UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

Report No. 3776

MEMORANDUM

To: Executive Committee of Faculty Council (November 19, 2024)
Faculty Council (December 18, 2024)

From: Professor Lisa Romkey
Chair, Engineering Graduate Education Committee

Date: November 8, 2024

Re: **Engineering Graduate Education Committee Update**

REPORT CLASSIFICATION

This is a routine or minor policy matter that will be considered by the Executive Committee for approving and forwarding to Faculty Council to receive for information.

MINOR MODIFICATION

The following modifications to the Graduate Emphasis in Robotics were approved by the Engineering Graduate Education Committee

Emphasis in Robotics	1. As a result of the creation of the Collaborative Specialization in Robotics in 2022, the Emphasis in Robotics was closed to MASc and PhD students, remaining open only to MEng students. It is proposed that the emphasis' admission requirements be updated to reflect this. 2. Expansion of elective course list (see Appendix 1).

NEW COURSES APPROVED

The following new courses have been approved by the Engineering Graduate Education Committee:

AER1405H: Metamaterials for Aerospace Applications	This course focuses on the properties, design, and manufacturing of metamaterials in the context of aerospace structures. Metamaterials (also called architectured materials or materials-by-design) are materials with carefully designed meso- and micro-structures to achieve macroscopic properties which are not typically observed in conventional engineering materials. Therefore, the geometry of metamaterials directly influences their properties, rather than their compositions, as found, for example, in typical alloy systems. Metamaterials are often characterized by a spatial symmetry. The most well-known category of metamaterials are truss structures in bridge and tower structures in civil engineering. Advances in additive manufacturing enabled the design and manufacturing of these truss networks on the meso-and micro-scale. They combine desirable mechanical properties, e.g., high stiffness, high strength, and high fracture toughness, while still maintaining a low density. This unique combination of mechanical properties creates highly sought-after materials for aerospace applications, such as stiffening components in reusable rockets, high-toughness aircraft fuselages, or zero thermal expansion structures in satellites. Other classes of metamaterials will be briefly explored in this course, which combine beneficial mechanical properties with e.g. the capability of manipulating electromagnetic waves (blocking wave-propagation, embedding sensors, or tailoring the sound propagation). Finally, novel classes of metamaterials will be discussed in this course, e.g. active materials and design for self-assembly.
APS1090H: Risk Engineering	Insurance has enabled each major socioeconomic transition over the last 600 years, whether underwriting shipping in the early days of international trade, to the introduction of machines, to advances in healthcare to capital infrastructure development. In the same way and at a much smaller scale, it allows entrepreneurs to secure loans, households to survive the accidental loss of a critical asset like a house or car, and manufacturers to retool and shift production. While each situation has a unique risk profile, there are four broad approaches to managing commercial risks. These range from the prescriptive practice most commonly associated with FMGlobal, to the incentivized actions such as FireSmart and Home Improvement, to generalized advice on risk & resilience such as the BOMA Canada guide, to a fully integrated corporate risk management regime. Assessing the risks for underwriting will follow either a quality assurance or quality control approach.

BME1455H: Microfluidics for Bioanalytical Research	Microfluidic devices leverage special properties of fluids at micron-scales to provide precise control over fluids and samples inside microfluidic channels. Inside microfluidic devices, fluids are highly predictable and controllable, making them versatile tools for biotechnology and biological research. This course will provide students with a foundational intuitive understanding of fluidic phenomena at the micron scale, microfluidic devices, how they are made, and their applications for bioanalytical research of biomolecular and cellular systems, including single-cell assays, immunological, and biochemical assays.
BME1530H: Robot Foundations & Programming for Biomedical Applications	The global medical robot market is valued over $20 billion and is in the same ballpark as other robot market sizes (e.g. industrial, household). With a current annual growth rate over 15%, medical robots will help to bridge lack of skilled professionals in the healthcare sector. Through this course, engineering students will be prepared interacting with robots and develop future innovations in biomedical robotics. The course covers the foundations of robotics for biomedical engineering. Students will learn about applications that range from biomedical lab automation, robot-assisted surgery, mobile and service robots in hospitals, as well as further smart robot types for healthcare purposes. The practical component of the course will allow students to interact and program collaborative robots in UTM's Robot Teaching Lab. Students will learn foundational concepts of robotics, i.e. forward and inverse kinematics, dynamics, trajectory generation, motion planning and execution for serial robots. Further on, they will learn to program robot motions in a preplanned, teleoperated and collaborative robot-style fashion. They will be familiarized with state-of-the-art methods like active constraints, admittance control, as well as coordinate system transformations through point-based and image-to-physical registration. In their course project, students have the chance to develop a robot application that is centered around their own research project, towards a lab automation task or hard- and software extensions ranging from designing dedicated end effectors, integrating sensors, or developing AI-based control methods.
CIV1251H: Introduction to Corrosion	This course will provide students with the understanding of basic science of corrosion and the tools used to predict corrosion behaviour in practice, selection of appropriate corrosion resistant materials for an application, and the analysis of corrosion failure in various engineering sectors. There will be several industry leaders joining us to talk about their specialized topics. This course will answer corrosion-related questions, including: (i) what is the worldly impact of corrosion-affected structures? (ii) what is the probability of corrosion occurrence in certain structures and designs? (iii) what forms of corrosion exist on

	a particular structure and how do we prioritize their solutions? (iv) how fast will structures deteriorate due to corrosion? (v) what destructive and non-destructive methods are used to characterize/test corrosion in the laboratory and field? and (vi) How do we protect against corrosion in newly built structures (i.e. material selection, optimized designs with sustainability, safety, and economic considerations, etc.). Although the course is aimed at civil engineering structures (e.g. reinforced concrete structures affected by corrosion due to exposure in marine and inland environment), many concepts and case-studies provided are applicable to corrosion-affected structures in other industries (e.g. automotive, aerospace, nuclear, biomedical, etc.)
CIV1284H: Introduction to Construction Claims	In this course, students study advanced topics in construction contracting. It is a follow-up to CIV1279, which provides a general introduction to contract documents. The course specifically focuses on the claims and alternative dispute resolution processes. The complexity of todays' contracts and the increasing dynamics of project scope and work plans can result in change orders and/or conflicts between project stakeholders—typically between the owner and the contractor. In this course, students study means to reduce conflict and claims through designing protocols for tracking project scope changes; evaluation of the conditions under which to file a claim (form the contractor perspective); and assess means to evaluate the merit of a claim (from the owner perspective). Because claims could be contentious, industry best practices have evolved to seek alternative mean to resolve conflicts in project plans. The students will compare alternatives for reducing conflicts and resolving claims, including their applicability to various project conditions, and how to manage an alternative dispute resolution process.
CIV1410H: Rock Engineering Design Practice	This course addresses practical considerations in the analysis and design of surface and underground excavations in rock. Topics covered include: Practical Rock Engineering Problems; Rock Mass Characterization; Rock Mass Classification; Rock Mass Failure Mechanisms; The Art of Rock Engineering Design; Ground Support Technology; Tunneling in Rock; Long Term Performance of Excavations; Forensic Investigations; Case studies in Rock Slope Engineering. Underground Excavations in Rock and Deep and High Stress Conditions.
ECE1257H: Integral Equation Methods for Computational Electromagnetism	Computational electromagnetism plays a crucial role in many areas of scientific research and industrial applications, including antennas, radar, metamaterials, integrated circuit design, quantum computing, energy generation and transmission, optics, medical imaging, sensing, radioastronomy. This course focuses on integral equation methods for solving Maxwell's equations, covering theory, implementation, applications and recent research developments.

	Electrostatic problems are first used to introduce students to fundamental concepts: integral formulations of Maxwell's equations, the Green's function, discretization and testing aspects, computation of singular integrals. After a review of direct and iterative methods to solve linear systems, we discuss the most prominent techniques for accelerating integral equation. methods, including fast multipole algorithms, FFT-based approaches, and hierarchical matrices. The general case of electrodynamics is considered next, including the choice of basis functions, modeling of excitations, postprocessing of results, modeling penetrable objects. Finally, selected topics from recent research will be presented. Throughout the course, examples drawn from real applications will be presented, related to integrated circuit design, antenna modeling, and metamaterials. The course engages students in lectures with an active, hands-on approach based on learning notebooks that both exemplify the concepts covered in lectures, as well as require students to immediately put them into practice. Students will be required to solve 3-4 assignments and work on a final project, typically related to their research interests. The project deliverables will be: an IEEE- formatted report, a presentation, and the submission of the developed codes.
MIE1630H: Reinforcement Learning for Research	This course is to provide fundamental concepts and mathematical frameworks for reinforcement learning. Specific topics include Markov decision processes, tabular reinforcement learning, policy gradient methods, function approximation and model-based methods. The course is technical and intended for advanced students with a strong mathematical background and programming skills. Emphasis will be placed on recent developments and principled approaches.
MIE 1632H: Symbolic AI Methods for Combinatorial Optimization	Combinatorial optimization problems consist of making a set of discrete but inter-related decisions to optimize some objective function. While such problems are economically important across many industries and services, they also grow exponentially in difficulty with problem size. Thus there exists a substantial literature on the theory and practice of combinatorial problem solving with Artificial Intelligence (AI) and Operations Research (OR). This course will provide students with advanced conceptual, theoretical, and implementational knowledge and skills for modeling and solving such problems. The course will cover the fundamental components of developing mathematical models within existing AI frameworks of SAT, Constraint Programming, AI planning, and Domain-Independent Dynamic Programming while also teaching the fundamental mathematics and algorithms with which the frameworks solve the problem thus modeled. Basic knowledge of symbolic AI approaches as typically taught in undergraduate courses as well as a familiarity with computational complexity is recommended. Knowledge of Operations

	Research approaches to combinatorial optimization is an asset.
MSE1003H: Advanced A.I. for Accelerated Materials Discovery	This course delves into the cutting-edge field of AI-driven materials discovery, equipping students with the tools to develop advanced algorithms that can autonomously learn from data, make predictions, and direct future experiments. Students will explore how AI models such as decision trees, Bayesian optimization, and other statistical methods can be combined with adaptive strategies to propose new experiments and calculations in an iterative loop. This hands-on course emphasizes the design and implementation of AI optimization workflows. Students will practice balancing exploration and exploitation strategies, as well as design their own. The course culminates in a final project where students will deploy their workflows to control a self-driving lab, guiding an autonomous materials optimization campaign.
MSE1059H: Synthesis of Nanostructured Materials	This course offers an overview of synthesis techniques to produce various nanostructured materials, including quantum dots, carbon-based nanomaterials, metal-based nanomaterials, metal oxide nanomaterials, and superlattice nanocomposites. These synthesis techniques are categorized into chemical methods and physical methods. The chemical methods module discusses the general principles of nucleation and growth, as well as specific nanomaterial synthesis by reductions, calcination, precipitation, micelles, ion-exchange, sol-gel, electrochemical methods, etc. The physical methods module introduces various nanomaterials synthesis by solid-state processing, liquid phase processing, vapour phase processing, etc. In addition, this course also introduces the nanomaterial development, the fundamental properties of nanomaterials (i.e., quantum confinement, surface effect, Brownian motion, electric double layer, etc.), and the basic solid-state physics for nanocrystalline materials (i.e., crystallography, defect structures, etc.). Advanced technologies for the material characterizations (i.e., XRD, TEM, SEM, EDS, XPS, DLS, etc.) are also discussed, particularly with specific examples of their applications for nanomaterials.
MSE1070H: Biomedical and Clinical Devices	This course provides an opportunity for students to study current health issues directly from local clinical and industry guest lecturers. Students will broaden their understanding and knowledge of medical problems based on body site (e.g., the heart, vascular system, and brain) and apply their engineering background to propose solutions (e.g., a new biomedical device, biomaterial, etc.). Students will also learn the process behind developing biomedical devices from ideation to commercial release. The format is interactive with students and faculty, with student groups preparing proposed solutions, presented in class, and receiving real-time feedback.

TEP1440H: To Engineer is Human: Human Interaction Dynamics and Social Context in Engineering Work	Behind every engineering feat is a human story. Students will learn to examine this often-overlooked perspective of engineering and its implications for engineering work. Engineering is at its core a human activity geared at helping to attain human goals, which requires the integration of many viewpoints, technical and non-technical. Drawing on perspectives from humanities and social science disciplines (e.g., sociology, anthropology, psychology, history, and political science) students will explore aspects of the human condition as it relates to engineering work: particularly the complexity of individuals, the contexts in which they operate, and how this shapes collaborative work. They will develop an appreciation for and skills to engage in the interdisciplinary work that engineering entails by examining conceptions of engineering, as well as the humanities and social sciences, and their intersections with engineering. Students will integrate these themes in projects that investigate the human stories behind various technologies.

COURSE MODIFICATIONS

The following courses have had minor modifications approved by the Engineering Graduate Education Committee:

APS1101H: System-Theoretic Accident and Risk Analysis	Course name changed from “System Dynamic Risk Assessment” to “System-Theoretic Accident and Risk Analysis” to reflect course content.
CHE1152H: Membrane Engineering	Minor updates to course description, assessment and topics. Revised course description: Membranes are essential components in energy-efficient industrial separations (e.g., reverse osmosis, ultrafiltration, gas separations, electrodialysis) and electrochemical devices (e.g., electrolyzers, fuel cells, batteries). This course focuses on the fundamentals of membrane science, as relevant for industrial separations and electrochemical devices. Electrolyte systems are relatively emphasized. The course discusses transport of solvents (e.g., water), solutes, and ions in membranes; polymer chemistry, membrane synthesis, and membrane morphology; and details and requirements of specific applications. The course is relevant for water treatment, mining and metals, chemical processing, and electrochemical engineering.
MIE1721H: Reliability and Asset Management	Change is the amalgamation of MIE1723 and MIE1721 (MIE1723 is no longer running with this change). Revised course description: The goal of the course is to introduce students

	to principles of reliability from a practical point of view. The course covers principles of quality, principles of reliability, reliability of systems, failure rate data and models, quality and reliability in design and manufacturing, and reliability and availability in maintenance including cost models. Determination of optimal maintenance and replacement practices for components and capital equipment, including preventive maintenance policies and inspection policies are covered. A moderate knowledge of probability and statistics is a requirement.

RECOMMENDATION FOR COUNCIL

For information.

University of Toronto
Minor Modification Proposal

Change to an Existing Graduate Program or Collaborative Specialization

This template was developed by the Office of the Vice-Provost, Academic Programs and updated on March 6, 2018. It should be used to bring forward all proposals for minor modifications to program or admissions requirements for existing graduate programs or collaborative specializations under the University of Toronto's Quality Assurance Process.

Program/Collaborative Specialization being modified:	MEng, Emphasis in Robotics
Graduate unit:	Mechanical & Industrial Engineering (MIE) Electrical & Computer Engineering (ECE) University of Toronto Institute for Aerospace Studies (UTIAS)
Faculty/academic division:	Faculty of Applied Science & Engineering (FASE)
Dean's Office contact:	Prof. Julie Audet, Vice-Dean Graduate Studies Caroline Ziegler, Governance & Programs Officer
Version date:	September 24, 2024

1. Summary

- *Check box for type(s) of change.*
- *Summarize what the change is, including details about any changes to FCEs.*

X	Changing admission requirements		Renaming field, concentration or emphasis*
X	Changing program requirements		Renaming of program or collaborative specialization (please notify VPAP before governance)
	Changing timing of program requirements		Creating a new emphasis
			Changes to programs affecting an MOA

* Anything with a changed/new name requires consultation with VPAP Office prior to governance; if name change implies significant change to what is being offered or how it is being offered, this may be a major modification or new program.

This proposal covers two changes:

1. As a result of the creation of the Collaborative Specialization in Robotics in 2022, the Emphasis in Robotics was closed to MASc and PhD students, remaining open only to MEng students. It is proposed that the emphasis' admission requirements be updated to reflect this.
2. Expansion of course options: expand the list of eligible courses to include existing pre-approved substitutions to reflect the increase in new robotics and robotics-related course offerings. This includes:
    - ECE 1635 – Special Topics in Control I
    - ECE 1505 – Convex Optimization
    - ECE 1513 – Intro to Machine Learning
    - ECE 1508 – Special Topics in Communications: Applied Deep Learning
    - ECE 1508 – Special Topics in Communications: Reinforcement Learning
    - MIE 1517 – Introduction to Deep Learning
    - MIE 1077 – Artificial Intelligence for Robotics III (AIR III): Advanced AI-Based Robot Applications
    - MIE 1076 – AI Applications in Robotics II
    - MIE 1080 – Introduction to Healthcare Robotics
    - MIE 1050 – Design of Intelligent Sensor Networks
    - CSC 2606 – Continuum Robotics
    - CSC 2626 – Imitation Learning for Robotics
    - STA 2104 – Statistical Methods for Machine Learning II

2. Effective Date of Change

January 2025

3. Academic Rationale

- *State academic reasons for the change(s).*

The Institute for Robotics & Mechatronics (currently known as the University of Toronto Robotics Institute) was formed in 2010 as an EDU:C to unite robotics research and launch undergraduate and graduate robotics training options within the Faculty. The institute subsequently helped launch and supports the Engineering Science Major in Robotics Engineering, the undergraduate Minor in Robotics & Mechatronics, and the graduate Emphasis in Robotics.

The emphasis was initially open to MEng, MASc and PhD students in Aerospace Engineering, Electrical and Computer Engineering, and Mechanical and Industrial Engineering. However, in 2022 a proposal to establish a Collaborative Specialization in Robotics was approved. The collaborative specialization, created with the support of the University of

Toronto Robotics Institute, is available to MASc and PhD students in FASE, the Faculty of Arts & Science, the Temerty Faculty of Medicine, and the University of Toronto Mississauga.

The collaborative specialization is meant to complement the Emphasis in Robotics, which remains available in FASE only to MEng students. It is proposed that the emphasis' admission requirements be updated accordingly.

Re. the expansion of course offerings, Robotics is a growing and highly interdisciplinary field with courses offered across multiple departments including MIE, ECE and UTIAS. By adding pre-approved course substitutions to the approved course list, the emphasis will better reflect the increase in robotics course offerings and the growth of robotics at U of T. It will also reduce admin time for faculty and staff who receive and manage requests from students about course substitutions.

4. Impact on Students

- *Outline the expected impact on continuing and incoming students, if any, and how they will be accommodated.*

The creation of the Collaborative Specialization in Robotics in 2020 has had minimal impact on enrolment in the emphasis and no effect on FASE MEng students.

MASc and PhD students who were enrolled in the emphasis when the collaborative specialization was created are still eligible to complete it. Since 2020, MASc and PhD students who are interested in the emphasis have been directed to the collaborative specialization.

Re. the course list update, currently, students are limited by requesting only one substitution, whether from a pre-approved list or on a case-by-case basis. By updating the approved course list with pre-approved substitutions, students can better take advantage of the range of robotics courses offered at U of T, broaden their application and understanding of this interdisciplinary field, and take more courses aligned with their interests. It will also improve clarity for students about course requirements.

This change is not anticipated to impact current or incoming students other than providing more course options that can be counted towards their emphasis requirements.

5. Consultation

- *Describe any consultation undertaken with the students, faculty, Dean and chair/director. Address any major issues discussed.*

The proposal to create the Collaborative Specialization in Robotics, with the intention to restrict the Emphasis in Robotics in FASE to MEng students only, underwent wide consultations and was supported by students, faculty, stakeholders and academic leadership within Dean's Office, UTIAS and affected Faculties.

Graduate studies chairs noted that spaces in some courses may be limited for MEng students depending on the department they are enrolled in. We will ensure MEng students are aware of this by including the following disclaimer on the Robotics Emphasis webpage:

Important note about course registration: if you are not enrolled in the department offering the course(s) you are interested in, some courses may reach their registration cap due to limited seats open to students outside the department. For questions about enrollment, please contact your department graduate advisor.

The course list was circulated to department graduate studies chairs for consideration and approval. This included:

- ECE – Antonio Liscidini
- MIE – Eric Diller
- UTIAS – Chris Damaren
- CompSci – Faith Ellen
- Statistical Sciences – Stanislav Volgushev

6. Resources

- *Describe any resource implications of the change(s) including, but not limited to, faculty complement, space, libraries and enrolment/admissions).*

There are no resource implications associated with these changes.

7. Governance Approval

University of Toronto Institute for Aerospace Studies (UTIAS) sign-off	Sept 2024
Engineering Graduate Education Committee (EGEC) approval	
Council of the Faculty of Applied Science & Engineering (FASE) approval	Dec 18, 2024

8. Appendix A: Calendar Entry

- *Changed text is indicated in red.*

Emphasis: Robotics **(MEng only)** [Note: This change is reflected in the 2023-2024 SGS calendar.]

Students must successfully complete **four courses (2.0 full-course equivalents [FCEs])** chosen from at least two of the following groups, and no more than two in any given group:

Group 1: Planning and Control

AER1516H, AER1517H,
ECE557H (exclusion: ECE410H), ECE1635H, ECE1636H, ECE1647H, ECE1653H, ECE1657H, MIE1064H.

Group 2: Perception and Learning

AER1513H, AER1515H,
CSC2503H, CSC2506H, CSC2515H, CSC2541H, CSC2548H, **CSC2626H**
ECE516H, **ECE1508H**, ECE1511H, ECE1512H, **ECE1513H**
JEB1433H,
MIE1076H, MIE1077H, MIE1517H,
ROB501H,
STA2101H.

Group 3: Modelling and Dynamics

AER506H, AER1503H, AER1512H,
JEB1444H
ECE1505H
MIE1001H

Group 4: Systems Design and Integration

AER525H (exclusion: ECE470H), AER1216H, AER1217H
CSC2606H, CSC2621H,
ECE470H (exclusion: AER525H)
MIE505H, MIE506H, **MIE1050H**, MIE1070H, MIE1075H, MIE1076H, MIE1080H, MIE1809H,
ROB521H, ROB1514H