damental hardware. Digital and analogue transducers, actuators, filters, interfaces and processors. Fundamental software: Process assembler language and machine architecture, real time operating systems, process oriented subsystems, interrupts, drivers, service routines. **Professor Zsombor-Murray**

● ◎ **305-557B MECHATRONIC DESIGN.** 3(3-1-5) (Prerequisites: 304-461, 305-383 and 305-412) Team project course on the design, modeling, model validation, and control of complete mechatronic systems, constructed with modern sensors, actuators, real time operating systems, embedded controllers, and intelligent control. **Professor Buehler**

◎ **305-561B BIOMECHANICS OF MUSCULOSKELETAL SYSTEMS.** 3(3-0-6) (Prerequisites: 305-321, 305-315 or 305-412) The musculoskeletal system; general characteristics and classification of tissues and joints. Biomechanics and clinical problems in orthopaedics. Modelling and force analysis of musculoskeletal systems. Passive and active kinematics. Load-deformation properties of passive connective tissue, passive and stimulated muscle response. Experimental approaches, case studies. **Professor Ahmed**

● ◎ **305-562A ADVANCED FLUID MECHANICS.** 3(3-0-6) Conservation laws, control volume analysis, Navier stokes equations, dimensional analysis and limiting forms of N-S equation, laminar viscous flows, boundary layer theory, inviscid potential flows, lift and drag, introduction to turbulence. **Professors J. Lee and Cortelezzi**

◎ **305-565B FLUID FLOW & HEAT TRANSFER EQUIP.** 3(3-1-5) (Prerequisites: 305-240, 305-341, 305-331 and 305-346) Fluid flow machinery and systems. Metering devices and control system. Heat exchange systems. Boilers and condensers. Fouling, corrosion and vibration problems. Air conditioning and refrigeration. Humidifiers and dehumidifiers. Space heating and ventilation system. Monitoring and control units. Building materials and insulation. **Professor Baliga**

◎ **305-572A MECHANICS OF ROBOTICS SYSTEMS I.** 3(3-0-6) (Prerequisites: 189-266 and 305-220 or permission of the instructor. Not open to students who have taken 305-573.) Manipulator hardware structure, planning and control. Rigid-body three-dimensional statics, kinematics and dynamics. Direct and inverse kinematics and dynamics. Trajectory planning. Manipulator control. In-depth study of serial manipulators. **Professor Angeles**

● ◎ **305-573B MECHANICS OF ROBOTIC SYSTEMS II.** 3(3-0-6) (Prerequisite: Permission of the instructor.) Numerical methods for the kinematic inversion of serial manipulators. The handling of redundancies and singularities. Kinematics and dynamics of parallel manipulators, manipulator performance evaluation and optimization, multifingered hand grasping and manipulation, robot compliant and constrained motion. Obstacle avoidance. **Professor Angeles**

◎ **305-576A COMPUTER GRAPHICS AND GEOM. MODELLING.** 3(2-3-4) (Prerequisites: 189-266 and 305-290 or 305-291) Review of pertinent linear algebra and projective geometry. Explicit, implicit and parametric polynomial forms. Splines: curves and surfaces. Properties: curvature, twist, continuity. Ruled surfaces and other quad patches. Constructive solid models; Octree/Voxel, sweep wire frame, Boolean, boundary representation. Mechanical Engineering applications. **Professor Zsombor-Murray**

● ◎ **305-577A OPTIMUM DESIGN.** 3(2-3-4) The role of optimization within the design process: Design methodology and philosophy. Constrained optimization: The Kuhn-Tucker conditions. Techniques of linear and non-linear programming. The simplex and the complex methods. Sensitivity of the design to manufacturing errors. Robustness of the design to manufacturing and operation errors. **Professor Angeles**

● ◎ **305-578B ADVANCED THERMODYNAMICS.** 3(3-0-6) Review of classical mechanics; Boltzmann statistics, thermodynamics of ideal gases; Fermi-Dirac and Bose-Einstein statistics, Gibbsian ensembles; elementary kinetic theory of transport processes, Boltzmann equation, Boltzmann H-theorem and entropy, KBG approximation, discussion on the solution of Boltzmann equation; Maxwell transport equations, derivation of Navier Stokes equations. **Professor J. Lee**

● ◎ **305-581A NONLINEAR DYNAMICS AND CHAOS.** 3(3-1-5) (Prerequisite: 305-319 or 305-315) Approximate solutions to nonlinear dynamical systems: Lindstedt's, multiple-scale and averaging techniques; centre manifold, normal form theorem; applications. Transcritical, saddle-node, pitchfork, Hopf, period-doubling and homoclinic bifurcations; fractal dimensions, Lyapunov exponents and chaos. Applications to two-well potential oscillator, van der Pol, Lorenz, fluid elastic systems. **Professor Paidoussis**

### GRADUATE 600-LEVEL COURSES

Generally, undergraduate students are not permitted to enrol in graduate 600-level courses. However, in exceptional circumstances, the Faculty of Graduate Studies and Research does grant this permission upon the request of the Department on behalf of the student. A list of such courses is described in detail in the Faculty of Graduate Studies and Research Calendar.

## 4.7 Department of Mining and Metallurgical Engineering

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*Chair*
Robin A.L. Drew; B.Tech.(Bradford), Ph.D.(Newcastle)

*Emeritus Professors*
William M. Williams; B.Sc., M.Sc.(Brist.), Ph.D.(Tor.), Eng. *(Henry Birks Emeritus Professor of Metallurgy)*

*Professors*
George P. Demopoulos; Dipl. Eng.(NTU Athens), M.Sc., Ph.D.(McG.), Eng.
Robin A.L. Drew; B.Tech.(Bradford), Ph.D.(Newcastle)
James A. Finch; B.Sc.(Birm.), M.Eng., Ph.D.(McG.), Eng. *(Industry Professor of Mineral Processing)*
John E. Gruzleski; B.Sc., M.Sc.(Qu.), Ph.D.(Tor.), Eng. *(Gerald G. Hatch Professor of Mining and Metallurgy)*
Rod I.L. Guthrie; B.Sc., Ph.D.(Lond.), D.I.C., A.R.S.M., Eng. *(William C. Macdonald Professor of Mining and Metallurgy)*
Farmaraz (Ferri) P. Hassani; B.Sc., Ph.D.(Nott.), C.Eng.(U.K. Reg.) *(George Boyd Webster Professor of Mining Engineering)*
John J. Jonas; B.Eng.(McG.), Ph.D.(Cantab.), F.A.S.M., Eng. *(Henry Birks Professor of Metallurgy)*
Jerzy Szpunar; B.Sc., M.Sc., Ph.D., D.Sc.(Krakow)

*Associate Professors*
Michel L. Bilodeau; B.Eng.(Montr.), M.Sc.App., Ph.D.(McG.), Eng.
Phil A. Distin; B.Sc., Ph.D.(Lond.), D.I.C.
Ralph Harris; B.Sc.(Qld), M.Eng., Ph.D.(McG.)
Mainul Hasan; B.Eng.(Dhaka), M.Sc.(Dhahran), Ph.D.(McG.)
André Laplante; B.A.Sc., M.A.Sc.(Montr.), Ph.D.(Tor.), Eng.
Hani S. Mitri; B.Sc.(Cairo), M.Eng., Ph.D.(McMaster), Eng. (Director, Mining Engineering Program)
Frank Mucciardi; B.Eng., M.Eng., Ph.D.(McG.), Eng.
Jacques Ouellet; B.A.Sc., M.A.Sc, Ph.D.(École Polytechnique)
Steve Yue; B.Sc., Ph.D.(Leeds)

*Assistant Professor*
Janusz A. Kozinski; B.A., M.Eng., D.Sc.(Krakow)

*Faculty Lecturer*
John Mossop; B.Eng.(McG.), Eng.

*Adjunct Professors*
William Caley; Wilfred Comeau, Eng.; Roussos Dimitrakopoulos; Bryn Harris; Ahmad Hemami; Hani Keira, Eng.; Yves Lizotte, Eng.; Bibhu Mohanty; Malcolm J. Scoble, P.Eng.; William T. Thompson; Viwek Vaidya, Eng.; Albert E. Wraith

*Metallurgy CO-OP Program Director*

James A. Finch

*Mining CO-OP Program Coordinator*

Michel Vachon

The Department of Mining and Metallurgical Engineering offers programs leading to the Bachelor of Engineering degree in Mining Engineering or Metallurgical Engineering. The curriculum is dynamic and evolves along with new technology in both the mining and metallurgical industries. In addition to regular courses and laboratories, the curriculum includes seminars, colloquia, and student projects reinforced by field trips to industrial operations.

The equipment operated by the Department is the best available. On the metallurgical side there is a full range of laboratory facilities for mineral processing, hydrometallurgy and high temperature extractive process metallurgy as well as excellent materials characterization and processing facilities. In mining engineering the Department has rock engineering laboratories to test the mechanical properties of both rock and backfill materials and computer-aided mine design facilities. The Department houses laboratories for two McGill Research Centres: the McGill Metals Processing Centre (MMPC) and the Canadian Centre for Automation and Robotics in Mining (CCARM), which focus on R & D and high technology applications for the minerals, metals and materials industries at large.

**Metallurgical Engineering (CO-OP).** The Metallurgical Engineering degree is a cooperative program leading to a B.Eng. and includes formal industrial work periods. It is built around a strong background of mathematics, basic sciences, computer skills and applications, and specific engineering and design courses to provide up-to-date training in metals/materials engineering. Students take core courses covering a complete range of the industry, from metal extraction to processing, fabrication and applications. The program conforms with requirements of the Canadian Engineering Accreditation Board (CEAB) and is designed to offer students the best training for employment in Canada's large and vital metallurgical and manufacturing industries. The basic courses are supplemented by complementary courses which provide a good choice of specialties for the graduating engineer. The course structure is reinforced with laboratory exercises. Graduates in Metallurgical Engineering find employment in a wide range of industries which include the mineral/metal producing and processing sectors, as well as the aerospace and manufacturing industries. Students in the CO-OP program benefit from the practical learning experience arising from work-term employment in meaningful engineering jobs. Students also benefit from the non-tangible learning experience arising from the increased responsibilities required to obtain and successfully complete the work terms.

**Mining Engineering (CO-OP).** McGill, which has the oldest mining engineering program in Canada, has always been noted for the excellence of its courses and for the training it provides in mining technology, mineral economics and mining practice. Graduates in mining engineering are in demand not only in Canada but throughout the world. Technical developments have been rapid in recent years. These offer a challenge to the imaginative student with a strong engineering interest. The Department offers a cooperative program leading to the B.Eng. degree in Mining Engineering. The CO-OP program is offered in collaboration with the Department of Mineral Engineering at École Polytechnique in Montreal, and includes formal industrial work periods. Students registered at McGill are required to take a series of technical mining courses from École Polytechnique in the latter part of the program. These courses are designated as such in the listings below.

**Scholarships.** The Department offers Entrance Scholarships each year, valued at $2,500; these scholarships are renewable. A substantial number of other scholarships and bursaries are awarded by the Department as well as by the Canadian Mineral Industry Education Foundation.

## CURRICULUM FOR THE B.ENG. DEGREE IN METALLURGICAL ENGINEERING – CO-OP PROGRAM

| REQUIRED COURSES | | COURSE CREDITS | |
|---|---|---|---|
| **Non-Departmental Courses** | | | |
| 180-233B | Selected Topics in Physical Chemistry | 3 | |
| 189-260A | Intermediate Calculus | 3 | |
| 189-261A | Differential Equations | 3 | |
| 189-265C | Advanced Calculus | 3 | |
| 303-205A | Statics | 3 | |
| 303-207A | Solid Mechanics | 4 | |
| 308-208A | Computers in Engineering | 3 | **22** |
| **Departmental Courses** | | | |
| 306-202A | Eng. Communication Skills | 2 | |
| 306-209B | Mathematical Applications | 3 | |
| 306-212B | Engineering Thermodynamics | 3 | |
| 306-221A | Engineering Professional Practice | 1 | |
| 306-250A | Introduction to Extraction Metallurgy | 3 | |
| 306-260B | Materials Science and Engineering | 3 | |
| 306-280T | Industrial Training I | 2 | |
| 306-310A | Engineering Economy | 3 | |
| 306-311B | Modelling and Automatic Control | 3 | |
| 306-317C | Materials Characterization | 3 | |
| 306-341B | Introduction to Mineral Processing | 3 | |
| 306-324B | Electrotechnology for Mining, Metallurgical and Materials Engineers | 3 | |
| 306-350B | Extractive Metallurgical Engineering | 3 | |
| 306-352A | Hydrochemical Processing | 3 | |
| 306-354C | Process Engineering Laboratory | 2 | |
| 306-355A | Heat, Mass and Fluid Flow | 3 | |
| 306-360A | Phase Transformations in Solids | 3 | |
| 306-362A | Engineering Materials | 3 | |
| 306-380B | Industrial Training II | 2 | |
| 306-410B | Research Project | 3 | |
| 306-412C | Corrosion and Degradation | 3 | |
| 306-442A | Modelling in Mineral Processing | 3 | |
| 306-450B | Process Design | 3 | |
| 306-455B | Advanced Process Engineering | 3 | |
| 306-456B | Steelmaking and Steel Processing | 3 | |
| 306-463B | Deformation Processing of Materials | 3 | |
| 306-465A | Ceramic Engineering | 3 | |
| 306-480T | Industrial Training III | 2 | |
| 306-481A | Industrial Training IV | 2 | **79** |

## COMPLEMENTARY COURSES

**Technical Courses** **6**

Two courses may be taken; one of these can be chosen from the Faculty list (see section 4.1.1).

NOTE: Not all courses are given annually; verification with course instructor is advised.

| | | |
|---|---|---|
| 302-481A | 3 | Polymer Engineering |
| 306-361B | 3 | Liquid State Processing of Materials |
| 306-367B | 3 | Electronic Properties of Materials |
| 306-451A | 3 | Environmental Controls |
| 306-457B | 3 | Light Metals Extraction |
| 306-515A | 3 | Advanced Metallurgical and Materials Thermodynamics |
| 306-544A | 3 | Mineral Processing Systems I |
| 306-545B | 3 | Mineral Processing Systems II |
| 306-551B | 3 | Electrochemical Processing |
| 306-555A | 3 | Thermal Remediation of Wastes |
| 306-560B | 3 | Joining Processes |
| 306-561A | 3 | Materials Design and Selection |
| 306-563A | 3 | Hot Deformation of Metals |
| 306-564B | 3 | X-ray Diffraction Analysis of Materials |
| 306-566B | 3 | Texture, Structure and Properties of Polycrystalline Materials |
| 306-567B | 3 | Aluminum Casting Alloys |
| 306-569B | 3 | Electron Beam Analysis of Materials |

| | |
|---|---|
| **Social Sciences and Humanities Courses** (see section 3.3 on page 227) | **6** |
| **TOTAL*** | **113** |

* Change in Program credit total from 116 to 113 Awaiting University Approval

Advanced credit is given for 189-260 Intermediate Calculus upon successful completion of a placement test (see section 2.3).

**A fee of $500 is assessed by the University for each Industrial Training course.**

## CURRICULUM FOR THE B.ENG. DEGREE IN MINING ENGINEERING – CO-OP PROGRAM

| REQUIRED COURSES | | COURSE CREDITS | |
|---|---|---|---|
| **Non-Departmental Courses** | | | |
| 186-221A | General Geology | 3 | |
| 186-225A | Properties of Minerals | 1 | |
| 189-260A,B | Intermediate Calculus | 3 | |
| 189-261A,B | Differential Equations | 3 | |
| 189-265C | Advanced Calculus | 3 | |
| 303-205A,B | Statics | 3 | |
| 303-207A,B | Solid Mechanics | 4 | |
| 305-290A | Graphics | 3 | |
| 308-208A,B | Computers in Engineering | 3 | **26** |
| **Departmental Mining Courses** | | | |
| 306-200A | Mining Technology | 3 | |
| 306-202A | Eng. Communication Skills | 2 | |
| 306-203C | Mine Surveying (2 weeks at beginning of summer) | 2 | |
| 306-209B | Mathematical Applications | 3 | |
| 306-221A,B | Engineering Professional Practice | 1 | |
| 306-260A,B | Materials Science and Engineering | 3 | |
| 306-290T | Industrial Work Period I | 2 | |
| 306-291T | Industrial Work Period II | 2 | |
| 306-310A,B | Engineering Economy | 3 | |
| 306-322B | Rock Fragmentation | 3 | |
| 306-323B | Rock and Soil Mass Characterization | 3 | |
| 306-324B | Electrotechnology for Mining, Metallurgical & Materials Engineers | 3 | |
| 306-325A | Mineral Industry Economics | 3 | |
| 306-333B | Materials Handling | 3 | |
| 306-340A | Applied Fluid Dynamics | 3 | |
| 306-341B | Introduction to Mineral Processing | 3 | |
| 306-392B | Industrial Work Period III | 2 | |
| 306-419C or T | Surface Mining | 3 | |
| 306-420B | Feasibility Study | 3 | |
| 306-426C or T | Development and Services | 3 | |
| 306-484A,B,T | Mining Project | 3 | |
| 306-494A,B,T | Industrial Work Period IV | 2 | **58** |
| **École Polytechnique Mining Courses** | | | |
| 309-320A | CAO et informatique pour les mines | 3 | |
| 309-321B | Mécanique des roches et contrôle des terrains | 3 | |
| 309-326A | Recherche opérationnelle minière I | 3 | |
| 309-328C or T | Environnement minier | 3 | |
| 309-329A | Géologie minière | 2 | |
| 309-330A | Mécanique des matériaux meubles | 3 | |
| 309-421C or T | Exploitation en souterrain | 3 | |
| 309-422A | Ventilation minière | 3 | **23** |

## COMPLEMENTARY COURSES

**Technical Courses** **6**

Two courses selected from those listed below or, 6 credits of any other approved technical course(s).

NOTE: Not all courses are given annually; verification with course instructor is advised.

| | | |
|---|---|---|
| 306-320A,B,C | 3 | Extraction of Energy Resources |
| 306-442B | 3 | Modelling in Mineral Processing |
| 306-520B | 3 | Stability of Rock Slopes |
| 306-521C or T | 3 | Stability of Underground Openings |
| 306-526A,B | 3 | Mineral Economics |
| 306-528B | 3 | Mining Automation |
| 306-544A | 3 | Mineral Processing Systems I |
| 306-545B | 3 | Mineral Processing Systems II |
| 309-327A,B | 3 | Hyrdrogéologie appliquée |

| | |
|---|---|
| **Social Sciences and Humanities Courses** See section 3.3. | **6** |
| **TOTAL** | **119** |

Advanced credit is given for 189-260 Intermediate Calculus upon successful completion of a placement test (see section 2.3).

**A fee of $250 is assessed by the University for each Industrial Work Course.**

### Student Advising

Students entering the Mining or Metallurgical Engineering programs must plan their schedule of studies in consultation with one of the departmental advisors: Professors Harris and Kozinski (Metallurgy) or Mr. J. Mossop (Mining).

## COURSES OFFERED BY THE DEPARTMENT

- ● Denotes courses not offered in 2000-01
- ◎ Complementary Courses

Courses offered by the Department have been numbered to conform with the following classification system. The first three digits (i.e. 306) represent the departmental code. The next digit is the level of instruction. The last two digits are classified as follows:

| | |
|---|---|
| 00 to 19 | Common foundation courses |
| 20 to 39 | Mining courses |
| 40 to 49 | Mineral processing courses |
| 50 to 59 | Extractive and process metallurgy courses |
| 60 to 69 | Materials engineering courses |
| 80 to 99 | Co-op work terms |

## DEPARTMENTAL METALLURGY COURSES

Courses associated with the CO-OP program in Mining Engineering are listed separately following this section.

**306-202A ENG. COMMUNICATION SKILLS.** 2(1-2-3) Basic forms of engineering communication: memoranda, executive summaries, letters, proposals, evaluations, oral presentations and presentation graphics, email, groupware, workflow, internet, graphics and presentation tools. Adaptation into engineering. Short assignments and oral presentations. **Professor Harris**

**306-209B MATHEMATICAL APPLICATIONS.** 3(3-2-4) Introduction to stochastic modelling of mining and metallurgical engineering processes. Description and analysis of data distributions observed in mineral engineering applications. Modelling with linear regression analysis. Taylor series application to error and uncertainty propagation. Metallurgical mass balance adjustments.
**Professor Laplante**

**306-212B ENGINEERING THERMODYNAMICS.** 3(3-1-5) Macro versus microscopic approach: patterns of Nature. First and second laws and their use. Property relationships: free energies, chemical potentials, activities, heat capacity. Chemical equilibrium. Reaction kinetics. Phase equilibrium for a pure substance. Experimental methods. Engineering applications: high-temperature metallurgical reactors, turbines, mixtures and solutions, phase diagrams, superconductivity. **Professor Kozinski**

**306-250A INTRODUCTION TO EXTRACTION METALLURGY.** 3(2-3-4) Raw materials, processes and products of metallurgical operations. Mineral processing: comminution including size classification, separation of minerals with emphasis of flotation, waste disposal. Extractive metallurgy: roasting, smelting, refining, hydrometallurgy, environmental protection. **Professors Finch, Harris and Demopoulos**

**306-260A,B MATERIALS SCIENCE AND ENGINEERING.** 3(2-2-5) Structure properties and fabrication of metals, polymers, ceramics, composites; engineering properties: tensile, fracture, creep, oxidation, corrosion, friction, wear; fabrication and joining methods; principles of materials selection. **Professors Drew and Jonas**

**306-280T INDUSTRIAL TRAINING I.** 2 Four-month work period in industry. Work term report required upon completion. **Professor Finch**

**306-308A SOCIAL IMPACT OF TECHNOLOGY.** 3(3-0-6) (Enrolment encouraged by students outside the Faculty of Engineering.) Critical examination of the socio-economic costs and benefits of technology, case studies of old engineering works and new technologies. The integration of applied ethics and engineering practice, analysis of basic concepts of technology assessment, the inter-connected processes of risk assessment, management, and communication. **Staff**

**306-310A,B ENGINEERING ECONOMY.** 3(3-1-5) Introduction to the basic concepts required for the economic assessment of engineering projects. Topics include: accounting methods, marginal analysis, cash flow and time value of money, taxation and depreciation, discounted cash flow analysis techniques, cost of capital, inflation, sensitivity and risk analysis, analysis of R&D, ongoing as well as new investment opportunities. **Professors Bilodeau and Laplante**

**306-311B MODELLING AND AUTOMATIC CONTROL.** 3(3-2-4) (Prerequisite: 308-208A,B) Mass and energy conservation laws. Dynamic versus steady state models, dynamic behaviour of first and higher order metallurgical systems, linear and nonlinear models, interacting and noninteracting systems. Laplace domain dynamics and transfer functions. Feedback control, control valves and controllers, transducers. Feedback-feedforward control, introduction to cascade, adaptive and statistical control strategies. Digital computer control, instruments and interfaces. **Professor Hasan**

**306-317C MATERIALS CHARACTERIZATION.** 3(2-3-4) (Prerequisite: 306-260A,B) Bulk, surface and microanalytical techniques for materials characterization. Bulk analysis: spectrophotometry using UV, visible, flame and atomic absorption, x-ray diffraction and x-ray fluorescence. Surface and microanalysis: infrared spectroscopy, scanning and transmission electron microscopy, Auger electron and x-ray photoelectron spectroscopy. **Professors Szpunar, Kozinski and Yue**

**306-341B INTRODUCTION TO MINERAL PROCESSING.** 3(2-3-4) (Prerequisite: 306-250A) Theory and practice of unit operations including: size reduction-crushing and grinding; size separation-screening and classification; mineral separation-flotation, magnetic and gravity separation. Equipment and circuit design and selection. Mass balancing. Laboratory procedures: grindability, liberation, magnetic and gravity separation, flotation, and solid-liquid separation. **Professor Finch**

**306-350B EXTRACTIVE METALLURGICAL ENGINEERING.** 3(2-3-4) (Prerequisites: 306-250A, 306-212B) Principle non-ferrous base-metal pyrometallurgical extraction processes, relevant thermodynamics, heat and mass balances, transport phenomena (copper, nickel, lead, zinc, aluminum magnesium). Ores, gangue, fuels slag, fluxes, recovery, refining, minor elements, byproducts and the environment. Roasting, drying, smelting, converting, reverberatory furnaces, flash furnaces, continuous and batch operations, injection practices and oxygen enrichment. Simulation, modelling, control and optimization. **Professor Harris**

**306-352A HYDROCHEMICAL PROCESSING.** 3(3-2-4) (Prerequisites: 180-233B, 306-212B, 306-250A) (Corequisite: 306-355A) Analysis and description of dissolution (leaching), solute separation (solvent extraction, ion exchange, carbon adsorption) and deposition operations (precipitation, crystallization, electrolysis) in aqueous reaction media as these apply to: (i) the hydrometallurgical extraction of metals from primary/secondary sources; (ii) the treatment of effluents and (iii) the production of inorganic materials. **Professor Demopoulus**

**306-354C PROCESS ENGINEERING LABORATORY.** 2(0-3-3) (Prerequisite: 306-355A) A series of laboratory exercises which cover various transfer phenomena encountered in metallurgical and materials processing including mass transfer in aqueous and high temperature systems, laminar and turbulent flow characteristics, particle and bubble motion in liquids, mixing and settling. **Professors Kozinski, Harris and Guthrie**

**306-355A HEAT, MASS AND FLUID FLOW.** 3(3-3-3) (Prerequisites: 306-212B, 189-261) Applications of heat, mass and fluid flow in metallurgical processing operations. Fluid statics and dynamics, Newton's laws of viscosity and motion, differential vs. macroscopic control volume analyses. Navier Stokes, Euler, Bernoulli and Steady Flow Energy Equations, turbulence and Reynolds stress equations. Molecular conduction/diffusion processes in heat and mass transfer (Fourier/Fick Laws). Convective flows. Fundamental origins of transport coefficients in slags, metals and gases. Radiative heat transfer. Transient/steady state flows. **Professor Guthrie**

**306-360A PHASE TRANSFORMATIONS IN SOLIDS.** 3(2-3-4) (Prerequisites 306-212B and 306-260A,B, 180-233B) Free energy (equilibrium) and kinetic (non-equilibrium) considerations, phase diagrams and TTT diagrams, solid state diffusion, diffusional (nucleation and growth) and shear (martensitic) transformations. **Professor Yue**

◎ **306-361B LIQUID STATE PROCESSING OF MATERIALS.** 3(2-3-4) (Prerequisites: 306-260A,B; 306-360A) Liquid-solid phase transformation in material processing. Topics covered include: casting techniques, nucleation and grain refining, freezing of pure materials, alloy freezing, solute redistribution, segregation, constitutional undercooling, solidification microstructures, ingot structures, gases in liquid metals, liquid metal cleansing, modification of phase morphology. **Professor Pugh**

**306-362A ENGINEERING MATERIALS.** 3(2-3-4) (Prerequisite 306-360) Stress-strain behaviour. Elasticity and plasticity of metals, ceramics and polymers. Dislocations theory. Single crystal and polycrystalline slip. Mechanical twinning. Strengthening mechanisms. Process-property and microstructure-property relationships. Notch toughness and fracture mechanics. Failure, fracture and damage accumulation. Fatigue. Creep and creep rupture. Fractography. Design considerations in materials selection. **Professor Szpunar**

◎ **306-367B ELECTRONIC PROPERTIES OF MATERIALS.** 3(3-3-3) (Prerequisite: 306-260) Structure of materials, electronic structure, electrical and thermal conductivity, semiconducting materials, fundamentals of magnetism, hard and soft magnetic materials, superconductivity and superconductive materials, dielectric materials, optical properties of materials, thermoelectricity. Advanced materials and their technological applications. **Professor Szpunar**

**306-380B INDUSTRIAL TRAINING II.** 2 Four-month work period in industry. Work term report required upon completion. **Professor Finch**

**306-410A,B RESEARCH PROJECT.** 3(0-6-3) (Prerequisite: Recommendation of Instructor.) A research project will be carried out, usually in groups, under the guidance of a staff member. A technical report will be prepared at the end and formal presentation will be made on the research topic. **Professor Guthrie**

**306-412C CORROSION AND DEGRADATION.** 3(2-3-4) (Prerequisites: 306-260A,B; 306-352B) Electrochemical principles of metal oxidation in aqueous environments, Use of polarization diagrams for corrosion rate prediction. Characteristics of stress corrosion and related phenomena. High temperature, non-aqueous degradation; growth kinetics and structure of oxide films. Corrosion prevention in aqueous systems; fundamentals and applications of cathodic and anodic protection, inhibitors, metallic coatings and industrial priming paints. Use of non-metallics and their degradation; glasses, cement, plastics. Corrosion as a factor in selection of materials; use of iso-corrosion charts. **Professor Distin**

**306-442A MODELLING IN MINERAL PROCESSING.** 3(2-3-4) (Prerequisite: 306-341B) Basic kinetic modelling: perfect mixers, plug-flow, zero and first-order kinetics, residence time distributions. Grinding: breakage and selection functions. Overview of the modelling of flotation and gravity separation. Introduction to control: economic incentives, basic PI control, applications to grinding and flotation circuits. **Professor Laplante**

**306-450B PROCESS DESIGN.** 3(3-0-6) (Prerequisites: 306-350B, 306-355A) Design of new metallurgical plants, processes and products based on knowledge acquired in previous core courses. Material and heat balances, metal economics, design and optimization. **Professor Mucciardi**

● ◎ **306-451A ENVIRONMENTAL CONTROLS.** 3(3-2-4) (Prerequisite: 306-352A) A survey of the mineral/metallurgical industries from the standpoint of environmental impact and control. Characterization of gaseous, aqueous and solid wastes. Their effects on the ecosystem and government regulations. Methods of control: Particulate collection and detoxification of gaseous streams; Aqueous effluent treatment techniques; Disposal of solid wastes and their stability/containment. **Professors Demopoulos, Finch and Kozinski**

**306-455B ADVANCED PROCESS ENGINEERING.** 3(3-1-5) (Prerequisite: 306-355A) Transport phenomena in non-idealized systems. Solutions for transient heat and mass transfer processes involving thermal and molecular diffusion in materials processing systems. Natural and forced convection in heat and mass transfer. Dimensionless correlations. Fick's Laws and Fourier's Laws. Exact solutions. Numerical approximations for transient systems. Equivalences between heat and mass transfer. Finite difference modelling of conduction, convection and radiation heat transfer and diffusion and convection mass transfer. **Professor Mucciardi**

**306-456B STEELMAKING & STEEL PROCESSING.** 3(2-2-5) (Prerequisites: 306-360A, 306-455B) The production and refining of liquid iron in the iron blast furnace, the production and refining of liquid steel, secondary refining operations, continuous casting and thermomechanical processing (hot rolling). Specialty steels and newly emerging technologies (e.g. thin slab casting, direct ironmaking) are also discussed in terms of process/environment and productivity. "Downstream" topics will include cold rolling, batch and continuous annealing, and coating operations. **Professors Guthrie and Jonas**

● ◎ **306-457A LIGHT METALS EXTRACTION.** 3(2-0-7) (Prerequisites: 306-350B, 306-352A) Physiochemical, kinetic and economic aspects of light metals extraction, refining and finishing for marketing. Alumina production, aluminum electrolysis, carbon technology, alloying and casting, magnesium smelting and electrolysis, strontium, lithium, sodium extraction. **Professor Harris**

**306-463B DEFORMATION PROCESSING OF METALS.** 3(3-3-3) (Prerequisite: 306-362A) Basic plasticity theory (yield criteria, plastic stress/strain relationships, etc.); friction and lubrication; analysis of simple forming operations, e.g. rolling of flat products. Workability; concept and measurement; effect of process variables, material properties and microstructure. Effect of hot and cold processing on microstructure and properties technology and equipment; computer-aided design of deformation processing. **Professor Jonas**

**306-465A CERAMIC ENGINEERING.** 3(2-3-4) (Prerequisite: 306-360) Classification of technical ceramics, refractories and glasses. Powder metallurgy. Structure and bonding of ceramics and glasses. Common crystal structures. Physical properties. Mechanical properties and fracture behaviour. Powder processing and consolidation techniques. Sintering and densification of powders. Refractories: production and applications. Glass forming systems, processing and properties. **Professor Drew**

**306-480T INDUSTRIAL TRAINING III.** (2) Four-month work period in industry. Work term report due upon completion of 306-481A (see details listed under 306-481A). **Professor Finch**

**306-481A INDUSTRIAL TRAINING IV.** (2) Four-month work period in industry. This course is intended to be taken immediately after 306-480T at the same work location. One work term report and one seminar is required upon completion of this course. If 306-480T and 306-481A are in different work locations, the work term report should be in two parts following the co-op handbook guidelines. **Professor Finch**

◎ **306-515A ADVANCED METALLURGICAL & MATERIALS THERMODYNAMICS.** 3(2-2-5) (Prerequisite: 306-212B) Computational thermodynamics including phase diagram estimation, Gibbs energy minimization, solution modelling are considered in view of the Facility of Chemical Thermodynamics (F*A*C*T) computer database. Students undertake projects developed in consultation with the instructor and prepare verbal and written reports. **Metallurgical Staff**

◎ **306-544A MINERAL PROCESSING SYSTEMS I.** 3(2-3-4) (Prerequisite: 306-341B) The course covers three main topics: principles of separation, including data presentation, properties of recovery/yield plots, technical and economic efficiency and identification of limits to separation; column flotation, hydrodynamics of collection and froth zones, mixing, scale-up and design, measurements and control; surface and electrochemistry, including absorption, surface charge, coagulation, electron transfer reactions, electrochemistry in plant practice. **Professor Finch and Dr. Rao**

● ◎ **306-545B MINERAL PROCESSING SYSTEMS II.** 3(4-2-3) (Prerequisite: 306-341B) Gold recovery (as a Professional Development Seminar): methods of recovery (gravity, flotation, cyanidation), refractory gold (roasting, pressure oxidation, bacterial leaching), dissolved gold recovery (Merrill-Crowe) and activated carbon methods. Sampling: definition of errors, sample extraction, size, and processing. Mass balancing: basic considerations, definition of networks, software. Blending: auto-correlation functions, transfer functions, blending systems. Effect of feed variability. **Professor Laplante**

◎ **306-551B ELECTROCHEMICAL PROCESSING.** 3(3-2-4) (Prerequisite: 306-352B) Characterization of aqueous, fused salt and solid electrolytes; laws of electrolysis; ion transport mechanisms; interfacial phenomena (electrolyte-electrolyte, electrode-electrolyte); reversible cells and potentials; electrode kinetics, overpotential and potential-current laws; industrial applications; electrolytic winning and refining, electroplating, surface cleaning and coating, electrodialysis and electrochemical sensors. **Professor Demopoulos**

◎ **306-555A THERMAL REMEDIATION OF WASTES.** 3(3-0-6) (Prerequisites: 180-111B and 306-212B or equivalent) Process technology and environmental concerns in thermal remediation of wastes. Design of thermal remediation systems. Waste combustion. Nature and pathways of pollutant streams during thermal treatment of wastes. Reduction and control of harmful products. Toxic metal encapsulation. Particulate removal. Destruction of gaseous contaminants. Use of models in system design. **Professor Kozinski**

**306-560B JOINING PROCESSES.** 3(3-3-3) (Prerequisite: 306-361B or equivalent) Physics of joining; interfacial requirements; energy sources, chemical, mechanical and electrical; homogeneous hot-joining, arc-, Mig-, Tig-, gas-, thermite- and Plasma-welding; Autogeneous hot-joining, forge-, pressure-, friction-, explosive-, electron beam- and laser-welding; Heterogeneous hot-joining, brazing, soldering, diffusion bonding; Heterogeneous cold joining, adhesives, mechanical fastening; Filler materials; Joint metallurgy; Heat affected zone, non-metallic systems; joint design and economics; defects and testing methods. **Mr. Vaidya**

◎ **306-561A MATERIALS DESIGN AND SELECTION.** 3(0-4-5) (Prerequisite: 306-362A or equivalent) Advanced topics in materials design problems. Discussion and laboratory work, supplemented by detailed technical reports. Special attention is given to selection, design and failure problems in various materials systems. **Professors Drew, Gruzleski and Yue**

● ◎ **306-563A HOT DEFORMATION OF METALS.** 3(2-2-5) (Prerequisite: 306-463B and 306-360A) High temperature deformation processing of metallic materials. Topics include static and dynamic recrystallization, recovery, precipitation; effect of deformation on phase transformations and microstructural evolution during industrial processing. Mathematical modelling of microstructural evolution. **Professor Yue**

◎ **306-564B X-RAY DIFFRACTION ANALYSIS OF MATERIALS.** 3(2-3-4) (Prerequisite: 306-317A) The techniques of X-ray and neutron diffraction are discussed as applied to the minerals and materials production industries. Special emphasis is placed upon automated X-ray powder diffractometry as employed for determining the structure and composition of materials. The application of X-ray techniques to studies of crystal structure, crystal orientation,

residual stress, short-range order in liquid metals, phase diagram determination, order-disorder transformation and chemical analysis are presented. **Professor Szpunar**

● ◎ **306-566B TEXTURE, STRUCTURE & PROPERTIES OF POLYCRYSTALLINE MATERIALS.** 3(2-3-4) (Prerequisite: 306-317A) Concepts and quantitative methods for the description of the structure of minerals and materials are discussed. Special emphasis is placed on experimental techniques of texture measurement. Procedures are demonstrated for the control of deformation and recrystallization textures in order to obtain the properties required of industrial products. Finally, the correlation between texture and the anisotropy of elastic, plastic and magnetic properties of engineering materials is described and analyzed. **Professor Szpunar**

● ◎ **306-567B ALUMINUM CASTING ALLOYS.** 3(3-0-6) (Prerequisite: 306-361B or equivalent) The family of aluminum foundry alloys; alloy systems, intermetallic phases and their formation, heat treatment processes, mechanical and physical properties of aluminum casting alloys, foundry properties, eutectic modification, porosity formation, gassing and degassing, refinement of hypereutectic alloys, grain refinement, filtration; non destructive control of microstructure. **Professor Gruzleski**

● ◎ **306-569B ELECTRON BEAM ANALYSIS OF MATERIALS.** 3(2-3-4) (Prerequisite: 306-317A) Emphasis on operation of scanning and transmission electron microscopes. Topics covered are electron/specimen interactions, hardware description; image contrast description; qualitative and quantitative (ZAF) x-ray analysis; electron diffraction pattern analysis. **Professor Yue and Ms. Campbell**

## DEPARTMENTAL MINING COURSES

**306-200A MINING TECHNOLOGY.** 3(3-3-3) Economic importance of the mining industry. Definition of a mining venture, and responsibilities of the mining engineer. Relevant legislation, regulations, and professional organizations. Criteria for exploiting an ore deposit. Surface and underground mining methods: preliminary selection procedure. Mining methods and mining equipment. Ethics and professionalism in the practice of engineering. **Mr. Mossop**

**306-203C MINE SURVEYING.** 2 (Prerequisite: 306-200 or permission of instructor) A two-week field school with laboratories and assignments. The role of the mine surveyor. Techniques and instrumentation for measurement of levels, angles and distances. Shaft, raise, drift and stope surveying techniques. Graphical presentation of survey data and computer applications. Monitoring techniques for mining excavations with deformation and displacement measurements. **Dr. Momayez and Mr. Vachon**

**306-221A,B ENGINEERING PROFESSIONAL PRACTICE.** 1(1-0-2) Professional practice and ethics, professional liability, occupational health and safety, environmental responsibility. University Code of Student Rights and Responsibilities. **Professors Ouellet and Hassani**

**306-290T INDUSTRIAL WORK PERIOD I.** 2 (Prerequisites: 306-200 or 306-203) A four-month work period in the mineral industry, to expose the student to an industrial environment. Candidates will receive basic industrial training. A complete report must be submitted at the end of the term. **Mr. Vachon**

**306-291T INDUSTRIAL WORK PERIOD II.** 2 (Prerequisite: 306-290) A four-month industrial work period in a mining company, research laboratory or government agency. The student will receive formal industrial training in a technical position. A complete report must be submitted at the end of the term. **Mr. Vachon**

◎ **306-320B EXTRACTION OF ENERGY RESOURCES.** 3(3-0-6) The extraction of energy resources, i.e. coal, gas, oil and tar sands. After a brief geological review, different extraction techniques for these substances will be discussed. Emphasis on problems such as northern mining and offshore oil extraction with reference to Canadian operations. Transportation and marketing. **Professor Hassani**

**306-322B ROCK FRAGMENTATION.** 3(3-3-3) (Prerequisite: 306-200) Principles of drilling, penetration rates, performance and factors to consider in the choice of a drilling method. Characteristics of explosives, firing systems and blast patterns. Blasting techniques in surface and underground workings and in permafrost. Special blasting techniques at excavation perimeters. Vibration and noise control. Economics of drill/blast practice, interface with transport and crushing systems. Legislation and safety in explosives use and handling. Ripping and fullface boring machines. **Professor Comeau**

**306-323B ROCK AND SOIL MASS CHARACTERIZATION.** 3(3-3-3) (Prerequisites: 186-221 and 306-200) Characteristics of soil and rock masses and the stability of mine workings. Mechanical properties of rocks and soils related to physical/chemical properties. Characterization of rock mass discontinuities. Laboratory and in-situ techniques to define mechanical properties of soils, rocks and discontinuities. Permeability and groundwater flow principles. In-situ stresses and their measurement. Rock mass quality and classification systems. **Professor Hassani**

**306-324B ELECTROTECHNOLOGY FOR MINING, METALLURGICAL & MATERIALS ENGINEERS.** 3(3-3-3) (Prerequisites: 189-261 and 189-265) AC theory including vector and complex number representation of sinusoidal currents, voltages and impedances. Effect of frequency on LCR circuit outputs. Logic circuits including two-state logic and logic components, logic ports and toggles, Boolean algebra, and complex circuits. Microprocessors including organization logic, programming, and microcomputers. Data acquisition including sensors, noise, A/D and D/A converters, and programming. Operational amplifiers. Applications to systems control. **Professor Hemami**

**306-325A MINERAL INDUSTRY ECONOMICS.** 3(3-1-5) (Prerequisite: 306-310) Geographical distribution of mineral resources. Production, consumption and prices of minerals. Market structure of selected minerals. Economic evaluation aspects: grade-tonnage considerations; capital and operating cost estimation; assessment of market conditions; estimation of revenue; taxation; sensitivity and risk analyses; economic optimization of mine development and extraction. **Professor Bilodeau**

**306-333B MATERIALS HANDLING.** 3(3-3-3) (Prerequisite: 306-200) Physical and mechanical characteristics of materials related to loading, transport and storage. Dynamics of particles, systems and rigid bodies, mass-acceleration, work-energy, impulse-momentum. Types and selection of excavation and haulage equipment. Layout of haul roads. Rail transport. Conveyor belts and chain conveyors. Mine hoists. Layouts of mine shafts. **Professor Mitri**

**306-340A APPLIED FLUID DYNAMICS.** 3(3-3-4) (Prerequisite: 303-205) Flow analysis and manometry. Conservation of mass and momentum. Flow in pipes and ducts, analysis of pipe networks. First and second law of thermodynamics and their applications. Open channel flows. Dimensional analysis and similitude. Flow measurements. Settling and separation of particles. Non-Newtonian flow and slurry transport. Fluidized beds. Filtration of liquid/solid mixtures. **Professor Hasan**

**306-392B INDUSTRIAL WORK PERIOD III.** 2 (Prerequisite: 75 credits including 306-291) A four-month industrial work period in a mining company, research laboratory or government agency. Based on the experience gained during the first two work periods, the student may be asked to undertake more challenging technical tasks. A complete report must be submitted at the end of the term. **Mr. Vachon**

**306-419C OR T SURFACE MINING.** 3(3-3-3) (Prerequisites: 306-322, 306-333 and 306-325) Choice of a surface mining method. Analysis of soil and rock mass properties related to surface mining. Calculation and monitoring of stripping ratios, ultimate pit depth, slope stability, rock reinforcement, bench and berm dimensioning and ramp design. Loading and hauling systems. Surface layout and development. Water drainage systems. Productions and cost analysis. Computerized design techniques. **Professor Ouellet**

**306-420B FEASIBILITY STUDY.** 3(1-2-6) (Prerequisites: 306-419, 306-426 and 309-421) This course consists of a case study exercise in the application of the specialist skills which the student has developed in the mining engineering program. The objective is to combine these skills in carrying out a professional appraisal of the

technical feasibility and economic viability of developing a mineral deposit. Students are required to prepare a professional level report and present seminars on particular aspects of the feasibility analysis. **Mr. Mossop and Professor Bilodeau**

**306-426C OR T DEVELOPMENT AND SERVICES.** 3(3-3-3) (Prerequisite: 306-324 and 306-333) Selection and design of the facilities required to start production at both surface and underground mines, based on design criteria dictated by mining plans, geography, geology and government regulations. Scheduling of development and construction. Staffing and health and safety considerations during development, construction and operations. **Mr. Mossop**

**306-484A,B,T MINING PROJECT.** 3(0-0-9) (Corequisites: 306-419, 306-426, 309-328 and 309-421) A mining research project to be completed during one semester. The project must be approved by an academic advisor. A comprehensive report and a seminar presentation are required for the project. **Mr. Mossop**

**306-494A,B,T INDUSTRIAL WORK PERIOD IV.** 2(0-0-6) (Prerequisites: 306-419, 306-426, 309-328 and 309-421) A four-month industrial work period after which the student must submit a report. **Mr. Vachon**

◎ **306-520B STABILITY OF ROCK SLOPES.** 3(3-0-6) (Prerequisite: permission of instructor.) The properties of rock masses and of structural discontinuities. Influence of geological structure on stability. Linear, non-linear, and wedge failures. Site investigations. Methods of slope stabilization. **Professor Hassani**

◎ **306-521C OR T STABILITY OF UNDERGROUND OPENINGS.** 3(3-3-3) (Prerequisite: permission of instructor) The properties of rock masses and stability classification systems. The influence and properties of geological structural features. Stability related to the design of underground openings and mining systems. Site investigations. Methods of stabilization. **Professor Mitri**

● ◎ **306-524B MINERAL RESOURCE ECONOMICS.** 3(3-0-6) (Prerequisite: 306-310 or equivalent, or permission of instructor.) Analysis of significant factors affecting mineral supply, including oil and gas. Role of governments, concept of economic rent and determinants of a mineral policy. Objectives, strategies and concerns of mining and oil and gas companies. International resource environment, commodity associations, mineral investment and trade patterns. **Mr. Ortslan**

◎ **306-526A,B MINERAL ECONOMICS.** 3(3-1-5) (Prerequisite: 306-310 or equivalent) Mineral project evaluation techniques and applications. Topics covered include grade-tonnage relationships, capital and operating cost estimation techniques, assessment of mineral market conditions, taxation, discounted cash flow analysis, risk analysis, and optimization of project specifications with respect to capacity and cutoff grade. (This course is given only once per academic year.) **Professor Bilodeau**

● ◎ **306-528B MINING AUTOMATION.** 3(3-3-3) (Prerequisite: 306-426) System analysis and design in the frequency domain. Review of optimization methods. Mining system modelling applied to rock cutting, materials transport, and bunkerage, pitch, yaw and roll steering of mining machines. Control and robotics: digitization, discrete systems, sensors, actuators and real time algorithms. Data communication in mines. Simulation exercises. **Professor Mitri**

## COURSES OFFERED BY ÉCOLE POLYTECHNIQUE

**309-320A CAO ET INFORMATIQUE POUR LES MINES.** 3(2-3-4) (Prérequis: 306-200 et 308-208) Présentation de techniques informatisées et de logiciels permettant d'appliquer l'informatique dans le cadre des diverses opérations reliées à l'exploitation des mines. Utilisation de logiciels de support: chiffrier électronique, traitement de texte, éditeur graphique, utilitaires de DOS. Utilisation de graphisme, de traceurs à plumes, de tablettes numérisantes, d'interfaces pour capteurs analogique/numérique et numérique/analogique. Notions de géometrie descriptive appliquées à des problèmes miniers. **Professor Corthésy**

**309-321B MÉCANIQUE DES ROCHES ET CONTRÔLE DES TERRAINS.** 3(3-3-3) (Prérequis: 306-323) Pressions de terrains au pourtour des excavations: solutions analytiques et numériques. Stabilité des excavations souterraines et à ciel ouvert: analyse des instabilités structurales par projection stéréographique méridienne, analyse des instabilités causées par les excès de contraintes. Soutènement. Surveillance. Études de cas. **Professor Aubertin**

**309-326A RECHERCHE OPÉRATIONNELLE MINIÈRE I.** 3(3-3-3) (Prérequis: 189-260) Logistique minière. Modèles de localisation optimale: Steiner, HAP, construction itérative. Modèles de détermination des contours optimaux des exploitations à ciel ouvert: conventionnels, Lerchs et Grossman, Ford et Fulkerson. Programmation dynamique et modèles d'optimisation du taux de production et de la teneur de coupure. Modèles de planification: cheminement critique et PERT, programmation linéaire et non-linéaire, théorie des graphes. Modèles de capacité: théorie des files d'attente, simulation, silos et stockage. Modèles de mélange. **Professor Gamache**

◎ **309-327A,B HYDROGÉOLOGIE APPLIQUÉE.** 3(3-3-3) (Prérequis: 186-221 et 189-261) Eau souterraine et cycle hydrologique. Aquifère et aquitard. Charge hydraulique et piézomètre. Mouvement de l'eau souterraine. Loi de Darcy. Mesures et valeurs de perméabilité. Réseau d'écoulement. Essais de pompage: régime transitoire permanent, effet de frontière, drainage. Facteurs influençant les niveaux d'eau. Qualité des eaux souterraines. Types de pollutants et leur propagation. Méthodes de traitement et d'étanchéisation. Techniques de modélisation. Exploration et gestion des eaux souterraines. Recharge artificielle. Intrusions salines. **Professor Chapuis**

**309-328C OR T ENVIRONNEMENT MINIER.** 3(3-3-3) (Prérequis: 306-200 et 306-291) Effets du milieu de travail sur l'homme (hygiène du travail): législation; contraintes thermiques, problèmes de bruit, de contaminants gazeux et de poussières; techniques de mesures. Effets de l'exploitation d'une mine sur le milieu (environnement et écologie): législation; études d'impacts; effluents miniers: origine, nature et traitement des effluents; entreposage des résidus; restauration des sites. **Professors Aubertin and Simon**

**309-329A GÉOLOGIE MINIÈRE.** 2(2-2-2) (Prérequis: 186-221, 306-200 et 306-209) Méthodes de cartographie minière, de sondages et d'échantillonnage. Notion de teneur de coupure, calcul des réserves par les méthodes conventionnelles. Évaluation des réserves par les méthodes géostatistiques. **Professor Marcotte**

**309-330A MÉCANIQUE DES MATÉRIAUX MEUBLES.** 3(3-3-3) (Prérequis: 306-323) Propriétes mécaniques des matériaux meubles. Conception d'empilements et de digues de retention pour les matériaux miniers. Conception de structures enfouies. Problèmes particuliers avec les résidus miniers: liquéfaction, déposition, etc. Écoulement gravitaire des matériaux meubles. **Professor Aubertin**

**309-421C OR T EXPLOITATION EN SOUTERRAIN.** 3(3-3-3) (Prérequis: 306-322, 306-325 et 306-333) Étude des caractéristiques des principales méthodes d'abattage utilisées en souterrain. Méthodes d'analyse simplifiée d'un gisement quant à son exploitation en fosse ou en souterrain. Dimensionnement des ouvrages et choix des équipements. Calculs des quantités, des équipements et des coûts reliés aux excavations souterraines. Conception d'un circuit de remblai hydraulique. **Professor Simon**

**309-422B VENTILATION MINIÈRE.** 3(3-2-4) (Prérequis: 306-340) Description des composantes d'un système de ventilation. Ventilation naturelle et mécanique. Principes de mesure et de modélisation des écoulements de l'air dans les réseaux de ventilation. Techniques de calcul des pertes de charges dans un circuit. Choix des composantes pour assurer et régulariser les écoulements. Simulation informatisée des écoulements. Chauffage de l'air. **Professor Simon**

## 4.8 School of Urban Planning

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*Director*
David F. Brown

*Professors*
Jane M. Glenn; B.A., LL.B.(Qu.), D. en Droit(Stras.)
Ronald G. Rice; B.A.Sc.(Tor.), S.M.(MIT), Dipl.U.&R.Pl.(Tor.), Ph.D.(Tor.), P.Eng.
Jeanne M. Wolfe; B.Sc.(Lond.), M.Sc.(W.Ont.), M.A.(McG.)

*Associate Professor*
David F. Brown; B.A.(Bishop's), M.U.P.(McG.), Ph.D.(Sheffield)

*Assistant Professor*
Raphaël Fischler; B.Eng.(Eindhoven), M.Sc., M.C.P.(MIT), Ph.D.(U.C. Berk.)

*Associate Members*
Gordon O. Ewing; M.A.(Glas.), M.A., Ph.D.(McG.)
Mario Polèse; B.A.(CUNY), M.A., Ph.D.(Penn.)

*Instructor*
Pierre Gauthier; B.Arch.(Montr.), M.Arch.(Laval)

*Guest Lecturers*
Cameron Charlebois, Luc Danielse, Marc Denhez, David Farley, Andrew Hoffmann, Peter Jacobs, Brenda Lee, Damaris Rose, Lloyd Sankey, Martin Wexler

Modern urban planning developed into a profession in the early decades of the twentieth century, largely as a response to the appalling sanitary, social and economic conditions of rapidly developing industrial cities. Initially the disciplines of architecture, civil engineering and public health provided the nucleus of concerned professionals; beautification schemes and infrastructure works marked the early stages of public intervention in the nineteenth century. Architects, engineers and public health specialists were joined by economists, sociologists, lawyers and geographers as the complexities of the city's problems came to be more fully understood and public pressure mounted for their solution. Contemporary urban and regional planning techniques for survey, analysis, design and implementation developed from an interdisciplinary synthesis of these various fields.

Today, urban planning can be described as the collective management of urban development. It is concerned with the welfare of communities, control of the use of land, design of the built environment, including transportation and communication networks, and protection and enhancement of the natural environment. It is at once a technical and a political process which brings together actors from the public, private and community spheres. Planners participate in that process in a variety of ways, as designers and analysts, advocates and mediators.

McGill University was the first institution in Canada to offer a full-time planning program. An inter-disciplinary program was established in 1947, in which students combined a master's degree in Urban Planning with one in a related field. An autonomous program was established in 1972. It became the School of Urban Planning in 1976.

Students come to the School from diverse backgrounds, the physical sciences, the traditional professions, such as architecture and engineering, and the social sciences. Alumni of the School work as planners and designers at various levels of government, in non-profit organizations and with private consulting firms. Their expertise ranges from historic preservation to traffic management, from housing development to computer imaging. They devote their efforts in increasing numbers to environmental planning and sustainable development.

The School is a partner in the Montreal Interuniversity Group "Urbanization and Development", a consortium recognized by CIDA as a Centre of Excellence, which is devoted to the study of urban problems and the formulation of policies in developing regions. Faculty and students collaborate actively with members of other McGill departments, notably Architecture, Geography, Civil Engineering and Law, and with colleagues at other institutions in Canada and abroad.

The objective of the School is to produce qualified professional urban planners for the public and the private sectors. Training is provided at the post-graduate level; the degree offered is the Master of Urban Planning (M.U.P.). Upon completion of the two-year program of studies, graduates are expected to have acquired basic planning skills, a broad understanding of urban issues, and specialized knowledge in a field of their own choice.

The program of study offered by the School is fully recognized by the Ordre des Urbanistes du Québec (O.U.Q.) and the Canadian Institute of Planners (C.I.P.). Graduates can become full members of these professional organizations after meeting their internship requirements.

For details of the M.U.P. admission requirements and curriculum, consult the Faculty of Graduate Studies Calendar (available on the web at http://www.aro.mcill.ca).

While the School of Urban Planning is a graduate progam, a number of undergraduate courses are taught by the faculty members affiliated with the School. These are listed below.

### UNDERGRADUATE COURSES OFFERED BY THE SCHOOL

**409-501A,B PRINCIPLES AND PRACTICE I.** (2) This six-week intensive course exposes students to issues and techniques that are applicable in diverse professional planning contexts. The subject matter, geographic area, scale of intervention and institutional location of planning varies from semester to semester. The course focuses on a specific case study and is taught by a visiting lecturer with professional experience in the selected subject matter.
**Staff and Visitors**

**409-505B GEOGRAPHIC INFORMATION SYSTEMS.** (3) An introduction to fundamental geographic information system (GIS) concepts and a range of GIS applications in urban and regional planning.
**Professor Brown**

### UNDERGRADUATE COURSES OFFERED JOINTLY BY THE SCHOOL AND OTHER ACADEMIC UNITS

**183-351A APPLIED QUANTITATIVE METHODS IN GEOGRAPHY.** (3) Survey design; uni- and multi-dimensional scaling; cost-benefit analysis and matrix methods of plan evaluation; multiple regression and correlation; logic models; gravity models; population projection. **Professor Ewing**

**301-435B URBAN PLANNING I.** (2) Theory and practice. An examination of different basic approaches to urban planning with special reference to Quebec. **Professor Wolfe**

**301-436A URBAN PLANNING II.** (2) Urban Design and Project Feasibility. Theory and practice. The course considers the urban and real-estate development process, with a focus on economic and political constraints. It introduces students to techniques in urban design, zoning, and financial analysis. **Professor Fischler**

**303-433B URBAN PLANNING I.** (3) The City in History. The planning profession, evolution of planning in North America, Canada and Quebec. Planning theories, the general or master plan, planning processes and techniques, planning and design of residential subdivisions. Local planning issues, housing policies, planning laws.
**Professor Wolfe**

**490-004A LAND USE PLANNING LAW.** (3) A comparative study of private and public control of land use and development, involving master plans, zoning bylaws, subdivision control, urban re-development, expropriation, and regional planning.
**Professor J.M. Glenn**

### GRADUATE 600-LEVEL COURSES

Generally, undergraduate students are not permitted to enrol in graduate 600-level courses. However, in exceptional circumstances, the Faculty of Graduate Studies and Research does grant this permission upon the request of the Department on behalf of the student. A list of such courses, described in detail in

the Faculty of Graduate Studies and Research Calendar, is as follows:

| | |
|---|---|
| 409-604A | Planning Projects III |
| 409-605A,B | Graduate Seminar |
| 409-606B | Supervised Research Seminar |
| 409-607D | Reading Course |
| 409-609A | Planning Graphics |
| 409-612A | History and Theory of Planning |
| 409-614B | Urban Environmental Planning |
| 409-616A,B | Selected Topics I |
| 409-617A,B | Selected Topics II |
| 409-618A,B | Selected Topics III |
| 409-619B | Transport and Land Development |
| 409-620A | Computer Applications in Planning |
| 409-621B | Theories of Urban Form |
| 409-622A | Planning Projects I |
| 409-623B | Planning Projects II |
| 409-625A,B | Principles And Practice of Planning II |
| 409-626A,B | Principles And Practice of Planning III |
| 409-628A,B,C | Practical Experience |
| 409-630A,B,C | Supervised Research Project I |
| 409-631A,B,C | Supervised Research Project II |
| 409-632A,B,C | Supervised Research Project III |

# 5 Minor Programs and Choice of Electives or Complementary Courses

Minors are coherent sequences of courses which may be taken in addition to the courses required for the B.Eng. degree. Minor programs normally consist of 24 credits, allowing up to 12 credits of overlap with the degree program. The real credit cost to the student is typically 9 to 15 credits, representing one semester beyond the B.Eng. degree program. All courses in a Minor program must be passed with a grade of C or better.

Students of the Faculty have a considerable variety of complementary course choices, which fall into the categories of technical and complementary studies. Students should refer to their respective departments for information concerning complementary course selections. Departments also publish in this Calendar and in separate documents, information regarding the choice of courses. Students should also consult their course advisers.

Some general information applicable to all students of the Faculty is given below. This mainly covers the areas of materials engineering, management, biotechnology, economics, mathematics, arts, environmental engineering, computer science and chemistry. Further information is available through the Student Affairs Office, Macdonald Engineering Building, Room 378.

## 5.1 Arts Minor

Engineering students may obtain a Minor in Arts as part of their B.Eng. degree by satisfying the 24-credit requirement described below. In general, complementary studies courses given in the Faculty of Arts and listed under: (i) – "3 credits of studies of the Impact of Technology on Society" and (ii) – "the remaining credits to be elective social science and humanities courses" (see section 3.3), may be used to satisfy some of these requirements. In no case will more than 9 credits taken from these complementary studies requirements be credited towards the Minor in Arts.

**Requirements**

1. The program must consist of 24 credits as follows:
   a) at least two areas of concentration from within the Faculty of Arts must be chosen, with the minimum number of credits in any one area being 6,
   b) at least 12 credits must be at the 300 or above level.
2. All courses in the Minor program must be passed with a grade of C or better.
3. The selection of courses for the Minor is to be done in consultation with the Minor Advisor, Ms. Judy Pharo, ENGMD 378.

For further information, please contact Prof. B. Haskel, Political Science, or Ms. J. Pharo, Faculty of Engineering, ENGMD 378.

## 5.2 Biotechnology Minor

The Faculties of Engineering and of Science offer a Minor in Biotechnology for students interested in taking additional courses in this area. For Engineering students, the Minor has been designed specifically for students within the Chemical Engineering Department, however other Engineering students are invited to contact the Minor program supervisor, Professor Bennett, or Professor B. Volesky, Chemical Engineering (514) 398-4276, for further information. Students should identify an interest in the Minor to their academic adviser and the supervisor of the program during the U1 year, and at the time of registration for the U2 year. With the agreement of the academic advisor, students should submit their course list to the program supervisor who will certify that the proposed program conforms to the requirements for the Minor. The Biotechnology Minor Program is administered for the Faculties of Engineering and of Science by Prof. H. Bennett, Sheldon Biotechnology Centre (Lyman-Duff Building), phone 398-3998. A full description of the Minor program appears under the Biotechnology heading on page 368 of the Science section.

A Chemical Engineering student may complete the Biotechnology Minor by taking 177-200A, 177-201B, 177-202B, 528-211A, 202-505B, plus one course from the list of additional courses not including 306-310. The Department of Chemical Engineering permits students in the Minor program to complete 202-505B as one of their technical complementary requirements. The total course credit required for the Chemical Engineering student is 15 credits beyond the 110-credit B.Eng. program.

## 5.3 Chemistry/Chemical Engineering Minor

The Departments of Chemistry and Chemical Engineering offer a Minor Program in Chemistry, of particular interest to Chemical Engineering students and a Minor in Chemical Engineering, of interest to Chemistry students (described in the Science section). The Minor in Chemistry consists of 25 credits as follows:

1. Required courses, 10 credits: 180-212, 233 and 234 (or CEGEP equivalent)
2. At least 15 credits from the following list, two of which must be laboratory courses (* indicates lab). Note that 180-212 is a prerequisite for most of the courses listed below. If students take 180-222* instead of 180-234, they will receive credit for one of the two laboratories that are required but they must have a total of 25 Chemistry credits for the Minor.

**Inorganic Chemistry**

| | |
|---|---|
| 180-281A, | Inorganic Chemistry I |
| 180-371A,B | Inorganic Chemistry Laboratory* |
| 180-381A | Chemistry of Transition Elements |
| 180-591B | Advanced Coordination Chemistry |

**Analytical Chemistry**

| | |
|---|---|
| 180-257D | Introductory Analytical Chemistry* |
| or 180-277D | Classical Methods of Analysis* |
| 180-307A | Environmental Analysis |
| 180-367A | Instrumental Analysis I |
| 180-377B | Instrumental Analysis II |

**Organic Chemistry**

| | |
|---|---|
| 180-302A | Introductory Organic Chemistry III |
| 180-352B | Structural Organic Chemistry |
| 180-362A,B | Advanced Organic Laboratory* |
| 180-382B | Organic Chemistry of Natural Products |
| 180-402B | Advanced Bio-organic Chemistry |

**Physical Chemistry**

| | |
|---|---|
| 180-345A | Molecular Properties & Structure I |
| 180-355B | Molecular Properties & Structure II |
| 180-363A,B | Physical Chemistry Laboratory* |
| 180-393A,B | Physical Chemistry Laboratory* |
| 180-455A | Introductory Polymer Chemistry |

Please consult the program coordinators for more information: Prof. D. Cooper (Chemical Engineering) and Prof. M. Andrews (Chemistry). A passing grade for courses within the Minor is a C.

## 5.4 Computer Science Courses and Minor Program

The School of Computer Science offers an extensive range of courses for Engineering students interested in computers. The course explicitly for Engineering students, 308-208 Computers in Engineering, and other courses in the core of the various Engineering programs are listed in section 6.2. Descriptions of other Computer Science courses can be found on page 377 in the Faculty of Science section.

Engineering students may obtain a Minor in Computer Science as part of their B.Eng. degree by satisfying the 24-credit requirement described below. In general, complementary courses within Engineering Departmental programs may be used to satisfy some of these requirements, but the Minor in Computer Science will require at least 12 extra credits from Computer Science (308-) courses beyond those needed for the B.Eng. degree. Students should consult their departments about the use of complementaries, and credits that can be double counted.

Students should see the receptionist in 318 McConnell to pick-up the appropriate forms, and to make an appointment to see the Minor Advisor for approval of their course selection. Forms must be approved before the end of the Add/Drop period of the student's final term.

### Requirements

The program must consist of 24 credits, from courses passed with a grade of C or better, as follows:

**Required Courses** (9 credits)

| | | |
|---|---|---|
| | 308-203 | Introduction to Computing II |
| or | 308-250 | Introduction to Computer Science |
| | 308-302 | Programming Languages and Paradigms |
| | 308-350 | Numerical Analysis (or Numerical |
| or | 305-409 | Methods in Mechanical Engineering) |

**Complementary Courses** (15 credits)

Three credits, chosen from:

| | |
|---|---|
| 308-273 | Introduction to Computer Systems |
| 304-221 | Introduction to Computer Engineering I |

Three credits, chosen from any Computer Science course numbered 308-305 or higher.

Nine credits, chosen from:

(a) any Computer Science course numbered 308-305 or higher.

(b) any complementary course making considerable use of computing and approved by Computer Science for the Minor.

### Notes

A. Courses 308-202 Introduction to Computing I, and 308-208 Computers in Engineering (compulsory for some Engineering students) do not form part of the Minor.

B. 308-202 is a prerequisite for 308-203. Students with a substantial high level language programming course may forego this prerequisite. Some additional make-up effort may be needed at the start of the course.

### Courses in Other Departments

The following is a list of courses, offered by other departments, that will normally be approved for inclusion in the Minor program under (b) in the Complementary Courses list. This list is not necessarily complete.

**Department of Mathematics**

| | |
|---|---|
| 189-327B | Matrix Numerical Analysis |
| 189-328B | Computability and Mathematical Linguistics |
| 189-407B | Dynamic Programming |
| 189-417A | Mathematical Programming |
| 189-578A | Numerical Analysis |
| 189-579B | Numerical Differential Equations |

**Faculty of Engineering**

| | |
|---|---|
| 302-453A | Process Design |
| 302-455B | Process Control |
| 302-571B | Small Computer Application in Chemical Engineering |
| 303-208A | Civil Engineering Systems Analysis |
| 303-460A | Matrix Structural Analysis |
| 304-323A,B | Digital System Design |
| 304-425A | Computer Organization and Architecture |
| 304-426A,B | Microprocessor Systems |
| 304-512A | Digital Signal Processing I |
| 304-521A | Digital Communications I |
| 304-529A | Image Processing and Communications |
| 304-531B | Real-Time Systems |
| 304-532A | Computer Graphics |
| 304-543B | Numerical Methods in Electrical Engineering |
| 304-548A | Introduction to VLSI Systems |
| 305-474B | Operations Research |
| 305-540B | Modelling and Decision |
| 305-554A | Microprocessors for Mech. Sys. |
| 305-555B | Applied Process Control |
| 305-572A | Mechanics of Robotic Systems I |
| 305-573B | Mechanics of Robotic Systems II |
| 305-576A | Computer Graphics and Geometric Modelling |
| 306-311A | Modelling and Automatic Control |

**Faculty of Management**

| | |
|---|---|
| 273-431A,B | Information Systems Design |
| 273-432A,B | Information Systems Administration |
| 277-678A | Simulation of Management Systems |
| 277-679A | Applied Optimization I |
| 280-373A,B | Operations Research |

In addition, there are other courses that may be approved for inclusion under category (b). Students may consult with the School of Computer Science about the acceptability of particular courses. The courses in other departments are at a variety of levels. Some are required courses in the student's ordinary program; some are courses that may be taken as technical complementaries. Students should consult with their advisers about the possibility of taking specific courses.

**The following categories are a guideline to the content of the available courses:**

**Programming and Programming Languages**

308-203 or 308-250, 308-273, 308-302, 308-425, 308-426, 308-524.

**Software Design**

304-221, 304-425, 304-512, 304-521, 304-529, 304-532, 308-203, 308-310, 308-335, 308-360 (or 308-405), 308-420, 308-424, 308-426, 308-431, 308-433, 308-520, 308-530, 308-534, 308-535, 308-537, 308-538, 308-557, 308-560, 308-575.

**Hardware Design**

302-571, 304-221, 304-425, 304-426, 304-492, 304-512, 304-521, 304-532, 308-305.

**Real-Time Processes**

302-453, 302-455, 304-531, 305-475, 305-355.

**Operations Research**

189-407, 189-417, 277-679, 280-373, 303-208, 305-474, 308-566.

**Numerical Analysis**

189-327, 189-578, 189-579, 304-543, 308-350 (or 305-409), 308-540.

## 5.5 Construction Engineering and Management Minor

Students in the Faculty of Engineering may obtain a Minor in Construction Engineering and Management by completing 24 to 25 credits chosen from the required and complementary courses listed below. By a careful selection of complementary courses, a Civil Engineering student may obtain this Minor by completing as few as 9 additional credits. Students in other departments would typically require 12 to 15 additional credits to complete the Minor.

For further information, contact Professor L. Chouinard at (514) 398-6446, Room 484, Macdonald Engineering Building.

**Prerequisites:**

303-208A Civil Engineering Systems Analysis or an equivalent course in Operations Research
303-302B Probabilistic Systems or equivalent
306-310A,B Engineering Economy
308-208A,B Computers in Engineering or equivalent

**Requirements:**

The 24 to 25 credits listed below must be completed with a grade of C or higher in order to fulfil the requirements of the Minor.

**1. Management and Law:** 15 credits,as follows:

280-211 (3) Introduction to Financial Accounting
280-341 (3) Finance I
279-294 (3) Intro to Labour-Management Relations
300-220A (3) Law for Architects and Engineers

and one of:

303-324B (3) Construction Project Management
305-472A (3) Case Studies in Project Mgmt

**2. Either 3 or 4 credits,** as follows:

a) 4 credits - Any two of the following relating to Building Structures:

301-446A (2) Mechanical Services in Buildings
301-447A (2) Electrical Services
301-451B (2) Building Regulations and Safety
303-492A (2) Structures

or

b) 3 credits - One of the following relating to Heavy Construction:

306-322B (3) Rock Fragmentation
306-333B (3) Materials Handling

**3. Other Construction-Related Complementaries:** 6 credits
Any two of the following:

270-462 (3) Management of New Enterprises
274-445 (3) Real Estate Finance
303-446A (3) Construction Engineering
303-527A (3 Renovation & Preservation of Infrastructure
303-586A (3) Earthwork Engineering
304-281B (3) Electric Power
306-520A (3) Stability of Rock Slopes
306-521A (3 Stability of Underground Openings
309-321B (3) Mécanique des roches et contrôle des pressions de terrains
336-411A (3) Off-Road Power Machinery

**Total requirement: 24 or 25 credits**

## 5.6 Economics Minor

The Minor consists of 18 credits in courses given in the Economics Department. It consists of required courses and complementaries. In addition, it is presumed that all Engineering students will have a sufficient background in statistics. Engineering Economy, 306-310, does not form part of this minor. For more information see the Department of Economics, Leacock Room 443.

**Required Courses** (9 credits)

154-230D* Microeconomic Theory
154-209A,B** Macroeconomic Analysis and Applications

**Complementary Courses** (9 credits) from:

154-225A Economics of the Environment
154-302D Money and Banking
154-303D Canadian Economic Policy
154-305A Industrial Organization
154-306D Labour Economics and Institutions
154-308B Public Policies Toward Business
154-311A United States Economic Development
154-313D Economic Development
154-316A,B The Underground Economy
154-321A The Quebec Economy
154-326A Ecological Economics
154-329A The Economics of Confederation
154-330D Macroeconomic Theory
154-331A Economic Development: Russia and the USSR
154-332A Comparative Economic Systems
154-333B Topics in Comparative Economic Systems
154-335A The Japanese Economy
154-337A,B Introductory Econometrics I
154-344A The International Economy, 1830 - 1914
154-345B The International Economy Since 1914
154-347B Economics of Climate Change
154-404A,B Transportation
154-405A,B Natural Resource Economics
154-406A,B Topics in Economic Policy
154-408D Public Sector Economics
154-411A,B Economic Development: A World Area
154-416A,B Topics in Economic Development II
154-420A,B Topics in Economic Theory
154-423D International Trade and Finance
154-426A,B Labour Economics
154-434A,B Current Economic Problems
154-440A,B Health Economics
154-447A Economics of Information and Uncertainty
154-467D Econometrics - Honours
154-525B Project Analysis
154-534B The Pensions Crisis
154-546A Game Theory

Mining Engineering students will be permitted to include Mineral Economics (306-526A,B) among these 18 credits.

* Students may, with consent of instructor, take 154-250D Introduction to Economic Theory - Honours, in place of 154-230D.

** This requirement is waived for students who choose 154-330D from the list of complementaries. Students may not take both 154-209A,B and 154-330D.

## 5.7 Environmental Engineering Minor

The Environmental Engineering Minor is offered for students of Engineering and the Department of Agricultural and Biosystems Engineering wishing to pursue studies in this area. The Minor program consists of 27 credits in courses. Through a judicious choice of core and complementary courses listed below, students may minimize the number of additional credits required to obtain this Minor. The Minor typically requires a minimum of 9 to 15 additional credits. This minimum depends on the department/school in which the student is registered.

The Environmental Engineering Minor Program is administered by the Department of Civil Engineering and Applied Mechanics. Further information may be obtained from Professor S. Ghoshal, Room 475C, Macdonald Engineering Building.

**General Regulations**

To complete the Minor in Environmental Engineering, students must:

a) complete a minimum of 21 credits of Engineering courses (a minimum of 6 credits in this category must be chosen outside the student's principal departmental program) (see section A below),
b) complete a minimum of 6 credits of non-Engineering courses (each course must be chosen from a different department, and neither from the student's home department) (see section B below),
c) complete one of the corequisite courses listed below in addition to the 27 credits counted toward the Minor.
d) in the case of Agricultural and Biosystems, Chemical, and Civil Engineering students, select all courses for the Minor program in the student's principal program, other than those taken as part of the Humanities and impact course requirements,
e) obtain a grade of C or better in all approved courses in the Minor, and

f) satisfy the requirements of both the Minor and the student's departmental program.

**Note:** Not all courses listed below are offered every year. Students should consult with the department concerned about the courses which are offered in a given year.

**Corequisites**
(Not credited to the Minor Program)
302-230 Environmental Aspects of Technology
or 303-225 Environmental Engineering
or 306-308 Social Impact of Technology
or equivalent environmental impact course

**A. ENGINEERING COURSES** (21 credits)

**Agricultural Engineering (Macdonald Campus)**
336-217 Hydrology and Drainage
(not open to students who have passed 303-323)
336-322 Agro-food Waste Management
336-416 Engineering for Land Development
336-518 Pollution Control for Agriculture

**Chemical Engineering**
302-351 Separation Processes
302-370 Elements of Biotechnology
302-430 Technology Impact Assessment
(not open to students who have passed 375-437)
302-452 Particulate Systems (offered in alternate years)
302-471 Industrial Water Pollution Control
(not open to students who have passed 303-430)
302-472 Industrial Air Pollution Control
302-591 Environmental Bioremediation

**Civil Engineering and Applied Mechanics**
303-225 Environmental Engineering
(not part of the Minor for Civil Engineering Students)
303-323 Hydrology and Water Resources
(not open to students who have passed 336-217)
303-421 Municipal Systems
303-430 Water Treatment and Pollution Control
(not open to students who have passed 302-471)
303-451 Geoenvironmental Engineering
303-526 Solid Waste Management
303-550 Water Resources Management
303-553 Stream Pollution and Control
303-572 Advanced Hydraulics
303-574 Fluid Mechanics of Water Pollution
303-575 Fluid Mechanics of Air Pollution
303-577 River Engineering
303-585 Groundwater Hydrology

**Mechanical Engineering**
305-343 Energy Conversion
305-434 Turbomachinery
305-447 Combustion
305-525 Intro. to Nuclear Engineering
305-526 Manufacturing and the Environment
305-534 Air Pollution Engineering

**Mining and Metallurgical Engineering**
306-412 Corrosion and Degradation
306-451 Environmental Controls
306-555 Thermal Remediation of Wastes
309-327 Hydrogéologie Appliquée
309-328 Environnement Minier
309-422 Ventilation Minière

**B. NON-ENGINEERING COURSES** (6 credits)

**Agricultural Sciences (Macdonald Campus)**
338-510 Agricultural Micrometeorology
344-200 Biology of Organisms I
344-201 Biology of Organisms II
344-205 Principles of Ecology
349-315 Science of Inland Waters
350-380 Food Systems and the Environment
362-230 The Microbial World
(not open to students who have passed 302-370)
362-331 Microbial Ecology
(not open to students who have passed 302-370)
362-341 Mechanisms of Pathogenicity
372-210 Principles of Soil Science (not part of the Minor for Agricultural Engineering Students)
372-331 Soil Physics
374-420 Environmental Issues in Forestry
375-333 Physical and Biological Aspects of Pollution
375-375 Issues in Environmental Sciences
375-415 Conservation Law
375-437 Assessing Environmental Impact
(not open to students who have passed 302-430)

**Anthropology**
151-206 Environment and Culture

**Atmospheric and Oceanic Sciences**
195-210 Introduction to Atmospheric Science (not open to students who have passed 183-321)
195-220 Introduction to Oceanic Sciences

**Biology**
177-205 Biology of Organisms
177-208 Introduction to Ecology
177-432 Limnology
177-470 Lake Management

**Chemistry**
180-307 Environmental Analysis

**Earth and Planetary Sciences**
186-243 Environmental Geology (not open to students who have passed or who will take 186-221)
186-549 Groundwater Hydrology

**Economics**
154-225 Economics of the Environment
154-326 Ecological Economics
154-347 Economics of Climate Change

**Geography**
183-200 Geographical Perspectives on World Environmental Problems
183-201 Geographic Information Systems I
183-203 An Introduction to Environmental Studies
183-205 Global Change: Past, Present and Future
183-302 Environmental Analysis and Management
183-308 Air Photo Interpretation and Remote Sensing
183-321 Climatic Environments
(not open to students who have passed 195-210)
183-404 Environmental Management for Parks and Protected Areas

**Law**
389-580 Environment and the Law

**Microbiology and Immunology**
528-211 Biology of Microorganisms

**Religious Studies (Macdonald Campus)**
260-270 Religious Ethics and the Environment

**Sociology**
166-328 Environmental Sociology

## 5.8 Minor in Environment

Environmental studies involve the interactions between humans and their natural or technological environment. Environmental problems are frequently comprehensive and complex, and their satisfactory solutions require the synthesis of humanistic, scientific, and institutional knowledge. The Minor in Environment is offered and administered by the McGill School of Environment (MSE). Inquiries should be directed to Mr. Peter Barry, MSE. E-mail: info@mse.mcgill.ca or telephone: (514) 398-4306.

Since the program comprises a total of 18 credits for the Minor, additional credits beyond those needed for the B.Eng. degree are

required. Students wishing to receive the Minor should prepare a program and have it approved by both their regular Engineering Advisor and the School. For program details, see "Minor in Environment" on page 466 in the MSE section.

## 5.9 Management Courses and Minor Program

Many engineers begin to assume management functions within a few years of graduation. They can, at this stage, take up the study of economics, behavioural science and other management subjects. Students wishing to include such studies in their undergraduate program can take suitable courses from Engineering and Management as listed below.

Engineering Economy 306-310 introduces the concept of costs into evaluations of engineering projects and architectural proposals. Several additional courses are available, subject to timetable requirements, from the core program of the Faculty of Management.

Other courses from the Management core program have considerable overlap with Engineering courses and thus are not available to Engineering students.

**Note:** Course 280-211, a course in statistics, and a course in Micro-economics are prerequisite for 280-341. If included in the Minor in Management, 280-423 should be taken at the end of the program.

Engineering students may obtain a Minor in Management by completing 15 credits of courses from the following list of Faculty of Management courses with a grade of C or better. Successful completion of this Minor is noted on a student's transcript.

**Required Courses** (6 credits)

| | |
|---|---|
| 280-211 | Introduction to Financial Accounting |
| 280-320 | Managing Human Resources |

**Complementary Courses** (9 credits)

3 credits, one of List A:

| | |
|---|---|
| 280-213 | Introduction to Managerial Accounting |
| 280-341 | Finance I |
| 280-373 | Operations Research |
| 280-382 | International Business |

3 credits, one of List B:

| | |
|---|---|
| 270-462 | Management of New Enterprises |
| or 270-465 | Technological Entrepreneurship |
| 280-222 | Organizational Behaviour |
| 280-352 | Marketing Management I |
| or 275-360 | Marketing of Technology |
| 280-360 | Social Context of Business |
| 280-423 | Organizational Policy |

3 credits, any available 300 or 400-level Management course (for which the prerequisites, if any, have been met).

An Engineering course deemed equivalent by the Faculty of Management may be substituted for course 280-373. There are three courses in Engineering that qualify: 303-208, 305-474 and 309-326. It should be noted that 280-373 does not count as a technical complementary course.

A student embarking on the Minor must be prepared to take credits additional to the normal Engineering program. The student may choose the non-technical complementary course(s) required in his/her program from list B above, but under no circumstances will more than 6 credits of non-technical complementary courses count towards both the Engineering program and the Minor. Students considering this Minor should consult their adviser, or Ms. H. Van Eyk, Faculty of Management.

Prerequisite to entry to this Minor is a grade C or better in 306-310.

## 5.10 Materials Engineering Minor

Engineering students may obtain a Minor in Materials Engineering by completing 24 credits chosen from the required and complementary courses listed below. By a careful selection of complementary courses, Engineering students may obtain this Minor with a minimum of 15 additional credits. It should be noted that some departments (e.g. Mechanical Engineering) will allow their students to take courses from this list, providing they complete the Minor prior to graduation. For further information, please contact the coordinator, Prof. J. Szpunar, Room 2M020, Wong Building.

**Required Courses** (15 credits)

| | |
|---|---|
| 306-260A,B | Materials Science and Engineering |
| or 302-380A | Materials Science |
| 306-367B | Electronic Properties of Materials |
| 306-465B | Ceramic Engineering |
| 302-481A | Polymer Engineering |
| 302-484B | Materials Engineering |

**Complementary Courses** (9 credits)

Three courses to be chosen from the following list:

| | |
|---|---|
| 180-455A | Introductory Polymer Chemistry |
| 302-381B | Polymer Technology |
| 302-483B | Industrial Rheology |
| 302-487B | Chemical Processing in the Electronics Industry |
| 302-530C | Structure and Properties of Paper |
| 302-581B | Polymer Composites Engineering |
| 304-545A | Microelectronics Technology |
| 305-530B | Mechanics of Composite Materials |
| 306-360A | Phase Transformations in Solids |
| 306-361B | Liquid State Processing of Materials |
| 306-362A | Engineering Properties of Materials |
| 306-412A | Corrosion and Degradation |
| 306-560A | Joining Processes |
| 306-561B | Advanced Materials Design |
| 306-563B | Hot Deformation of Metals |
| 306-564B | X-Ray Diffraction Analysis of Materials |
| 306-566A | Texture, Structure and Properties of Polycrystalline Materials |
| 306-569B | Electron Beam Analysis of Materials |

## 5.11 Mathematics Minor

The Minor in Mathematics for students in the Faculty of Engineering requires satisfactory passes in 24 credits of approved courses in Mathematics not including 189-247 (or -223), -260 (or -222), -261 (or -315 or -325), -265 (or -248 or -314), -266, -270, -319.

At least 18 credits must be chosen from the Mathematics and Statistics courses approved for the Mathematics Majors or Honours program, or from Mathematics 189-249, -363, -381, -386. The remaining credits may be chosen from mathematically allied courses.

In addition to an Engineering Adviser, each student in the Minor program must have an Adviser designated by the Department of Mathematics and Statistics, normally beginning in the U2 year. The selection of courses for the Minor is to be done in conjunction with the Minor Adviser. Please consult the Department of Mathematics and Statistics for an Adviser.

## 5.12 Physics Minor

Students in Honours Electrical Engineering may obtain a Minor in Physics as part of their B.Eng. degree by satisfying the 18-credit requirement listed below:

| | |
|---|---|
| 198-253B | Thermal Physics |
| 198-357A | Quantum Physics I |
| 198-457B | Quantum Physics II |

and at least 9 credits chosen from the following:

| | |
|---|---|
| 198-332B | Physics of Fluids |
| 198-362B | Statistical Mechanics |
| 198-451B | Classical Mechanics |
| 198-514B | General Relativity |
| 198-551A | Quantum Theory |
| 198-557A | Nuclear Physics |
| 198-558A | Solid State Physics |
| 198-559A | Advanced Statistical Mechanics |
| 198-562B | Electromagnetic Theory |
| 198-567B | Particle Physics |

Students who take 198-357A and 198-457B can omit 198-271B from their normal Electrical Engineering program. Candidates must go to the Department of Physics at registration time in their U3 year to fill out a Minor Program Form.

### 5.13 Technological Entrepreneurship Minor

Engineering students may obtain a Minor in Technological Entrepreneurship by completing 6 courses (18 credits) as listed below. Up to two courses (6 credits) may be double-counted for credit towards the Humanities and Social Sciences Complementary Courses.

This Minor is offered jointly by the Faculties of Engineering and Management. It will appeal to those students who have a concept, process or product idea in mind and who want to explore the opportunity of commercializing it. It will also be of interest to students who have a general interest in entrepreneurship and intend to pursue a career in small and medium sized high technology/ engineering companies.

Students considering the Minor should consult Ms. Judy Pharo, the Student Advisor in the Faculty of Engineering at the following address: advisor@emf.lan.mcgill.ca

**Required Courses** (18 credits)

| | | |
|---|---|---|
| 280-320A | (3) | Managing Human Resources |
| 272-321B | (3) | Leadership |
| 270-465B | (3) | Technological Entrepreneurship |
| 275-360A,B | (3) | Marketing of Technology |
| 276-562B | (3) | Organizational Strategies for Advanced Technology Firms |
| 300-480B | (3) | Technological Entrepreneurship Project |

### 5.14 Software Engineering Minor

This Minor will prepare an engineering student for a career in software engineering. It will provide a foundation in basic computer science, computer programming and software engineering practice.

The Minor consists of 24 credits (8 courses). Up to four of the courses (12 credits) may be double-counted for credit towards the B. Eng. degree in Electrical Engineering or Computer Engineering. Students in other programs may double-count up to three courses (9 credits).

Students considering this Minor should contact Ms. Judy Pharo, the Student Advisor in the Faculty of Engineering at the following address: advisor@emf.lan.mcgill.ca.

**Required Courses** (12 credits)

| | | |
|---|---|---|
| 304-221 | (3) | Introduction to Computer Engineering I |
| 304-222 | (3) | Introduction to Computer Engineering II |
| 304-321 | (3) | Introduction to Software Engineering |
| 304-428 | (3) | Software Engineering Practice |

**Complementary Courses** (12 credits)
one course (3 credits), either:

| | | |
|---|---|---|
| 308-203 | (3) | Introduction to Computing II |
| or 308-250 | (3) | Introduction to Computer Science |

At least one course (3 credits) must be selected from the following list of engineering courses:

| | | |
|---|---|---|
| 302-458 | (3) | Computer Applications |
| 302-571 | (3) | Small Computer Applications in Chemical Eng. |
| 303-460 | (3) | Matrix Structural Analysis |
| 303-550 | (3) | Water Resources Management |
| 303-572 | (3) | Computational Hydraulics |
| 304-424 | (3) | Human-Computer Interaction |
| 304-427 | (3) | Operating Systems |
| 304-526 | (3) | Artificial Intelligence |
| 304-531 | (3) | Real Time Systems |
| 304-532 | (3) | Computer Graphics |
| 305-474 | (3) | Selected Topics in Operations Research |
| 305-524 | (3) | Computer Integrated Manufacturing |
| 305-539 | (3) | Computational Aerodynamics |
| 305-545 | (3) | Advanced Stress Analysis |
| 305-576 | (3) | Computer Graphics and Geom. Modeling |

No more than two courses (6 credits) can be selected from the following list of courses offered by the School of Computer Science:

| | | |
|---|---|---|
| 308-302 | (3) | Programming Languages and Paradigms |
| 308-335 | (3) | Software Engineering Methods |
| 308-420 | (3) | Files and Database Systems |
| 308-421 | (3) | Introduction to Database Systems |
| 308-424 | (3) | Topics in Artificial Intelligence |
| 308-426 | (3) | Automated Reasoning |
| 308-431 | (3) | Algorithms and Data Structures |
| 308-433 | (3) | Personal Software Engineering |
| 308-538 | (3) | Person-Machine Communication |

## 6 Courses Given by other Faculties for Engineering Students

● Denotes courses not offered in 2000-01
▭ Courses with limited enrolment

### 6.1 Department of Chemistry

**180-233B SELECTED TOPICS IN PHYSICAL CHEMISTRY.** 3(3-0-6) (For Chemical Engineers only.) Introduction to chemical kinetics, surface and colloid chemistry and electrochemistry. The topics to be discussed will be of particular interest to students in chemical engineering. **Professors Barrett, Galley and Lennox**

**180-234A,B SELECTED TOPICS IN ORGANIC CHEMISTRY.** 3(3-0-6) (Prerequisite: 180-212A,B or equivalent. For Chemical Engineers only.) Modern spectroscopic techniques for structure determination. The chemistry of alkyl halides, alcohols, ethers, carbonyl compounds and amines with special attention to mechanistic aspects. Special topics. **Professors Chin (A) and Farrell (B)**

### 6.2 School of Computer Science

▭ **308-202A,B INTROUCTION TO COMPUTING 1.** (3 credits) (3 hours) (Prerequisite: a CEGEP level mathematics course.) (Credit cannot be obtained for both 308-202 and 308-208.) Overview of components of microcomputers, the internet design and implementation of programs using a modern highlevel language, an introduction to modular software design and debugging. Programming concepts are illustrated using a variety of applications. **Professor Hendren**

**308-208A,B COMPUTERS IN ENGINEERING.** (3 credits) (3 hours) (Prerequisite: differential and integral calculus. Co-requisite: linear algebra: determinants, vectors, matrix operations.) (Credit cannot be held for both 308-202 and 308-208.) Introduction to computer systems. Concepts and structures for high level programming. Elements of structured programming using FORTRAN 90 and "C". Assignments in both mainframe and microcomputer environment. Numerical algorithms such as root finding, numerical integration and differential equations. Non-numerical algorithms for sorting and searching. **Professor Ratzer**

**308-250A,B INTRODUCTION TO COMPUTER SCIENCE.** (3) (3 hours) (Prerequisites: Familiarity with a high level programming language and CEGEP level Math.) An introduction to the design of computer algorithms, including basic data structures, analysis of algorithms, establishing correctness of programs and program testing. Overview of topics in computer science. **Professor Panangaden**

▭ **308-302A,B PROGRAMMING LANGUAGES AND PARADIGMS.** (3) (3 hours) (Prerequisite: 308-250 or 308-203) Programming language design issues and programming paradigms. Binding and scoping, parameter passisng, lambda abstraction, data abstraction, type checking. Functional and logic programming. **Professors Friedman and Panangaden**

### 6.3 Department of Earth and Planetary Sciences

**186-221A GENERAL GEOLOGY.** 3(2-3-4) An introductory course in physical geology designed for majors in civil and mining engineering. Properties of rocks and minerals, major geological processes, together with natural hazards and their effects on engineered

structures are emphasized. The laboratory is an integral part of the course which includes rock and mineral identification, basic techniques of airphoto and geological map interpretation, and structural geology. **Staff**

**186-225A PROPERTIES OF MINERALS.** (1) (1 hour lecture, 1 hour laboratory) (Not open to students who have taken 186-210A) Survey of the physical and chemical properties of the main mineral groups. Discussion of their relationships to the chemical composition and structure of minerals. The practical exercises emphasize the physical and chemical properties that relate to industrial uses and environmental issues, and the identification of hand specimens. **Professor Paquette**

## 6.4 Faculty of Education

▭ **455-206A,B COMMUNICATION IN ENGINEERING.** (3 credits) Written and oral communication in Engineering (in English): strategies for generating, developing, organizing, and presenting ideas in a technical setting; problem-solving; communicating to different audiences, editing and revising; and public speaking. Course work based on academic, technical, and professional communication in engineering. Attendance at first class is imperative. **Staff**

## 6.5 Department of Mathematics and Statistics

**189-247B LINEAR ALGEBRA.** (3 credits) (Prerequisite: 189-133 or equivalent. Intended for Honours Physics and Engineering students. Not open to students who have taken or are taking 189-236 or 189-223 or 189-251.) Matrix algebra, determinants, systems of linear equations. Abstract vector spaces, inner product spaces, Fourier series. Linear transformations and their matrix representations. Eigenvalues and eigenvectors, diagonalizable and defective matrices, positive definite and semidefinite matrices. Quadratic and Hermitian forms, generalized eigenvalue problems, simultaneous reduction of quadratic forms. Applications.

**189-248A ADVANCED CALCULUS I.** (3 credits) (Prerequisites: 189-133 and 222 or consent of Department. Intended for Honours Mathematics, Physics and Engineering students. Not open to students who have taken or are taking 189-314.) Partial derivatives; implicit functions; Jacobians; maxima and minima; Lagrange multipliers. Scalar and vector fields; orthogonal curvilinear coordinates. Multiple integrals; arc length, volume and surface area. Line integrals; Green's theorem; the divergence theorem. Stokes' theorem; irrotational and solenoidal fields; applications.

**189-249B ADVANCED CALCULUS II.** (3 credits) (Prerequisite: 189-248. Intended for Honours Physics and Engineering students. Not open to students who have taken or are taking 189-316.) Functions of a complex variable; Cauchy-Riemann equations; Cauchy's theorem and consequences. Taylor and Laurent expansions. Residue calculus; evaluation of real integrals; integral representation of special functions; the complex inversion integral. Conformal mapping; Schwarz-Christoffel transformation; Poisson's integral formulas; applications.

**189-260A,B INTERMEDIATE CALCULUS.** 3(3-1-5) (Prerequisites: 189-141, 189-133 or equivalent) Review of sequences and series. Power series, Taylor's theorem and Taylor's series, computations using series. Review of vectors, lines and planes, curves and curvature, conics, polar coordinates. Surfaces. Differential calculus of several variables. Double and triple integrals.

**189-261A,B DIFFERENTIAL EQUATIONS.** 3(3-1-5) (Corequisite: 189-260) Ordinary differential equations: first order, linear second-order and higher order, linear with constant coefficients. Solution by series, by Laplace transform, and by some simple numerical methods.

**189-265A,B ADVANCED CALCULUS.** 3(3-1-5) (Prerequisites: 189-260 or 189-222 or 189-151B or equivalent) Implicit functions, constrained and unconstrained extrema for functions of several variables. Change of variables in multiple integrals, Jacobians, surface integrals. Scalar and vector fields, line integrals, vector operators. Green's, divergence and Stokes' theorems, applications to heat flow, electrostatics and fluid flow.

**189-266A,B LINEAR ALGEBRA AND BVP.** 4(4-1-7) (Prerequisites: 189-261, 189-265) Review of matrix algebra, vector spaces and linear transformations, eigenvalue problems and applications to systems of linear ordinary differential equations. Partial differential equations in engineering, Fourier analysis, Sturm-Liouville theory, solutions of boundary value problems in cartesian, cylindrical and spherical coordinates.

**189-270A,B APPLIED LINEAR ALGEBRA.** 3(3-1-5) (Prerequisite: 189-261) Review of matrix algebra, solution of linear equations, triangular factorization and Gaussian reduction, vector spaces, inner products, orthogonality concepts, projections, least squares. Eigenvalues and eigenvectors, diagonalization of matrices and quadratic forms, Cayley-Hamilton theorem, the exponential matrix, analytical and numerical techniques for solving linear systems of ordinary differential equations, nonlinear equations and stability.

**189-325A,B ORDINARY DIFFERENTIAL EQUATIONS.** 3(3-0-6) (Prerequisite: 189-222. Intended for Honours Mathematics, Physics and Engineering programs. Not open to students who have taken or are taking 189-315) First and second order equations; linear equations; series solutions; elementary numerical methods; Laplace transforms.

**189-363B DISCRETE MATHEMATICS.** 3(3-0-6) (Prerequisites: 189-265 and either 189-270 or consent of instructor) Logic and combinatorics. Mathematical reasoning and methods of proof. Sets, relations, functions, partially ordered sets, lattices, Boolean algebra. Propositional and predicate calculi. Recurrences and graph theory.

**189-381A,B COMPLEX VARIABLES AND TRANSFORMS.** 3(3-1-5) (Prerequisite: 189-265) Analytic functions, Cauchy-Riemann equations, simple mappings, Cauchy's theorem, Cauchy's integral formula, Taylor and Laurent expansions, residue calculus. Properties of one and two-sided Fourier and Laplace transforms, the complex inversion integral, relation between the Fourier and Laplace transforms, application of transform techniques to the solution of differential equations. The Z-transform and applications to difference equations.

● **189-386A APPLIED PARTIAL DIFFERENTIAL EQUATIONS.** 3(3-1-5) (Prerequisite: 189-325. Pre- or Co-requisite: 189-249) Steady fluid flow. Diffusion of heat. Transverse waves on strings, vibrations of membranes. Separation of variables in rectangular, cylindrical and spherical coordinates. Eigenvalues and eigenfunctions. Fourier analysis. Sturm-Liouville theory. Solution of boundary value problems. Wavelength, energy, power, phase and group velocities. Longitudinal waves in gases and solids. Integral transform methods and Green's functions.

## 6.6 Department of Physics

**198-251A CLASSICAL MECHANICS I.** (3 credits; 3 hours lectures) (Prerequisite: CEGEP physics; Corequisite: 189-222A,B) Newton's laws, work energy, angular momentum. Harmonic oscillator, forced oscillations. Inertial forces, rotating frames. Central forces, centre of mass, planetary orbits, Kepler's laws.
**Professor Hanna**

**198-271A,B QUANTUM PHYSICS.** 3(3-0-6) (Prerequisite: 198-251 or 303-281) The observed properties of atoms and radiation from atoms. Electron waves. The Schroedinger Equation in one dimension. Quantum mechanics of the hydrogen atom. Angular momentum and spin. Quantum mechanics of many electron systems. Basic ideas of electrons in solids and solid state physics.
**Professors Ryan and Cline**

**198-350A ELECTROMAGNETISM.** (3 credits) (3 hours lectures) (Prerequisites: 189-248A,B, 325B. Honours students or permission of the instructor) Fundamental laws of electric and magnetic fields in both integral and differential form. **Professor Lovejoy**