UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

Report No. 3672 Revised

MEMORANDUM

To: Executive Committee of Faculty Council (November 5, 2020)
Faculty Council (December 2, 2020)

From: Professor Evan Bentz
Chair, Undergraduate Curriculum Committee

Date: November 5, 2020

Re: **Major Curriculum Changes for the 2021-2022 Academic Year**

REPORT CLASSIFICATION

This is a major policy matter that will be considered by the Executive Committee for endorsing and forwarding to Faculty Council for vote as a regular motion (requiring a simple majority of members present and voting to carry).

SUMMARY

The Undergraduate Curriculum Committee is tasked with managing the curriculum change process for the Faculty. This report summarizes course changes proposed for the 2021-2022 academic year.

PROCESS AND CONSULTATION

These changes have been reviewed and approved by the Undergraduate Curriculum Committee, which is comprised of faculty representatives from undergraduate programs; undergraduate student representatives; the Vice-Dean, Undergraduate Studies; The First Year Office; the Associate Dean, Cross-Disciplinary Programs; and the Registrar. The Committee meets regularly to review and approve proposed changes to the undergraduate curriculum. The impact of these changes on students in the relevant programs has been considered.

PROPOSAL/MOTION

THAT the proposed curriculum changes for the 2021-2022 academic year, as described in Report 3672 Revised, be approved as amended.

PROPOSED CURRICULUM CHANGES

1. ENGINEERING SCIENCE

Foundation Curriculum Changes

1.1 Update course description for **MAT292H1: Ordinary Differential Equations**

CURRENT: Existence and uniqueness of solution for first-order differential equations, general second-order linear ODEs, homogeneous equations, nonhomogeneous equations, variable coefficients, variation of parameters ODEs in matrix form, Fourier series, Fourier and Laplace transforms, optimization, single-variable functions, interpretation of problems in mathematical -s, multivariable functions, hessians, optimization in the presence of constraints, Lagrange multipliers, introduction to numerical methods, introduction to numerical and computational methods.

PROPOSED: Existence and uniqueness of solution for first-order differential equations, general second-order linear ODEs, homogeneous equations, nonhomogeneous equations, variable coefficients, variation of parameters, , Systems of ODEs, Fourier series, Laplace transform, interpretation of problems in mathematical terms, single-step numerical methods for ODEs. Introduction to Partial Differential Equations.

- *Red signifies text to be removed and green to be added. This text better represents what is covered through the present scope of the course.*

1.2 Update course exclusion for **ESC203H1: Engineering and Society**

CURRENT:
Recommended Preparation: ESC102H1

PROPOSED:
Recommended Preparation: ESC102H1
Exclusion: CME2XXH1 (Formerly APS301)

1.3 Move **ESC204H1: Praxis III** from the Second Year Winter term to Third Year Fall term (all Majors). **Move CHE374H1: Economic Analysis and Decision Making** from Third Year Fall term (all majors) to the Second Year Winter term.

- *This is a temporary change in response to COVID-19.*

Major Curriculum Changes

1.4 Update course description for **ESC384H1: Partial Differential Equations**

CURRENT: Introduces analytical techniques for partial differential equations (PDEs). Concepts covered include Fourier series, Sturm-Liouville theory, Green's functions, characteristics, and Laplace transform method. Applications are in model PDEs in continuum mechanics: diffusion, transport, heat, and wave equations.

PROPOSED: Introduces techniques to analyze and solve partial differential equations (PDEs). Concepts covered include Fourier series, Sturm-Liouville theory, separation of variables, fundamental solutions, Green's functions, method of characteristics, and numerical methods. Applications are in model PDEs in continuum mechanics: heat, Laplace's, wave, and transport equations.

- *The proposed description is more consistent with the material taught.*

Biomedical Systems Engineering

1.5 Update course description (including removing recommended preparation) for **BME396H1: Biomedical Systems Engineering III: Molecules and Cells**

CURRENT: A quantitative approach to understanding cell and molecular biology. Using engineering tools (especially derived from transport phenomena and chemical kinetics) to model molecular dynamics in living cells and make predictions about cellular behaviour. Specific topics include: receptor-ligand interactions, morphogens, trafficking, signal transduction, cell adhesion and migration, and mechanotransduction. Examples from in vitro tissue culture systems and model organisms in vivo are used.

Prerequisite: BME350H1, BME395H1
Recommended Preparation: BME225H1

PROPOSED: Understanding diversity of cell behaviour at the molecular level. Through discussion of molecular dynamics in living cells in the context of varied microenvironments, develop an understanding of cellular behaviour based on intracellular events in response to extracellular stimuli. Specific topics include receptor-ligand interactions, morphogens, signal transduction, cell growth & differentiation, cell adhesion and migration, trafficking, and mechanotransduction. Examples from in vitro culture systems and model organisms in vivo are used to support discussions.

Prerequisite: BME350H1, BME395H1

- *Course description being updated to reflect the updated course content.*

Electrical and Computer

1.6 Add new technical elective to the Electrical and Computer Engineering Major (electromagnetics and energy systems elective group): **ECE526H1: Power System Protection and Automation**

1.7 Add **ECE367 (Matrix Algebra and Optimization)** as technical elective (technical elective group)

- *New course being offered with relevance to the ECE major as a technical elective.*

1.8 Add new technical elective to the Electrical and Computer Engineering Major (computer hardware and computer networks elective group): **ECE532H1: Digital Systems Design**

- *Course is a common request for technical elective substitutions, adding it to the list based on student demand.*

1.9 Update course description for **ECE350H1: Semiconductor Electronic Devices**

CURRENT: An explanation of the basic operation, design and limitations of semiconductor electronic devices, such as diodes and transistors. The topics covered include: electrons in semiconductors, semiconductors in equilibrium, transport of carriers, p-n diodes, metal-semiconductor contacts, bipolar junction transistors, metal-oxide-semiconductor (MOS) capacitors, and MOS field effect transistors. In addition, optoelectronic devices (e.g. photodiodes, light emitting diodes and lasers), semiconductor heterostructures, nanostructures and transistor scaling will be discussed.

Prerequisite: PHY294H1
Exclusion: ECE335H1, ECE330H1

PROPOSED: An explanation of the basic operation, design and limitations of semiconductor electronic devices, such as diodes and transistors. The topics covered include: electrons in semiconductors, semiconductors in equilibrium, transport of carriers, p-n diodes, metal-semiconductor contacts, bipolar junction transistors, metal-oxide-semiconductor (MOS) capacitors, and MOS field effect transistors. In addition, optoelectronic devices (e.g. photodiodes, light emitting diodes and lasers), semiconductor heterostructures, nanostructures **(quantum dots, qubits)** and transistor scaling will be discussed.

Prerequisite: PHY294H1
Exclusion: ECE335H1, ECE330H1

- *Update to reflect current content covered in the course.*

Energy Systems Engineering

1.10 Update Year 3 Winter Term Core Curriculum – Remove **AER372H1: Control Systems** and replace with **ECE356H1: Introduction to Control Theory**

- *The ECE Control Systems course will better align with the ECE courses in the Energy Systems Major. An analysis of material has taken place, and students are well-prepared for the course. Graduating students suggested this change.*

1.11 Add new course to technical electives list: **ECE526H1: Power System Protection and Automation**

- *New course being offered with relevance to the Energy Systems Curriculum as a new possible technical elective.*

Machine Intelligence

1.12 Update course description, prerequisites, and title for **ECE324H1: Introduction to Machine Intelligence**

CURRENT: **ECE324H1: Introduction to Machine Intelligence**

Provides students with an introduction to machine learning engineering, as a software and engineering discipline. It focuses on the neural network method. Lectures will cover the basic mathematics and intuitions behind neural networks, in particular deep convolutional neural networks, and their application as classifiers and predictions using regression. There will be a focus on conveying known methods to make neural network training succeed. Other topics may include Natural Language Processing basics, recurrent neural networks, transfer learning and generative adversarial networks. There will be reflection on ethics in machine learning. A significant component of the course will be hands-on exposure to a machine-learning software framework, culminating in a design project.

PROPOSED: **ECE324H1: Machine Intelligence, Software and Neural Networks**

Focuses on machine learning engineering, through the sense of neural networks, dealing with the data collection and software development as an engineering discipline. After reviewing the essentials of the neural network approach, including convolutional and recurrent neural networks, the course will focus on applications of classification, regression and various kinds of prediction. Practical techniques in machine learning will be covered, including data collection, data augmentation, the use of pre-trained networks, auto encoders and generative adversarial networks. A key topic will include natural language processing, attention and Transformer networks. There will be reflection on ethics in machine learning. A significant component of the course will be hands-on exposure to a machine-learning software framework through assignments and a major design project.

Prerequisite: ESC190H1, ECE286H1, ECE421H1
Exclusion: APS360

- *Update includes the addition of prerequisites, (which were already added to the calendar), to better reflect the required background for the course. The description change reflects an update to practice, and a better differentiation from another course in the Major.*

1.13 Update Machine Intelligence Core Curriculum:

a. Year 4: Current

One of:
ECE419H1: Distributed Systems
ECE454H1: Computer Systems Programming

Proposed:

One of:
ECE352H1: Computer Organization
ECE419H1: Distributed Systems

b. Move **ECE324H1: Introduction to Machine Intelligence** to the Winter term, with **ECE421H1: Introduction to Machine Learning** moving to the Fall term

1.14 Add new course to technical electives list: **ECE454H1: Computer Systems Programming**

- *These changes are the result of extensive feedback collection process with students. Students have indicated that they would like more background on Machine Learning before taking ECE324, which is project-based. The year 4 technical elective change reflects concern that some (but not all) students do not feel prepared for ECE419/ECE454, and offers them a more introductory course in the area.*

Robotics Engineering

1.15 Update prerequisites for **ROB501H1: Computer Vision for Robotics**

CURRENT:
Prerequisite: ROB301H1
Exclusion: CSC420H1
Recommended Preparation: CSC263H1

PROPOSED:
Prerequisite: ROB301H1/**ECE324H1**
Exclusion: CSC420H1
Recommended Preparation: CSC263H1

- *Update prerequisites for Machine Intelligence students, who can take this course as a technical elective.*

1.16 Update course exclusion for **ROB313H1: Introduction to Learning from Data**

CURRENT: This course will introduce students to the topic of machine learning, which is key to the design of intelligent systems and gaining actionable insights from datasets that arise in computational science and engineering. The course will cover the theoretical foundations of this topic as well as computational aspects of algorithms for unsupervised and supervised learning. The topics to be covered include: The learning problem, clustering and k-means, principal component analysis, linear regression and classification, generalized linear models, bias-variance tradeoff, regularization methods, maximum likelihood estimation, kernel methods, the representer theorem, radial basis functions, support vector machines for regression and classification, an introduction to the theory of generalization, feedforward neural networks, stochastic gradient descent, ensemble learning, model selection and validation.

Prerequisite: ECE286H1, MAT185H1, MAT195H1, CSC263H1/ECE358H1
Exclusion: ECE421H1, CSC411H1

PROPOSED: This course will introduce students to the topic of machine learning, which is key to the design of intelligent systems and gaining actionable insights from datasets that arise in computational science and engineering. The course will cover the theoretical foundations of this topic as well as computational aspects of algorithms for unsupervised and supervised learning. The topics to be covered include: The learning problem, clustering and k-means, principal component analysis, linear regression and classification, generalized linear models, bias-variance tradeoff, regularization methods, maximum likelihood estimation, kernel methods, the representer theorem, radial basis functions, support vector machines for regression and classification, an introduction to the theory of generalization, feedforward neural networks, stochastic gradient descent, ensemble learning, model selection and validation.

Prerequisite: ECE286H1, MAT185H1, MAT195H1, CSC263H1/ECE358H1
Exclusion: ECE421H1, CSC411H1, **STA314H1**

1.17 Create new course: **ROB4XXH1: Robotics Capstone Design**

The Robotics Capstone Design course is structured to provide students with an opportunity to integrate and apply the technical knowledge gained throughout their degree program towards the solution of a challenging real-world robotics problem. During the half-year course, students work in small teams and have considerable freedom to explore the design space while developing a complete robotic hardware and software system. The challenge task incorporates all aspects of the "sense-plan-act" robot design paradigm, with designs assessed based on engineering quality and performance relative to a series of benchmarks. In addition, each student completes a critical reflection on their team's performance and the evolution of their experience

with design during their undergraduate program. Students are supported by a teaching team comprised of domain experts.

Prerequisites: ROB301, ROB310, ROB501

2. CHEMICAL ENGINEERING & APPLIED CHEMISTRY

Formal statement: The shifting of courses is due to the pandemic and will only be a one-off shift. The need of shifting laboratory courses is due to the challenge to meet the learning objectives and outcomes, as our operation is virtual learning into the Winter 2021 semester. There is no change in naming, course description nor course weighting.

Shifts for the current second year cohort

2.1 Move **CHE205H1S: Chemical Engineering and Applied Chemistry- Laboratory II** (1/3/0/0.25) to the Fall 2021 from Winter 2021

- *Moving this second year lab course will enable the second year cohort to better meet their learning objectives and outcomes. The movement of this course assumes we will be fully back and operational for Fall 2021. This laboratory course will be delivered in Fall 2021 along with CHE304 "Chemical Engineering and Applied Chemistry - Laboratory III" and instructors will work collaboratively to coordinate delivery of each laboratory course.*

- *This is a temporary change in response to COVID-19.*

2.2 Move **CHE399H1F: Professional Engineering Consultancy** (1/0/2/0/0.25) to Winter 2021 from Fall 2021

- *Moving this third year course into the Winter 2021 and delivered to the second year cohort will fill the gap for the Winter 2021 and open a gap for the Fall 2021 to enable CHE205 to be delivered in the Fall 2021. The course weighting is equivalent and this course has a different learning outcomes than the fundamental courses delivered in the winter of the second year of CHE. This course can be delivered virtually and learning objectives can be met.*

- *This is a temporary change in response to COVID-19.*

2.3 Open up **Complementary Studies/Humanities and Social Sciences Elective (0.5)** to the second year cohort

- *This is normally offered in the fall of their third year. This will be **optional** should students be interested in extra load for Winter 2021 to relieve load for Fall 2021 given the presence of two laboratory courses.*

- *This is a temporary change in response to COVID-19.*

Given these shifts, the current second year cohort will be back onto the normal curriculum map for the beginning of Winter 2022.

Shifts for the current third year cohort

2.4 Move **CHE305H1S: Chemical Engineering and Applied Chemistry - Laboratory IV** (0/6/0/0.5) to the Fall 2021 from Winter 2021

- *Moving this third year lab course will enable the third year cohort to better meet their learning objectives and outcomes. This movement of this course assume we will be fully back and operational for Fall 2021.*

- *This is a temporary change in response to COVID-19.*

2.5 Move **CHE403H1S: Professional Practice** (2/0/0/0) to the Winter 2021 from Winter 2022

- *This course is typically offered in the Winter of the fourth year of CHE. There is no prerequisite for it. This course will be offered to the third year cohort to fill the gap for the Winter 2021 and will be co-delivered with the fourth year cohort.*

- *This is a temporary change in response to COVID-19.*

2.6 Move **CHE430: Chemical Plant Design** (2/0/6/1.0) to Winter 2022 from Fall 2021 *but continue to offer a Fall 2021 slot of CHE430 for certain student circumstances and continue consultations with the Chemical Engineering student body*[1]

- *As CHE305 is moved to Fall 2021 we will move CHE430 Chemical Plant Design to the Winter 2022 (normally delivered in the Fall semester). This movement was to balance work load on key/core chemical courses/learning outcomes.*

- *This is a temporary change in response to COVID-19.*

Given these shifts, there are still things to consider as PEY student return in the Fall 2022. This is an ongoing action item.

[1] The red text in 2.6 was added by motion to amend at the Faculty Council meeting of December 2, 2020.

2.7 Move **Free Elective** (x/x/x/0.5) to Fall 2021 from Winter 2022

- *As CHE430 is moved the winter of 2022, we will move the Free Elective to the fall term (normally available in the winter semester). This movement was to also balance work load for students are they are taking the key fourth year core course CHE430: Chemical Plant Design.*

- *This is a temporary change in response to COVID-19.*

3. MECHANICAL AND INDUSTRIAL ENGINEERING

3.1 New Course Proposal: **MIE5XXH1: Finite Element Analysis in Engineering Design** (Fall)

PROPOSED description: Finite Element Method (FEM) is a very powerful numerical tool that has a wide range of applications in a multitude of engineering disciplines; such as mechanical, aerospace, automotive, locomotive, nuclear, geotechnical, bioengineering, metallurgical and chemical engineering. Typical applications include: design optimisation, steady and transient thermal analysis/stress analysis, wave propagation, natural frequencies, mode shapes, crashworthiness analysis, nuclear reactor containment, dynamic analysis of motors, manufacturing process simulation, failure analysis, to name a few. The focus of this course is to provide seniors and graduate students with a fundamental understanding of the principles upon which FEM is based, how to correctly apply it to real engineering problems using a commercial code. Specifically, participants will learn the principles governing model generation, discretization of a continuum, element selection, applying the loads and the constraints to real world problems. Participants will also learn how to scrutinize their model predictions, and avoid the pitfalls of this essential design tool.

PROPOSED prerequisites: A solid grasp of fundamentals of engineering sciences, calculus and mechanics typically covered in senior years of undergraduate engineering curricula and graduate students with the appropriate degrees.

- *MIE has received interest to offer this course at both the undergraduate and graduate level.*

3.2 Change prerequisites for **MIE424H1: Optimization in Machine Learning** from **MIE365 or MIE376** or equivalent to **MIE365/MIE376/ECE367/ROB310** or equivalent

- *Expand accessibility of course to other majors.*

3.3 Change prerequisites for **MIE368H1: Analytics in Action** from **MIE237H1, MIE262H1, MIE263H1** to **MIE237/ECE286, MIE262/MIE376, MIE263/STA347**, or permission of the instructor

- *Expand accessibility of course to other majors.*

3.4 Change course description for **MIE451H1: Decision Support Systems**

CURRENT: This course provides students with an understanding of the role of a decision support system in an organization, its components, and the theories and techniques used to construct them. The course will cover basic technologies for information analysis, knowledge-based problem solving methods such as heuristic search, automated deduction, constraint satisfaction, and natural language understanding.

PROPOSED: Provides students with an understanding of the role of a decision support system in an organization, its components, and the theories and techniques used to construct them. Focuses on information analysis to support organizational decision-making needs and covers topics including information retrieval, descriptive and predictive modeling using machine learning and data mining, recommendation systems, and effective visualization and communication of analytical results.

- *Update the course description to better fit a modern data-driven perspective of decision support systems.*

3.5 Add prerequisite **MIE346: Analog and Digital Electronic for Mechatronics** to **MIE404H1 Control Systems I**

- *MIE346 and MIE404 are a sequence of mandatory courses for students enrolled in the Mechatronics stream. MIE404, the second half of the stream, requires the content of MIE346 as prerequisite preparation, which previously had not been explicitly specified.*

3.6 New course proposal for **APS5XXH1: Inventions and Patents for Engineers** (Winter)

PROPOSED description: Teaches the process of preparing a patent application for an invention for engineers and scientists. Teaches methods to take an invention from conception to a level that a patent application can be filed on it. Describes how to write an invention disclosure. Describes how to prepare the background section, brief listing of figures, detailed description of the invention, independent and dependent claims, abstract, and artwork. Teaches use of patent search engines.

PROPOSED prerequisites: None

- *There is perceived demand throughout engineering for a general course on patenting inventions.*

3.7 Change title, description and course hours for **MIE566H1: Decision Analysis**

CURRENT title: **MIE566H1: Decision Analysis**

PROPOSED title: **MIE566H1: Decision Making Under Uncertainty**

CURRENT description: The purpose of this course is to provide a working knowledge of methods of analysis of problem and of decision making in the face of uncertainty. Topics include decision trees, subjective probability assessment, multi-attribute utility approaches, goal programming, Analytic Hierarchy Process and the psychology of decision making.

PROPOSED description: Methods of analysis for decision making in the face of uncertainty and opponents. Topics include subjective discrete and continuous probability, utility functions, decision trees, influence diagrams, Bayesian networks, multi-attribute utility functions, static and dynamic games with complete and incomplete information, Bayesian games. Supporting software.

CURRENT hours: (LEC/PRA/TUT): 3/-/2

PROPOSED hours: (LEC/PRA/TUT): 3/2/2

- *The description change reflects modern theory and practice in the area of decision analysis and the name change better reflects modern recognized terminology for the course content. The added PRA hours reflect the addition of hands-on instruction to apply theory taught in the course.*

3.8 Change title, course code, description, and prerequisites for **MIE508H1: Fluids of Biological Systems** plus consequent changes to 4F Bioengineering stream core and elective courses

CURRENT course code and title**: MIE508H1: Fluids of Biological Systems**

PROPOSED course code and title: **MIE4XXH1: Biofluid Mechanics**

CURRENT description: This course will teach students how to apply fundamental fluid mechanics to the study of biological systems. The course is divided into three modules, with the focus of the first two modules on the human circulatory and respiratory systems, respectively. Topics covered will include blood rheology, blood flow in the heart, arteries, veins and microcirculation, the mechanical properties of the heart as a pump; air flow in the lungs and airways, mass transfer across the walls of these systems, the fluid mechanics of the liquid-air interface of the alveoli, and

artificial mechanical systems and devices for clinical aid. The third and final module will cover a range of other fluid problems in modern biology.

PROPOSED description: Application of fundamental fluid mechanics to the study of biological systems. Review of basic fluid mechanics principles and governing equations, and introduction to advanced topics including blood rheology and viscoelastic materials. Analysis of blood flow in the heart, arteries, veins and microcirculation, mechanical properties of the heart as a pump, air flow in the lungs and airways, mass transfer across the walls of these systems, fluid mechanics of the liquid-air interface of the alveoli, and artificial mechanical systems and devices for clinical aid. Other biofluids such as bone marrow, mucus, sweat, tears, and synovial fluid in joints will also be discussed.

CURRENT prerequisites: None

PROPOSED prerequisites: MIE312 or equivalent

PROPOSED stream change: Replace Bioengineering stream 4F core course **MIE520H1: Biotransport Phenomena** with this newly proposed **MIE4XXH1: Biofluid Mechanics** and move **MIE520H1: Biotransport Phenomena** to an elective option in 4W

- *These changes reflect an effort to provide a more logical progression for the biology fluids side in the Bioengineering stream by making "MIE4XXH1: Biofluid Mechanics" an introductory core course in 4F and moving the more advanced course (MIE520H1) to an elective option in 4W.*

4. CIVIL & MINERAL ENGINEERING

Civil Engineering

4.1 **APS301: Technology in Society and the Biosphere I** renumber course to **CME2XX**

- *Instructor currently teaching this course has challenging load in the fall and for this and content delivery reasons it would be helpful to have this course in the Winter term.*

4.2 Move **CME2XX: Technology in Society and the Biosphere I** to Winter term from Fall

- *Rename course as it is proposed to be core for all second year CIV and MIN students.*

4.3 Move **CIV235: Civil Engineering Graphics** to Fall term from Winter

- *This will balance the change from item 4.1.*

Mineral Engineering

4.4 Withdraw **MIN225: Introduction to the Resource Industries** from 2F, replace with **MSE202: Thermodynamics I**

- *Required modification: change to term 2F.*

- *Curriculum changes implemented in 2020-2021 in response to course revisions made by the Department of Earth Sciences now require a change to term 2F for 2021-2022 onwards. This was anticipated and planned for at the time of proposing the 2020-2021 changes.*

- *The 2020-2021 change replaced MIN225 (2F) with MIN120 (1S); it is now necessary to make a concomitant change to 2F and the proposal is to withdraw MIN225 and replace it with MSE202 Thermodynamics (currently offered in 3F). Alternatives to this moving of MSE202 have been examined in detail, but as all would require significant additional changes to the curriculum they have been deferred pending further overall review of the curriculum.*

- *Moving MSE202 will require changes to term 3F in 2022-2023; these will be examined during summer 2021 and presented in October 2021.*

4.5 Replace existing **2S HS/CSS** elective with core course **CME2XX: Technology in Society and the Biosphere I**

- *Proposed modification: compulsory 2S HSS course CME2xx* Technology in Society and the Biosphere I.

- *Currently, term 2S contains a CS/HSS elective. The CIV program includes the compulsory HSS course APS301 Technology in Society and the Biosphere I which, for operational reasons, is proposed to move to 2S. Paraphrasing the course description, APS301 "teaches future engineers to look beyond their specialized domains of expertise in order to understand how technology functions within human life, society and the biosphere. By providing this context for design and decision-making, students will be enabled to... [prevent or significantly reduce] undesired consequences". This course is thus appropriate for the MIN program. Furthermore, the APS301 instructor has indicated that the course content would be modified to explicitly include material of direct relevance to mineral engineering should the MIN program adopt the course. The proposal is therefore to replace the existing term 2S CS/HSS elective with the HSS compulsory course CMExx Technology in Society and the Biosphere I (the course would be*

renumbered from APS301 to CME2xx in recognition of it being a core course for both the CIV and MIN programs).

Should 3.4 and 3.5 be accepted, the year 2 curriculum will be as follows (changes shown in bold):

Year 2 Fall		**Year 2 Winter**	
Solid Mechanics I	CME210	Engineering Mathematics II	CME262
Engineering Mathematics I	CME261	Prob. Theory for Civil and Mineral Engineers	CME263
Fluid Mechanics I	CME270	Rocks and Minerals	ESS224
Earth Systems Processes	ESS262	Surface Mining	MIN250
Thermodynamics	***MSE202***	***HSS: Tech. in Society & the Biosphere I***	***CME2XX***

4.6 Move **MIN565: Design and Support of Underground Mine Excavations** to term 4F from term 4S

- *Proposed modification: MIN565 term change.*

- *Material contained in MIN565 Design and Support of Underground Mine Excavations, currently offered in term 4S, is needed in the 4S capstone course. To better prepare students for the term 4S capstone course, it is proposed to move MIN565 to term 4F.*

4.7 Add the following courses to the list of recognised technical electives:

Term 4F

CIV420: Construction Engineering
ESS452: Geophysical Imaging with Non-seismic Methods
CIV300: Terrestrial Energy Systems

Term 4S

CIV300: Terrestrial Energy Systems
CIV580: Engineering and Management of Large Projects
CIV440: Environmental Impact and Risk Assessment
APS502 Financial Engineering

- *Proposed modification: revision of technical elective list.*

- *Over the past few years a number of courses that are not part of the list of recognised technical electives have become popular with MIN students. It is therefore proposed to update the list of recognised technical electives to acknowledge this.*

4.8 Add the following statement to the Calendar:

"Technical Electives outside of the group of courses listed below must be approved in advance. Students wishing to take elective courses from other departments need to ensure that they have the appropriate background and prerequisites. Students with an overall average of 75% or greater in their third year may take up to two graduate level (1000-series) courses, depending upon availability. In all cases the interested student should consult with the Department's Office of Student Services (GB116) to obtain further information and the appropriate permission."

- *Calendar maintenance: revision of Calendar entry.*

- *The MIN program is currently unique in not indicating in the Calendar whether or how students can select technical electives that are not shown on the list of recognised courses. The other engineering programs allow such selection by permission of the Associate Chair, and the MIN program has informally been using this procedure for some time. To formalise and clarify the current procedure it is proposed to modify the Calendar by including a statement that is derived from those used by other programs.*

5. FIRST YEAR OFFICE

First-Year Core-8/Track 1

5.1 COVID-19 special one-term change to add 1 HR/week Practical to **MAT187: Calculus II** course

- *To accurately reflect the pedagogical approach on student timetables.*

- *This is a temporary change in response to COVID-19.*

6. MATERIALS SCIENCE & ENGINEERING

6.1 Move **MSE318H1S** to **MSE218H1S: Phase Transformations** from 3S to 2F, Add 2h lab, update course description

- *During our curriculum review it was identified that MSE 316 (Mechanical Behaviour of Materials) should build on many of the concepts taught in MSE318. MSE318 will be moved to the spring of second year and renamed MSE218.*

6.2 Add 1a hour lab to **MSE298H1Y: Communications** 1/1a/1/0.5

- *This change is largely in response to industry feedback as well as requests from undergraduates to have increased exposure to CAD software.*

6.3 Add 2h hour lab to **MSE316H1F: Mechanical Behaviour of Materials** 3/2/1/0.5

- *Laboratory activities that had been moved into MSE398 are now being moved back into this course to facilitate a better connection between the labs and lectures.*

6.4 Move **MSE351H1F: Design and Simulation of Materials Processes** 3/2/1/0.5 to the Fall term

- *Moving this course from Winter to Fall to allow better integration with the project work in MSE398 in the winter.*

6.5 Move **MSE332H1S: Heat and Mass Transfer for Materials Processing** 3/-/2/0.5 to Winter term

- *Moving to account for MSE351 moving to Fall term.*

6.6 Change course title for and add description to **MSE398Y1Y: Materials Manufacturing and Design** 2/4/-/1.0

- *Reference to "Laboratory" removed from title to better reflect design focus, with traditional laboratories moving back to their originating courses.*

6.7 Change course description for **MSE401: Materials Selection in Design**

- *Reduce emphasis in description on CES software and include reference to AI and machine learning as new topics taught.*

6.8 New Course: **MSE4XX: Data Sciences and Analytics for Materials Engineers**

7. ELECTRICAL AND COMPUTER ENGINEERING

7.1 New course: **ECE295H1: Hardware Design and Communication**

PROPOSED description:
This course is an introduction to engineering design processes, illustrated through the design and implementation of a hardware system. In addition to familiarizing students with hardware design practices, tools, and skill sets, it also aims to develop effective oral and written communication in a team context. Principles of hardware design, project management and teamwork are developed in the lectures and tutorials, and students apply these concepts in the laboratories as they work in a team to design and implement a complex hardware system. Students learn and

practice oral and written communication techniques in lectures and in meetings with their communication instructor, and apply these techniques in a variety of documents and presentations, such as short status reports and longer design proposals and design reviews. The learning outcomes for the course are as follows. By the end of this course, students will be able to: 1. Work in a team environment in developing a complex hardware project; 2. Intepret design specifications and translate them into a design that attempts to achieve them; 3. Be familiar with agile methods in hardware development, and apply ideas from these methods in their own design process with their team; 4. Demonstrate proficiency using computer aided design (CAD) and electronic design automation (EDA) techniques for hardware development, in particular, schematic capture and printed circuit board layout tools; 5. Demonstrate ability to solder components, familiarity with surface-mount technology, and awareness of the restriction of hazardous substances directive (RoHS); 6. Be familiar with electrostatic discharge (ESD) handling guidelines and protection; 7. Confidently use using laboratory instruments and apply them for testing circuits and systems; 8. Assemble instruments and controlling software for the purpose of automated hardware testing (test automation); 9. Be aware of standards and regulatory compliance when pursuing industrial design; and 10. Demonstrate confidence preparing oral presentations and written documents on technical engineering hardware design.

PROPOSED prerequisites: ECE212H1, ECE241H1, ECE244H1
PROPOSED exclusion: ECE297H1

- *This course will be been introduced to run in parallel with ECE297 which has a software focus. There is a desire in the department to better prepare/expose students to the hardware side (EE) of ECE at an early stage. The course was developed with broad consultation within the department and all affected instructors. Students will select between ECE297 and ECE295 (Hardware design and communication).*

7.2 Move **ECE526H1: Power System Protection and Automation to the Fall term in 2021**

- *The course has already been approved and will be offered for the first time next term. We are now requesting to move it to the Fall term in 2021, to better accommodate graduate students who need this as background knowledge for other graduate courses in the Winter term.*

7.3 Change course description for **MAT291H1: Calculus III**

CURRENT: The chain rule for functions of several variables; the gradient. Multiple integrals; change of variables, Jacobians. Line integrals, independence of path, Green's theorem. The gradient, divergence and curl of a vector field. Surface integrals; parametric representations, applications from electromagnetic fields, Gauss' theorem and Stokes' theorem. Maxima and minima, Lagrange multipliers.

PROPOSED: The chain rule for functions of several variables; the gradient. Multiple integrals; change of variables, Jacobians, line integrals, the divergence and curl of a vector field. Surface integrals; parametric and explicit representations, Divergence theorem and Stokes' theorem and applications from electromagnetic fields and Green's theorem.

- *We are requesting a course description modification to remove 'Lagrange multipliers' from the course as a result of 3 lost lectures from the Fall reading week. Downstream course instructors have been consulted and agreed that the topic is treated elsewhere.*

7.4 New course description for **ECE427: Photonic Devices**

CURRENT: Introduction to photonic devices and components useful in a wide range of applications from bio-sensors to optical communications. Fundamentals in the operation and design of the devices will be covered. Topics include: electromagnetic waves; birefringence and polarization; periodic structures and thin films; optical waveguides; interferometers and resonators; couplers and splitters; amplifiers and lasers; photonic intergration; nano-photonics.

PROPOSED: The human visual interface is rapidly evolving with the emergence of smart glasses, AR/VR wearable display, and autonomous vehicles. This course examines the photonic devices and integrated systems that underlie such technologies, and how they are shaped by human visual perception and acuity. Advanced integrated photonic systems in optical display and sensing will be deconstructed and the underlying fundamental concepts studied. Topics include introduction to: heads up and wearable display, optical lidar, optical fiber, waveguide circuits, holography, optical switches, light sources (LED, laser), detectors and imaging sensors.

- *This course has not been offered for a few years due to low enrollment. Regretfully, the number of active photonics courses is below critical and we have been reviewing how we may attract more students so we can provide a minimal background for photonics engineering. The approach here is to present the existing course content from a technology point of view rather than on a*

physics fundamentals view. The fundamentals are now taught by reverse engineering of state of the art photonic systems such as head up display, AR/VR near-eye display, autonomous vehicles, etc.

7.5 Update list of pre-requisites for **ECE295: Hardware Design and Communication** (remove APS112) to include **ECE212H1, ECE241H1, ECE244H1** and exclude **ECE297**

- *Based on the hardware design in the course, we have selected the minimum set of courses (or equivalent) that is needed. This can address special cases (transfer students, etc.) who may not have sufficient background in hardware/circuits.*

7.6 Update list of pre-requisites for **ECE297: Software Design and Communication** to include **ECE244** and exclude **ECE295**

- *Based on the introduction of the new course ECE295, we need to exclude ECE295 from ECE297 due to overlap in some of the non-technical content (ie: communication aspects). We intend that students take one or the other. In order to be consistent with ECE295 pre-requisites, we have re-examined the core software oriented courses needed for ECE297; these include ECE244 (new addition as a pre-req) and we keep APS105 (existing pre-req).*

7.7 Remove course **ECE442: Introduction to Micro- and Nano-Fabrication Technologies**

- *There has been very little interest in this course, and has resulted in the course being cancelled for the last 5 years. There has always been hesitation in removing it because it is a core course in the Nano-engineering minor. The minor has adapted so now people take this course or do a thesis/capstone that is based on a Nano topic.*

8. CROSS DISCIPLINARY PROGRAMS[2]

Environmental Engineering Minor

8.1 Switch **APS301H1 F** to **CME2XXH1 S: Technology in Society and the Biosphere I** (CIV curriculum change)

AI Engineering Minor

8.2 Add **MIE562H1: Scheduling** to Category 5 (addition requested by MIE)

[2] Item 8.11 "Remove pre-requisites for APS321H1S: Representing Science and Technology in the Popular Media from course calendar", which was in the original Report 3672R, was removed on December 7, 2020 as it had been included in error.

8.3 Add **ECE353H1: Systems Software** to Category 6 - Eng Sci equivalent of ECE344H1 Operating Systems (Core 8)

Engineering Business Minor

8.4 **APS5XXH1: Inventions and Patent for Engineers** (MIE new course)

Advanced Manufacturing Minor

8.5 Add **MIE5XXH1: Finite Element Analysis** as an Advanced Elective (MIE new course)

Nanoengineering Minor

8.6 Delete **ECE442H1: Introduction to Micro- and Nano-Fabrication Technologies** from Requirement #2 (ECE deleting course) – Course has not been offered in last 5 years, and a replacement for the requirement had already been approved/implemented

Forensic Engineering Certificate

8.7 Add **MSE401H1: Materials Selection in Design** (student requested and approved by D Perovic)

8.8 Add **MSE415H1: Environmental Degradation of Materials** (student requested and approved by D Perovic)

Mineral Engineering Certificate

8.9 Revamped by MIN due to curriculum change and desire to attract more students, implementing "thematic" course path

1. MIN120H1
2. MIN250, MIN351/MIN301, MIN450/MIN250,MIN330/MIN301,MIN33

Course Changes

8.10 **APS360H1: Applied Fundamentals of Machine Learning** prerequisite changes.

- *Following from course description and title changes last March, the way the course is now taught, there is less emphasis on the theoretical background that necessitated the stats/probability background for this course – move to "recommended prep" (n.b. still necessary for downstream courses!). "Corequisite" never really made sense. Minimum pre-requisite background is first year programming, calc 1, calc 2, linear algebra.*

CURRENT

Prerequisite:
CHE223H1/CME263H1/ECE302H1/MIE231H1/MIE236H1/MSE238H1/STA286H1/ECE286H1
Corequisite: Course in Python, differential and integral calculus, linear algebra

PROPOSED

Prerequisite: APS105H1/APS106H1/ESC180H1/CSC180H1; (programing)
(MAT186H1,MAT187H1)/(MAT194H1,MAT195H1)/(ESC194H1, ESC195H1); (Calc 1, Calc 2)
MAT185H1/MAT188H1 (lin alg)
Recommended preparation:
CHE223H1/CME263H1/ECE302H1/MIE231H1/MIE236H1/MSE238H1/STA286H1/ECE286H1

9. <u>BME</u>

9.1 Update course description for **BME331H: Physiological Control Systems**

CURRENT: This course introduces physiological concepts and selected physiological control systems present in the human body to undergraduate students. The course is organized into four parts: (1) introduce physiology and give an overview of the main physiological systems, (2) introduce endocrine system and its subsystems, including glucose regulation, thyroid metabolic hormones, and the menstrual cycle, (3) introduce cardiovascular system and related aspects such as cardiac output, venous return, control of blood flow by the tissues, and nervous regulation of circulation, and (4) introduce central nervous system, the musculoskeletal system, proprioception, kinaesthetic, and control of voluntary motion. These topics allows us to combine linear control theory, physiology, and neuroscience with the objective of explaining how these complex systems operate in a healthy human body.

PROPOSED: Introduces physiological concepts and selected physiological control systems present in the human body, and proposes quantitative modeling approaches for these systems. Topics covered will include (1) the endocrine system and its subsystems, including glucose regulation and the stress response, (2) the cardiovascular system and related aspects such as cardiac output, venous return, control of blood flow by the tissues, and nervous regulation of circulation, and (3) the nervous and musculoskeletal systems, including the control of voluntary motion. Linear control theory will be used to develop skills in system modeling and examine concepts of system response and system control in the context of a healthy human body.

- *The instructor would like to change the description as the current description underemphasizes the control theory portion, which is ~40% of the course.*

9.2 Update course description for **BME352H: Biomaterials and Biocompatibility**

CURRENT: The course presents an introduction to the field of biomaterials, covering also the relevant basics in materials science and biology. Topics include the physical and chemical principles of materials science, structure-property relations, biomaterials processing and degradation. Cell/tissue biomaterials interactions will be discussed as determinants of biocompatibility.

PROPOSED: An introduction to the science of biomaterials, focusing on polymeric biomaterials and biocompatibility. Topics include biomaterial surface analysis, hydrogel rheology and swelling, protein adsorption, cell adhesion and migration and the foreign body response. Primary focus is on implantable biomaterials but some attention will be given to applications of biomaterials in biotechnology and drug delivery. Specific device or other examples as well as the research literature will be used to illustrate the topic at hand.

- *Previous versions of the course had a material science focus. Now the emphasis has shifted to the "bio" in biomaterials, consistent with the course being a BME course and the change in instructor. Similarly, the shift to surface science and interface biology provides the opportunity to integrate the course with others in the BME curriculum.*

9.3 Update course description for **BME440H: Biomedical Engineering Technology and Investigation**

CURRENT: An introduction to the principles of fundamental technologies used in biomedical engineering research including but not limited to tissue culture, protein assays or colourimetric enzymatic-based assays, spectroscopy, fluorescence microscopy, PCR, electrophoresis, DNA manipulation and transfection. Since these technologies enable the investigation of a wide range of research questions with important clinical implications, the main focus of the course is learning these technologies while subsequent application within the lab will allow evidence-based investigation into specific research questions. Scientific literature (both good and bad) pertaining to each technology will be reviewed as examples of conducting investigations.

PROPOSED: Fundamental biomedical research technologies with specific focus on cellular and molecular methodologies. Examples include DNA and protein analysis and isolation, microscopy, cell culture and cellular assays. Combines both theoretical concepts and hand-on practical experience via lectures and wet labs, respectively. Specific applications as applied to biotechnology and medicine will also be outlined and discussed.

- *Instructor wanted to update what was being taught as the course description from last year contains MRI and Ultrasound, which is no longer being taught.*

9.4 Update course description for **BME498Y: Biomedical Engineering Capstone Design**

CURRENT: In this project-based design course teams of students from diverse engineering disciplines (enrolled in the biomedical engineering minor) will engage in the bio-medical technology design process to identify, invent and implement a solution to a unmet clinical need. The students will learn about medical technology development and will engage in the process through lectures, guest lectures delivered by medical technology experts, "hands-on" practicums and a student driven design project. *Approval to register in the course must be obtained from the Associate Chair, IBBME - Undergraduate*.

PROPOSED: In this project-based design course, teams of students from diverse engineering disciplines (enrolled in the biomedical engineering minor) will engage in the biomedical technology design process to identify, invent and implement a solution to an unmet clinical need defined by external clients and experts. This course emphasizes "hands-on" practicums and lectures to support a student-driven design project. The UG Office will reach out in the summer to 4th year BME Minor students regarding course registration. For A&S students, approval to register in the course must be obtained from the course instructor by completing the application available through the BME UG Office.

- *We no longer have an Associate Chair of Undergrad at BME so have updated the description with what we would like students to do for course enrollment.*

9.5 Update course description for **BME455H: Cellular and Molecular Bioengineering II**

CURRENT: Quantitative approach to understanding cellular behaviour. Using engineering tools (especially derived from transport phenomena and chemical kinetics) to integrate and enhance what is known about mammalian cell behaviour at the molecular level. The course combines mathematical modeling with biology and includes numerical methods, factorial design, statistics, empirical models, mechanistic models and mass transfer. Specific topics include: receptor-ligand interactions, cell adhesion and migration, signal transduction, cell growth and differentiation. Examples from gene therapy, and cellular and tissue engineering are used.

PROPOSED: Engineering and biophysical tools are used to integrate and enhance our understanding of animal cell behaviour from the molecular to the tissue level. Quantitative methods are used to mathematically model the biology of cell growth, division and differentiation to tissue formation. Specific topics include receptor-ligand interactions, cell adhesion and migration, signal transduction, cell growth and differentiation. Examples from the literature are used to highlight applications in cellular and tissue engineering.

- *Instructor edited his course description to be less ambiguous and more succinct.*

9.6 Update course description for **BME595H: Medical Imaging**

CURRENT: This is a first course in medical imaging. It is designed as a final year course for engineers. It has a physical and mathematical approach emphasizing engineering concepts and design. It describes magnetic resonance and ultrasound and X ray imaging in detail. These topics allow engineers to apply principles learned in the first two years in: computer fundamentals, dynamics, calculus, basic EM theory, algebra and differential equations, signals systems. It is a depth course complementing the kernels: communication systems (modulation), fields and waves (wave propagation) and on probability and random processes (Poisson and Gaussian noise). It will introduce students to the concept of measurement as an "inverse problem". The laboratory will involve hands on NMR and Ultrasound measurements as well as image analysis of MRI data.

PROPOSED: An introductory course to medical imaging and is designed as a final year course for engineers. The main clinical imaging modalities are covered: magnetic resonance imaging, ultrasound imaging, x-ray and computed tomography, nuclear medicine, and clinical optical imaging. Emphasis is placed on the underlying physical and mathematical concepts behind each modality, and applications are discussed in the context of how different modalities complement one another in the clinical setting. Early year engineering concepts are extensively used, including: basic electromagnetics theory, fields and waves, signals and systems, digital signal processing, differential equations and calculus, and probability and random processes. The laboratories involve image reconstruction and analysis for the various imaging modalities and a live animal imaging session.

- *The main reason she edited the course description is to better reflect the content, which places more emphasis on clinical medical imaging modalities (therefore, MRI/CT/PET/ultrasound were all augmented but microscopy was eliminated).*

- *There were several other reasons for this change. First, students complained about the microscopy section year to year, saying it was disconnected (and it was). Second, "medical imaging" does not include microscopy. Third, other BME courses cover microscopy. Fourth, there were too many modalities at the expense of going sufficiently deep into any one modality. With the removal of 3 weeks' lectures on microscopy, she can now go deeper into MRI, CT, and ultrasound, and she has added nuclear medicine, which is an important medical imaging technique.*

9.7 Change course code for **BME430H: Human Whole Body Biomechanics** to **BME530**

Note that 500-level courses are unable to have prerequisites assigned to them so BME430 would no longer have prerequisites (CHE353H1 or BME205H1 or MIE100H1).

- *Human biomechanics is an applied engineering topic where engineering background is used in combination with physiology. Human biomechanics is not very often taught at engineering departments. Therefore, students who start working on researches in rehabilitation engineering often struggle in experiments due to lack of basic knowledge/experiences in human biomechanics. Thus, Kei thinks that to make the course available for graduate students would help those students. Since starting the course 4 years ago, he has been getting requests from 1-2 graduate students at each year who want to take this course. The expected number of students are this much small but at least the course could have helped those students.*