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.
NOTE: This course cannot be used for credit in any ENCS degree or certificate program.

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)

ENGR 371 Probability and Statistics in Engineering (3 credits)

ENGR 391 Numerical Methods in Engineering (3 credits)
Prerequisite: ENGR 213, 233; COMP 249 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 cumulative GPA 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)

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 342 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
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: one hour per week. Laboratory: two hours per week. 

**NOTE:** Students who have received credit for ELEC 372 or MECH 371 may not take this course for credit.

AERO 417  **Standards, Regulations and Certification**  (3 credits)
Prerequisite: ENGR 201. 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 498 number may not take this course for credit.

AERO 431  **Principles of Aeroelasticity**  (3 credits)

**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)

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  **Turbo Machinery and Propulsion**  (3 credits)

**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, Prandtl-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)

**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)

**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 232; 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; Tsiolkovsky’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 ELEC 415 or MECH 480 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 ELEC 415 or MECH 480 may not take this course for credit.

AERO 487  **Design of Aircraft Structures**  (3 credits)

**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.
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: two hours 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

BCEE 466 Simulations and Design of Construction Operations (3 credits)

BUILDING ENGINEERING

BLDG 212 Building Engineering Drawing and Introduction to Design (3 credits)

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)

BLDG 366 Acoustics and Lighting (3.5 credits)

BLDG 371 Building Service Systems (3 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)

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)

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)

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 encompasses 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 and environmental impact issues are 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 490A  **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 encompasses 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 and environmental impact issues are 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.

**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.

**CE 331  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.

**CIVI 412  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 499  Topics in Building Engineering** (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.
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)

CIVI 435  Foundation Design (3 credits)

CIVI 437  Advanced Geotechnical Engineering (3 credits)

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)

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

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.

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, alternate weeks.

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
COMPUTER ENGINEERING

COEN 212  Digital Systems Design I (3.5 credits)
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). 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: division algorithm. Induction and recursion: induction on natural numbers; recursive definitions. Functions and relations: cartesian products and relations; functions; function composition and inverse functions; equivalence relations. 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. Finite-state machines (FSM) deterministic and nondeterministic machines; regular languages; FSM with output; composition of FSM. Lectures: three hours per week. Tutorial: one hour per week.

COEN 243  Programming Methodology I (3 credits)
Prerequisite: MATH 204 (Cegep Mathematics 105). Introduction to computer hardware and software, programming and programming paradigms; including low-level programming. Boolean algebra: operators, expressions and truth tables. 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)
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)

COEN 313  Digital Systems Design II (3.5 credits)

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 (3.5 credits)

COEN 317 Microprocessor Systems (3.5 credits)
Prerequisite: COEN 311 or COMP 228 or SOEN 228; COEN 313. 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. Custom hardware units and multi-core systems. Benchmarking and comparative study of recent microprocessor systems. Lectures: three hours per week. Tutorial: 15 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 (3.5 credits)

COEN 346 Operating Systems (3.5 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: 15 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 231, 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, 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** (3.5 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: 15 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 242  Continuous-Time Signals and Systems** (3 credits)

**NOTE:** Students who have received credit for ELEC 264 may not take this course for credit.

**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)

ELEC 311 **Electronics I** (3.5 credits)
Prerequisite: ELEC 273. Diodes: terminal characteristics of junction diodes; analysis of diode circuits; the small signal model and its application; operation in the reverse-breakdown region — Zener diodes; rectifiers, limiting and clamping circuits. Principle of signal amplification: small signal models; linearity; loading effects; cascaded amplifiers. MOSFETs: structure and physical operation; current-voltage characteristics; MOSFET as switch, DC analysis; biasing considerations; small signal analysis, models and parameters; three basic configurations: common gate, common source, common drain, or amplification. Overview of BJTs circuits: structure and physical operation of BJT; DC analysis; biasing considerations: small signal analysis and parameters; basic configurations for amplification. PSPICE: laboratory pre-labs and extensive simulation exercises. Lectures: three hours per week. Tutorial: two hours per week. Laboratory: 15 hours total.

ELEC 312 **Electronics II** (3.5 credits)
Prerequisite: ELEC 311; ELEC 342 or 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; common gate, common source, common drain configurations; common base, common emitter, common collector configurations; wide-band amplifiers. Feedback: general feedback structure; properties of negative feedback; the four basic feedback configurations; loop gain and stability problems. Power amplifiers: classification and output stages; class A, B, C, and AB amplifiers; biasing the class AB amplifier. Introduction to filters, tuned amplifiers, oscillators and mixers. PSPICE: Laboratory pre-labs and extensive simulation exercises. Lectures: three hours per week. Tutorial: one hour per week. Laboratory: 15 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)

ELEC 342 **Discrete-Time Signals and Systems** (3.5 credits)
ELEC 351  Electromagnetic Waves and Guiding Structures (3 credits)

ELEC 353  Transmission Lines, Waves and Signal Integrity (3 credits)
Prerequisite: ELEC 242 or 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 364  Signals and Systems II (3.5 credits)
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)
NOTE: Students who have received credit for ELEC 261 or 362 may not take this course for credit.

ELEC 367  Introduction to Digital Communications (3.5 credits)
Prerequisite: ELEC 342 or 364; ENGR 371. Analog communications and frequency multiplexing; pulse-code-modulation and time multiplexing; additive white Gaussian noise; matched filter and correlator receiver; maximum likelihood receiver and error probability; intersymbol interference, pulse shaping filter; Signal Space Analysis; Union Bound on the probability of error; Pass-band communication Systems; coherent and non-coherent communication systems; linear block codes, syndrome-based decoding; coding vs. modulation. Lectures: three hours 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 372  Fundamentals of Control Systems (3.5 credits)
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). Structures and characteristics of diodes, solar cells, bipolar transistors, and fundamentals of MOSFETs. Planar silicon junctions and transistors will be designed, fabricated and evaluated in the laboratory, including resistivity measurements, semiconductor cleaning, oxidation, diffusion, photolithography, etching, metalization, 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. FinFETs, SOI FETs, velocity modulation transistors, and HFETs. Role of strain in operation of modern FETs. 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

**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)

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)

**ELEC 434 Behaviour of Power Systems** (3.5 credits)

NOTE: This course is usually offered in the French language.

**ELEC 435 Electromechanical Energy Conversion Systems** (3.5 credits)

**ELEC 436 Protection of Power Systems** (3.5 credits)

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)
NOTE: This course is usually offered in the French language.

ELEC 439  Hybrid Electric Vehicle Power System Design and Control (3 credits)

ELEC 440  Controlled Electric Drives (3.5 credits)
Prerequisite: ELEC 331, 372. 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)

ELEC 442  Digital Signal Processing (3 credits)
Prerequisite: ELEC 342 or 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)

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)

ELEC 457  Design of Wireless RF Systems (3 credits)

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.

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ELEC 463  **Telecommunication Networks** (3 credits)
Prerequisite: ELEC 342 or 364; ENGR 371. 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 367. 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. Convolutional codes, Viterbi decoder; wireless standards from first generation to fourth generation; OFDM: an architecture for the fourth generation. Extensive communication system simulation exercises. Lectures: three hours per week.

ELEC 465  **Networks Security and Management** (3.5 credits)

ELEC 466  **Introduction to Optical Communication Systems** (3.5 credits)

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)
**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 $p^\infty$ 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; TQM; 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; INDU 211. 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)
Prerequisite: ENGR 301 previously or concurrently. 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)

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 previously or concurrently; INDU 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)

INDU 442  Logistics Network Models (3 credits)

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)

MECH 215  Programming for Mechanical and Industrial Engineers (3.5 credits)

MECH 221  Materials Science (3 credits)
Prerequisite: CHEM 205 (Cégep 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)

Lectures: two hours per week, alternate weeks.

MECH 352  **Heat Transfer I** (3.5 credits)

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, Thévenin 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 and Analysis of Dynamic Systems** (3 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 dynamic systems containing individual or mixed mechanical, electrical, fluid and thermal elements. Block diagrams representation and simulation techniques using MATLAB/Simulink. Time domain analysis. Transient and steady-state characteristics of dynamic systems. Linearization. Transfer functions. Introduction to feedback control 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 ELEC 370 may not take this course for credit.

MECH 371  **Analysis and Design of Control Systems** (3.75 credits)

**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: two hours 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)

MECH 421 **Mechanical Shaping of Metals and Plastics** (3.5 credits)

MECH 422 **Mechanical Behaviour of Polymer Composite Materials** (3 credits)

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)
MECH 426  Stress and Failure Analysis of Machinery (3 credits)
Prerequisite: ENGR 233, 244; MECH 321. Analysis of stresses, strains and deformations in machine elements; non-symmetric bending of beams; shear centre for thin-walled bars; 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)

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)

MECH 453  Heating, Ventilation and Air Conditioning Systems (3 credits)

MECH 454  Vehicular Internal Combustion Engines (3 credits)

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)

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.