Engineers*** (3.5 credits)
Prerequisite: MATH 204 (Cegep mathematics 105). Writing programs using assignment and sequences. Variables and types. Operators and expressions. Conditional and repetitive statements. Input and output. File access. Functions. Program structure and organization. Pointers and dynamic memory allocation. Introduction to classes and objects. Mechanical and industrial engineering applications. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: one hour per week.

MECH 221 ***Materials Science*** (3 credits)
Prerequisite: CHEM 205 (Cegep Chemistry 101). Relationships between properties and internal structure, atomic bonding; molecular, crystalline and amorphous structures, crystalline imperfections and mechanisms of structural change. Microstructures and their development from phase diagrams. Structures and mechanical properties of polymers and ceramics. Thermal, optical, and magnetic properties of materials. Lectures: three hours per week. Tutorial: one hour per week.

MECH 311 ***Manufacturing Processes*** (3.75 credits)
Prerequisite: MECH 313; ENGR 244 previously or concurrently. Fundamentals of manufacturing processes and their limitations, metrology, machine shop practice, safety and health considerations, forming, conventional machining and casting processes, welding and joining, plastic production, and non-conventional machining techniques. Sustainable technologies. Laboratory includes instruction and practice on conventional machine tools and a manufacturing project. Lectures: three hours per week. Tutorial: two hours per week, including industrial visits and field trips to local industries. Laboratory: three hours per week, alternate weeks.

MECH 313 ***Machine Drawing and Design*** (3 credits)
Prerequisite: MECH 211. Introduction to engineering design and design process. Problem definition, solution formulation, model development and collaboration aspects of design process.The use of drawings and other graphical methods in the process of engineering design. Industrial standards and specifications, design of fits, linear and geometrical tolerances. Design projects based on design philosophies will involve design and selection of many standard machine components like mechanical drives, cams, clutches, couplings, brakes, seals, fasteners, springs, and bearings. Drawing representation of standard components. Design projects are an integral part of this course. Lectures: three hours per week. Tutorial: two hours per week.

MECH 321 ***Properties and Failure of Materials*** (3.5 credits)
Prerequisite: MECH 221. The service capabilities of alloys and their relationship to microstructure as produced by thermal and mechanical treatments; tensile and torsion tests; elements of dislocation theory; strengthening mechanisms; composite materials. Modes of failure of materials; fracture, fatigue, wear, creep, corrosion, radiation damage. Failure analysis. Material codes; material selection for design. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.

MECH 343 ***Theory of Machines*** (3.5 credits)
Prerequisite: ENGR 213, 233, 243. Introduction to mechanisms; position and displacement; velocity; acceleration; synthesis of linkage; robotics; static force analysis; dynamic force analysis; forward kinematics and inverse kinematics; introduction to gear analysis and gear box design; kinematic analysis of spatial mechanisms. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.

MECH 344 ***Machine Element Design*** (3 credits)
Prerequisite: ENGR 244; MECH 313; MECH 321, 343 previously or concurrently. Introduction to machine design; static failure theories; failure of ductile vs. brittle materials under static loading. Fatigue failure theories; fatigue loads; notches and stress concentrations; residual stresses; designing for high cycle fatigue. Design of shafts, keys and couplings. Design of spur gears. Spring design. Design of screws and fasteners. Design of bearings. Case studies. Lectures: three hours per week. Tutorial: two hours per week.
NOTE: Students who have received credit for MECH 441 may not take this course for credit.

MECH 351 ***Thermodynamics II*** (3.5 credits)
Prerequisite: ENGR 251. Brief review of ideal gas processes. Semi-perfect gases and the gas tables. Mixtures of gases, gases and vapours, air conditioning processes. Combustion and combustion equilibrium. Applications of thermodynamics to power production and utilization systems: study of basic and advanced cycles for gas compression, internal combustion engines, power from steam, gas turbine cycles, and refrigeration. Real gases. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.

MECH 352 ***Heat Transfer I*** (3.5 credits)
Prerequisite: ENGR 311, 361. Analytical and numerical methods for steady-state and transient heat conduction. Empirical and practical relations for forced- and free-convection heat transfer. Radiation heat exchange between black bodies, and between non-black bodies. Gas radiation. Solar radiation. Effect of radiation on temperature measurement. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.

MECH 361 ***Fluid Mechanics II*** (3.5 credits)
Prerequisite: ENGR 361. Differential analysis of fluid flows, vorticity, stream function, stresses, and strains. Navier-Stokes equations and solutions for parallel flows. Euler's equations, irrotational and potential flows, plane potential flows. Viscous flows in pipes, laminar and turbulent flows, major and minor losses. Flow over immersed bodies, boundary layers, separation and thickness. Drag, lift and applications. Introduction to compressible flows, speed of sound, Mach cone, and some characteristics of supersonic flows. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.

MECH 368 ***Electronics for Mechanical Engineers*** (3.5 credits)
Prerequisite: PHYS 205; ENGR 311 previously or concurrently. Dependent sources, voltage and current dividers, voltage and current sources, superposition, Thevenin and Norton equivalent sources, linear and nonlinear circuit analysis. Semiconductors and diodes. Bipolar Junction Transistors (BJT), Field Effect Transistors (FET); amplifiers and switches. Operational amplifiers; circuits and frequency response. Digital logic components and circuits. Digital systems. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.
NOTE: Students who have received credit for MECH 470 may not take this course for credit.
NOTE: Electrical Engineering and Computer Engineering students may not take this course for credit.

MECH 370 ***Modelling, Simulation and Control Systems*** (3.5 credits)
Prerequisite: PHYS 205; ENGR 213; ENGR 311 previously or concurrently; ENGR 245 or 243. Definition and classification of dynamic systems and components. Modelling of system components: mechanical, electromechanical, and electro-hydraulic systems. Nonlinear systems and linear representations of nonlinear components. Time domain analysis. Transfer function models. Transient and steady-state characteristics of dynamic systems. State variable models. Block diagrams and signalflow graphs. Characteristics and performance of linear feedback control systems. System stability. Simulation techniques using Matlab/Simulink. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.
NOTE: Students who have received credit for ELEC 370 may not take this course for credit.

MECH 371 ***Analysis and Design of Control Systems*** (3.75 credits)
Prerequisite: ENGR 311; MECH 370. Stability of linear feedback systems. Root-Locus method. Frequency response concepts. Stability in the frequency domain. Feedback system design using Root Locus techniques. Compensator concepts and configurations. PID-controller design. Simulation and computer-aided controller design using Matlab/Simulink. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: three hours per week, alternate weeks.
NOTE: Students who have received credit for ELEC 372 may not take this course for credit.

MECH 375 ***Mechanical Vibrations*** (3.5 credits)
Prerequisite: ENGR 311; MECH 370. Transient vibrations under impulsive shock and arbitrary excitation: normal modes, free and forced vibration. Multi-degree of freedom systems, influence coefficients, orthogonality principle, numerical methods. Continuous

systems; longitudinal torsional and flexural free and forced vibrations of prismatic bars. Lagrange's equations. Vibration measurements. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.
NOTE: Students who have received credit for MECH 443 may not take this course for credit.

MECH 390 ***Mechanical Engineering Design Project*** (3 credits)
Prerequisite: MECH 311, 343; MECH 344 previously or concurrently. The design process; product cost, quality and time to market, open and concept design problems, problem description. Geometric and type synthesis. Direct and inverse design problems. Material selection and load determination. Mathematical modelling, analysis, and validation. Introduction to Computer-Aided Design and Engineering (CAD and CAE). Product evaluation for performance, tolerance, cost, manufacture, assembly, and other measures. Design documentation. A team-based design project is an intrinsic part of this course. Lectures: three hours per week. Tutorial: two hours per week.

MECH 411 ***Instrumentation and Measurements*** (3.5 credits)
Prerequisite: ENGR 311; AERO 371 or MECH 370. Unified treatment of measurement of physical quantities; static and dynamic characteristics of instruments — calibration, linearity, precision, accuracy, and bias and sensitivity drift; sources of errors; error analysis; experiment planning; data analysis techniques; principles of transducers; signal generation, acquisition and processing; principles and designs of systems for measurement of position, velocity, acceleration, pressure, force, stress, temperature, flow-rate, proximity detection. The course includes demonstration of various instruments. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.
NOTE: Students who have received credit for MECH 373 may not take this course for credit.

MECH 412 ***Computer-Aided Mechanical Design*** (3.5 credits)
Prerequisite: MECH 313. Introduction to computational tools in the design process. Introduction to the fundamental approaches to computer-aided geometric modelling, physical modelling and engineering simulations. Establishing functions and functional specifications with emphasis on geometric tolerancing and dimensioning, manufacturing and assembly evaluation. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

MECH 414 ***Computer Numerically Controlled Machining*** (3.5 credits)
Prerequisite: MECH 311, 412. Computer aided design and manufacturing (CAD/CAM) hardware and software. Essentials of Computer Numerical Control (CNC) machine tools and systems. Process planning and tooling systems for CNC machining. Theory of CNC programming of sculptured parts. Multi-axis CNC tool path generation. Project using CAD/CAM software; CATIA for complex mechanical parts design and a CNC machine tool to manufacture parts. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

MECH 415 ***Advanced Programming for Mechanical and Industrial Engineers*** (3 credits)
Prerequisite: MECH 215. Class definitions. Designing classes and member functions. Constructors and destructors. Class libraries and their uses. Input and output. Data abstraction and encapsulation. Introduction to software engineering. Computer graphics and visualization. Numerical methods. Advanced mechanical and industrial engineering applications. This course includes a substantial project. Lectures: three hours per week. Tutorial: one hour per week.

MECH 421 ***Mechanical Shaping of Metals and Plastics*** (3.5 credits)
Prerequisite: MECH 221. Metal forming: extrusion, forging, rolling, drawing, pressing, compacting; shear line theory, sheet forming limits. Metal cutting, machinability, tooling. Plastics shaping: extrusion, moulding, vacuum forming. Consideration of the mechanical parameters critical for process control and computer applications. Interaction of materials characteristics with processing to define product properties: cold working, annealing, hot working, super plasticity, thermomechanical treatment. Energy conservation, safety, product quality, and liability. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

MECH 422 ***Mechanical Behaviour of Polymer Composite Materials*** (3 credits)
Prerequisite: ENGR 233, 244; MECH 221. General applications of polymer composite materials in aircraft, aerospace, automobile, marine, recreational, and chemical processing industries. Mechanics of a unidirectional lamina. Transformation of stress, strain, modulus, and compliance. Off-axis engineering constants, shear and normal coupling coefficients. In-plane and flexural stiffness and compliance with different laminates, including cross-ply, angle-ply, quasiisotropic, and general bidirectional laminates. Hygrothermal effects. Strength of laminates and failure criteria. Micromechanics. Lectures: three hours per week.

MECH 423 ***Casting, Welding, Heat Treating, and Non-Destructive Testing*** (3.5 credits)
Prerequisite: MECH 221. Comparative analysis of the various techniques of casting, welding, powder fabrication, finishing, and non-destructive testing. Consideration of the control parameters that are essential to define both automation and robot application. Materials behaviour which determines product micro-structure and properties. Technology and theory of solidification, normalizing, quenching, surface hardening, tempering, aging, and thermomechanical processing for steels, cast irons and Al, Cu, Ni and Ti alloys. Energy conservation, worker safety, quality control, and product liability. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: two hours per week, alternate weeks.

MECH 424 ***MEMS — Design and Fabrication*** (3.5 credits)
Prerequisite: MECH 311, 343. Introduction to microsystems and devices; mechanical properties of materials used in microsystems; microfabrication and post-processing techniques; sacrificial and structural layers; lithography, deposition and etching; introduction and design of different types of sensors and actuators; micromotors and other microdevices; mechanical design, finite element modelling; design and fabrication of free-standing structures; microbearings; special techniques: double-sided lithography,

electrochemical milling, laser machining, LIGA, influence of IC fabrication methods on mechanical properties; application examples in biomedical, industrial, and space technology areas; integration, bonding and packaging of MEMS devices. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

MECH 425 ***Manufacturing of Composites*** (3.5 credits)
Prerequisite: MECH 311. Fibres and resins. Hand lay up. Autoclave curing. Compression molding. Filament winding. Resin transfer molding. Braiding. Injection molding. Cutting. Joining. Thermoset and thermoplastic composites. Polymer Nanocomposites. Process modelling and computer simulation. Non-destructive evaluation techniques. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

MECH 426 ***Stress and Failure Analysis of Machinery*** (3 credits)
Prerequisite: ENGR 233, 244. Analysis of stresses, strains and deformations in machine elements; non-symmetric bending of beams; shear centre for thin-walled beams; curved beams; torsion of non-circular shafts and tubes; thick wall cylinders; plates and shells; contact elements; stress concentrations; energy methods; failure modes, analysis and prevention; buckling, fracture, fatigue and creep. Lectures: three hours per week.

MECH 444 ***Guided Vehicle Systems*** (3 credits)
Prerequisite: MECH 375. Definition and classification of guided transportation systems. Track characterization: alignment, gage, profile, and cross-level irregularities. Wheel-rail interactions: rolling contact theories, creep forces. Modelling of guided vehicle components: wheel set, suspension, truck and car body configurations, suspension characteristics. Performance evaluation: stability hunting, ride quality. Introduction to advanced vehicles. Lectures: three hours per week.

MECH 447 ***Fundamentals of Vehicle System Design*** (3.5 credits)
Prerequisite: MECH 343. Mechanics and construction of wheels and tires: rolling resistance, tractive and braking forces, brake system design: components of mechanical, hydraulic and pneumatic brake systems, braking efficiency, antilock braking devices, performance characteristics of road vehicles: transmission design, driving condition diagrams, acceleration, speed and stopping distance, gradability, steering mechanisms: design and kinematics, suspension spring and shock absorbers: anti-roll and anti-pitch devices, chassis and body design considerations. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

MECH 448 ***Vehicle Dynamics*** (3 credits)
Prerequisite: MECH 447 previously or concurrently. Tire-terrain interactions; side-slip, cornering and aligning properties of tires; camber angle and camber torque; estimation of braking/tractive and cornering forces of tires; steady-state handling of road vehicles; steering response and directional stability; handling and directional response of vehicles with multiple steerable axles; handling of articulated vehicles; handling and directional response of tracked and wheeled off-road vehicles; directional response to simultaneous braking and steering. Lectures: three hours per week.

MECH 452 ***Heat Transfer II*** (3.5 credits)
Prerequisite: MECH 351, 352, 361. Heat exchangers. Condensation and boiling heat transfer. Principles of forced convection. Analysis of free convection from a vertical wall. Correlations for free convection in enclosed spaces. Mass transfer. Special topics of heat transfer. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

MECH 453 ***Heating, Ventilation and Air Conditioning Systems*** (3 credits)
Prerequisite: MECH 352. Heating and cooling load calculation. Overview of heating and air conditioning systems. Review: Vapour compression refrigeration cycles, refrigerant properties, psychometrics. Performance characteristic of components: evaporators, condensers, compressors, throttling devices (expansion valves, capillary tubes). System performance characteristics: calculation of system operating conditions based on the capacities of its components and outdoor and indoor conditions. Controls: operational, capacity. Computer-aided design methods. Defrosting. Estimation of energy consumption for heating with heat pumps. Fundamentals of refrigerant piping, water piping, and air distribution systems. Experimental methods for system development. Lectures: three hours per week.

MECH 454 ***Vehicular Internal Combustion Engines*** (3 credits)
Prerequisite: MECH 351, 361. Mechanical design of vehicular engines for different applications. Gas exchange and combustion engine processes. Combustion chambers design. Fuels for vehicular engines. Fuel supply, ignition and control systems. Cooling and lubrication of engines. Emissions formation and control. Engines' operational characteristics — matching with vehicles. Enhancement of engine performance. Engine testing. Environmental impact of vehicular engines on global pollution. Recent developments in energy efficient and "clean" engines. Design or calculation project of vehicular engine. Lectures: three hours per week.

MECH 460 ***Finite Element Analysis*** (3.75 credits)
Prerequisite: ENGR 244, 391. Formulation and application of the finite element method to modelling of engineering problems, including stress analysis, vibrations, and heat transfer. Examples illustrating the direct approach, as well as variational and weighted residual methods. Elements and interpolation functions. Meshing effect. Error analysis. One- and two-dimensional boundary value problems. Development of simple programs and direct experience with general purpose packages currently used in industry for design problems. Lectures: three hours per week. Laboratory: three hours per week, alternate weeks.

MECH 461 ***Gas Dynamics*** (3.5 credits)
Prerequisite: MECH 361. Review of one-dimensional compressible flow. Normal and oblique shock waves; Prandtl-Meyer flow; combined effects in one-dimensional flow; non-ideal gas effects; multi-dimensional flow; linearized flow; method of characteristics.

Selected experiments in supersonic flow, convergent-divergent nozzles, hydraulic analog and Fanno tube. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

MECH 463 ***Fluid Power Control*** (3.5 credits)
Prerequisite: ENGR 361; ELEC 372 or MECH 371. Introduction to fluid power; pneumatic devices; fluidic devices; hydraulic system components; hydraulic and electro-hydraulic systems; dynamic performance of fluid power systems; fluid logic. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

MECH 471 ***Microcontrollers for Mechatronics*** (3.5 credits)
Prerequisite: ENGR 311; MECH 368. Introduction to the concepts and practices of microcontrollers and their application for the control of electromechanical devices and systems. Study of the internal architecture of microcontrollers; programming in assembly language for specific microcontroller functions and controller algorithms; timing of the microcontroller and interfacing with peripheral devices. Students undertake hands-on project work by controlling the position or speed of a DC motor with a feed-back sensor. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

MECH 472 ***Mechatronics and Automation*** (3.5 credits)
Prerequisite: MECH 215; MECH 371 previously or concurrently. Design and analysis of mechatronic and automation systems. Selection and integration of actuators, sensors, hardware, and software. Computer vision. Programming and software design for mechatronic systems. Modelling and simulation. Design of logic control systems. Finite state machine methods. Feedback control and trajectory generation. Safety logic systems. Case studies including automation systems, mobile robots, and unmanned vehicle systems. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

MECH 473 ***Control System Design*** (3.5 credits)
Prerequisite: ELEC 372 or MECH 371. Analog and digital controller designs. Analog controllers: lead/lag compensators, pole placement, model matching, two-parameter configuration, plant input/output feedback configuration. Digital controllers: difference equations, Z-transform, stability in the Z-domain, digital implementation of analog controllers, equivalent digital plant method, alias signals, selection of sampling time. Introduction to analog/digital state-space: controllability, observability, state feedback, state estimator. PI and PID controllers. Simulink assignments and project. Hardware laboratory project: analog and digital controller design for motor with inertial plus generator load. Lectures: three hours per week. Laboratory: two hours per week, alternate weeks.

MECH 474 ***Mechatronics*** (3.75 credits)
Prerequisite: ELEC 372 or MECH 371. Introduction to mechatronics; basic elements of mechatronic systems. Measurement systems: including principles of measurement systems; sensors and transducers; signal conditioning processes and circuits; filters and data acquisition. Actuation systems: mechanical actuation systems and electrical actuation systems. Controllers: control modes; PID controller; performance measures; introduction to digital controllers and robust control. Modelling and analysis of mechatronic systems; performance measures; frequency response; transient response analysis; stability analysis. Lectures: three hours per week. Laboratory: three hours per week, alternate weeks.

MECH 490A ***Capstone Mechanical Engineering Design Project*** (4 credits)
Prerequisite: 75 credits in the program; ENCS 282; ENGR 301; MECH 344, 390. A supervised design, simulation or experimental capstone design project including a preliminary project proposal with complete project plan and a technical report at the end of the fall term; a final report by the group and presentation at the end of the winter term. Lectures: one hour per week, one term. Equivalent laboratory time: three hours per week, two terms.
NOTE: Students will work in groups under direct supervision of a faculty member. Each student will undertake project work in the area of their option.

MECH 490B ***Capstone Mechanical Engineering Design Project*** (4 credits)
Prerequisite: 75 credits in the program; ENCS 282; ENGR 301; MECH 344, 390. A supervised design, simulation or experimental capstone design project including a preliminary project proposal with complete project plan and a technical report at the end of the fall term; a final report by the group and presentation at the end of the winter term. Lectures: one hour per week, one term. Equivalent laboratory time: three hours per week, two terms.
NOTE: Students will work in groups under direct supervision of a faculty member. Each student will undertake project work in the area of their option.

MECH 490C ***Capstone Mechanical Engineering Design Project*** (4 credits)
Prerequisite: 75 credits in the program; ENCS 282; ENGR 301; MECH 344, 390. A supervised design, simulation or experimental capstone design project including a preliminary project proposal with complete project plan and a technical report at the end of the fall term; a final report by the group and presentation at the end of the winter term. Lectures: one hour per week, one term. Equivalent laboratory time: three hours per week, two terms.
NOTE: Students will work in groups under direct supervision of a faculty member. Each student will undertake project work in the area of their option.

MECH 498 ***Topics in Mechanical Engineering*** (3 credits)
Prerequisite: Permission of the Department Chair. This course may be offered in a given year upon the authorization of the Mechanical and Industrial Engineering Department. The course content may vary from offering to offering and will be chosen to complement the elective courses available in a given option or options. Lectures: three hours per week.

DEPARTMENT OF COMPUTER SCIENCE AND SOFTWARE ENGINEERING

Section 71.70

Faculty

Chair
SUDHIR P. MUDUR, PhD *Bombay University*, PEng; *Professor*

Associate Chair
THOMAS FEVENS, PhD *Queen's University*; *Associate Professor*

Professors
SABINE BERGLER, PhD *Brandeis University*
TIEN D. BUI, PhD *York University*, ing.
GREGORY BUTLER, PhD *University of Sydney*
VACLAV CHVATAL, PhD *University of Waterloo*; *Provost's Distinction*
BIPIN C. DESAI, PhD *McGill University*
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TERRILL FANCOTT, DSc *Université de Paris,* ing.
PETER GROGONO, PhD *Concordia University*, PEng
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HOVHANNES A. HARUTYUNYAN, PhD *Armenian Academy of Sciences*
BRIGITTE JAUMARD, PhD *École Nationale Supérieure des Télécommunications*
ADAM KRZYZAK, PhD *University of Wroclaw*; *Provost's Distinction*
LATA NARAYANAN, PhD *University of Rochester*, ing.
JUERGEN RILLING, PhD *University of Illinois*
CHING Y. SUEN, PhD *University of British Columbia*; *Provost's Distinction*

Distinguished Professors Emeriti
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JOHN MCKAY, PhD *University of Edinburgh*; *Provost's Distinction*

Professors Emeriti
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DAVID FORD, PhD *Ohio State University*
CLEMENT LAM, PhD *California Institute of Technology*
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G. MARTIN, MSc *University of New Brunswick*
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TODD EAVIS, PhD *Dalhousie University*
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RAJAGOPALAN JAYAKUMAR, PhD *Concordia University*
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YUHONG YAN, PhD *Tsinghua University/Leipzig University*, PEng

Assistant Professors
TIBERIU POPA, PhD *University of British Columbia*
PETER RIGBY, PhD *University of Victoria*
NIKOLAOS TSANTALIS, PhD *University of Macedonia*

Extended Term Appointment
AIMAN HANNA, MCompSc *Concordia University*, PEng

Affiliate Professors
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T. KASVAND, PhD *University of British Columbia*
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T. KENGATHARAM, PhD *Concordia University*
M. MOHAMMAD, PhD *Concordia University*
K. PITULA, 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 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 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 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 the General Program and 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)		*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	3.00
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
		32.00

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.
- 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 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. General Program

	Credits
Computer Science Core	32.00
Complementary Core	6.00
Computer Science Electives*	31.00
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	32.00
Complementary Core	6.00
Computer Games Electives	24.00
Computer Science Electives	7.00
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 (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	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 *.

		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	32.00
Complementary Core	6.00
Computer Systems Electives	22.00
Computer Science Electives	9.00
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	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

6. 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 *.

		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	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.

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
12 MATH 202[3], 203[3], 204[3], 205[3]
6 Chosen from courses in Humanities or Social Sciences in Section 71.20.2
12 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:*
12 elective credits chosen from outside the Faculty of Engineering and Computer Science, in consultation with the undergraduate program director.

b) *Computation Arts Option:*
12 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:*
12 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:*
12 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) *Computer Systems Option:*
CHEM 205[3]
PHYS 204[3], 205[3]
and 3 elective credits chosen from outside the Faculty of Engineering and Computer Science, in consultation with the undergraduate program director.

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 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. The student must successfully complete the course COMP 490.
3. For students in the General Program, and 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. 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	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
		72.50

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
		22.00

Basic Science Courses
Two Basic Science courses must be selected from the following:

		Credits
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

General Program
Students must complete at least 17 credits chosen from the electives list.

Options
Students must complete at least 17 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 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 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
SOEN 491	Software Engineering Project	1.00
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 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 229 ***System Software*** (3 credits)
Prerequisite: COMP 228; COMP 248; MATH 203 or Cegep Mathematics 103 or NYA; MATH 204 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 Cegep Mathematics 103 or NYA previously or concurrently; MATH 204 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: 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 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.
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 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.

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 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 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 232 or COEN 231; COMP 335; 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. 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 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.

SOFTWARE ENGINEERING

SOEN 228 ***System Hardware*** (4 credits)
Prerequisite: MATH 203 or Cegep Mathematics 103, MATH 204 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 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. 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 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.

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. 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 architectures and their software. Development environments. Operating system configuration. Interprocessor and remote communication. Interface, timer and interrupt configuration. Control of physical systems. Design, implementation 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. 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 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.

COMPUTATION ARTS AND COMPUTER SCIENCE *Section 71.80*

Faculty

Undergraduate Program Director
TODD EAVIS, PhD *Dalhousie University*; *Associate Professor*

Location

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

Objectives

The Faculty of Engineering and Computer Science and the Faculty of Fine Arts have created a program of study which combines a comprehensive education in computer science and a complementary set of courses of equivalent value in the fine arts. This program resides in both Faculties. In the Faculty of Engineering and Computer Science, it is offered under the aegis of the Bachelor of/Baccalaureate in Computer Science, Computer Applications Option. According to their preferences and aspirations, students may apply either for a Bachelor of/Baccalaureate in Computer Science program, or a Bachelor of/Baccalaureate in Fine Arts program. The Fine Arts offering is described in §81.90. The Computer Science program is described below.

Curriculum

The Computer Applications Option may be taken with a Major in Computation Arts. It consists of 45 credits in Computer Science complemented by 45 credits of study in Fine Arts. It provides a foundation for the integration of the arts and computer science as hybrid digital media arts and multimedia productions.
The Computation Arts core focuses on three areas of digital media: image works, sound exploration, and 3D modelling/animation. Through the integration of theory and practice, the programs aim at developing interdisciplinary cultural and technological practices, for independent arts initiatives, industry, and client-based productions.
The core courses are open-ended and flexible to accommodate change that will run parallel to technological advancements in industry and give students a strong base in multimedia research. Design Art, Electroacoustics, Film Animation, and the Studio Electronic Arts provide the Fine Arts electives, which further supports the cross-disciplinary nature of the program directives.
This program will give graduates the conceptual abilities and technical skills they need to practise as hybrid cultural workers in the rapidly expanding field of multimedia. Students will have many more options to fine-tune a multimedia program according to their individual needs and expectations. Courses have been restructured into three credits to facilitate computer lab access, and flexibility in course sequencing and offerings, as well as to accommodate completion of the program within a co-op structure.
Students of Computation Arts must bear the costs of annual laboratory fees.

Structure of the Program

Computation Arts Option
The program consists of 45 credits in Computer Science and 45 credits in Fine Arts, as described below:

		Credits
	Computer Science Core (see §71.70.2)	32.00
	Complementary Core (see §71.70.2)	6.00
	Computation Arts Core (see §81.90.2)	45.00
COMP 345	Advanced Program Design with C++	4.00
COMP 371	Computer Graphics	4.00
		91.00

Admission Requirements

The Computation Arts Major is limited to students who are enrolled in or simultaneously applying for the Computer Science Applications Option and who are qualified for the Fine Arts component. Applicants must fulfill the admission requirements for the Computer Science Option in Computer Applications (see §71.10.2) and be accepted into the Computer Applications Option.
In addition to the normal admission procedure of Concordia University, there is a distinct admission procedure for applicants to the Major in Computation Arts. All applicants must submit a portfolio to the Program Office, Visual Arts Building, Room 244, on or before March 1. Further information may be obtained by contacting the Department of Design and Computation Arts.

MATHEMATICS AND STATISTICS AND COMPUTER APPLICATIONS

Section 71.85

Faculty

Undergraduate Program Director
TODD EAVIS, PhD *Dalhousie University*; *Associate Professor*

Location

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

Objectives

The Faculty of Engineering and Computer Science and the Faculty of Arts and Science have created a program of study which combines a comprehensive education in computer science and mathematics. This program resides in both Faculties. In the Faculty of Engineering and Computer Science, it is offered under the aegis of the Bachelor of/Baccalaureate in Computer Science, Computer Applications Option. According to their preferences and aspirations, students may apply either for a Bachelor of/Baccalaureate in Computer Science program, Bachelor of/Baccalaureate in Science program, or Bachelor of/Baccalaureate in Arts program. The Arts and Science offering is described in §31.200. The Computer Science program is described below.

Curriculum

The Computer Applications Option may be taken with a Major in Mathematics and Statistics. It provides a foundation for integrated studies in computer science and mathematics.
The mathematics component of the program includes topics that overlap with computer science, such as modelling, symbolic computation, and combinatorics, as well as the standard topics of a mathematical curriculum.

Structure of the Program

The program consists of 90 credits.

Mathematics and Statistics Option	*Credits*
Computer Science Core (see §71.70.2)*	32.00
Complementary Core (see §71.70.2)	6.00
Mathematics and Statistics Core	36.00
Computer Science Electives (see §71.70.2)	4.00
General Electives (see §71.70.2)	12.00
	90.00

*COMP 232 may be replaced by MAST 217. COMP 233 must be replaced by MAST 221.

Mathematics and Statistics Core		*Credits*
COMP 339	Combinatorics*	3.00
COMP 361	Elementary Numerical Methods**	3.00
COMP 367	Techniques in Symbolic Computation***	3.00
COMP 465	Design and Analysis of Algorithms	3.00
MAST 218	Multivariable Calculus I	3.00
MAST 219	Multivariable Calculus II	3.00
MAST 224	Introduction to Optimization	3.00
MAST 232	Mathematics with Computer Algebra	3.00
MAST 234	Linear Algebra and Applications I	3.00

MAST 235	Linear Algebra and Applications II	3.00
MAST 331	Mathematical Modelling	3.00
MAST 333	Applied Statistics	3.00
		36.00

*COMP 339 may be replaced by MATH 339.
**COMP 361 may be replaced by MAST 334.
***COMP 367 may be replaced by MAST 332.

Admission Requirements

The Computer Science and Mathematics and Statistics program is restricted to students who are enrolled in or simultaneously applying for the Computer Science Applications Option and who are qualified for the mathematics component. Applicants must fulfill the admission requirements for the Computer Science Option in Computer Applications (see §71.10.2) and be accepted into the Computer Applications Option. For admission requirements for the mathematics component, see §31.200.

CENTRE FOR ENGINEERING IN SOCIETY *Section 71.90*

Faculty

Chair
DEBORAH DYSART-GALE, PhD *University of Pittsburgh*; *Associate Professor*

Associate Chair
GOVIND GOPAKUMAR, PhD *Rensselaer Polytechnic Institute*; *Assistant Professor*

Assistant Professors
MATTHEW HARSH, PhD *University of Edinburgh*
KETRA SCHMITT, PhD *Carnegie Mellon University*

Assistant Professor Emerita
BERNICE GOLDSMITH, BA *Concordia University*

Extended Term Appointment
NANCY ACEMIAN, MCompSc *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 002.257
514-848-2424, ext. 5443

Objectives

The Centre for Engineering in Society (CES) has been created with two major objectives. The primary objective of the CES is to blend the teaching of engineering and technology with skills needed for students to become professionals who are responsible, articulate and ethical. The CES brings complementary skills and knowledge to engineering and information technology training by offering suitable courses.
An additional objective of the CES is to coordinate and manage those graduate and undergraduate courses in engineering, engineering mathematics, and computer science that are common to multiple departments within the Faculty of Engineering and Computer Science.

CONCORDIA INSTITUTE FOR INFORMATION SYSTEMS ENGINEERING

Section 71.100

Faculty

Director
RACHIDA DSSOULI, PhD *Université de Montréal*; *Professor*

Associate Director
AMR YOUSSEF, PhD *Queen's University*, PEng; *Professor*

Professors
CHADI ASSI, PhD *City University of New York*, PEng
NOEL CRESPI, PhD *University Paris 6*
MOURAD DEBBABI, PhD *Université de Paris*
AMIN HAMMAD, PhD *Nagoya University*
RUIXUAN LI, PhD *Huazhong University of Science and Technology*
YONG ZENG, PhD *University of Calgary*, PEng

Associate Professors
ANJALI AWASTHI, PhD *University of Metz*, PEng
ABDESSAMAD BEN HAMZA, PhD *North Carolina State University*, PEng
JAMAL BENTAHAR, PhD *Université Laval*, PEng
NIZAR BOUGUILA, PhD *Université de Sherbrooke*, PEng
ROCH GLITHO, PhD *Royal Institute of Technology, Sweden*
CHUN WANG, PhD *University of Western Ontario*, PEng
LINGYU WANG, PhD *George Mason University*, PEng

Assistant Professors
JEREMY CLARK, PhD *University of Waterloo*
MOHAMMAD MANNAN, PhD *Carleton University*
ANDREA SCHIFFAUEROVA, PhD *Université de Montréal*

Affiliate Professor
PRABIR BHATTACHARYA, PhD *University of Oxford*

Affiliate Associate Professors
FRANÇOIS COSQUER, PhD *Technical University of Lisbon*
STÉPHANE CÔTÉ, PhD *University of Southhampton*
BENJAMIN FUNG, PhD *Simon Fraser University*, PEng
SIMON LI, PhD *University of Toronto*, PEng
MARTIN MAIER, PhD *Technical University of Berlin*
MAKAN POURZANDI, PhD *Université de Lyon I*
ZHIGANG TIAN, PhD *University of Alberta*
ANDREW L. VALLERAND, PhD *Université Laval*
FAYI ZHOU, PhD *University of Alberta*

Affiliate Assistant Professors
MAURICE KHABBAZ, PhD *Concordia University*
HADI OTROK, PhD *Concordia University*
SAMIR SEBBAH, PhD *Concordia University*
ADEL SERHANI, PhD *Concordia University*
KHALED SHABAN, PhD *University of Waterloo*

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 007.640
514-848-2424, ext. 5847

Objectives

The Concordia Institute for Information Systems Engineering is an interdisciplinary fundamental research and R&D learning institute, housing state-of-the-art research in innovative applications of information systems to a wide range of areas, among them systems, telecommunications, software development, electronics, multimedia, aerospace, finance and banking, automotive, manufacturing, and building and construction management.
The Concordia Institute for Information Systems Engineering offers only graduate programs.