SECTION 18: GRADUATE COURSE DESCRIPTIONS

Each course description is followed by a list of the credit hours (cr) and on occasion the contact hours are also listed for the course. Contact hours are divided into lecture (lec), laboratory (lab), tutorial (tut) and other (oth) hours. A course with a listing of 3 cr, 3 lec, 3 lab, 1 tut, 2 oth, is weighted at three credit hours with three hours of lectures, three laboratory hours, one hour of tutorial and two other contact hours per week. If the contact hours are not listed, your professor will discuss the contact hour breakdown with you once the class commences.

Courses offered in condensed format will have the number of contact hours prorated accordingly.

APBS 6010G Research in Applied Bioscience. This is a required team-taught course designed to provide a foundation for the graduate program in Applied Bioscience. The course will provide students with current background knowledge and skills needed for research in applied bioscience and will expose students to current issues and problems that this area of research may target. The course will introduce such topics as principles of experimental design, data interpretation and analysis of results and how to present and communicate scientific information in both oral and written formats. Students will also learn about the grant and scholarship process and how to write a research proposal and they will be introduced to such issues as research ethics and intellectual property. 3 cr, 2 lec. Prerequisite: enrolment in the APBS graduate program.

APBS 6020G MSc Thesis in Applied Bioscience. Students must prepare and successfully defend a written thesis related to their supervised research project at the end on the program. The student's advisory committee must approve the commencement of the writing of the thesis. The thesis will be evaluated by an examination committee and accompanied by an oral presentation. The student must receive a satisfactory report on the written thesis and must demonstrate a thorough understanding of the research topic. The student will receive a grade of either pass or fail. 21 cr. Prerequisite: enrolment in the APBS graduate program.

APBS 6030G Seminar in Applied Bioscience. This course will require students to present a thorough overview of their thesis research, including relevant background material and research results and their interpretation. The presentation will be expected to be appropriate for an interdisciplinary audience in science. This is a required, but non-credit course in the Applied Bioscience program. Seminars will be focused on specific research projects in applied bioscience. Student seminars will be regularly scheduled as needed. The student will receive a grade of either pass or fail. 0 cr. Prerequisite: good standing in the APBS graduate program.

APBS 6100G Advanced Cell and Molecular Biology. This will be a non-lecture based course where students and the faculty coordinator discuss current research in cell and molecular biology. The course will be a combination of group discussions and presentations. Each week a student will present either a research article or a synopsis of the current knowledge regarding a topic related to the course and possibly their own research interests. This will allow the students to apply basic concepts learned as undergraduate students to the current state of knowledge in cell and molecular biology. 3 cr, 2 lec. Prerequisite or corequisite: enrolment in the APBS graduate program.

APBS 6200G Environmental Determinants of Health. This course will explore interactions between environment and human health. It will comprehensively address principles of environmental health, followed by specific issues regarding harmful environmental agents, and Canadian and global environmental health challenges. It will be designed to be delivered by an interdisciplinary faculty team potentially including members from the Faculties of Criminology, Justice and Policy Studies, Health Sciences, Science and Engineering and Applied Science. It will attract health and non-health graduate students interested in the multi-factorial nature of environmental diseases. At the end of this course, students should have a broad understanding of how human health is contextually determined by our environment and be familiar with published seminal environmental health research. 3 cr, 3 lec. Prerequisite or corequisite: enrolment in the APBS graduate program.

APBS 6300G Advanced Topics in Biological Chemistry. This graduate course will explore a range of research topics at the intersection of chemistry and biology through examples selected from the current scientific literature. Topics to be covered include: protein engineering, enzymes, receptors, cofactors, enzymes for organic synthesis, biotransformations, catalytic properties of nucleic acids, bio-inorganic chemistry. 3 cr, 3 lec. Prerequisite or corequisite: enrolment in the APBS graduate program.

ENGR 5001G MASc Thesis. The thesis is the major component of the MASc program and is carried out under the direction of the student's supervisor. The thesis may involve an investigation that is fundamental in nature, or may be applied, incorporating creative design. Through the thesis, candidates are expected to give evidence of competence in research and a sound understanding of the area of specialization involved. The student will receive a grade of either pass or fail. 15 cr.

ENGR 5002G MEng Project. The MEng Project provides students with the opportunity, under the supervision of a faculty member, to integrate and synthesize knowledge gained throughout their program of study. The chosen topic will be dependent on the area of specialization of the student. The student will receive a grade of either pass or fail. 9 cr.

ENGR 5003G Seminar. Participation in a program of seminars by internal and external speakers on current research topics. All MASc students will be required to give a seminar on their thesis research during the second year of their program. The student will receive a grade of either pass or fail.

ENGR 5004G Directed Studies. Faculty permission may be given for supervised research projects, individual study, or directed readings. Students wishing to pursue a course of directed studies must, with a faculty member who is willing to supervise such a course, formulate a proposal accurately describing the course content, the intended method and extent of supervision and the method by which work will be evaluated. This course may only be taken once. 3 cr.

ENGR 5005G Special Topics. Presents material in an emerging field or one not covered in regular offerings. This course may be taken more than once, provided the subject matter is substantially different. 3 cr.

ENGR 5010G Advanced Optimization. The objective of this course is to understand the principles of optimization and its application to engineering problems. Topics covered include: the steepest descent and Newton methods for unconstrained optimization; golden section, quadratic, cubic and inexact line searches; conjugate and quasi-Newton methods; the Fletcher-Reeves algorithm; fundamentals of constrained optimization theory; simplex methods for linear programming; modern interior-point methods; active-set methods and primal-dual interior point methods for quadratic and convex programming; semi-definite programming algorithms; sequential quadratic programming and interior-point methods for non-convex optimization. In addition, implementation issues and current software packages/algorithms for optimization will be covered. Global optimization, including genetic algorithms and simulated annealing, will be introduced. 3 cr.

ENGR 5011G Advanced Engineering Design. This course covers the basics of design philosophy, methodology, principles, and theory as a foundation for surveying current research areas in the product development process. A brief introduction to concurrent design and life cycle design is followed by addressing the application of the design process to problem solving. The relationship between creativity and the design process is explored by using tools for solving engineering system design and synthesis problems. Computer, mathematical, and/or physical modelling of the problem and solution, the axiomatic design approach, Taguchi robust design, design of experiments and prototyping are strongly emphasized topics. 3 cr.

ENGR 5012G Advanced and Smart Materials. The core material will consist of: basic features of physical transducer behaviour, mathematical constitutive models and material properties, characterization methods and experimental data, sensor and actuator devices, translation of material behaviour to device behaviour, solid state devices, nonsolid state devices (motors and pumps), mesoscale and MEMS devices, adaptive structures. However, due to the rapid evolutions in the field, the syllabus will be dynamic to respond to the new developments in materials and their applications. The topics will be continually reviewed and monitored for currency. Some of the topics from the following list will also be included covering fundamental principles, mechanisms and applications: piezoelectric materials, 'negative' materials, conductive polymers, advanced composites, shape memory materials, magneto-rheological fluids and intelligent textiles. 3 cr.

ENGR 5100G Advanced Energy Systems. Advanced power and refrigeration cycles. Advanced gas turbine systems. Combustion systems and applications. Energy storage. Nuclear reactor technology. Fuel cells. Solar power. Wind power. Hydro power. Co- and trigeneration. Geothermal district heating systems. Energy and exergy analysis of advanced energy systems. 3 cr.

ENGR 5101G Thermal Energy Storage. General introductory aspects for thermal engineering including energy storage systems, thermal energy storage methods, thermal energy storage and environmental impact, energy storage and energy savings, solar energy and thermal energy storage, heat transfer and stratification in sensible heat storage systems. latent heat storage systems, heat storage with phase change, thermodynamic optimization of thermal energy storage systems, energy and exergy analyses of thermal energy storage systems and thermal energy storage case studies. 3 cr.

ENGR 5102G Fuel Cells and Hydrogen Systems. Introduction to hydrogen and hydrogen fuel cells. Efficiency and open circuit voltage. Operational fuel cell voltages. Proton exchange membrane fuel cells. Alkaline electrolyte fuel cells. Direct methanol fuel cells. Medium and high-temperature fuel cells. Fuelling fuel cells. Components of fuel cell power systems. Delivering fuel cell power. Analysis of fuel cell systems. Fuel cell calculations. Tests. 3 cr.

ENGR 5120G Advanced Fluid Mechanics. Derivation of three-dimensional conservation equations of mass, momentum and energy for compressible viscous fluids. General properties of Navier-Stokes equations. Examples of exact solutions of the Navier-Stokes equations. Approximate solutions for creeping motions. Laminar boundary layer equations and methods of solution: derivation of boundary layer equations, boundary layer separation, general properties of boundary layer equations; Von Karman momentum-integral equations; finite-difference solutions. Stability of laminar flows: theory of small disturbances; Orr-Summerfield equation, transition. Introduction to turbulence. Applications. 3 cr.

ENGR 5121G Advanced Turbo Machinery. Basic thermodynamics and fluid mechanics equations and definitions of efficiencies in turbomachines. Twodimensional cascades (cascade analysis, performance of cascades and cascade correlations). Axial flow turbines. Radial flow turbines. Axial flow compressors. Centrifugal compressors and fans. Applications of turbomachinery to engineering problems. Design, analysis and performance analyses of turbomachines. Transport phenomena aspects. Software use and tests. 3 cr.

ENGR 5122G Computational Fluid Dynamics. Introduction to CFD modelling and mesh generation software. Basic equations of fluid flow and commonly used approximations. Turbulence modelling (one and two equation models, and higher order models). Iterative solution methods and convergence criteria. Practical analysis of turbulent pipe flow mixing elbow and turbomachinery blade problems. Software use and tests. 3 cr.

ENGR 5140G Advanced Heat Transfer. Introduction and conservation equations. Conservation equations and gas kinetics. Unidirectional steady conduction. Multidirectional steady conduction. Time dependent conduction. External forced convection. Internal forced convection. Natural convection. Convection with change of phase. Heat exchangers. Radiation. Mass transfer principles. 3 cr.

ENGR 5141G Heat Exchanger Design and Analysis. Basic mechanisms of heat transfer, such as conduction, convection, boiling, condensation and radiation. Classification of heat exchangers according to flow. Heat exchanger analysis using LMTD, 2-NTUc-R-P-F and NTU methods. Selection criteria of heat exchangers. Thermal-hydraulic and mechanical design of shell-and-tube heat exchangers. Design and analysis of double-pipe heat exchangers. Design and performance evaluation of finned tube heat exchangers. Energy and exergy analyses of heat exchangers. Performance evaluation of plate-fin heat exchangers. Design considerations in boilers and condensers. Fouling growth models and its impact on heat exchanger performance and life-cycle analysis. Flow-induced vibration. Software use/tests. 3 cr.

ENGR 5160G Advanced Thermodynamics. Axiomatic representation of fundamentals of classical thermodynamics. First law of thermodynamics. Equilibrium. Euler and Gibbs-Duhem relations. Second law of thermodynamics. Entropy production. Exergy and irreversibility. Energy and exergy analysis of advanced power and refrigeration cycles. Legendre transformations and Extremum principle. Maxwell relations and thermodynamics derivatives. Stability. Phase transformations. Nernst postulate. Chemical reactions and equilibrium. Case study problems. 3 cr.

ENGR 5161G HVAC and Refrigeration Systems Design and Analysis. Basic concepts. Elements of heat transfer for buildings. Thermodynamic processes in buildings. Energy use and environmental impact. Human thermal comfort and indoor air quality. Fluid mechanics in building systems. Solar radiation. Heating and cooling loads. Annual energy consumption. Heat transfer equipment. Cooling equipment. Thermal energy storage. Software use/tests. 3 cr.

ENGR 5180G Advanced Nuclear Engineering. The course is an introduction to advanced topics in nuclear engineering, with emphasis on reactor physics. Covered topics include neutron slowing down, resonance absorption, multigroup transport and diffusion equations, reactor kinetics, and homogenization methods. Lattice and full-core numerical methods are also covered. This course presumes a knowledge of nuclear physics, differential equations, and vector calculus. 3 cr.

ENGR 5181G Advanced Radiation Engineering. This course introduces advanced concepts in radiation engineering, with an emphasis on how ionizing radiation interactions with matter may be modelled. The course reviews fundamental particle interaction mechanics, measurement and detection of radiation, evaluation of nuclear cross sections and various solutions to the Boltzmann transport equation. This course presumes a knowledge of nuclear physics, differential equations, and statistics. 3 cr.

ENGR 5221G Computer-Integrated Manufacturing. This course covers Computer-Integrated Manufacturing (CIM) with a particular focus on automated manufacturing process planning. It provides advanced instruction in design and implementation of integrated CAD/CAM, robotics, and flexible manufacturing systems. It also provides emphasis on concurrent engineering principles, manufacturing process engineering, computer-aided process planning, NC programming, and CAD/CAM integration. The course provides experience with CAD/CAM software and NC machines. 3 cr.

ENGR 5222G Polymers and Composite Processing. Polymer structure-property relations, linear and nonlinear viscoelasticity, dynamic mechanical analysis, time temperature superposition, creep and stress relaxation, mechanical models for prediction of polymer deformation, rubber elasticity, experimental methods for viscosity-temperatureshear rate measurements, application to melts, filled systems and suspensions. Processes for polymers; injection, extrusion, thermoforming, blow molding, rotational molding, compression and transfer molding, calendaring and post-manufacturing operations. Fibre types and properties, fibre forms, polymeric matrix and interfaces, typical composite properties. Processes for long fibre/thermoset composites, pre-pregging, resin transfer moulding, filament winding, pultrusion, autoclave cure. 3 cr.

ENGR 5223G Advanced Manufacturing Processes and Methodologies. This course is about implementing advanced manufacturing processes and methodologies into production operations as the strategy for achieving reductions in inventory costs, faster manufacturing turnaround times, fewer faulty products and using less floor space for production. It addresses the next generation manufacturing and production techniques that take advantage of the opportunities offered by selective use of new materials and emerging technologies for high efficient machining, coating, forming, assembly operations, etc. Virtual manufacturing methodologies and multi-objective optimization in terms of design, performance, safety, cost, and environment as well as advanced manufacturing methodologies such as lean manufacturing are also addressed. 3 cr.

ENGR 5240G Advanced Dynamics. This course builds upon the knowledge students have gained in a first dynamics course to cover more advanced dynamical systems. Topics covered will include: 3-D kinematics and kinetics of particles and systems of particles using Newton's method; equations of motion in normal and tangential, cylindrical, and spherical coordinates; two body central force motion with applications in orbital dynamics, and particle on a rotating earth. 3-D kinematics and kinetics of rigid bodies, Euler angles, single and multiple rotating reference frames, Coriolis acceleration, inertial reference frames, equations of translational motion, angular momentum, rotational motion, body axes and rotation relative to a coordinate system, Euler's and modified Euler's equations of motion with applications in dynamics of gyroscopes, robots, and vehicles. Variational mechanics, constraints, generalized coordinates, principles of virtual work, D'Alembert, and Hamilton's principle, concept of Hamiltonian, Hamilton's canonical equations. Lagrange's equation for system of particles and rigid bodies, generalized force and moment, calculus of variations, concepts of Lagrangian and Lagrange multiplier, Lagrange's equations for holonomic and nonholonomic systems, stability analysis of autonomous and non-autonomous dynamical systems. Numerical solutions of dynamic systems, explicit methods include finite difference and Rung-Kutta, and implicit methods are Houbolt, Wilson-theta, Park stuffy stable, and Newark-beta. 3 cr.

ENGR 5241G Advanced Mechanics of Materials. This course builds upon the knowledge students have gained in the first solid mechanics course to cover more advanced mechanics of materials. Topics covered include: the general state of stress and strain in three dimensions; formulation of general equilibrium equations; compatibility conditions; constitutive relationships; elasto-plastic relationships; Airy stress function; analytical solutions of special problems including thick-walled cylinders, rotating disks, bucking of columns, stress concentration, and curved beams; energy methods in elasticity; torsion problem; bending of beams; contact stresses; analysis of flat plates; creep and relaxation; introduction to fracture mechanics; fatigue and failure theories. 3 cr.

ENGR 5242G Advanced Vibrations. This course builds upon the knowledge students have gained in a first vibration course to cover more advanced vibrating systems. Topics covered include: Lagrange's equations of motion, generalized coordinates and force, virtual work, linearization of equations for small oscillations, multi-degree of freedom linear systems, mass matrix, flexibility and stiffness matrix, natural frequencies and mode shapes, orthogonality of the mode shapes, modal matrix and decoupling procedure, harmonic force, and series solution for arbitrary excitation. Linear continuous systems, free vibration of strings, rods and shafts, lateral vibration of Euler-Bernoulli beams, effect of rotary inertia and shear on the vibration of beams, orthogonality of the mode shapes, harmonic excitation of beams, mode summation method in the case of arbitrary excitation. Approximate methods for free vibration analysis: Rayleigh, Dunkerly, Rayleigh-Ritz, Holzer, Myklestud, and matrix iteration methods. Vibration of plates, free vibration analysis using analytical methods, Rayleigh and Rayleigh-Ritz methods, harmonic excitation, and Galerkin's method in forced vibration analysis of plates. 3 cr.

ENGR 5260G Advanced Robotics and Automation. This course builds upon the knowledge students have gained in a first robotics course to cover more advanced kinematics topics and their application to more complex robotic systems such as redundant manipulators and parallel mechanisms. Topics covered include: point, direction, line, and screw motion descriptions; homogeneous transformations; line and screw coordinates; quaternion representations; inverse displacement solutions by analytic, root finding, hybrid, and numerical methods; appropriate frames of reference; screw systems and transforms; local and globally optimum solutions of redundant rates; over determined and near degenerate solutions; singularity analysis; and parallel manipulator kinematics. 3 cr.

ENGR 5261G Advanced Mechatronics: MEMS and Nanotechnology. This course is designed to be an introduction to MEMS (micro-electromechanical systems) and nanotechnology and their applications. Topics covered include: introduction to MEMS and nanotechnology; working principles of MEMS and nanotechnology; design and fabrication of MEMS and nano-systems; microfabrication and micromachining; materials for MEMS and nanotechnology; and applications of MEMS and nanotechnology. 3 cr.

ENGR 5262G Manipulator and Mechanism Design. This course is designed to teach students the necessary skills to design or synthesize mechanisms and manipulators to perform desired tasks. Topics covered include: synthesis of mechanisms for function generation, path generation, and rigid body guidance; graphical, analytical, and optimization based methods of synthesis; mechanism cognates, Chebychev spacing, Burmister curves; manipulator joint layout synthesis for spatial positioning and orientation; conditions of singularity and uncertainty; and solution of nonlinear problems of kinetics involved in mechanism synthesis using compatibility equations, 1/2 angle substitutions, and dialytic elimination. 3 cr.

ENGR 5263G Advanced Control. This course builds upon the knowledge students have gained in a first control course to cover more materials in advanced control systems. Topics covered include: a. State variables and state space models: Relations between state space models and the transfer-function models (controllable and observable canonical forms, and diagonal form), Jordan form, solutions of linear state equations, transition matrix. b. Controllability and observability: Definition and criteria, state feedback and output feedback, pole assignment via state feedback, design of servo-controlled systems. c. State estimation and observer: Observer state-variable feedback control. d. Multi-input multi-output (MIMO) systems: Pole assignment via state feedback. e. Introduction to nonlinear systems: Describing functions for kinds of nonlinear systems (on/off, dry friction, dead zone, saturation, and hystersis), phase plane trajectories, concept of limit cycle. f. Stability analysis: Lyapunov function, and Lyapunov stability criterion. g. Introduction to optimal control: Linear quadratic regulator (LQR), Riccati equation, properties of LQR systems. h. Sampled data systems: Pulse transfer function, zero and first order hold systems, stability and root locus in the z-plane, transformations, Routh Hurwitz stability criterion in the zplane, system compensation in the z-plane using root locus, and generalized PID controllers. 3 cr.

ENGR 5300G Automotive Engineering. Components of the automobile. Engineering factors in all components and sub-system areas of automobile design. Vehicle characteristics and dynamic interactions. Systems modelling approach and mathematical models for ride, vibration, handling control and powertrains of automobiles. Tire mechanics, including construction, rolling resistances, traction/braking properties, cornering and aligning properties and measurement methods. Vehicle mobility, motion performance of the vehicle, characterization of resistances, propulsion system and tractive efforts. Brake system design, braking performance, brake distribution. Steady state handling. Measurement methods. Suspension system design considerations. Design and performance of an automobile from a systems point of view. External factors such as markets, financing, and sales. 3 cr.

ENGR 5310G Automotive System Dynamics. Introduction to transport systems related to vehicle dynamics behaviour. Pneumatic tire mechanics – ride, cornering and aligning properties. Transient and steady-state directional dynamics and handling analyses of road vehicles. Directional response and stability analysis in small and large perturbation maneuvers; roll dynamics and rollover; braking performance analyses; directional responses to simultaneous steering and braking inputs; performance measures. Characterization of road roughness; ride vibration analyses; assessment of ride comfort. Measurement methods and data analyses techniques. Vehicle-driver interactions – analysis of the closed loop vehicle-driver system. Introduction to typical control strategies for vehicle dynamic control. 3 cr.

ENGR 5320G Automotive Aerodynamics. Formulation of fluid mechanics and aerodynamics for automotive design. Inviscid and viscous flow. Wind tunnels and their applications to external aerodynamics. Aerodynamic drag coefficient and its effect on vehicle performance. Experimental methods, drag force measurements and wind tunnel instrumentation. Computational aerodynamics. Comparisons between experimental results and numerical results. Aerodynamic design for drag reduction. Aerodynamics of engine cooling. Fluid structure interactions. Aerodynamic noise. 3 cr.

ENGR 5330G Automotive Powertrains. Design of automotive power transmission systems. Loads on the vehicle. Evaluation of various engine and vehicle drive ratios on acceleration performance and fuel economy. Manual transmission and automatic transmission. Combustion in CI and SI engines. Selection of combustion chamber type and shape, intake and exhaust systems. Differences between engine types. Cylinder number, configuration, size and material selection. Selection of mixture preparation, firing order. Mechanism of combustion. Fuel and additive characteristics. Fuel metering and ignition systems. Exhaust emissions and control systems. Heat transfer, friction and lubrication systems. Air pollution. Exhaust systems. Effects of emission on air quality. Sources of auto emission. 3 cr.

ENGR 5340G Automotive Noise, Vibrations and Harshness. Evaluating the vibration and acoustic characteristics of automotive systems and components. Human comfort and annoyance guidelines and standards. Sound, hearing and physiological effects of noise and vibration. Modelling and experiment methods. Modal analysis and digital signal processing. Noise sources such as gears, bearings, rotating imbalance, gas flow, combustion, impact. Source-path-receiver identification. Sound transmission, air-borne and structure-borne noise. Structural-acoustic interactions. Noise and vibration passive/active control. 3 cr.

ENGR 5350G Automotive Materials and Manufacturing. Materials in the automotive industry. Selection of materials and shapes. Materials processing and design. Interaction of materials. Performance of materials in service. Examples of new materials. Role of environmental regulations and societal pressures on the selection of alternate materials. Manufacturing processes, including casting, forging, forming, machining and molding for the automotive industry. Quality control and techniques, process selection and methods. Manufacturing considerations for various lightweight automotive structural materials. Stiffness, fatigue, vibrations, dent resistance and crush resistance. Methods of producing lightweight automotive structures are discussed. Design for manufacturing, assembly, disassembly and recycling. 3 cr.

ENGR 5360G Automotive Electronics and Software. Electrical systems in automobiles, including power supplies, junction transistors, sensors and rectifiers. Signal amplifiers, gain bandwidth limitations and circuit models. Motor drive control, inverters, actuators, PWM controllers, active filters, signal conditioners, power electronics and regulators. Battery chargers and solar cells. Vehicle software systems. Onboard software systems and corresponding algorithms. Software interfaces between electronics and drivers and passengers. Embedded software in vehicles. 3 cr.

ENGR 5370G Automotive Design Engineering. Methodology of vehicle system design, including the overall objectives and constraints relevant to vehicles. Total design of an automobile, from an initial concept, to creation, use and disposal. Design issues for various lightweight automotive structural materials (plastics, mouldings, composites), including stiffness, fatigue, vibrations, dent and crush resistance. Crashworthiness and design for safety. Design for manufacturing, automation, assembly, disassembly and recycling. Automotive applications of computer-aided design (CAD). Applications of automotive engineering design tools, such as FEA, CFD, particularly including PACE software like ADAMS, Fluent, Autostudio, Unigraphics, Nastran and LS-DYNA. Students will use PACE tools in an automotive design project, using the software for structural, aerodynamic, materials, thermal and/or other design aspects of automotive systems. 3 cr.

ENGR 5610G Stochastic Processes. Review of probability theory including, random variables, probability distribution and density functions, characteristic functions, convergence of random sequences, and laws of large numbers. Random processes, stationarity and ergodicity, correlation and power spectral density, cross-spectral densities, response of linear systems to stochastic input, innovation and factorization, Fourier and K-L expansion, mean square estimation, Markov chains and processes, queuing theory. Applications in communications and signal processing, emphasis on problem-solving using probabilistic approaches. 3 cr.

ENGR 5620G Digital Communications. Optimum receiver principles: AWGN, geometric representation of signals, maximum likelihood criterion and optimum decision regions, correlation receivers and matched filters, probability of error and union bound; digital bandpass modulation (ASK, FSK, PSK, QAM, CPFSK, CPM), baseband systems (PAM, PRS), performance comparisons: bit error rate, bandwidth, power, complexity; fundamental limits in information theory: entropy and the source coding theorem; channel capacity and the channel coding theorem; information capacity theorem and design trade-offs. 3 cr.

ENGR 5630G Statistical Signal Processing. Detection Theory: fundamentals of detection theory, Neyman-Pearson theorem, receiver operating characteristics, minimum probability of error, Bayes risk, binary multiple hypothesis testing, minimum Bayes risk detector, Maximum Likelihood detector, Chernoff bound, detection of deterministic and random signals. Estimation Theory: mathematics of estimation theory, minimum variance unbiased estimation, Cramer-Rao lower bund, linear models, general minimum variance unbiased estimation, best linear unbiased estimators, Maximum Likelihood estimation. 3 cr.

ENGR 5640G Advanced Wireless Communications. Wireless communications systems, technologies, and standards; propagation environments (indoor/outdoor, fixed/mobile, cordless/wireless, voice/data/video/multimedia, radio/infrared/optical, terrestrial/satellite); spread spectrum techniques; multiple access schemes (TDMA, OFDM, MC-CDMA), duplexing methods and diversity techniques; mobile cellular systems: frequency reuse, cell splitting, cellular traffic, call processing, hand-off, roaming, location determination; radio link analysis; multipath fading and fading models; wireless security and protocols, ad hoc mobile and sensor networks; link design aspects for emerging techniques (UWB, RFID). 3 cr.

ENGR 5650G Adaptive Systems and Applications. This course covers algorithms, filter structures, and applications in adaptive systems. Basic information-processing operations and recursive algorithms are discussed. Also, distinct methods for deriving recursive algorithms for the operation of adaptive filters are identified. Lastly, applications of adaptive filters, mainly to digital communication systems, are explored in detail. 3 cr.

ENGR 5660G Communication Networks. Transmission media: guided (twistedpair/ coaxial/fibre) and non-guided (infrared/radio/optical); network types and topologies; multiplexing (FDM, TDM, WDM), circuit switching and telephone network; the Internet and communications layers; broadband systems (T1, xDSL, cable modems); error detection schemes (parity, CRC, checksum); Automatic Repeat Request mechanisms; random access techniques (ALOHA, CSMA); controlled access techniques (reservation, polling); wired/wireless LANs; congestion control and quality of service; delay and loss performance in basic queuing models. 3 cr.

ENGR 5670G Cryptography and Secure Communications. This course covers diverse topics on cryptography and security including classical encryption, symmetric and public-key cryptography, key management, message authentication, digital signatures, denial-of-service (DoS), distributed DoS, malicious software, and intrusion detection systems. 3 cr.

ENGR 5710G Network Computing. This course will introduce the students to topics in Internet Programming, Distributed Software Components, Network Computing Paradigms, and Service Oriented Architectures. 3 cr.

ENGR 5720G Pervasive and Mobile Computing. An introduction and comprehensive view into technologies relevant to pervasive and mobile computing. An overview of cellular and personal wireless area networks, service discovery protocols, context-aware computing, and middleware platforms and software to support pervasive and mobile computing. 3 cr.

ENGR 5730G Algorithms and Data Structures. This course studies the mathematical foundations of algorithms and data structures, covering sorting and searching algorithms, stacks, queues, lists, trees, hash tables, search trees, binomial heaps, minimum spanning trees, shortest paths, the theory of NP-completeness, and approximation algorithms. 3 cr.

ENGR 5740G User Interface Design. This course is an introduction to user interface design and implementation on a wide range of hardware platforms. It covers the basic techniques used in user interface design, how users behave, implementation tools and techniques and the evaluation of user interface designs. It covers both desktop and mobile environments, including the design of user interfaces for cell phones, PDAs and mobile games. 3 cr.

ENGR 5750G Software Quality Management. An intensive investigation into software quality engineering issues, including testing techniques, defect detection and prevention, reliability engineering, examination of maintenance issues and configuration management. Software evolution issues, including planning for evolution, round out the course. Students will do a major team project examining issues in defect reduction. The course will have a strong industrial flavour. 3 cr.

ENGR 5760G Software Metrics. Analysis of software metrics. Introduction to the techniques of measurement. Syntax and semantics of software metrics. Planning a metrics program. Using metrics for prediction (quality, project time estimations). Case studies. 3 cr.

ENGR 5770G Service Computing. This course introduces the fundamental concepts and applications of service computing. Service computing, as a new cross discipline, addresses how to enable IT technology to help people perform business processes more efficiently and effectively. One of the fundamental components in service computing is web service. Web services are Internet-based application components published using standard interface description languages and universally available via uniform communication protocols. Web services let individuals and organizations do business over the Internet using standardized protocols to facilitate application-to-application interaction. 3 cr.

ENGR 5780G Advanced Computer Architecture. This course covers evolution of computer architecture and factors influencing the design of hardware and software elements of computer systems. Topics include processor micro-architecture and pipelining, performance measures, instruction set design, cache and virtual memory organizations; protection and sharing; I/O architectures, hazards and exceptions, dependencies, branch prediction, instruction-level parallelism, memory hierarchies, cache organization, buses, rotating storage and I/O subsystem design. 3 cr.

ENGR 5850G Analog Integrated Circuit Design. This course covers modelling of IC devices, current sources and mirrors, gain stages, level shifters, analysis and design of BJT and MOS operational amplifiers, current feedback amplifiers, wideband amplifiers and comparators. Frequency response of amplifiers, feedback techniques, analysis and design, stability and compensation of amplifiers, high slew-rate topologies, noise in IC circuits, fully differential circuits, analog multipliers and modulators, CAD tools for circuit design and testing. 3 cr.

ENGR 5860G Digital Integrated Circuit Design. This course covers the analysis and design of digital integrated circuits. Students are instructed in methods and the use of computer-aided design tools for the design and testing of large-scale integrated digital circuits. 3 cr.

ENGR 5910G Embedded Real-Time Control Systems. This course focuses on the design and implementation techniques for embedded real-time control systems. It covers embedded system design, instruction sets for microprocessor architecture, I/O, interrupts, hardware and software of embedded systems, program design and analysis, practical issues, multi-tasking operating systems, scheduling and system design techniques. 3 cr.

ENGR 5920G Analysis and Control of Nonlinear Systems. Introduction to nonlinear systems, phase plane analysis, stability determination by Lyapunov direct method, advanced stability theory, existence of Lyapunov functions, describing function analysis, nonlinear control system design by feedback linearization, sliding control, variable structure control, adaptive control of linear and nonlinear systems, control of multi-output systems, control of multi-input multi-output systems. 3 cr.

ENGR 5930G Adaptive Control. This is a course on the general principles of adaptive control and learning. This course will cover real-time parameter estimation, deterministic self-turning regulators, stochastic and predictive self-tuning regulators, model reference adaptive systems, gain-scheduling, properties of adaptive systems, robust adaptive control schemes, adaptive control of nonlinear systems, practical issues and implementation. 3 cr.

ENGR 5940G Intelligent Control Systems. With the advance of increasingly faster computing hardware and cheaper memory chips, computational intelligence, also known as a part of "soft computation", is becoming more and more important in control engineering. This course will equip the student with the essential knowledge and useful resources to solve some of the systems control problems not easily solved using conventional control methods. This course will cover: fundamentals of fuzzy set theory, structures of fuzzy logic controllers, structures of neural networks, learning algorithms, genetic algorithms. 3 cr.

ENGR 5950G Computational Electromagnetics. This course covers the theory, development, implementation, and application of the finite element method and its hybrid versions to electromagnetics. It also makes efficient and accurate formulations for electromagnetics applications and their numerical treatment. It employs a unified coherent approach dealing with both integral and differential equations using the method of moments and finite-element procedures. 3 cr.

ENGR 5960G Power System Operations, Analysis and Planning. Transmission lines. Steady state transmission capacity; network compensation; voltage management; load flow simulation; transient stability simulation; system security; system planning; symmetric operation of power systems. 3 cr.

ENGR 5970G Power Electronics. This course covers fundamentals of lossless switching techniques: zero-voltage switching, zero-current switching; resonant converters: series, parallel and series-parallel topologies; softswitching converters: natural and auxiliary commutation converter topologies control techniques: variable frequency phase-shift and hybrid control; applications to singlephase three-phase and multi-level converters; line- and force-commutated converters; high power ac/dc and dc/ac converter structures and switching techniques; principles of HVDC and HVAC systems. 3 cr.

ENGR 5980G Advances in Nuclear Power Plant Systems. A combination of lectures, self-paced interactive CD-ROM study and the use of power plant simulators imparts to students the advances in the key design and operating features of the main nuclear power plan types, including reactors using pressure vessels and pressure tubes, pressurized water, boiling water and gas cooled reactors; the use of natural versus enriched fuel, converters and breeders; overall plant control systems, load following capabilities, islanding operations; safety systems, responses to abnormal and emergency events. Self-paced interactive CD-ROM and operation of power plant simulators will be used throughout the course. 3 cr.

ENGR 6001G Dissertation. The dissertation is the primary component of the PhD degree requirement. The research must lead to an original contribution to knowledge in the field and must be reported fully in the candidate's dissertation. The research is carried out under the direction of the candidate's supervisor or co-supervisors, in co-operation with a supervisory committee. The student will receive a grade of either pass or fail. 40 cr.

ENGR 6002G Workshops. The course consists of a series of mandatory workshops to aid in the professional development of PhD candidates. Workshop topics include: project management; intellectual property; grantsmanship; communications, and career management. The student will receive a grade of either pass or fail.

ENGR 6003G Seminar. Students will participate in seminars by internal and external speakers on current research topics. All PhD students are required to give two seminars on their thesis research, typically within the second and final years of their program. The student will receive a grade of either pass or fail.

MCSC 6000G Graduate Seminar in Modelling and Computational Science. This course is a year-long seminar series on Modelling and Computational Science which will take place weekly for the entire academic year. Every graduate student enrolled in this course must give a presentation on a research topic. In addition to the student presentations, the seminar will feature speakers from UOIT and invited speakers from academia, industry and government. Successful completion of the course will also require attendance at the UOIT Faculty of Science Colloquium Series. The student will receive a grade of either pass or fail. 0 cr, 1 lec. Prerequisite: Successful completion of all core courses in the program.

MCSC 6001G MSc Thesis. The thesis is the major component of the MSc program and is carried out under the direction of the student's supervisor. The thesis involves an investigation of a research topic with the possibility of leading to a peer reviewed article. Through the thesis, candidates are expected to give evidence of competence in research and a sound understanding of the area of specialization involved. Students must prepare and successfully defend a written thesis at the end of the program related to the research they have undertaken. The student's advisory committee must approve the commencement of the writing of the thesis. The thesis will be evaluated by an examination committee and accompanied by an oral presentation. The student must receive a satisfactory report on the written thesis and must demonstrate a thorough understanding of the research topic. The student will receive a grade of either pass or fail. 12 cr. Prerequisite: Enrolment in the Modelling and Computational Science graduate program.

MCSC 6002G MSc Research Project. The MSc Research Project provides students with the opportunity, under the supervision of a faculty member, to integrate and synthesize knowledge gained throughout their program of study. The chosen topic will be dependent on the area of specialization of the supervisor. Students must prepare a written research report related to their supervised project at the end of the program. The student's advisory committee must approve the commencement of the writing of the report. The research report will be evaluated by an examination committee. The student will be required to give a 30-minute presentation of the research report. The student must receive a satisfactory report on the written research report and must demonstrate a thorough understanding of the research topic. The student will receive a grade of either pass or fail. 6 cr. Prerequisite: Enrolment in the Modelling and Computational Science graduate program.

MCSC 6010G Mathematical Modelling. This is a core course and forms an essential part of the MSc program. The student will get familiar with the fundamental principles and techniques in mathematical modelling, showcased through the use of classical and advanced models in physics, biology and chemistry. Several analytical techniques will be introduced through the study of the mathematical models presented. Topics may include: Population models and epidemiology, neuron and cell dynamics, nonlinear waves in biological, chemical and physical systems, fluid dynamics, pattern formation (in fluid experiments, animal coat patterns, chemical reactions, visual cortex), coupled systems (neurons, traffic flow, lattice systems). 3 cr, 3 lec. Prerequisite: Admission to the MSc program in Modelling and Computational Science.

MCSC 6020G Numerical Analysis. Numerical analysis is the study of computer algorithms developed to solve the problems of continuous mathematics. Students taking this course gain a foundation in approximation theory, functional analysis, and numerical linear algebra from which the practical algorithms of scientific computing are derived. A major goal of this course is to develop skills in analyzing numerical algorithms in terms of their accuracy, stability, and computational complexity. Topics include best approximations, least squares problems (continuous, discrete, and weighted), eigenvalue problems, and iterative methods for systems of linear and nonlinear equations. Demonstrations and programming assignments are used to encourage the use of available software tools for the solution of modelling problems that arise in physical, biological, economic, or engineering applications. 3 cr, 3 lec. Prerequisite: Admission to the MSc program in Modelling and Computational Science.

MCSC 6030G High-Performance Computing. The goal of this course is to introduce students to the tools and methods of high-performance computing (HPC) using state-of-the-art technologies. The course includes an overview of high-performance scientific computing architectures (interconnection networks, processor arrays, multiprocessors, shared and distributed memory, etc.) and examples of applications that require HPC. The emphasis is on giving students practical skills needed to exploit distributed and parallel computing hardware for maximizing efficiency and performance. Building on MCSC 6020G, students will implement numerical algorithms that can be scaled up for large systems of linear or nonlinear equations. Topics may include: survey of computer architectures; efficiency guidelines for HPC; parallel algorithm design; programming tools; timing, profiling, and benchmarking; optimizations. 3 cr, 3 lec. Prerequisite: MCSC 6020G.

MCSC 6060G Advanced Statistical Mechanics (cross-listed with PHY4010U). Macro and microstates, statistical weight, Boltzmann and Gibbs distributions, partition and grand partition functions; microcanonical, canonical and grand canonical ensembles; statistical mechanics of isolated and interacting systems. Bose-Einstein and Fermi-Dirac statistics. Quantum statistics of ideal gases; blackbody radiation; paramagnetism in solids. 3 cr, 3 lec. Prerequisite: Statistical Mechanics.

MCSC 6070G Advanced Quantum Mechanics (cross-listed with PHY4020U). Expands upon the concepts covered in introductory Quantum Mechanics, with particular emphasis on applications to real systems. This course examines approximation methods, including time-independent and dependent perturbation theory, variational methods, the WKB approximation and scattering theory. Mathematical computer programs will be used to solve problems. 3 cr, 3 lec. Prerequisite: Quantum Mechanics.

MCSC 6120G Numerical Methods for Ordinary Differential Equations. Differential equations are an indispensable tool for the modelling of physical phenomena. However, most often in practice, analytical solutions to model equations cannot be found, and numerical approximations must be made. In this course, practical computational techniques for the numerical solution of ordinary differential equations will be covered, with an emphasis on their implementation and the fundamental concepts in their analysis. Topics include: Numerical methods for initial value problems: forward and backward Euler and trapezoidal scheme; implicit and explicit Runge-Kutta methods, including general formulation; Linear multistep methods: Adams-Bashforth, Adams-Moulton, Backward Differentiation Formulae (BDF); Numerical methods for boundary value problems: simple and multiple shooting and difference schemes. In association with the techniques, topics such as convergence, accuracy, consistency, 0-stability, absolute stability, Astability, stiffness, and error estimation and control will be discussed. 3 cr, 3 lec. Prerequisite: MCSC 6020G or equivalent.

MCSC 6125G Numerical Methods for Partial Differential Equations. Partial differential equations (PDEs) constitute a vital modelling tool on science and a rich field of mathematical research. This course is an introduction to the mathematical concepts required to develop accurate, reliable, and efficient numerical software for the approximate solution of PDEs. Essential model problems of elliptic, parabolic, and hyperbolic type are examined with corresponding numerical approximation techniques. Approximation schemes are compared and contrasted with an emphasis on the convenience of available software as well as error estimation, consistency, stability, and convergence. Topics may include: finite-difference, finite-element, finite-volume, and spectral collocation methods; Von Neumann analysis; time-stepping algorithms and the method of lines; dissipation and dispersion; error estimates; iterative methods. 3 cr, 3 lec. Prerequisite: MCSC 6020G.

MCSC 6140G Dynamical Systems and Bifurcations. This course provides an introduction to the modern theory of dynamical systems and bifurcation theory, including chaos theory. Dynamical systems theory is an important tool in the modelling of many physical systems, but it is also a rich field of mathematical research in itself. By the end of this course, the student will have acquired a large toolkit of techniques to analyze the dynamical features of ordinary differential equations and discrete dynamical systems. Topics include: Structural stability, invariant manifolds, local and global bifurcations, reduction methods, routes to chaos, applications. 3 cr, 3 lec. Prerequisite: Undergraduate modern theory of ordinary differential equations.

MCSC 6150G Fluid Dynamics. This course will give a unified view of fluid dynamics by emphasizing mathematical structures that reappear in different guises in almost all subfields of fluids. The student will become familiar with the fundamental principles, techniques and basic equations in fluid dynamics and will come to appreciate the basic nonlinear nature of most fluid flows. Topics include: Reynolds number and other non-dimensional parameters, stability and scaling, turbulence and the transition from laminar flow to turbulence, Newtonian and non-Newtonian flows, eigenmodes of a flow problem, including nonlinear exchange of energy between modes, lattice gas and Boltzmann models. 3 cr, 3 lec. Prerequisite: Admission to the MSc program in Modelling and Computational Science.

MCSC 6160G Transport Theory. The course is a general introduction to transport theory. Continuous-medium transport and discrete particle transport are presented in a unified manner through the use of the probability distribution function. Various types of transport problems are presented together with analytic solutions for the simpler problems that allow them. Approximate and numerical methods are also covered. Topics include: Particle distribution functions, generic form of transport equation, particle streaming, one-speed transport theory, linear collision operators, the Boltzmann collision term, diffusion theory, hydrodynamic equations, eigenvalue problems, boundary value problems, perturbation and variational approximation methods, deterministic numerical methods, Monte Carlo simulations. 3 cr, 3 lec. Prerequisites: Linear algebra, differential equations, vector calculus.

MCSC 6165G Monte Carlo Methods. This course provides an introduction to the simulation of stochastic processes using Monte Carlo methods. Concepts presented will include pseudo-random number and random variate generation, Markov chain models, Monte Carlo integration, variance reduction, and numerical optimization. Applications may include: solution to the Boltzmann transport equation (specifically for radiation transport) statistical physics, biophysics, and queuing theory. 3 cr, 3 lec. Prerequisites: Undergraduate-level theory of ordinary and partial differential equations, and introductory statistics.

MCSC 6170G Computational Chemistry. Accessible introduction to the fundamental principles underlying different methods from classical to quantum theories, and from first principles through to the latest advances in the area. The main focus is on molecular structures and energetics. Molecular properties and aspects of spectroscopy and dynamics are also covered. Topics include: forcefield and electronic-structure methods, electron correlation, basis sets, density functional theory, relativistic methods, hybrid quantal/classical models, excited electronic states, wave function analysis, molecular properties, transition state theory and reaction dynamics, optimization techniques. 3 cr, 3 lec. Prerequisites: Introductory quantum mechanics and undergraduate mathematics. MCSC 6010G, MCSC 6020G.

MCSC 6180G Computational Physics. The course introduces the fundamental principles which form the basis for carrying out modern HPC simulations in physics, chemistry and materials science, their realization in the form of various numerical algorithms, and applications to different problems and real-world systems. The main focus is the study of advanced methods of studying quantummechanical and statistical mechanical systems. Approaches considered will include: density functional theory (DFT) and its formulation in terms of pseudopotential and allelectron methods (DFT will be extended to treat excited states and in particular, the optical properties of materials); molecular dynamics simulation, which will be used to describe ground-state properties such as atomic structure, vibrations and phase transitions, and the structural properties of fluids and fluid mixtures; and Monte Carlo simulation, which will be used to provide molecularlevel descriptions of various materials, fluids and fluid mixtures. 3 cr, 3 lec. Prerequisites: Undergraduate-level quantum mechanics and statistical mechanics.

MCSC 6210G – Advanced Topics in Mathematical Modelling. This course builds on the core course Mathematical Modelling and elaborates on some of its topics in greater detail. In addition, it introduces a variety of special topics in applied mathematics with a focus on industrial and natural processes and phenomena. The topics will be chosen according to the needs and demands of the students and the available faculty resources. Topics and application may include: Auto-correlation of data sets, bifurcations in time-series, embedding time series, modelling stochastic systems, perturbation methods for partial differential equations, traveling wave phase plane, advanced reaction-diffusion phenomena and transition layers, Hausdorff measures, fractal dimension, Belousov-Zhabotinsky reaction, analysis of heartbeat time-series, fractals in science and medicine, chaotic dynamics in symmetric coupled cell systems, time series in the stock market and other financial products. 3 cr, 3 lec. Prerequisite: MCSC 6010G.

MCSC 6220G Advanced Topics in Numerical Analysis. This course explores recent problems in numerical analysis that are at the forefront of current research. The main objective of the course is to familiarize students with contemporary theoretical results and practical algorithms as preparation for doctoral research. The topics will be chosen according to the needs and demands of the students. Potential topics include: level-set methods, finite element methods, finite volume methods, spectral methods, numerical optimization, multigrid methods, numerical linear algebra, Krylov subspace methods, preconditioning iterative methods. 3 cr, 3 lec. Prerequisite: MCSC 6020G.

MCSC 6230G Advanced Topics in High-Performance Computing. This course explores recent topics in high-performance computing that are at the forefront of current research. The main objective of the course is to familiarize students with contemporary implementations and practical algorithms as preparation for doctoral research. The topics will be chosen according to the needs and demands of the students. Potential topics include: distributed computing, cluster computing, grid computing, numerical linear algebra for high-performance computers, domain decomposition methods, parallel preconditioners. 3 cr, 3 lec. Prerequisite: MCSC 6030G.

MCSC 6240G Advanced Topics in Dynamical Systems. This course builds on the topics covered in MCSC 6140G. The course covers advanced material, including recently developed tools, for the analysis of dynamical systems. By the end of the course, the student will be able to perform a bifurcation analysis of models that they will encounter in research or industry, including judging when such analysis is appropriate, choosing the right tools and interpreting the results. The topics will be chosen according to the needs and demands of the students. Potential topics include: equivariant bifurcation theory and applications, bifurcations in delay and partial differential equations, numerical continuation of bifurcations for ordinary, delay and partial differential equations, bursting in biological phenomena and other systems. 3 cr, 3 lec. Prerequisites: MCSC 6140G, MCSC 6020G, MCSC 6280G.

MCSC 6280G Advanced Topics in Computational Science. This course explores recent problems in computational science that are at the forefront of today's research. The main objective of the program is to bring students up to date with the current state of the art of computational science and make them ready for PhD research. The topics will be chosen according to the needs and demands of the students and the availability of faculty. Potential topics include: computational cluster science, quantum computing: concepts, advantages and problems, quantum Monte Carlo: applications in computational physics, advanced molecular simulations, advanced optimization, advanced Monte Carlo simulations. 3 cr, 3 lec. Prerequisites: MCSC 6010G, MCSC 6020G. Co-requisites: As required by the subject matter; e.g., MCSC 6170G Computational Chemistry, MCSC 6180G Computational Physics, MCSC 6165G Monte Carlo Methods.

MITS 5100G Law and Ethics of IT Security. This course covers the many ways in which commercial law applies to information technology security. As more and more business transactions and communications are now conducted electronically, the IT function within an institution has become the custodian of the official business records. This course introduces the laws governing the daily business of an institution or government agency, as those laws apply to the protection of information and computer systems. Emerging issues, such as privacy and information disclosures, will be discussed in the course. 3 cr, 3 lec.

MITS 5200G Advanced Communications Networks. Networks are the essential components to information transmission, without which there are no communications. This course presents an overview of telecommunications networks and the fundamental concepts of the field, as well as advanced topics and detailed network architectures. This course blends an accessible technical presentation of important networking concepts with many business applications. Addressing networks from a top-down approach, this course shows students the big picture of networks in general so that they may see how the various parts of the network fit in to the picture. The course gives detailed descriptions of the principles associated with each layer and highlights many examples drawn from the Internet and wireless networks. The TCP/IP protocol stack will be discussed in detail with a variety of examples on its various layers. This course also describes all aspects of various wireless systems, from cordless phones, pagers, PDAs to mobile phones and wireless computers. The wide deployment of cellular phones for M-commerce applications and wireless LANs in corporate environments have resulted in interesting security challenges. 3 cr, 3 lec, 3 lab (biweekly).

MITS 5300G Operating Systems Security. Theoretical Foundations of IT Security and their implications to the design and operation of Operating Systems. Operating Systems fundamentals will be covered to provide a basic for the remainder of the course. The laboratory part of this course puts a particular focus on the Windows and Unix/Linux operating systems. It provides an overview of the security risk and management of the specified operating systems, and the preventive efforts to use the security features built in within the systems and third-party applications. Understand and familiarize with various essentials reference sources available on the subjects on computer security, including organizations such as CERT. 3 cr, 3 lec, 3 lab (biweekly).

MITS 5400G Secure Software Systems. Computer security is a bigger problem today than ever before even though most organizations have firewalls, antivirus software, and intrusion detection in place to keep attackers out. The simple cause for the problem at the heart of all computer security problems is bad software. This course takes a proactive approach to computer security and covers areas from the technical side of coding secure software to more managerial and project management tasks. Common coding problems like buffer overflows, random number generation and password authentication are addressed. A secondary focus is set on the software design process; it needs to be set up so that security is built in at the very early stages and considered throughout the design process and not patched in a later point of time. Risk management in the development cycle as well as software and system audits will be discussed within the course. Prerequisite: Knowledge of computer programming. 3 cr, 3 lec, 3 lab.

MITS 5500G Cryptography and Secure Communications. Secrecy is certainly important to the security or integrity of information transmission. Indeed, the need for secure communications is more profound than ever, recognizing that the conduct of much of our commerce and business is being carried out today through the medium of computers and digital networks. This course is on cryptography, the umbrella term used to describe the science of secret communications. In this course, students with strong mathematical background learn the details about the transformation of a message into coded form by encryption and the recovery of the original message by decryption. This course describes cryptography through which secrecy, authentication, integrity, and non-repudiation can all be provided. 3 cr, 3 lec.

MITS 5610G Special Topics in IT Security – Cybercrime. This course covers the issue of cyber crime as it applies to the use of computers or other electronic devices via information systems to facilitate illegal behaviours. Globalization, corporate responsibility, legal and investigative requirements will be discussed. Emerging issues, such as privacy and information disclosures, will be discussed in the course. 3 cr, 3 lec.

MITS 5620G Special Topics in IT Management – Contemporary Management for IT Security Professionals. The business world has changed dramatically over the past five years, with increasing pressures on managers to not only integrate information technology into all aspects of an organization's business operations but also to improve efficiency and customer responsiveness and understand and manage diversity and other key human resource issues in the workplace. This course integrates contemporary management theories and approaches into the analysis of management and organizations by covering a wide range of topics, including the fall of the dot-coms and problems and challenges encountered by the dot-coms; moods and emotions; emotional intelligence; how managers create culture; ethical organizational cultures; different kinds of diversity; groups and teams; effective communication; how information technology is making the world smaller; designing global information technology systems; B2Bnetworks and information technology; knowledge management and

Information Technology; control systems and information technology; employee stock options and other motivational devices; and transformational leadership. 3 cr, 3 lec.

MITS 5700G Advanced Network Design. Advanced Network Design is a graduate course designed to give the students the skills they need to architect, build and analyze the next generation networks. The course material will cover the design process from the requirement analysis phase to architectural design, technology selection, implementation, and performance evaluation. The course will address the theoretical aspects of network design, such as fundamentals of queuing theory, delay analysis, flow optimization and topology design, as well as practical aspects of network architectural design for efficient addressing and routing, multi-protocol integration, security, VPNs, and network management solutions. The class will also include lab work with network simulation and modeling packages such as OPNET and optimization tools such as MATLAB and AMPL/CPLEX (subject to availability). 3 cr, 3 lec, 3 lab. Prerequisites: An undergraduate or graduate course in computer communication networks, e.g. MITS 5200G, or ENGR 5660G.

MITS 6100G Attack and Defence. The course covers the fundamental theories of vulnerabilities in network protocols, intrusion detections and defence against network attack. It also discusses the latest cutting-edge insidious attack vectors, and the patterns of denial-of-service attacks. This course also presents the understanding tools needed to defend against attackers maintaining access and covering their tracks. This course examines and reviews various types of hacking tools and ways to harden the system or application against the attack. The course also discusses defences and attacks for Windows, Unix, switches, routers and other systems. 3 cr, 3 lec, 3 lab. Prerequisites: MITS 5200G, MITS 5300G.

MITS 6200G eCommerce Infrastructure Security. This course introduces the main components of an eCommerce setup and covers the security related problems with these components. This course will visit some topics, that are addressed in context of Advanced Networking or Operating System Security. It will provide an e-Commerce context to these more technical issues. Major components that will be discussed are VPNs in business contexts, Mail Systems, WebServers, and in particular Middleware Suites like Microsoft's .NET framework and Sun's J2EE architecture and it's implementation in industrial strength products like JBOSS and IBM's WebSphere. Strategy and policy topics on how to find the right balance between security and usability will be addressed as well as the maintenance of a secure infrastructure. 3 cr, 3 lec, 3 lab. Prerequisites: MITS 5200G, MITS 5300G, MITS 5500G.

MITS 6300G IT Security Capstone Research Project I. This course provides students with an opportunity to gather knowledge and skills learned from the program coursework and to conduct a research project with industrial applications. Students are expected to do a research literature review and to develop a set of hypotheses for a research project in IT security. A research proposal outlining alternative remedies to the problem and hypotheses should be submitted to the research faculty advisor by the end of the course semester. 3 cr, 3 lec. Prerequisite: 18 credit hours in MITS courses.

MITS 6400G Biometrics/Access Control and Smart Card Technology. This course discusses the theoretical constructs around Access Control in detail and provides an overview of the fundamental background. Traditionally, most security systems authenticate you based on something you know, i.e., a password. However, where security really matters, it makes sense to add a second layer, which could be something you have (e.g., a smartcard). Also, as a third option, probably the most authentic method, it could be something you are, something that, at least theoretically, would be virtually impossible to forge. To this end, this course is about biometric controls, where biometrics is generally the study of measurable physical characteristics and behavioural patterns. This course deals with various authentication techniques their effectiveness, cost, intrusiveness, and accuracy. 3 cr, 3 lec, 3 lab. Prerequisites: MITS 5400G, MITS 5200G, MITS 5500G.

MITS 6500G Incident Handling, Recovery, Policies, and Risk Management. This course introduces a practical approach for responding to computer incidents, a detailed description of how attackers undermine computer systems in order to learn how to prepare, detect, and respond to them. The course will also explores the legal issues associated with responding to computer attacks, including employee monitoring, working with law enforcement, and handling evidence. This course will also focus in particular on practical, computer-assisted techniques for risk related modelling and calculations. Identification of threats through Hazard and Operability Analysis [HAZOP]) and PHA (Process Hazards Analysis) will be illustrated, as well as probabilistic techniques for estimating the magnitude and likelihood of particular loss outcomes. 3 cr, 3 lec, 3 lab. Prerequisites: MITS 5200G, MITS 5300G, MITS 6100G.

MITS 6600G IT Security Capstone Research Project II. The research outlined in the MITS 6300G proposal should be completed during the winter semester. The final report of the research findings and recommendations for the problem addressed should be submitted to the research faculty advisor, along with a presentation of the results. The results should have direct practical applications and/or be publishable in refereed publications. 3 cr, 3 lec, 3 lab. Prerequisite: MITS 6300G.

MTSC 6000G Graduate Seminar in Science Communication I (non-credit). The goal of this course is to assist students in developing the skills necessary to effectively communicate technical information to a diverse scientific audience. Seminars by second-year students will also expose students to the range of research carried out within the program. A series of oral and written exercises will each be followed by constructive review by both peers and faculty. Early in the course speaking exercises will include a 10 minute presentation to the class on a basic topic in the student's discipline and towards the end of the course a 25 minute presentation on a journal article. Writing exercises will include abstracts of seminars by second-year students and a brief discussion of a journal article. Evaluation will focus on clarity, precision and the care with which the audience is guided to the presenter's objective. The student will receive a grade of either pass or fail. 0 cr.

MTSC 6010G Physics and Chemistry of Materials. This one-semester course examines in depth the fundamental principles and concepts used by physicists and chemists to describe materials. It covers scientific and practical interrelations in physics, chemistry and biology of materials, emphasizing the structure, physical and chemical properties of all classes of materials. Prerequisite: In light of the interdisciplinary nature of the program, all students should have completed at least one full year of study in undergraduate physics, chemistry, and mathematics (to the level of differential and integral calculus). Some exposure to quantum mechanics is desirable. 3 cr.

MTSC 6020G Advanced Topics in Materials Science. In this one-semester course, specialized topics relevant to individual faculty in the program (but of potentially broad interest) are taught in a modular fashion. Topics may be selected from those involving the structure and properties of materials related to atomic, molecular, crystalline structures and their electron properties. The course also highlights the processing, properties, and uses of a broad class of materials for a variety of applications. 3 cr. Prerequisite: MTSC 6010G.

MTSC 6050G MSc Thesis. The graduate thesis is an original work and is the major component of the MSc program. The thesis research will be carried out under the direction of the student's supervisor; it involves an investigation of a research topic with the possibility of leading to a peer reviewed article. Through the thesis, candidates are expected to give evidence of competence in research and a sound understanding of the area of specialization. Students must prepare and successfully defend a written thesis at the end of the program related to the research they have undertaken. The thesis will be evaluated by an examination committee including an assessment by an external examiner and will include an oral presentation and defence. The student must receive a satisfactory report on the written thesis and its oral presentation and defence, and must demonstrate a thorough understanding of the research topic. The student will receive a grade of either pass or fail. Prerequisite: enrolment in the Materials Science graduate program. 18 cr.

MTSC 6100G Graduate Seminar in Science Communication II (non-credit) . The goal of this course is to further the students' development of strong scientific communication skills. Each student will make a 30 minute presentation of their research to all students in both the first and second years of the program and answer questions. Students will evaluate their peers' presentations and will receive both peer and faculty reviews of their own presentations. The student will receive a grade of either pass or fail. 0 cr.

MTSC 6110G Thermodynamics and Statistical Mechanics of Materials. This one-semester course provides a comprehensive introduction to thermodynamics and statistical mechanics of materials, such as semiconductors, amorphous and soft materials, liquids and their mixtures, polymers, and inhomogeneous materials. It covers phase transitions and phase equilibrium, order-disorder phenomena, point defects in crystals, and the statistical thermodynamics of interfaces. Non-equilibrium thermodynamics will be briefly introduced. The course provides the background knowledge for students to read the literature in the field and to use it in their research. 3 cr. Prerequisites: Undergraduate thermodynamics, statistical mechanics and satisfaction of admission requirements for MSc program.

MTSC 6120G Theory of the Solid State. This course develops the theoretical foundations of a variety of condensed matter systems at a higher level of mathematical sophistication than earlier in the curriculum. 3 cr.

MTSC 6130G Surface Science and Catalysis. This course is one-semester long. It covers the fundamental science required to understand the atomic and electronic structure of surfaces and their chemical reactivity and the most common tools for surface characterization. 3 cr. Corequisite: MTSC 6010G.

MTSC 6140G Experimental Techniques in Materials Characterization. This one-semester long course is a techniques-oriented course covering high resolution experimental solid-state characterization. The course will include theoretical background but will focus on practical aspects of techniques. Content will include bulk, surface and molecular characterization. Where practical, demonstrations and hands-on operation of specific instruments will be included. 3 cr. Prerequisite: Good standing in program.

MTSC 6240G Biomaterials. The course provides an introduction to naturally derived materials and their applications. The properties of materials of animal and plant origins and the potential uses of these materials will be discussed in the first part of the course. The second half of the course will explore the application of biotechnology to manipulate and create novel materials that are not normally found in nature. 3 cr. Prerequisite: Undergraduate chemistry or biology.

MTSC 6250G Polymer Science & Engineering. The course introduces the fundamental characteristics of polymers, visco-elasticity and non-Newtonian fluid mechanics. It describes the effects of temperature, crystallinity and diffusivity on polymer processing and properties. 3 cr. Prerequisites: MTSC 6010G and undergraduate mathematics.

MTSC 6260G Topics in Applied Materials Science I. This course will focus on topics that may vary depending on the interests of the students and the availability of faculty. Each course may focus on a different topic, allowing students to take both courses if they wish and this is approved by their Supervisory Committee. Some suggested topics are nanotechnology, optical applications, electrochemistry and mass transport in fuel cells. 3 cr.

MTSC 6270G Topics in Applied Materials Science II. This course will focus on topics that may vary depending on the interests of the students and the availability of faculty. Each course may focus on a different topic, allowing students to take both courses if they wish and this is approved by their Supervisory Committee. Some suggested topics are nanotechnology, optical applications, electrochemistry and mass transport in fuel cells. 3 cr.

NUCL 5001G MASc Thesis. The thesis is the major component of the MASc program and is carried out under the direction of the student's supervisor. The thesis may involve an investigation which is fundamental in nature or applied, and may incorporate elements of analysis, design and development. Through the thesis, candidates are expected to give evidence of competence in research and a sound understanding of the area of specialization involved. The student will receive a grade of either pass or fail. 15 cr.

NUCL 5003G Seminar. Students are required to participate in a program of seminars led by internal and external speakers on current research topics. All MASc students will be required to give a seminar on their thesis research during the second year of their program. The student will receive a grade of either pass or fail. 3 cr, 3 lec.

NUCL 5004G Directed Studies. Faculty permission may be given for supervised research and development projects, individual study, or directed readings. Students wishing to pursue a course of directed studies must, with a faculty member who is willing to supervise such a course, formulate a proposal that accurately describes the course content, the learning goals, the intended method and extent of supervision, and the method(s) by which the student's work will be evaluated. This course may only be taken once. 3 cr, 3 lec.

NUCL 5005G Special Topics. The course covers material in an emerging area or in a subject not covered in regular offerings. This course may be taken more than once, provided the subject matter is substantially different. 3 cr, 3 lec.

NUCL 5006G Industrial Research Project. Students enrolled part-time in a course-based MEng program may designate a period of approximately four months in an industrial laboratory to carry out an industry-oriented project under the supervision of a suitably qualified staff engineer or scientist and a university co-supervisor. The school will work with the candidate and consult the candidate's employer to arrange a suitable industrial project. A satisfactory project topic and appropriate arrangements are required for the project to be approved by the school and it is possible that in some cases this may not be feasible. Upon completion, the candidate will submit a substantial report on the project and make a presentation on it at the university. The industrial research project can only be undertaken after at least half the required courses have been taken. The student will receive a grade of either pass or fail. 6 cr.

NUCL 5009G Graduate Research Project. The MEng Project provides students with the opportunity, under the supervision of a faculty member, to integrate and synthesize knowledge gained throughout their program of study. The chosen topic will be dependent on the area of specialization of the student, using resources normally available on campus. The student will receive a grade of either pass or fail. 9 cr.

NUCL 5010G Project Management for Nuclear Engineers. This course in project management prepares nuclear engineers and scientists in the application of this discipline in their work. It is an intensive investigation into the major principles of project management slanted towards, but not exclusively about, the management of nuclear engineering projects. The course uses the Project Management Institute's PMBOK (Project Management Body of Knowledge) as a skeleton and expands that coverage with relevant examples from nuclear, software and general engineering. Special emphasis will be placed on risk management, particularly in the area of safety-critical projects. The graduates will be well-positioned both to apply the knowledge in their area of engineering and to sit the PMI's PMP examination. The course will be taught using many case studies from industry and engineering. 3 cr, 3 lec.

NUCL 5020G Mathematical Methods in Nuclear Applications. Numerical analysis is the study of computer algorithms developed to solve the problems of continuous mathematics. Students taking this course gain a foundation in approximation theory, functional analysis, and numerical linear algebra from which the practical algorithms of scientific computing are derived. A major goal of this course is to develop skills in analyzing numerical algorithms in terms of their accuracy, stability, and computational complexity. Topics include best approximations, least squares problems (continuous, discrete, and weighted), eigenvalue problems, and iterative methods for systems of linear and nonlinear equations. Demonstrations and programming assignments are used to encourage the use of available software tools for the solution of modelling problems that arise in physical, biological, economic, or engineering applications. 3 cr, 3 lec.

NUCL 5030G Transport Theory. This course is a general introduction to transport theory. Continuous-medium transport and discrete-particle transport are presented in a unified manner through the use of the probability distribution function. Various types of transport problems are presented together with analytic solutions. Approximate and numerical methods are also covered. This course is cross-listed with MCSC 6160G – Transport Theory. Prerequisite(s): Linear Algebra, Differential Equations, Vector Calculus. 3 cr, 3 lec.

NUCL 5040G Monte Carlo Methods. This course provides an introduction to simulation of stochastic processes using Monte Carlo methods. The emphasis of the course will be Monte Carlo solution to the Boltzmann transport equation, specifically for radiation transport. Other applications of Monte Carlo analysis will be introduced to include, but not be limited to, molecular dynamics, statistical physics, biophysics, and queuing theory. Concepts presented will include pseudo-random number and random variate generation, direct simulation of physical processes, Monte Carlo integration and variance reduction, detector response and estimators, and Monte Carlo optimization 3 cr, 3 lec. Prerequisites: Undergraduate theory of ordinary and partial differential equations and introductory statistics.

NUCL 5050G Applied Risk Analysis. This course presents principles and methods for assessing and managing technological risks. The following subjects will be covered: probability theory; failure rates; availability; reliability; test frequencies; dormant and active systems; initiating events; fault trees and event trees; dual failures; defense in depth; principle of control, cool, contain; accident prevention, mitigation and accommodation; separation and independence; redundancy; common mode events; safety culture; safety analysis techniques; inherent safety features; plant safety systems; probability evaluation for simple systems; quantitative and probabilistic safety assessment; calculation of frequency and consequences of power plant accidents; risk-based decision making; and risk-based regulation. Applications include aerospace, energy, and nuclear systems safety analysis. 3 cr, 3 lec.

NUCL 5060G Nuclear Concepts for Engineers and Scientists. The course is a fast introduction to atomic, nuclear and reactor physics for graduate students without an adequate background in these areas. Topics covered include nuclear structure, radioactivity, interaction of radiation with matter, neutron flux, neutron diffusion, nuclear reactors, reactor kinetics. Prerequisites: Differential Equations, Partial Differential Equations, Vector Calculus. 3 cr, 3 lec.

NUCL 5070G Environmental Modelling. The transport of pollutants through the total environment depends upon complex interactions between the atmosphere, geosphere and hydrosphere. Understanding the details of pollutant transport between source, environmental compartments and receptors allow for determination of potential dose, and thereby estimation of risk. This course explores the fundamental theory, equations and solutions to standard environmental transport models (with emphasis on radiolonuclide transport). In addition, this course introduces the student to the RESRAD codes for environmental modeling. Prerequisites: undergraduate courses in physics, chemistry, differential equations, and statistics. A working knowledge of MS EXCEL is required. 3 cr, 3 lec.

NUCL 5080G Advanced Topics in Environmental Degradation of Materials. Predicting the corrosion performance-lifetime of components is an ongoing area of interest in maintaining nuclear power plants. Unexpected or premature degradation of components often occurs by localized corrosion processes such as pitting, crevice, or stress-assisted corrosion. In this course, we will examine current theories of various localized corrosion mechanisms, current practices for measuring and identifying corrosion processes, models and methodologies for predicting the occurrence of localized corrosion and the application of this knowledge to specific aspects of the nuclear fuel cycle. 3 cr, 3 lec. Prerequisite: undergraduate course in corrosion.

NUCL 5090G Occupational Health and Safety. Predicting the corrosion performance-lifetime of components is an ongoing area of interest in maintaining nuclear power plants. Unexpected or premature degradation of components often occurs by localized corrosion processes such as pitting, crevice, or stress-assisted corrosion. In this course, we will examine current theories of various localized corrosion mechanisms, current practices for measuring and identifying corrosion processes, models and methodologies for predicting the occurrence of localized corrosion, and the application of this knowledge to specific aspects of the nuclear fuel cycle. 3 cr, 3 lec.

NUCL 5200G Reactor Physics. The course is a graduate-level treatment of reactor physics, with emphasis on reactor statics. Topics covered include: static neutron balance equations, neutron slowing down, resonance absorption, multi-group transport and diffusion equations, homogenization methods and variational methods. Lattice and full-core numerical methods are also covered. Prerequisites: undergraduate courses in linear algebra, differential equations, vector calculus. 3 cr, 3 lec.

NUCL 5210G Advanced Reactor Physics. The course is a graduate-level treatment of reactor physics, with emphasis on reactor dynamics. Topics covered include: point kinetics, space-time kinetics, perturbation and generalized perturbation theory, fuel depletion, fission-product poisoning, elements of reactor control. 3 cr, 3 lec. Prerequisite: NUCL 5200G Reactor Physics.

NUCL 5215G Advanced Reactor Engineering. The course is comprised of advanced topics in nuclear engineering, with emphasis on reactor physics. Topics covered include neutron slowing down, resonance absorption, multigroup transport and diffusion equations, reactor kinetics, and homogenization methods. Lattice and full-core numerical methods are also covered. This course is cross-listed with ENGR 5180G Advanced Nuclear Engineering. 3 cr, 3 lec. Prerequisites: Courses in linear algebra, differential equations, vector calculus.

NUCL 5220G Fuel Management in Nuclear Reactors. Nuclear fuel cycles are studied from mining to ultimate disposal of the spent fuel, including the enrichment processes and the reprocessing techniques, from a point of view of the decision-making processes and the evaluation of the operational and economical consequences of these decisions. For the steps within the fuel cycles, the method of determining the associated costs, in particular those relevant to the disposal of nuclear waste and the overall fuel cycle costs are described. Burn-up calculations are performed for the swelling time of the fuel within the reactor core. The objectives and merits of in-core and out-of-core fuel management for CANDU Pressurized Heavy Water Reactors (PHWR) and Light Water Reactors (LWR) are analyzed in detail, for the refueling equilibrium as well as for the approach to refueling equilibrium. The course also covers fuel management for thorium-fuelled CANDU reactors and other advanced fuels such as MOX containing plutonium from discarded nuclear warheads, and DUPIC (Direct Use of PWR fuel in CANDU reactors). The fuel management problem is treated as an optimization problem, with objective functions or performance indexes identified, as well as decision variables and appropriate constraints (active and non-active). The course also includes a review of the major work done in this area along with the most important computer codes. 3 cr, 3 lec. Prerequisite: knowledge of reactor physics at the undergraduate level is recommended.

NUCL 5230G Advanced Nuclear Thermalhydraulics. This course expands on the importance of thermalhdyraulics in Nuclear Power Plant Design, Operation and Safety. Thermalhydraulic problems and solutions relevant to Nuclear Power Plants and Nuclear Research Reactors will be discussed. The course will discuss in detail Mass, Momentum, and Energy Equations and discuss various numerical techniques for solving these equations especially for applications to two-phase flow. Boiling, condensation, cavitation and waterhammer problems will be discussed. Special topics of recent interest such as Impact of Ageing Phenomena and Application of Electrohydrodynamic and Magnetohydrodynamic forces will be presented. 3 cr, 3 lec. Prerequisites: undergraduate courses in fluid mechanics and heat transfer.

NUCL 5240G Heat Transfer in Nuclear Reactor Applications. This course will discuss advance heat transfer phenomena related to nuclear reactors in both current and future designs. Topics include: Heat transfer phenomena (conduction, convection, radiation); boiling and condensation phenomena; critical heat flux and boiling crisis; supercritical fluids; correlations for heat transfer at high pressure and high temperature; advanced numerical methods. Prerequisite: undergraduate course in heat transfer. 3 cr, 3 lec.

NUCL 5250G Power Plant Thermodynamics. This course presents the theoretical and practical analysis of the following with particular reference to CANDU plants. Thermodynamic Cycles: Nuclear versus conventional steam cycles, regenerative feedwater heating, moisture separation and reheating, turbine expansion lines, heat balance diagrams, available energy, cycle efficiency and exergy analysis; Nuclear Heat Removal: Heat conduction and convection in fuel rods and heat exchanger tubes, heat transfer in boilers and condensers, boiler influence on heat transport system, boiler swelling and shrinking, boiler level control, condenser performance; Steam Turbine Operation: Turbine configuration, impulse and reaction blading, blade velocity diagrams, turbine seals and sealing systems, moisture in turbines, part load operation, back pressure effects, thermal effects and turbine governing. Prerequisite: undergraduate course in thermodynamics. 3 cr, 3 lec.

NUCL 5260G Reactor Containment Systems. This course covers the design and main operating features of nuclear reactor containment systems, considering both normal and accident conditions. The course includes definition and purpose of containment, design requirements and considerations, a survey of containment designs in actual use and the use of simulation for safety analysis and design. Prerequisite: undergraduate course in thermodynamics. 3 cr, 3 lec.

NUCL 5270G Control, Instrumentation and Electrical Systems in CANDU based Nuclear Power Plants. This course covers the basic control, instrumentation and electrical systems commonly found in CANDU based nuclear power plants. The course starts with an overall view of the dynamics associated with different parts of the plant, i.e. reactor, heat transport systems, moderator, steam generator, turbine, and electrical generator. Based on such knowledge, the control and regulation functions in the above systems are then defined. Different instrumentation and measurement techniques are examined, along with control strategies. The time and frequency domain performance characterizations of control loops are introduced with consideration of actuator and sensor limitations. Different controller design and tuning methods and instrumentation calibration procedures are discussed. Two modes of operation of CANDU plants will be analyzed, i.e. normal mode and alternate mode. Advanced control technologies, such as distributed control systems, field bus communication protocols are introduced in view of their potential applications in the existing and newly constructed CANDU power plants. The electric systems in the CANDU plant will be examined. The modeling of the dynamics and control devices for the generator will be covered in detail. The dynamic interaction between the power plants and the rest of the electric power grid with other generating facilities and various types of loads will be studied. 3 cr, 3 lec. Prerequisite: undergraduate course in process control.

NUCL 5280G Advanced Reactor Control. This course presents the state-variable approach and the application of various state-space techniques to reactor dynamics and control. Topics include: state variables and the concept of the system state; stability in the state space; various definitions of stability; the second method of Liapunov; stability of nuclear systems; centralized versus distributed control; analogue and digital control; hardware and software; licensing requirements; computers in shutdown systems; and applying the principles of separation, diversity, redundancy. 3 cr, 3 lec. Prerequisite: undergraduate course in control theory.

NUCL 5290G Advances in Nuclear Power Plant Systems. A combination of lectures, self-paced interactive CD-ROM study and the use of power plant simulators imparts to students the advances in the key design and operating features of the main nuclear power plant types, including reactors using pressure vessels and pressure tubes, pressurized water, boiling water and gas cooled reactors; the use of natural versus enriched fuel, converters and breeders; overall plant control systems, load following capabilities, islanding operations; safety systems, responses to abnormal and emergency events. Nuclear plant simulators will be used throughout the course. 3 cr, 3 lec. Prerequisite: undergraduate course in power plant systems.

NUCL 5300G Advanced Topics in Radioactive Waste Management. This course will examine the various international approaches used for the development of publicly acceptable radioactive waste disposal facilities. Particular emphasis will be placed on the technical aspects of geologic disposal systems, used/recycled fuel disposal, and the assessment of radioisotope release. The influence of public acceptance on the selection and implementation of technical solutions will also be considered. 3 cr, 3 lec. Prerequisite: undergraduate course in radioactive waste management.

NUCL 5400G Advanced Radiation Science. This course introduces advanced concepts in radiation engineering, with an emphasis on how ionizing radiation interactions with matter may be modelled. The course reviews fundamental particle interaction mechanics, measurement and detection of radiation, evaluation of nuclear cross sections and various solutions to the Boltzmann transport equation. Prerequisites: Undergraduate courses in nuclear physics, differential equations, and statistics. This course is cross-listed with ENGR 5181G Advanced Radiation Engineering. 3 cr, 3 lec. Prerequisite: undergraduate course in radiation science.

NUCL 5410G Physics of Radiation Therapy. A study of the uses of various types of radiation for therapeutic applications, including X-rays, gamma radiation, electrons, neutrons, lasers, UV, visible, infrared, radio-frequency, and microwaves. Topics include: production of radiation for therapeutic purposes; external beam radiotherapy, brachytherapy, electron beam therapy, boron neutron capture therapy, heavy ion therapy and photodynamic therapy; therapeutic dose calculation and measurement; dose calculation algorithms, treatment planning, optimization and verification; equipment calibration; dose impact on patients and workers. This course is cross-listed with RADI 4320 Therapeutic Applications of Radiation Techniques. 3 cr, 3 lec. Prerequisite: NUCL 5060G Nuclear Concepts for Engineers and Scientists, or equivalent.

NUCL 5420G Aerosol Mechanics. Aerosols, or particles suspended in the air, are generated from numerous processes and used in numerous ways. Some examples of commonly encountered aerosols are smoke from power generation, cigarette, forest fire, atmospheric aerosols causing ozone depletion, reduced visibility, rain, snow, cloud, fog, and respiratory deposition or drug delivery through respiratory system. Some aerosols cause significant health and environmental problems while others improve the quality of life. To prevent the formation of undesired pollutants or to produce materials of desired properties, it is important to understand the mechanics of aerosols. This course explores the properties, behaviour and measurement of airborne particulate. Concepts related particle motion, particle size statistics, forces acting on particles, respiratory and mechanical filtration and physicochemical properties of particles will be discussed. Real-world examples of particle transport will be used to reinforce the issues being discussed. Prerequisites: undergraduate courses in physics, chemistry, differential equations, and statistics. A working knowledge of the MATLAB code is required. 3 cr, 3 lec.

NUCL 5430G Advanced Dosimetry. This course covers advanced concepts in radiation dosimetry linking fundamental radiation physics with metrological theory and practice for therapeutic, external and internal dosimetry. The course reviews basic radiation and charged particle interaction processes and the underlying quantities and units used in dosimetry and radiation monitoring. Cavity theory and the application of ionization chamber methods of dosimetry for photon and electron beams will be covered and a review of passive integrating dosimeters such as radiochromic film, chemical dosimeters and biological dosimetry given. The properties and role of various pulse-mode detectors in dosimetry and monitoring will be discussed along with the metrological relationship between measured quantities and effective dose. Internal dosimetry and dose assessment will be studied in terms of in-vitro and in-vivo monitoring methods along with the standard codes and methods used for assessing dose from bioassay data. The course will conclude with a survey of dosimetry practice under special circumstances and environments such as that encountered in space and in accident scenarios. 3 cr, 3 lec. Prerequisite: undergraduate course in dosimetry.

NUCL 5440G Advanced Radiation Biophysics and Microdosimetry. This course introduces advanced concepts in radiation biophysics with an emphasis on the stochastic nature of radiation interaction with biological systems and the microdosimetric analysis of radiation effects. The course reviews fundamental charged particle interaction processes and the measurement of radiation energy deposition on the microscopic and sub-microscopic scale and how this knowledge can be used to quantify radiation quality. Microdosimetric descriptions of radiation quality will also be discussed in terms of low-dose radiation protection, medical applications of low Light Energy Transfer radiation and high LET radiation therapy as well as the special nature of radiation fields encountered in space. Prerequisites: Undergraduate courses in nuclear physics; radiation detection and the interaction of radiation with matter; statistics. 3 cr, 3 lec. Prerequisite: undergraduate course in biophysics and/or dosimetry.

NUCL 5450G Non-Destructive Analysis. This course introduces a wide variety of non-destructive analysis techniques for use in research, design, manufacturing and industrial service. The course instructs how each technique works, how it can be applied, when and where it can be used and each technique's capabilities and limitations. The course describes how to take an industrial non-destructive analysis problem and determine which technique is best suited for the job, how to apply a given technique and which information the technique will provide. Laboratories will provide hands-on experience with non-destructive analysis equipment. Pre-requisites: Undergraduate courses in physics, differential equations, and statistics. 3 cr, 3 lec.

NUCL 5460G Industrial Radiography. The course will describe the fundamental physics of neutron, x-ray, gamma ray, and infra-red radiography. Traditional and modern techniques currently in practice will be discussed as well as discussing recent advances in the technology. Applications of radiography to industrial environments will be presented. Considerations for radiography system design will be discussed. Topics include: x-ray imaging and radiography; gamma-ray imaging and radiography; neutron imaging and radiography; infra-red imaging and radiography; film based techniques; digital techniques; image processing and image enhancement; x-ray and gamma ray sources; neutron sources; industrial applications of radiography. 3 cr, 3 lec.

NUCL 5470G Nuclear Forensic Analysis. There are many techniques available to forensic investigators to investigate suspect criminal activity. In addition, there are many times when forensic techniques are required to investigate nuclear-related events. This course will explore nuclear and chemical techniques related to the nuclear technology and forensics. Both radiation and analytical chemistry techniques will be introduced. Risks and hazards associated with nuclear forensic investigations will be reviewed and mitigation strategies developed. Data integrity and communication of results will be emphasized. There are many techniques available to forensic investigators to investigate suspect criminal activity. In addition, there are many times when forensic techniques are required to investigate nuclear-related events. This course will explore nuclear and chemical techniques related to the nuclear technology and forensics. Both radiation and analytical chemistry techniques will be introduced. Risks and hazards associated with nuclear forensic investigations will be reviewed and mitigation strategies developed. Data integrity and communication of results will be emphasized. 3 cr, 3 lec.