CHEMICAL ENGINEERING

Departmental Facilities

The Chemical Engineering department is based in Dupuis Hall, which is a multi-purpose facility with extensive research laboratories, and large-and small-group teaching classrooms. Department researchers in the bioengineering and bioremediation fields also have laboratory facilities in the multi-disciplinary Biosciences complex, Nicole Hall, and in the Centre for Health Innovation at Kingston General Hospital. We are a medium-sized department, with sufficient size to ensure a breadth of research activities, yet small enough to foster a cohesive learning environment. Research serials and books are housed in the Engineering and Science Library, and a variety of search and document delivery facilities are available on-line. Research is being conducted in the fields of materials and interfaces, bioengineering, sustainable energy sources, and data analytics, optimization and control. Facilities within the polymer and reaction engineering field include a variety of bench and pilot scale polymerization reactors (gas-phase polyolefin, solution and emulsion free-radical, living-radical and condensation polymer systems), polymer processing equipment (twin-screw extruder, Haake internal mixer), rotational and capillary rheometers, fuel cell equipment, and the biomedical research facilities include cell and tissue culture labs. The Chemical Engineering Analytical Facility (ChEAF) was established for the measurement of polymeric physical, thermal and structural properties, and is supported by the Senior Research Engineer. Physical measurements and chemical analyses are carried out using a variety of instruments such as gas chromatographs, elemental analyzer, HPLCs, gel permeation chromatographs, BET surface area analyzer, capillary hydro-dynamic fractionation submicron particle size analyzer, spectrophotometers, IR, FTIR, GC mass spectroscopy, and also by means of novel probes based in light scattering, absorption and fluorescence. Research computations are conducted using a wide range of symbolic computation, numerical analysis, statistical analysis and process simulation software. The research laboratories are supported by two departmental laboratory technologists while the computing facilities are supported by the Faculty of Engineering and Applied Science Information Technology Group.

Researchers in the department are affiliated with the Centre for Health and Innovation (https://www.queensu.ca/hmrc/), the Dunin-Deshpande Innovation Centre (https://www.queensu.ca/innovationcentre/ (https://www.queensu.ca/innovationcentre/)), and the Beaty Water Research Centre (https://waterresearchcentre.ca/ (https://waterresearchcentre.ca/)).

Financial Support

The Department of Chemical Engineering endeavours as much as possible to ensure that every full-time graduate student engaged in research has adequate financial support during his or her graduate program. This support may come from several sources, either individually or in combination with National or Provincial scholarships, Queen's University scholarships and awards, research fellowships provided by faculty researchers, and Departmental teaching assistantships. The minimum level of financial support is presently $25,000 per year for both Master's and Doctoral students. Students who are National Scholarship winners can expect overall financial support that is competitive with that provided by any Chemical Engineering department in Canada.

Fields of Research

The fields of research in the department are Biochemical Engineering, Polymers and Reaction Engineering, and Process Systems Engineering. Within these broad areas, the department has significant research activity in the following areas:

- **Biochemical Engineering:** Biological conversion of biological feedstocks to energy, materials and useful ends (e.g., degradation of pollutants). Feedstocks may be virgin sourced or may be waste material such as agricultural waste. Separation of products is also studied including the use of phase partitioning bioreactors to combine bioreaction and separation. Researchers: Andrew Daugulis, Juliana Ramsay, Bruce Ramsay and Pascale Champagne.
- **Environmental Engineering:** Biological conversion of pollutants to benign products using fermenters or in situ processing of contaminated soils. Work is also underway examining turbulent dispersion in the environment, primarily for air quality. Researchers: Juliana Ramsay, Bruce Ramsay and Andrew Daugulis.
- **Macro-molecular Processes and Products:** Polymer & reaction engineering with a broader title to include biological macro-molecules as well. The department has a particularly strong research concentration in this area, with one of the largest polymer engineering groups in North America and elsewhere internationally. The research expertise spans the entire range of polymer engineering, from polymer reaction chemistry, to polymer reaction engineering, to processing and compounding. Expertise in biopolymers and biomaterials includes hydrogels, scaffold material for tissue regeneration, encapsulation of bioactive materials, polyurethanes

for biomedical application and polymer gel dosimetry. Researchers: Brian Amsden, Michael Cunningham, A. Jeffrey Giacomin, Robin Hutchinson, Marianna Kontopoulou, Kim McAuley, Scott Parent, and Kim Woodhouse.

- **Biomedical Engineering:** Tissue engineering including scaffolds for adipose and muscle tissue regeneration, mechanical stimulation to promote regeneration, interaction between surfaces and cells in regeneration, oral delivery of insulin and polymer gel dosimeters. Researchers: Brian Amsden, Lindsay Fitzpatrick, Laura Wells, and Kim Woodhouse. More information about the program can be found at: https://engineering.queensu.ca/programs/graduate-professional/collaborative/bme/.
- **Process Systems Engineering:** Process control, optimization and applied statistics, including extremum-seeking control, parameter estimation in nonlinear dynamic models, diagnostics for statistical model building and parameter estimation, and systems biology. Researchers: Martin Guay, Tom Harris, Xiang Li, Kim McAuley, Jim McLellan and Nicolas Hudon.
- **Fuel Cells:** PEM and solid oxide fuel cells, alternative feeds to fuel cells including conversion of agricultural or municipal waste, low platinum electrodes, electrokinetics, control of fuel cell systems and parameter estimation for fuel cell models. Researchers: Dominik Barz, Kunal Karan and Brant Peppley.
- **Microfluidics and Biosensors:** Microfluidics and Biosensors, electrokinetics, pathogen and biomarker detection methods,Raman spectroscopy, surface plasmon resonance, on-chip cell manipulation and analysis. Researchers: Dominik Barz, Aris Docoslis and Carlos Escobedo.

Collaborative Biomedical Engineering Program

This collaborative program links the graduate programs in Chemical, Electrical and Mechanical Engineering and provides shared learning experiences with interdisciplinary content, bringing students from a variety of backgrounds together to learn about research methodology and professional practice in the field of Biomedical Engineering. Students are registered in one of the three home departments in a Master’s or Doctoral program and will receive the designation of “specialization in Biomedical Engineering” upon graduation. More information about the program can be found at https://engineering.queensu.ca/programs/graduate-professional/collaborative/bme/ and in this calendar at Biomedical Engineering (https://queensu-ca-public.courseleaf.com/graduate-studies/programs-study/biomedical-engineering/).

Collaborative Graduate Specialization in Computational Science and Engineering

A three-course specialization that teaches you the latest methods for applying the power of high-performance computing to scientific problems in your area of study. From advanced numerical analysis, mathematical modelling and simulation, and parallel programming, these methods support and enhance more traditional approaches based on theory and experimentation. Completion of requirements entitles you to a special degree notation on your transcripts.

Degree Programs

Applicants for the following programs are accepted under the general regulations of the School of Graduate Studies.

Note that courses of instruction are provided in term length (3.0 credit units) weight or modular six-week (1.5 credit units) types. Click on Chemical Engineering's Courses of Instruction (https://www.queensu.ca/sgs/graduate-calendar/courses-instruction/chemical-engineering-courses/) for details.

Faculty

Head
Amsden, B.G.

Associate Head
Guay, M.

Coordinator of Graduate Studies
Docoslis, A.C

Professor
Amsden, B.G., Cunningham, M.F., Docoslis, A., Giacomin, A.J.[1], Guay, M., Hutchinson, R.A., Kontopoulou, M., McAuley, K.B., McLellan, P.J., Parent, J.S., Peppley, B.A., Woodhouse, K.A.

Associate Professor
Barz, D., Escobedo, C., Li, X.

Assistant Professor
Dinh, C.T., Fitzpatrick, L., Hudon, N., Hungler, P., Koupaie, E., Meunier, L., Wells, L., Yang, L.[2]

Professor Emeritus
Daugulis, A.J., Harris, T.J., Neufeld, R.J., Ramsay, J.A.

1 Canada Research Chair (Tier I) Rheology
2 Queen's National Scholar

Programs

- Chemical Engineering - Doctor of Philosophy (https://queensu-ca-public.courseleaf.com/graduate-studies/

programs-study/chemical-engineering/chemical-engineering-phd/)
- Chemical Engineering - Master of Applied Science (https://queensu-ca-public.courseleaf.com/graduate-studies/programs-study/chemical-engineering/chemical-engineering-mas/)
- Chemical Engineering - Master of Engineering (https://queensu-ca-public.courseleaf.com/graduate-studies/programs-study/chemical-engineering/chemical-engineering-meng/)

Courses

NOTE Most courses are one term in length and are 3.0 credit units in weight; however, modules are 6-weeks in length and are 1.5 credit units in weight (as shown in the relevant course descriptions). Not all courses are offered in every session.

APSC 801 Master of Engineering Foundations
An introduction to the Master of Engineering (MEng) graduate studies program at Queen's University. The course provides students with essential administrative information, an introduction to information literacy within the Faculty of Engineering and Applied Science, as well as an overview of the various support services on campus. Additionally, the course contains several modules on professional and career skills. This non-credit course is comprised of a number of individual modules, and its completion is a requirement to graduate from the MEng program. Graded on a Pass/Fail basis.
Prerequisite: Enrolment in the MEng program.
Exclusion: Students not enrolled in the MEng program.

APSC 810 Teaching and Learning in Engineering
This course is an introduction to learning principles and effective teaching in engineering, intended to prepare for roles like teaching assistant, university course instruction, or training in engineering industry. The course includes relevant theories of teaching and learning with practical elements like classroom management, designing sessions and assessments, signature engineering teaching approaches, and using digital pedagogies.

APSC 812 AI Ethics and Society
This course investigates the ethical implications of Artificial Intelligence (AI) as a social, technological and cultural phenomenon. Given the increasing use of intelligent systems for decision-making and autonomous control, it is essential that designers and developers are aware of the ethical and social implications that AI can have. The course materials will examine fundamental ethical principles related to the application of AI and investigate its influence in a number of industries including self-driving vehicles, healthcare, law and defense. The course will also examine the delicate balance between innovations in AI versus regulation, privacy, and individual rights. This course is graded on a Pass/Fail basis.

APSC 877 Engineering Project Management
The course will examine the essential skills and knowledge required for effective engineering project management. The foundational principles of project management including integration, scope, cost, time, human resources, stakeholders and procurement are examined. The course will be delivered online.
Exclusions: MECH 896, APSC 223

APSC 888 Engineering Innovation and Entrepreneurship
This course will help learners from across engineering develop an entrepreneurial mindset capable of turning problems into opportunities. Learners will investigate the relationships between innovation and industrial dynamics, and seek to understand the fundamental forces that drive the science and technology industries' evolution and industry life cycles.
EXCLUSION: CHEE 410

APSC 896 Engineering Leadership
The course is designed to develop a range of leadership skills essential for engineering professional practice. Students will explore their own leadership abilities and develop their competencies in areas such as managing conflict, team dynamics and developing others. The course content will be presented through lectures, case studies, panel discussions and other active learning activities. Fall. P. Hungler

CHEE 801   Strategies for Process Investigations
The statistical design of experiments and the analysis of data in process investigations are considered. Empirical modelling of process behaviour is studied. Applications of factorial and fractional factorial experimental designs in screening studies and methods of response surface exploration are examined. Traditional North American approaches to quality and productivity improvement are compared with those practiced in Japan. Fall. J. McLellan.
PREREQUISITE: CHEE 209 or equivalent.

CHEE 803   Transport Phenomena
Basic concepts, generalized control volume analysis and balance equations. Constitutive equations, kinetic models, thermodynamic considerations, and prediction equations for transport properties. Coupled transport processes: Onsager's theory; forced diffusion; and thermo-chemical, thermo-electric, and electro-chemical effects. Special phenomena in biological and macromolecular systems. Phenomena at surfaces. Effects of flow and chemical reaction. Analogies between energy, material and momentum transport. Examples in the analysis of complex problems. Winter. J. Giacomin.

CHEE 807 Current Topics in Chemical Engineering
Selected topics in chemical engineering including chemical reaction engineering, combustion, biochemical engineering, process control, environmental engineering, applied statistics, polymer reaction engineering, polymer processing, fluidization and turbulence. Only topics not covered in other graduate courses will be included. Topics will vary depending on the instructor(s). Not offered 2021-22.
PREREQUISITE: Permission of the Instructor.

CHEE 810 Fuel Cell Systems: Design and Analysis
This course will examine the design of fuel cell systems for a variety of applications ranging from large multi-megawatt stationary power systems to milliwatt scale portable electronics systems. Examples will be drawn from actual demonstration and pre-commercial prototype systems operating on a range of fuels including conventional hydrocarbons with integrated external fuel processing subsystems, anaerobic digester gas with external clean-up and preprocessing, natural gas fuelled systems with direct and indirect reforming, direct methanol fuel cells and hydrogen fuel cells. The design of combined heat and power systems (CHP) for large scale industrial applications and for small-scale residential applications will also be examined. In each of these case studies the impact of system configuration and individual component performance on efficiency will be examined and strategies for optimizing performance and minimizing complexity will be developed. In addition the effect of system design on greenhouse gas emissions will be considered. The course will consist of three design projects of increasing complexity and a final examination. Students will be expected to give a presentation on their final design project. Not offered 2021-22.

CHEE 811 Mathematical Modeling of Chemical Processes
The steps that are required to build comprehensive mathematical models are examined. These steps include: definition of the intended model use and user requirements; formulation of model equations; determination of model parameters from correlations and experimental data; parameter sensitivity and estimability analysis; solution of model equations using numerical techniques; model validation; and potential model applications. While the focus is on the development of fundamental models, empirical modeling techniques are also discussed. Process examples are selected from: reactive distillation, polymerization, bioreactors, heat exchangers, and fuel cells. Students complete a mathematical modeling project related to their research interests. Not offered 2021-22.
PREREQUISITE: Permission of the Instructor.

CHEE 820 Topics in Advanced Process Control
Researchers at Queen's and visiting professors will present selected topics in advanced process control, including control of distributed parameter systems, control of bioprocesses, control of polymer reactors, and hybrid systems. Not offered 2021-22.
PREREQUISITE: Permission of the Instructor.

CHEE 821 Process Control II
This is a second course in process control techniques. Topics covered will include: frequency response methods for stability analysis and controller design, deadtime compensation (e.g., Smith predictor), feedforward/ cascade control, the Internal Model Control formulation, introduction to multivariable control, and interaction analysis using the concept of relative gain. Specific applications to chemical processes will be presented. (Offered jointly with CHEE 434, with additional lectures and assignments.) Winter. M. Guay
PREREQUISITE: CHEE 319 or permission of the instructor.

CHEE 822 Model-Based Control
The course focuses on the use of explicit process models for multi-variable controller design. Linear and nonlinear control approaches are discussed in both discrete and continuous time formulations. Stability, performance and robustness issues are addressed. The role of observers for state estimation is considered. Not offered 2021-22.
PREREQUISITE: CHEE 319 and CHEE 821 or equivalent.

CHEE 827 System Optimization
A survey of optimization problems is made and mathematical procedures for their solutions are discussed. Comparisons of optimization techniques for various classes of problems are made using industrial examples and computer studies. Both linear and nonlinear programming methods are studied. Topics include the role of optimization, definitions of objective functions and constraints, conditions for existence of an optimum; one-dimensional strategies; analytical procedures for unconstrained and constrained multi-dimensional problems, numerical procedures for unconstrained and constrained multidimensional problems, introduction to multistage optimization. Winter. X. Li.
PREREQUISITE: Permission of the instructor

CHEE 828 Polymer Reaction Engineering
The fundamentals of polymerization kinetics are reviewed. The equations for batch and continuous flow reactors are developed and used in the calculation of polymerization rate and polymer quality measures. Process parameters which affect reaction rate, chain composition and molecular weight distribution are examined, and the design of polymer reactor systems is discussed. Consideration is also given to the problems of reactor design in heterophase polymerization. Winter. R.A. Hutchinson

CHEE 837 Transport & Kinetics with Application to Fuel Cells
The fundamentals of transport phenomena and reaction kinetics are considered and applied to fuel cells, with a view to a mechanistic understanding of fuel cell operation and limitations. Material covered includes the basic axioms of mechanics (conservation of mass, momentum, energy and charge) presented in indicial notation and applied to porous media. Emphasis is placed on the description of porous materials and the implications of porous media on transport, including the notion of effective transport coefficients. Ion transport in solid and polymer electrolytes due to electrochemical potential differences is considered. Diffusion models covered include Fick's law, Stefan Maxwell and Knudsen. Electrochemical reaction kinetics and mechanism are covered including rate-limiting steps, exchange current density and the fundamental definition of over potential. The course will include individual projects. Not offered 2021-22.
EXCLUSION: MECH 837

CHEE 838 Pollution and Risk Assessment
Chemicals of potential concern and their effects on human health and the environment are investigated. Principles of quantitative risk assessments are presented – including hazard identification, dose-response assessment, exposure, and risk characterization – in the context of regulations and applications in environmental engineering practice, addressing issues facing all stakeholders. (3.0 credits units. Term course delivered in one 12-week semester, 3 hours/week)
Prerequisite: undergraduate level chemistry course.
Exclusion: RMC course CC541 Toxicology and Risk Assessment

CHEE 872 Polymeric Biomaterials
This course is designed to appeal to students in all fields of this interdisciplinary field, from biomechanics to polymer chemistry. It will provide a thorough background in the underlying fundamental biological and polymer science principles involved in the use of polymers as medical materials. Topics include surface and bulk polymer properties, applications of polymeric biomaterials, the biological principles that dictate host response to a material, and biopolymer degradation. Winter. B. Amsden
PREREQUISITE: Permission of the Instructor.

CHEE 874 Tissue Engineering
This course is designed as a graduate level introductory course in tissue engineering: the interdisciplinary field that encompasses biology, chemistry, medical sciences and engineering to design and fabricate living systems to replace damaged or diseased tissues and organs. Topics to be discussed include: tissue anatomy, basic cell biology, cell scaffolds, cell sources and differentiation, design considerations, diffusion and mass transfer limitations, effects of external stimuli, bioreactors, methods used to evaluate the engineered product(s), and implantation. Case studies of specific tissue engineering applications will also be discussed. Students will be required to participate in as well as lead discussions on the course material as well as relevant journal articles. No previous background in biology is required. Winter. L. Fitzpatrick

CHEE 884 Bioremediation
Bioremediation as an option to treat contaminated soils, ground water, fresh water and the marine environments. Advantages and disadvantages of bioremediation compared to nonbiological processes. Factors affecting choice of in situ or ex situ processes. Assessment of biodegradability; biostimulation vs. bioaugmentation; mineralization vs. partial degradation; factors affecting microbial activity (choice of electron acceptor, toxicity of pollutant, C/N/P ratio, co-substrates, soil humidity, pH and temperature); bioavailability of pollutant. Biodegradation of specific contaminants (eg. diesel fuel, polychlorinated biphenyls, dyestuffs, aromatic and polyaromatic hydrocarbons) will be studied in detail. This course is co-taught with CIVL 889. Winter. L. Meunier.
PREREQUISITE: Permission of the instructor.
EXCLUSION: CIVL 889.

CHEE 885 Current Topics in Biochemical Engineering
The course surveys recent advances in Biochemical Engineering, through lecture material and seminars based on recent published advances, critical analysis and in depth review of recent published literature, academic and industrial guest speakers outlining advances in their respective research areas and through student presented seminars on assigned papers or topics.

CHEE 886 Computational Systems Biology for Biological Networks
Computational systems biology offers tools to predict and design cell behavior for bioengineering. Students will learn how to reconstruct a genome-scale metabolic network, analyze it with matrix decomposition, compute cell phenotypes (metabolism, proteome allocation, stress response), and contextualize big data in networks using machine learning. (3.0 credit units).
PREREQUISITE: permission of the instructor

CHEE 887 Cellular Bioengineering
This course will focus on applied cellular and molecular biology for the development of cell-based therapeutics in regenerative medicine. Emphasis will be placed on how engineering principles can be applied, in combination with an understanding of mammalian morphogenesis and

physiology, to control and manipulate cellular responses in vitro and in vivo. Not offered 2021-22.

CHEE 890 Advanced Polymer Structure, Properties and Processing
The first half of the course examines the elements of polymer science that relate to engineering applications. The second half examines polymer processing operations with an emphasis placed on the analysis of polymer flow. Specific topics include the rheology of thermoplastic melts, viscoelasticity, constitutive equations and polymer blends. Not offered 2021-22.

CHEE 897 Seminar
Graduate students working on theses must give a seminar on their research. The seminar carries no course credit but all graduate students are required to attend.

CHEE 898 Master's Project

CHEE 899 Master's Thesis Research

CHEE 901 Principles and Applications of Polymer Rheology
Rheology provides a valuable tool for the assessment of the processability of polymers in various operations, as well as the identification of their structure. This 6 week (3 hours/week) module will discuss the fundamental relations between the rheology and structure of polymers and the principles of rheometry. (1.5 credit unit weight). Winter. J. Giacomin.

CHEE 902 Bulk and Solution Polymerisation Processes
This course is intended to help the student to understand how the fundamentals acquired in CHEE 828, are used in the design and operation of melt or solution polymerisation processes of different types (chemistries, operational modes, etc.) Emphasis will be placed on reactor design and operation, but separation technology for product purification will also be studied. Case studies of specific commodity polymers will be used to illustrate the important concepts. (1.5 credit unit weight). Not offered 2021-22.

CHEE 903 Polymerisation in Dispersed Media
This is a product-focused course that will include use different (non-polyolefin) concrete examples to help the students understand the reasons for producing polymer in dispersed media, the types of product one can make and the relationship between process operation and polymer structure. Emphasis is placed on reactor design, advanced modelling of dispersed phases systems, and issues related to industrial production such as characterisation, scale-up and control. (1.5 credit unit weight). Winter. M. Cunningham.

CHEE 905 Advanced Chemical Engineering Thermodynamics and Applications
This module presents fundamentals of thermodynamics and advanced applications relevant in Chemical Engineering. The calculus of thermodynamics, equilibrium and stability criteria are derived. Properties of real fluids and mixtures are established. Statistical foundations are introduced, and the thermodynamics of polymers, electrochemical systems, and biological systems are presented. (1.5 credit units). Fall. N. Hudon.
PREREQUISITES: CHEE 210 and CHEE 311 or equivalent (or permission from the instructor).

CHEE 906 Entrepreneurship for Chemical Engineers
This course module focuses on assessing entrepreneurial opportunities in chemical engineering. This includes: business opportunity screening, IP issues, market and competitive analysis, regulatory/ legal issues and financial analysis. Students evaluate the commercial potential of a technology or opportunity of their choice. (1.5 credit unit weight). Not offered 2021-22.

CHEE 907 Current Topics in Chemical Engineering
Selected topics in chemical engineering including chemical reaction engineering, combustion, biochemical engineering, process control, environmental engineering, applied statistics, polymer reaction engineering, polymer processing, fluidization and turbulence. Only topics not covered in other graduate courses will be included. Topics will vary depending on the instructor(s). (1.5 credit unit weight). Fall. L. Wells

CHEE 909 Colloid and Surface Science Fundamentals
Various established theories on Colloids (e.g., DLVO, XDLVO) will be analyzed and subsequently used as tools towards the understanding and prediction of phenomena relevant to contact angles, surface wetting, emulsion or particle dispersion stability, and surfactant self -assembly.(1.5 credit units). Fall. A. Docoslis.

CHEE 910 Special Topics in Colloid and Surface Phenomena
This course provides an in-depth examination of selected topics in colloids of great interest to sciences and technology, such as emulsion stability, adsorption, particles electrokinetics and light scattering. In-class discussions and presentations, literature reviews, and individual projects, will provide graduate students with the solid fundamental knowledge and critical thinking required to approach problems related to these phenomena in a rigorous manner. This is not intended to be an introductory course in Colloids. Prior knowledge of Colloids and Surface Science principles is required. (1.5 credit units). Fall. A. Docoslis

CHEE 911 Microscale Transport Phenomena
This 6 week (3 hours/week) module will provide in-depth coverage of microscale transport phenomena motivated

by the emerging fields of Microfluidics and Lab-on-a-Chip. During this course, students will intensify and expand their knowledge of the fundamentals of heat, mass, charge and momentum transfer with emphasis on microscale geometries. The difference of macro- and microscale transport phenomena and the limitation of classical mechanics will be highlighted by scaling analysis. Additionally, an introduction into the fundamentals of selected electrohydrodynamic phenomena will be given. (1.5 credit units).Winter. D. Barz.

CHEE 912   Applied Lab-on-Chip Technologies
This 6 week (3 hours/week) module will provide an overview on the latest developments, fabrication techniques, and principles of operation of contemporary micro- and nanotechnologies used in lab-on-chip (LOC) type platforms. Small-scale subunit operations required in LOC systems, equally relevant across several disciplines in both life sciences and engineering fields, will be covered in detail. The knowledge acquired in these topics will be used during the last part of the course to analyze the design of LOC-based systems in key applications in different areas including biosensing, biotechnology and emerging energy technologies. (1.5 credit units). Winter. C. Escobedo.
PREREQUISITE: CHEE 911, or permission of instructor

CHEE 927   Global Optimization
This 6-week course introduces global optimization principles and methods for nonconvex continuous or mixed-integer programs, which can arise from a wide range of process systems engineering problems. The course consists of three parts. The first part discusses convex sets, convex functions, and Lagrangian duality theory. The second part introduces classical branch-and-bound based global optimization methods, along with convex relaxation and domain reduction techniques. The third part gives an overview of decomposition based large-scale global optimization. This course, although placed in the Department of Chemical Engineering, is designed for graduate students from across Queen's University. (1.5 credit units). Not offered 2021-22.
PREREQUISITES: CHEE 827 or permission of the instructor.

CHEE 990   Structure-Property Relationships of Polymer Materials
This six-week graduate module provides students with background in physical polymer science as it relates to the formulation of materials to satisfy engineering applications. Starting from the characterization of molecular weight and composition distributions, the fundamentals of phase transitions, solubility, adhesion and thermo-oxidative stabilization are discussed. (1.5 credit unit weight). Fall. M. Kontopoulou.
EXCLUSION.: CHEE 490

CHEE 991   Introduction to the Processing and Rheology of Polymeric Materials
This six-week graduate module examines polymer processing operations. Specific topics include extrusion and injection moulding, modeling approaches, polymer blends and composites. Particular emphasis is placed on the analysis of polymer flow. Principles of the rheology of thermoplastic melts and rheometry are presented. (1.5 credit unit weight). Not offered 2021-22.

CHEE 992   Polymeric Biomaterials
This six-week graduate module provides a thorough background in the underlying fundamental biological and polymer science principles involved in the use of polymers as medical materials. (1.5 credit unit weight). Not offered 2021-22.

CHEE 999   Ph.D. Thesis Research