UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

Report No. 3704 Revised

MEMORANDUM

To: Executive Committee of Faculty Council (November 24, 2021)
Faculty Council (December 16, 2021)

From: Professor Evan Bentz
Chair, Undergraduate Curriculum Committee

Date: November 14, 2021; revised December 16, 2021

Re: **Major Curriculum Changes for the 2022-2023 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 2022-2023 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 2022-2023 academic year, as described in Report 3704 Revised, be approved.

PROPOSED CURRICULUM CHANGES

1. MECHANICAL & INDUSTRIAL ENGINEERING

1.1. Move **MIE507: HVAC Fundamentals** to Fall from Winter (related to proposal for CIV578: Design of Building Enclosures to Winter from Fall)

A change in one course is driving a change in the other course so rationale will be presented together:

- *The fundamental building science course (listed as CIV375 for U/G and CIV575 for grads) is offered in the Fall term. CIV578 Design of Building Enclosures requires CIV375/575 as a prerequisite as it covers the application of these fundamentals. However, CIV578 is also offered in the Fall so students are learning the fundamentals and application concurrently. The integrated nature of the course content in CIV578 makes it difficult to adequately prepare the students by rearranging the CIV375/575 course content.*

- *Move CIV578 to the Winter term. Moving CIV578 to the Winter term would create an imbalance for our MEng students with a heavier course load in the Winter term because many of them also take MIE507 in Winter. Thus, it is proposed we move MIE507 to the Fall term. MIE507 does not have any prereqs.*

1.2. Update title for **MIE363: Resource and Production Modeling**

CURRENT: **MIE363: Resource and Production Modelling**

PROPOSED: **MIE363: Operations and Supply Change Management**

- *This phrasing better aligns with the course content and will make the course content more transparent from the title alone.*

1.3. Update prerequisites for **MIE342 Circuits with Applications to Mechanical Engineering Systems** to include **ECE110: Electrical Fundamentals**

CURRENT: MAT186H1, MAT187H1

PROPOSED: MAT186H1/ESC194H1, MAT187H1/ESC195H1, ECE110H1/ECE159H1

- *MIE342 is a continuation of ECE110. In the past, it was assumed that all third year MEC students completed ECE110. However, with a growing number of transfers, many MEC students do not have ECE110 completed by third year (CIV/MIN, MMS and CHE do not complete ECE110 in first year). ECE110 and MIE342 are also central to the Mechatronics stream which starts in 3S and is taken by the majority of our students. Adding ECE110 as a pre-requisite will ensure that all students complete it before third year. Other prereqs are added*

to include relevant EngSci courses.

1.4. Update title for **MIE510: Finite Element Analysis in Engineering Design**

CURRENT: **MIE510: Finite Element Analysis in Engineering Design**

PROPOSED: **MIE510: *Finite Element Analysis in Engineering Design**
(*approved design technical elective)

- *MIE510H1F is an approved design technical elective for MEC students. The proposal is to add an asterisk (*) in the title to indicate it as such.*

1.5. Update name, description, semester, and bio stream for **MIE439: Biomechanics I**

CURRENT: **MIE439: Biomechanics I (Winter)**
Introduction to the application of the principles of mechanical engineering - principally solid mechanics, fluid mechanics, and dynamics - to living systems. Topics include cellular mechanics, blood rheology, circulatory mechanics, respiratory mechanics, skeletal mechanics, and locomotion. Applications of these topics to biomimetic and biomechanical design are emphasized through a major, integrative group project.

PROPOSED: **MIE439: Cellular and Tissue Biomechanics (Fall)**
Introduction to the application of the principles of mechanical engineering - principally solid mechanics and rheology - to living systems. Topics include cellular mechanics and hard and soft tissue mechanics, with consideration of both experimental approaches and analytical modelling. Applications of these topics to biomimetic and biomechanical design are emphasized through a major, integrative group project.

PROPOSED Bioengineering Stream: Students will be required to take only one of MIE439 or MIE458H1F "Biofluid Mechanics" in 4F to complete the second half of the Bioengineering stream.

- *The new course description includes "cellular mechanics" and "skeletal mechanics" from the old course description. The topics removed are covered in MIE458 (blood rheology, aspects of circulatory mechanics, respiratory mechanics), MIE520 (aspects of circulatory mechanics), and BME530 (locomotion). The proposed change to MIE439 will resolve this redundancy of coverage between courses and within the ME biomechanics course stream.*

- *This proposal came out of discussions a couple of years ago now amongst the instructors who teach bioengineering stream courses – Lidan You (MIE520), Edmond Young (MIE458), Marianne Touchie (MIE439), and Kei Masani (BME530); David Steinman was involved as well as a Teaching Group lead. The changes were motivated to minimize overlap between course material and provide the students with logical course streams within the Bioengineering Stream – one focused on solid mechanics, the other on fluids/transport.*

- *Lisa Romkey @ EngSci and Warren Chan @ BME both indicated that they do not anticipate an issue with moving MIE439 to the Fall term for the EngSci BMS curriculum. Warren has asked that MIE explain the requested change to the Eng Sci Undergrad Curriculum Committee for their meeting next month.*

1.6. Reduce tutorial hours for **MIE320H1: Mechanics of Solids II** by 0.5

CURRENT: 38.4L/25.6T/19.2P = 3 L / 2 T / 1.5 P

PROPOSED: 38.4L/19.2T/19.2P = 3 L / 1.5 T / 1.5 P

- *Proposal for having the practical and computer labs 3 hours every week on alternating week each instead of 2 hours practice and 2 hours tutorials each weekly. The rationale is the current schedule only covers one hour tutorial and practice every week since there is not enough materials covered in the lectures per week to cover 2 hours tutorials and 2 hours practice. Having the practical and tutorials 3 hours and alternating them every two weeks will permit the student to have an extensive contents every two weeks either on the tutorials or practice on a full chapter which is normally covered in 2 weeks.*

1.7. Double code **MIE510: Finite Element Analysis in Engineering Design with MIE1804: Finite Element Method in Mechanical Engineering; Renumber as MIE410.**

- *The proposal is to have MIE510 double coded with a graduate course, MIE1804: Finite Element Method in Mechanical Engineering. Effective 2021-2022, the graduate level course (MIE1804) was restructured to allow senior undergraduates to benefit from an in-depth exposure to the use of Finite Element Analysis in engineering design, while maintaining the graduate nature of the course. As such, MIE510 should be changed to MIE410 so graduate students cannot take both courses.*

1.8. Remove **APS511** "Inventions and Patents for Engineers" from list of approved technical electives (4W) for AEINDBASC.

- This is an error correction since APS511 is 100% CS.

2. ELECTRICAL & COMPUTER ENGINEERING

2.1. Update course description for **ECE297: Software Design and Communication**

CURRENT: An introduction to engineering design processes, illustrated by the design and implementation of a software system, and to effective oral and written communication in a team context. Principles of software 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 software 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.

PROPOSED: An introduction to engineering design processes, illustrated by the design and implementation of a software system, and to effective oral and written communication in a team context. Principles of software 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 software 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. **Students learn software development tools such as version control (git), debuggers, code verifiers and unit test frameworks and gain experience in graphical user interface design and algorithm development.**

- *Makes a slightly more detailed description so the course content is less vague; gives a bit more detail on what the course teaches. This is likely to help students select between ECE 295 and ECE 297, and also may help students understand how the course maps to application areas of interest.*

2.2. Update and correct error in pre-requisite for **ECE314: Fundamentals of Electrical Energy Systems**

CURRENT: Introduction to 3-phase systems, single line diagrams and complex power flow. Energy conversion via switch-mode power electronic circuits: DC/DC converters, DC/AC converters. Energy conversions via magnetic devices: Faraday's law for time varying fields, characterization of hysteresis and eddy current losses in magnetic materials, modelling of magnetic circuits, transformer and inductor modelling and design. Introduction to electromechanical energy conversion: Lorentz Force, concepts of energy, co-energy, forces between ferromagnetic materials carrying flux, simple magnetic actuators.

PROPOSED: **High-efficiency** energy conversion via **switched-mode** power electronic circuits: **design and steady-state modeling** of DC/DC converters, DC/AC converters **using pulse-width modulation**. **Transistor switch realization and basic efficiency analysis in power electronic converters. AC power quality and power factor, including non-sinusoidal currents**. Energy conversion via magnetic devices: Faraday's law for time varying fields, characterization of hysteresis and eddy current losses in magnetic materials, modelling of magnetic circuits, transformer and inductor modelling and design. Introduction to electromechanical energy conversion: Lorentz Force, concepts of energy, co-energy, forces between ferromagnetic materials carrying flux, simple magnetic actuators, **introduction to synchronous machines**.

- *The description change is a reflection of how the course has been taught for at least 5 years. Changes and rationale: -Three-phase power is barely mentioned in ECE314 - more emphasized in ECE313 and to a lesser extent in ECE463.Three-phase power used to be covered in ECE212. -Single line diagrams are no longer part of ECE314 for several years (overlap with ECE313)? -Seems important to mention PWM explicitly - Emphasize a bit more switch realization, which connects with ECE231 -Adding concept of 'high efficiency' as a motivation for switched-mode power -Adding steady-state modeling (to differentiate from ECE520 which has dynamics) -Mention of power-factor and non-sinusoidal current (distortion factor) -Added intro to synchronous machines (last part of the course).*

2.3. Update course description for **ECE320: Fields and Waves**

CURRENT: Voltage and current waves on a general transmission line, reflections from the load and source, transients on the line, and Smith's chart. Maxwell's equations, electric and magnetic fields wave equations, boundary conditions, plane wave propagation, reflection and transmission at boundaries, constitutive relations, dispersion, Polarization; Poynting vector; waveguides.

PROPOSED: Voltage and current waves on a general transmission line, characteristic impedance, reflections from the load and source, transients on a transmission line, Smith's chart *and impedance matching*. Maxwell's equations, *wave equation*, constitutive relations, dispersion, boundary conditions. Plane wave propagation in lossless and lossy media, polarization, *power flow* and Poynting vector. Plane wave reflection and transmission at material boundaries. Waveguides; *propagating and evanescent waveguide modes and cut-off frequencies*.

- *The description lacked detail in some parts and needed updates to better describe how some topics (e.g., waveguides) are covered in the course. Also, I re-ordered some of the topics, following the order they are presented in the course. There is no change in the course itself that is proposed here.*

2.4. Update course description for **ECE342: Computer Hardware**

CURRENT: Arithmetic circuits, cubical representation of logic functions, digital system design, timing analysis, design of asynchronous circuits, testing of logic circuits.

PROPOSED: Design of digital hardware components and embedded systems. Finite state machines and the algorithmic state machine representation. Timing analysis of single and multi-clock designs. Numeric representation and arithmetic circuits: binary addition, subtraction, multiplication and division; IEEE 754 floating point representation. Introduction to hardware architecture of embedded systems; on-chip buses, particularly the AMBA/AXI standard. Processor design and pipelining. Memory types, interfacing and direct memory access. Off-chip peripherals and communication protocols.

- *The course outline contained material that professors (and TAs) consider obsolete. In particular asynchronous logic and cubical representations are removed. Also, to better connect with more advanced courses, the description should reflect topics such as ASM, multi-clock design, on-chip buses (AMBA/AXI), the notion of pipelining, memory and DMA, off-chip peripherals and communications protocols.*

- *The new description better supports ECE532 as well, and is very likely to provide the necessary background to courses such as ECE552 and other architecture/embedded systems courses.*

2.5. Remove **ECE411: Real-time Computer Control** and replace with **ECE4XX: Adaptive Control and Reinforcement Learning**

PROPOSED description: an ECE course that explores relationships between control theory, adaptive control, and model-based vs. model-free reinforcement learning. The course is proposed as a 400-level course open to EngSci and regular ECE students, for the Fall or Spring term.

PROPOSED prerequisites: **ECE311/ECE356** (and possibly concurrent enrollment in **ECE470**).

This is not a capstone course. The course would replace ECE411, which would be removed from the curriculum.

- *U of T's current engineering curriculum has a focus on supervised and unsupervised learning with their concomitant emphasis on model-free learning from data. We do not provide a course in the ECE curriculum that covers model-based reinforcement learning algorithms. ECE does not teach reinforcement learning in any form. Nor do we offer clarification on how learning algorithms sit within a hierarchy of other algorithms that afford autonomy to engineering systems, starting from low-level control loops. As such, students leave our program with no clear understanding of when to apply control theory, when to apply learning algorithms, when to use models, and when to eschew them.*

- *Meanwhile, the course ECE411, Real-time Computer Control, covers control design for discrete-time linear systems. This course has significant conceptual redundancy with ECE410; the material reflects an outdated concern with the limits of sampling rate on controller performance (processors are now so fast that the subject has become irrelevant); an enrollment in the course has been systematically low over many years. The Systems Control group would like to replace ECE411 with a more modern course. Our proposed replacement of ECE411 would still cover discrete-time systems, so part of the background material from ECE411 will be retained, while the part of ECE411 on control design duplicating ECE410 would be replaced.*

2.6. Update course description for **ECE463: Electric Drives**

CURRENT: Electro-mechanical mechanisms for force and torque production in rotating machines. DC machine theory and DC machine dynamics, synchronous machines and their dynamics, stepper motors. Introduction to space vectors and vector control of AC machines. Steady state and variable speed operation of the induction machine via V/f control.

PROPOSED: Electric drives comprise electric machines (i.e., motors/generators) together with power electronic actuation to enable the control of mechanical motion. Topics include electro-mechanical mechanisms for torque production relevant to rotating machines, speed-torque diagrams, DC machine analysis, dynamics and torque/speed/position control, introduction to space vectors and their application to motion control of synchronous machines and stepper motors. Steady state and variable speed operation of the induction machine using constant flux control is also be covered.

- *Additional details are provided for a better overview of course material covered.*

2.7. Update course description for **ECE526: Power System Protection and Automation**

CURRENT: Presents the concepts of short-circuit fault analysis, protective relaying, and automation in power systems. The course starts by discussing the causes and types of short-circuit faults using real-world examples. The consequences of faults for different power system components will be reviewed using event reports from field data. The method of symmetrical components for analyzing unbalanced three-phase systems will be introduced. Analytical methods and computer-based approaches for deriving fault voltages and currents will be discussed and the effect of system grounding during transient conditions, including faults, will be introduced. Students will also learn the concept of power system automation and its role in monitoring, protection, and control of modern power systems. Critical devices used in an automation system, such as breakers, relays, reclosers, capacitor bank controllers, and tap changer controllers will be presented.

PROPOSED: Presents the concepts of short-circuit fault analysis, protective relaying, and automation in power systems. The course starts by discussing the causes and types of short-circuit faults using real-world examples. The consequences of faults for different power system components **are** reviewed using event reports from field data. The method of symmetrical components for analyzing unbalanced three-phase systems **are** introduced. Analytical methods and computer-based approaches for deriving fault voltages and currents are discussed and the effect of system grounding during transient conditions, including faults, **are** introduced. **Students also** learn the concept of power system automation and its role in

monitoring, protection, and control of modern power systems. Critical devices used in an automation system, such as breakers, relays, reclosers, capacitor bank controllers, and tap changer controllers **are** presented.

- *The current course description uses the future tense, which is inconsistent with the descriptions of the other courses. Thus, I am requesting the change the course description and use the present tense. This change does not impact ECE students, other programs, etc.*

2.8. Update **ECE295: Hardware Design and Communication**

CURRENT: By the end of this course, students will be able to:

1. Work in a team environment in developing a complex hardware project;
2. Interpret 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.

Prerequisite: ECE212H1, ECE241H1, ECE244H1
Exclusion: ECE297H1

PROPOSED: Introduction to engineering design processes for hardware systems. 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 engineering design, project management and teamwork are developed and applied as students work in teams to: create and implement a complex hardware system comprising analog and digital electronic circuits. Students learn how to synthesize, prototype, and assemble designs realized using printed circuit board technology, as well as how to test them using modern measurement equipment. They learn about computer-aided design (CAD) and other development tools including those for electronic circuit simulation, schematic capture, board layout, version control (git), and instrument control. Students develop and apply

communication skills by preparing a variety of documents and presentations, including proposals, status reports, design reviews, and presentations.

Prerequisite: ECE212H1, ECE241H1, APS105H1

Co-Requisite: ECE231H1

Exclusion: ECE297H1

2.9. Update course description and prerequisites for **ECE444H1: Software Engineering**

CURRENT: The software development process. Software requirements and specifications. Software design techniques. Techniques for developing large software systems; CASE tools and software development environments. Software testing, documentation and maintenance.

PROPOSED: The collaborative software development process. Software requirements elicitation and specifications. Software design techniques. Techniques for developing large software systems. Software testing, quality assurance, documentation, and maintenance. Open-source software and web application design.

CURRENT prerequisite: **ECE344H1** or **ECE353H1**

PROPOSED prerequisite: **ECE297H1** or **ECE344H1** or **ECE353H1**

- *New instructor has significantly updated the course in the past few years, which is reflected in the description. ECE297 added as an alternative pre-requisite to make the course more accessible to students who did not take 344/353.*

3. BIOMEDICAL ENGINEERING

3.1. Change **BME396: Biomedical Systems Engineering III: Molecules and Cells** to remove BME225 as a prep course.

- *BME225 doesn't exist anymore and should be removed from calendar.*

3.2. Change instructional hours for **BME530: Human Whole Body Mechanics**

CURRENT: Lec 25.6/Prac 38.4 (2 hours lecture, 3 hours lab)

PROPOSED: Lec 25.6/Prac 25.6 (2 hours lecture, 2 hours lab)

- *Full three-hour labs not fully used so a two-hour slot will assist in scheduling*

3.3. Add **BME4XX: Introduction to Biomolecular Engineering**

PROPOSED: offers an opportunity to learn how the mechanics and dynamics of life operate at the molecular level by teaching you how to invent new biomolecules. You will learn the fundamentals of biomolecular structure, function, thermodynamics, and kinetics. You will discover how to apply this knowledge in the design, build and testing of proteins, DNA, and RNA for biomedical applications. You will be exposed to a broad range of state-of-the-art computational and experimental techniques, including atomistic simulations, bioinformatics, machine learning, high-throughput screening, and gene editing.

- *Biomolecular engineering is an emerging research field and job market. There is currently no introductory biomolecular engineering course offered at U of T. This course will also be part of the new BME minor's program in bioengineering (that will be submitted to UCC shortly).*

4. ENGINEERING SCIENCE

Foundation Curriculum Changes

4.1. Update course description for **ESC180H1: Introduction to Computer Programming**

CURRENT: The first of two courses that introduces students to programming and computational thinking, and prepares them for additional study across a breadth of programming fields. Students will learn to use the Python programming language to design and implement computational solutions to problems drawn from their 1F courses, with specific focus on algorithms, data structures, problem decomposition, and the use of programming paradigms appropriate to the problems being solved. Specifically, this course aims to have students work with and understand profiling and runtime analysis, searching and sorting algorithms, and the use of recursion.

PROPOSED: The first of two courses that introduce students to programming and computational thinking. Students will learn to use the Python programming language to implement computational solutions to problems, and will be introduced to the design and analysis of algorithms and data structures. Runtime analysis and searching and sorting algorithms will be introduced. Some computational problems will be drawn from other 1F courses.

- *Updates language to better reflect course content, and make the description more succinct and formal.*

4.2. Update course description for **ESC190H1: Computer Algorithms and Data Structures**

CURRENT: The second of two courses that introduces students to programming and computational thinking, and prepares them for additional study across a breadth of

programming fields. Students will develop an understanding of data structures and fundamental algorithms. The emphasis will be on (a) further refining their multiple introductory programming languages, and (b) understanding why diverse data structures exist, and how algorithms can be analyzed for their time and space complexity. Specifically, this course aims to have students work with and understand the list, stack, queue, tree, hash table, and graph data structures; a look at searching, sorting, and analysis of complexity will complement the presentation on the algorithms side.

PROPOSED: The second of two courses that introduce students to programming and computational thinking. The course introduces the C programming language as well as fundamental algorithms and data structures. Students will work with lists, stacks, queues, trees, hash tables, and graphs.

- *New description is more concise and formal.*

4.3. Update prerequisites for **ESC204H1: Praxis II**

CURRENT prerequisites: None
CURRENT recommended preparation: **ESC102H1, ESC190H1** and **ECE159H1**

PROPOSED prerequisites: **ESC102H1**
PROPOSED recommended preparation: **ESC190H1** and **ECE159H1**

- *Adds Praxis II as the prerequisite to Praxis III, which better reflects required background.*

4.4. Update prerequisite for **MAT292H1: Ordinary Differential Equations**

CURRENT prerequisite: **MAT195H1**

PROPOSED prerequisite: **MAT195H1/ESC195H1**

- *Reflects previous course change.*

<u>Engineering Science Majors</u>

4.5. Update course description for **ESC301: Engineering Science Option Seminar**

CURRENT: The Option seminar supports discipline specific discussions of ethics, professionalism, safety and standards and research in a seminar-based setting. Guest speakers, presentations and other activities will highlight various topics of interest, including the present and future research related to the Option. This course will be offered on a credit/no credit basis and the assessment will be through a combination of written assignments, presentations and tests. Concepts in Engineering Communication

will be emphasized to support discussion and the development of the course deliverables.

PROPOSED: The Option Seminar provides students with an introduction to their upper-year discipline of study, and encourages students to consider different educational and career pathways. Students will participate in sessions with other students from their Option/Major, with a focus on research and industry directions and the relationship between the Option/Major and it's social & environmental context. Students will also participate in program-wide seminars which feature opportunities for career exploration. This course is offered on a credit/no credit basis, and students receive credit for attending sessions and completing a small set written deliverable.

- *Description is a better reflection of current practice.*

Biomedical Systems Engineering

4.6. Update course title and description for **BME346H1: Biomedical Engineering and Omics Technologies**

CURRENT: **Biomedical Engineering and Omics Technologies**
An introduction to the principles and design of fundamental technologies used in biomedical engineering and "omics" research. Topics may include but are not limited to tissue culture; spectroscopy; electrophoresis; PCR, genomics, sequencing technologies, and gene expression measurement; protein expression assays and tagging strategies; fluorescence labeling tools, microscopy, and high content imaging; DNA manipulation and transfection, RNAi, and other genetic and molecular tools for transformation of organisms. Laboratories will provide hands-on experience with selected technologies. Students will engage in a major design project in which they will design an experimental plan to investigate a specific research question, also of their design, utilizing available laboratory technologies.

PROPOSED: **Biomedical Engineering Technologies**
An introduction to the principles and design of fundamental technologies used in biomedical engineering research. Topics may include but are not limited to tissue culture; spectroscopy; electrophoresis; PCR, genomics, sequencing technologies, and gene expression measurement; protein expression assays and tagging strategies; fluorescence labeling tools, microscopy, and high content imaging; DNA manipulation and transfection, RNAi, and other genetic and molecular tools for transformation of organisms. Laboratories will provide hands-on experience with selected technologies. Students will engage in a major design project in which they will design an experimental plan to investigate a specific research question, also of their design, utilizing available laboratory technologies.

- *Removing the word "Omics" from the course title and description, as it is redundant (as this is a BME technology) and limits what is taught in the course.*

4.7. Update Year 4 Core Curriculum

CURRENT:

Fall Session – Year 4		Lect.	Lab.	Tut.	Wgt.
ESC499Y1: Thesis	Y	3	2	-	1.00
BME428H1: Biomedical Systems Engineering IV: Computational Systems Biology	F	3	-	2	0.50
BME489H1: Biomedical Systems Engineering Design	F	1	-	4	0.50
CS/HSS or Technical Elective	F	-	-	-	0.50
CS/HSS or Technical Elective	F	-	-	-	0.50
Winter Session – Year 4					
ESC499Y1: Thesis	Y	3	2	-	1.00
MIE439H1: Biomechanics i	S	3	2	-	0.50
CS/HSS or Technical Elective	S	-	-	-	0.50
CS/HSS or Technical Elective	S	-	-	-	0.50
CS/HSS or Technical Elective	S	-	-	-	0.50

PROPOSED:

Fall Session – Year 4		Lect.	Lab.	Tut.	Wgt.
ESC499Y1: Thesis	Y	3	2	-	1.00
BME428H1: Biomedical Systems Engineering IV: Computational Systems Biology	F	3	-	2	0.50
BME489H1: Biomedical Systems Engineering Design	F	1	-	4	0.50
MIE439H1: Cellular and Tissue Biomechanics	F	3	2	-	0.50
CS/HSS or Technical Elective	F	-	-	-	0.50
Winter Session – Year 4					
ESC499Y1: Thesis	Y	3	2	-	1.00
CS/HSS or Technical Elective	S	-	-	-	0.50
CS/HSS or Technical Elective	S	-	-	-	0.50
CS/HSS or Technical Elective	S	-	-	-	0.50
CS/HSS or Technical Elective	S	-	-	-	0.50

- *Updated to reflect change in offering for MIE439*

4.8. Update course description for **ECE357H1: Electromagnetic Fields**

CURRENT: An introduction to transmission line theory: voltage and current waves, characteristic impedance, reflections from the load and source, transients on the line, Smith's chart, impedance matching. Fundamentals of electromagnetic theory: Maxwell's equations, Helmholtz's theorem, time retarded scalar and vector potentials, gauges, boundary conditions, electric and magnetic fields wave equations and their solutions in lossless and lossy medium. Plane wave propagation, reflection and transmission at boundaries. Constitutive relations and dispersion. Radiating dipole and waveguides.

Prerequisite: ECE259H1
Exclusion: ECE320H1

PROPOSED: An introduction to transmission lines: voltage and current waves, characteristic impedance, reflections from the load and source, transients on a transmission line, Smith's chart, impedance matching. Fundamentals of electromagnetic theory: Maxwell's equations, boundary conditions, wave equation and its solutions in lossless and lossy media. Constitutive relations and dispersion. Plane wave propagation, reflection and transmission at boundaries. Waveguides; propagating and evanescent waveguide modes and cut-off frequencies. Introduction to radiation and antennas.

Prerequisite: ECE259H1
Exclusion: ECE320H1

- *Update better reflects what has been taught in the course in recent years.*

4.9. Add tutorial hour for **ECE358: Foundations of Computing**

CURRENT: Hours - 38.4L / 12.8T

PROPOSED: Hours - 38.4L / 25.6T

- *Course is heavily based on tutorials where theory taught in class can be clarified, as well as cover necessary background (such as discrete math, which is no longer part of the ON curriculum) to build on other topics. Additionally, the Core-8 equivalent, ECE345H1, also has a two-hour tutorial.*

<u>Energy Systems Engineering</u>

4.10. Remove **MIE517H1: Fuel Cell Systems** as a Technical Elective

- *MIE517 is an exclusion from CHE469H1, which is now a 3W core course.*

Machine Intelligence

4.11. Update course description for **ECE324H1: Machine Intelligence, Software and Neural Networks**

CURRENT:
This course will focus on machine learning engineering, through the sense of neural networks, dealing with the data collection and software development as an engineering descipline (sic). 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 machine-learning software framework through assignments and a major design project.

PROPOSED:
An introduction to machine learning engineering, with a focus on neural networks. The entire process of developing a machine learning solution, from data collection to software development, as well as ethics in machine learning, will be discussed. Practical techniques in machine learning will be covered, including data augmentation and the use of pre-trained networks. Topics covered will include the fundamentals of neural networks, convolutional neural networks, recurrent neural networks, generative adversarial networks and transformer networks. Students will complete a major hands-on project in machine learning.

- *ECE324 now follows up on ECE421 in the student's curriculum (before ECE421 followed ECE324), which may indicate that substantive changes are needed in the description of ECE324. No changes to content are being proposed at this time.)*

4.12. Add **MIE376 – Mathematical Programming (Optimization)** as tech elective

- Addition of program relevant course to technical elective list.

4.13. Add **APM462H1: Nonlinear Optimizations** as a Technical Elective

- *Addition of program relevant course to technical elective list.*

Robotics Engineering

4.14. Add prerequisites for **MIE366H1: Electronics for Robotics**

CURRENT prerequisites: None

PROPOSED prerequisite: **ECE259H1**

- *Addition of prerequisites to provide better clarity on required background material*

Aerospace Engineering

4.15. Add **AER306H1 Introduction to Space Flight (3/-/1, 0.50)**

PROPOSED description: An introduction to the space environment and its impact on space vehicles, orbits and mission analysis, space system payloads, spacecraft power systems, attitude control sensors and actuators, thermal analysis and design, propulsion, space communication systems including antennas and link budgets, command and data handling, structures, mechanisms, and mass properties.

GA: 30% Natural Science, 70% Engineering Science

- *Adding this course serves three purposes: (i) Current curriculum does not have an introduction to space flight. This material was either covered extremely briefly in AER407 Space Systems Design or students needed to learn it on their own. The new course will allow AER407 to concentrate on the design aspect of space systems and will provide students with improved background knowledge. (ii) The current curriculum is biased towards aeronautics, adding an astronautics course helps alleviate this bias. (iii) Students have been requesting additional astronautics courses.*

4.16. Update course code for **AER315H1: Combustion Processes**

CURRENT: **AER315H1**

PROPOSED: **AER515H1**

- *Rationale provided in 4.18.*

4.17. Change **AER315H1** to Elective

- *Rationale provided in 4.18.*

4.18. Change **AER510H1: Propulsion** from Elective to Core

- *Propulsion is considered more essential for aerospace graduates than combustion, and combustion is generally considered a specialization within propulsion. Combustion was moved from 3F to 4F to make room for Introduction to Space Flight. Combustion was made a 500-level course as many UTIAS graduate students have not taken a combustion course thus this course can serve both the undergraduates and graduate students.*

4.19. Change **AER407H1: Space Systems Design** + **AER406H1: Aircraft Design** from Core to Elective with students required to take at least 1 of the 2 capstone design courses

- *Most aerospace programs allow for streaming between astronautics/aeronautics and over the past 10 years students have requested the ability to stream. This change allows for limited streaming in 4th year with the option to take both design courses if desired. Adding Introduction to Space in 3S provides students with some applied astronautics and that combined with Aircraft Flight, AER302H1S provides sufficient coverage of astro/aero if the equivalent design course is not selected. Note that we have sufficient design attributes for CEAB with only one design course.*

4.20. Remove **PHY492H1: Advanced Atmospheric Physics** + **APM446H1: Applied Nonlinear Equations** from elective list

- Other than ECE557, only AER and ROB courses are now specifically listed as electives. ECE557 was retained on the list as it has continued to have sustained modest enrolment numbers over the last 11 years where as PHY492 and APM446 have had very low enrolment.

4.21. Change number of electives in 4F from "Two of" to "Three of"

- *Required as AER407H1F changed from core to elective. Note that number of electives in 4S stays the same as AER406H1S was changed from core to elective but AER510H1S was changed from elective to core.*

4.22. Change Note 2 after 4th-year table and add Note 3.

CURRENT: Students must take at least two of **AER503H1, AER506H1, AER510H1, ROB521H1 or AER525H1**

PROPOSED: Students must take at least three of **AER503H1, AER506H1, ROB521H1, AER515H1, AER406H1, AER407H1 or AER525H1**

- *Change in courses from core to elective required an increase in number of aerospace courses need to achieve sufficient aerospace content. No real change in number of required aerospace courses.*

PROPOSED: Students must take at least one of **AER406H1** or **AER407H1**

- *Need to take at least one capstone design project.*

These Aerospace changes are summarized with the following tables:

CURRENT

YEAR 3 AEROSPACE ENGINEERING

Fall Session – Year 3		Lect.	Lab.	Tut.	Wgt.
AER301H1: Dynamics	F	3	-	1	0.50
AER303H1: Aerospace Laboratory I	F	-	1	-	0.15
AER307H1: Aerodynamics	F	3	-	1	0.50
AER315H1: Combustion Processes	F	3	-	1	0.50
CHE374H1: Economic Analysis and Decision Making	F	3	-	1	0.50
ESC301H1: Engineering Science Option Seminar	Y	1	-	-	0.25
ESC384H1: Partial Differential Equations	F	3	-	1	0.50
One of:					
MAT389H1: Complex Analysis	F	3	-	1	0.50
ROB310H1: Mathematics for Robotics	F	3	-	1	0.50

YEAR 4 AEROSPACE ENGINEERING

Fall Session – Year 4		Lect.	Lab.	Tut.	Wgt.
AER407H1: Space Systems Design	F	-	3	-	0.50
AER501H1: Computational Structural Mechanics and Design Optimization	F	3	-	1	0.50
Complementary Studies Elective	F	-	-	-	0.50
Two courses in:					
AER506H1: Spacecraft Dynamics and Control	F	3	-	1	0.50
AER507H1: Introduction to Fusion Energy	F	3	-	1	0.50
AER525H1: Robotics	F	3	1.50	1	0.50
ECE557H1: Linear Control Theory	F	3	1.50	1	0.50
ESC499H1: Thesis	F	3	2	-	0.50
ESC499Y1: Thesis	Y	3	2	-	1.00
PHY492H1	F	2	-	-	0.50
Other Technical Elective	F	-	-	-	0.50

Winter Session – Year 4		Lect.	Lab.	Tut.	Wgt.
AER406H1: Aircraft Design	S	-	-	3	0.50
Complementary Studies Elective	S	-	-	-	0.50
Three courses in:					
AER503H1: Aeroelasticity	S	3	-	1	0.50
AER510H1: Aerospace Propulsion	S	3	-	1	0.50
ESC499H1: Thesis	S	3	2	-	0.50
ESC499Y1: Thesis	Y	3	2	-	1.00
ROB521H1: Mobile Robotics and Perception	S	3	1.50	1	0.50
APM446H1: Applied Nonlinear Equations	S	3	-	-	0.50
Other Technical Elective	S	-	-	-	0.50

1. Students must take a half-year thesis in 4F or 4S, or take a full-year thesis.
2. Students must take at least two of AER503H1, AER506H1, AER510H1, ROB521H1 or AER525H1.
3. The Technical Elective may be chosen from any 400 or 500 level technical course offered in Engineering provided students have taken the pre-requisite course(s). Other non-Engineering courses may be taken with the approval of the Division of Engineering Science.

PROPOSED

YEAR 3 AEROSPACE ENGINEERING

Fall Session – Year 3		Lect.	Lab.	Tut.	Wgt.
AER301H1: Dynamics	F	3	-	1	0.50
AER303H1: Aerospace Laboratory I	F	-	1	-	0.15
AER306H1: Introduction to Space Flight	F	3	-	1	0.50
AER307H1: Aerodynamics	F	3	-	1	0.50
CHE374H1: Economic Analysis and Decision Making	F	3	-	1	0.50
ESC301H1: Engineering Science Option Seminar	Y	1	-	-	0.25
ESC384H1: Partial Differential Equations	F	3	-	1	0.50
One of:					
MAT389H1: Complex Analysis	F	3	-	1	0.50
ROB310H1: Mathematics for Robotics	F	3	-	1	0.50

YEAR 4 AEROSPACE ENGINEERING

Fall Session – Year 4		Lect.	Lab.	Tut.	Wgt.
AER501H1: Computational Structural Mechanics and Design Optimization	F	3	-	1	0.50
Complementary Studies Elective	F	-	-	-	0.50
And three of:					
AER407H1: Space Systems Design	F	-	3	-	0.50
AER506H1: Spacecraft Dynamics and Control	F	3	-	1	0.50
AER507H1: Introduction to Fusion Energy	F	3	-	1	0.50
AER515H1: Combustion Processes	F	3	-	1	0.50
AER525H1: Robotics	F	3	1.50	1	0.50
ECE557H1: Linear Control Theory	F	3	1.50	1	0.50
ESC499H1: Thesis	F	3	2	-	0.50
ESC499Y1: Thesis	Y	3	2	-	1.00
Other Technical Elective	F	-	-	-	0.50

Winter Session – Year 4		Lect.	Lab.	Tut.	Wgt.
AER510H1: Aerospace Propulsion	S	3	-	1	0.50
Complementary Studies Elective	S	-	-	-	0.50
And three of:					
AER406H1: Aircraft Design	S	-	-	3	0.50
AER503H1: Aeroelasticity	S	3	-	1	0.50
ESC499H1: Thesis	S	3	2	-	0.50
ESC499Y1: Thesis	Y	3	2	-	1.00
ROB521H1: Mobile Robotics and Perception	S	3	1.50	1	0.50
Other Technical Elective	S	-	-	-	0.50

1. Students must take a half-year thesis in 4F or 4S, or take a full-year thesis.
2. Students must take at least three of AER406H1, AER407H1, AER503H1, AER506H1, AER515H1, AER525H1 or ROB521H1.
3. Students must take at least one of AER406H1 or AER407H1.
4. The Technical Elective may be chosen from any 400 or 500 level technical course offered in Engineering provided students have taken the pre-requisite course(s). Other non-Engineering courses may be taken with the approval of the Division of Engineering Science.

Energy Systems Engineering/Electrical and Computer Engineering

4.23. Update course description for **ECE349H1: Introduction to Energy Systems**

CURRENT: Established and emerging sources of electrical energy: hydroelectric, thermal, wind, and solar. Three-phase AC systems and complex power. Mechanisms for electrical-electrical energy conversion: power electronic systems for DC-DC conversion, single-phase DC-AC and three-phase DC-AC conversion, transformers for single-phase and three-phase AC-AC conversion. Electro-mechanical energy conversion via the synchronous machine. Fundamentals of AC electrical energy networks: frequency regulation, voltage regulation, and protection.

PROPOSED: Design and steady-state modeling of DC/DC and DC/AC (single- and three-phase) converters using modified-square-wave and pulse-width modulation. Three-phase, balanced connections and analysis of harmonics via superposition. Modeling of non-ideal components in power electronic converters to determine practical conversion ratios and efficiency. Energy conversion based on magnetic field interactions: Faraday's law for time varying fields, characterization of primary loss mechanisms (hysteresis and eddy currents) in magnetic materials, magnetic circuit analysis, transformer and inductor modeling and design. Introduction to electromechanical energy conversion: Lorentz Force, calculation of electromechanical forces in conservative systems using energy and co-energy, simple magnetic actuators and sensors, introduction to synchronous machines.

- *Description better aligns with what has been taught in the course over the last few years. Updated description has been approved by ECE.*

5. CHEMICAL ENGINEERING & APPLIED CHEMISTRY

5.1. Update tutorial hours for **CHE324H1: Process Design**

CURRENT tutorial hours: 1

PROPOSED tutorial hours: 2

6. CIVIL & MINERAL ENGINEERING

6.1. Move **CIV578H1F: Design of Building Enclosures** to Winter from Fall

- ***CIV578*** *should follow* ***CIV575*** *(Fall) but they are offered concurrently right now. Moving* ***CIV578*** *to winter would create a more natural progression.*

6.2. Remove 2 hour scheduled lab component of **CIV500H1S: Fundamentals of Acid Rock Drainage**

CURRENT: 3/2/1

PROPOSED: 3/0/1

- This lab slot has not been used in some years and thus is being removed from the course.

6.3. Add **MIN5XXH1S: Mine Optimization**

PROPOSED timing: 3/0/1 with project focus

PROPOSED prerequisites: **MIN250: Surface Mining, MIN351: Underground Mining, and MIN466: Capstone Design** (MIN has 2 half credit capstone courses)

PROPOSED AUs: 50% design, 50% ES

PROPOSED description: Introduces principles and fundamental concepts involved in the optimization of different aspects of mineral resource extraction. Explores the key sources of uncertainty that affect a final mine plan and design such as orebody, technological and economic uncertainties. Stochastic simulation techniques will be introduced for the quantification of uncertainties and risk management. Other topics related to optimizing mine production and performance such as delaying or eliminating waste stripping, and more efficient resource use through better blending and cut-off grade decisions, as well as holistic mine-to-mill process optimization will be introduced.

Target students: The course is targeted toward fourth-year undergraduate and graduate Mineral Engineering students. The key optimization concepts that will be learned from this course can be applied to real-world challenges in the field of mining/geotechnical engineering.

6.4. Add **CME538H1F: Introduction to Data Science for Civil and Mineral Engineers**

PROPOSED timing: 3/0/1 with project focus

PROPOSED prerequisites: **APS106: Fundamentals of Computer Programming, CME261: Engineering Mathematics, CME263: Probability Theory for Civil and Mineral Engineers**

PROPOSED AUs: 100% ES

PROPOSED description: Bridges between APS106 and CME263 and upper-level machine learning, computer science and statistics courses. Explores key areas of Data Science including question formulation, data collection and cleaning, visualization, and applied

machine learning. All lessons are taught with code and a strong emphasis is placed on the development of a solid foundation in computer programming. This course touches on a range of topics from visualization to machine learning which serves to enhance the learning experience for students by allowing them to gain an appreciation for the close interplay between these topics. This course is introductory and is meant to develop a solid foundation to build on with more advanced courses offered by ECE, MIE, and CS.

Target students: This course is targeted toward Civil & Mineral Engineering undergraduate and graduate students whose only exposure to computer programming and data science has been through core courses such as APS106 (Fundamentals of Computer Programming) and CME263 (Probability Theory for Civil and Mineral Engineers). As such, this course is truly introductory and is meant to develop a solid foundation to build on with more advanced courses offered by ECE, MIE, and CS.

6.5. Changes to 4th year MIN program

Proposed: To reduce scheduling constraints for 4th year electives it is proposed to remove the requirement of one CS/HSS course in each of terms 4F and 4S, and replace it with the simple requirement that two CS/HSS electives must be taken in year 4.

Proposed: Add technical elective CME5XX to 4F (see 6.4, above)
Add technical elective MIN5XX to 4W (see 6.3, above)

6.6. Changes to 3rd year MIN program

As part of a series of multi-year set of restreaming changes to the MIN program, the following changes are proposed.

Proposed: Move MIN301 Mineral Reserve and Mineral Resource Estimation from 3S to 3F.

Proposed: Move MIN450 Mineral Economics from 4F to 3S.

7. INSTITUTE FOR STUDIES IN TRANSDISCIPLINARY ENGINEERING EDUCATION & PRACTICE

7.1. Add HSS Elective **TEP449: Intercultural Communication and Leadership (2/0/2)**

PROPOSED Session**:** In-Person Fall Course

PROPOSED description: A highly experiential but theoretically grounded exploration of intercultural communication developments and practices. The focus on intercultural communication will be applied to the practice of leadership in the many intercultural contexts students engage in as students and as junior engineers. Students will deepen their understanding of culture and leadership through developing a nuanced

understanding of culture and cultural practices beyond national, linguistic and ethnic boundaries. Concepts of cultural sensitivity, cultural competence and cultural humility will be related to models of leadership (authentic, collaborative, transformational, and ethical) to enable students to increase their cultural sensitivity, and humility beyond the classroom, in both multi- and intercultural contexts.

- *Students are being encouraged to explore global work as part of their PEY or post-graduation. This course will support students to be better equipped to work in new cultures and to explore how they can lead in those situations.*

7.2. Add HSS Elective **TEP328: Engineering Education (2/0/2)**

PROPOSED Session: Online Summer Course

PROPOSED description: Through both formal and informal mechanisms, engineers engage in the processes of teaching and learning across their careers. Drawing from the multidisciplinary field of Engineering Education, students will examine the various applications of educational theory to the engineering profession. Students will examine engineering education across five contexts: (1) undergraduate engineering education; (2) K-12 educational outreach and STEM education; (2) public education and stakeholder engagement; (4) professional education and training; and (5) Lifelong learning. Drawing from the learning sciences, educational philosophy and the sociology and history of education, students will deepen their understanding of their own learning processes, and engage in course activities that prepare them for teaching and learning in their future career as an engineer or engineering educator.

- *ISTEP has a focus to develop and improve engineering education. This course will allow students to critically reflect on their education experience, how they can continue learning post-graduation, and ways that they can influence the perception of STEM outside of the University. This course may also serve as a good opportunity for students to decide if they might want to pursue post graduate work in Engineering Education.*

8. MATERIALS SCIENCE & ENGINEERING

8.1. Split **MSE298H1Y** into two termed courses **MSE29XH1F** and **MSE29YH1S**

- *To help students going on exchange/probation so they don't have to repeat the half of the course they completed.*

8.2. Split **MSE398Y1Y** into two termed courses **MSE39XH1F** and **MSE39YH1S**

- *For students going on exchange/probation (with 3 consecutive lab sections PRA0101-0103).*

8.3. Change program status for **MSE401H1F** from Y4 F core to TE

- *Make space for MSE443 as core.*

8.4. Change program status for **MSE443H1F** from TE to Y4 F core

- *Composites course needed.*

8.5. Move **MSE438H1S** to Winter 2023

- *To balance instructor workload in S term due to 465 move to Fall.*

8.6. Add **MSE465H1F** as a course offering for Fall 2022

- *Course already offered at graduate level, Fundamentals of AI.*

8.7. Add **MSE467H1S** as a course offering for Winter 2023

- *Course already offered at graduate level, Materials Fracture.*

8.8. Add **MSE468H1S** as a course offering for Summer 2023

- *Course already offered at graduate level, Additive Manufacturing.*

8.9. Change **MSE443** to core from TE in Y4 F term

8.10. Change **MSE443** to TE from core in Y4 F term

8.11. Add **MSE403, MSE465, MSE467,** and **MSE468** as TEs

8.12. Change **MSE468** to Winter offering

8.13. Remove ESIP

- *Program to be phased out.*

9. CROSS-DISCIPLINARY PROGRAMS

9.1. New course **APS470H1 F – Engineering and Public Health** 3/0/1/0.5

This course will be the core course for the proposed Certificate in Engineering and Public Health

PROPOSED AUs: 70% ES/30% CS

PROPOSED description: An introduction to the disciplines of public health and the connections with engineering; quantitative and qualitative public health methods including study designs and statistical analysis; legal, regulatory and ethical frameworks

applicable to public health; the structure and regulation of the public health and health care system; examples of common public health hazards to illustrate public health toxicology, exposure measurement and modelling, data analysis and prevention strategies.

Proposed TE for CHE, IND, CIV; FE for ECE, MSE

9.2. Update title and description for **APS360H1**

CURRENT: **APS360H1: Applied Fundamentals of Machine Learning**
A basic introduction to the history, technology, programming and applications of the fast-evolving field of **machine learning**. Topics to be covered may include neural networks, autoencoders/decoders, recurrent neural networks, natural language processing, and generative adversarial networks. Special attention will be paid to fairness and ethics issues surrounding machine learning. An applied approach will be taken, where students get hands-on exposure to the covered techniques through the use of state-of-the-art machine learning software frameworks.

PROPOSED: **APS360H1: Applied Fundamentals of Deep Learning**
A basic introduction to the history, technology, programming and applications of the fast-evolving field of **deep learning**. Topics to be covered may include neural networks, autoencoders/decoders, recurrent neural networks, natural language processing, and generative adversarial networks. Special attention will be paid to fairness and ethics issues surrounding machine learning. An applied approach will be taken, where students get hands-on exposure to the covered techniques through the use of state-of-the-art machine learning software frameworks.

- *Differentiates from ECE 421 more, and lines up with the new title.*

9.3. Add **TEP448: System Mapping** as an elective to the Engineering Business Minor

9.4. Add **MSE403: Data Sciences and Analytics** for Materials Engineers to Requirement 5 (ML/AI additional emphasis) of AI Engineering Minor

9.5. Adding **TEP449: Intercultural Communication and Leadership** (new course) to Engineering Leadership Certificate and Communication Certificate