Course Outline: **Electromagnetic Technologies for Biomedicine**

Couse #: BMDE 517

Term and Year: Fall 2025

Number of Credits: 3

Contact hours: 3-0-6

Course Description: Introduction to concepts and characteristics of electromagnetic (EM) fields interacting with the body, from theory to practice. Electromagnetic properties of biological tissues, safety considerations, electrode- and antenna-based measurements, and existing and emerging medical technologies.

Canadian Engineering Accreditation Board (CEAB) Curriculum Content

CEAB curriculum category content	Number of AU's	Description
Math	0	Mathematics include appropriate elements of linear algebra, differential and integral calculus, differential equations, probability, statistics, numerical analysis, and discrete mathematics.
Natural science	3	Natural science includes elements of physics and chemistry, as well as life sciences and earth sciences. The subjects are intended to impart an understanding of natural phenomena and relationships through the use of analytical and/or experimental techniques.
Complementary studies	0	Complementary studies include the following areas of study to complement the technical content of the curriculum: engineering economics; the impact of technology on society; subject matter that deals with central issues, methodologies, and thought processes of the arts, humanities and social sciences; management; oral and written communications; healthy and safety; professional ethics, equity and law; and sustainable development and environmental stewardship.
Engineering science	18	Engineering science involves the application of mathematics and natural science to practical problems. They may involve the development of mathematical or numerical techniques, modeling, simulation, and experimental procedures. Such subjects include, among others, applied aspects of strength of materials, fluid mechanics, thermodynamics, electrical and electronic circuits, soil mechanics, automatic control, aerodynamics, transport phenomena, elements of materials science, geoscience, computer science, and environmental science.
Engineering design	18	Engineering design integrates mathematics, natural sciences, engineering sciences, and complementary studies in order to

		develop elements, systems, and processes to meet specific needs. It is a creative, iterative, and open-ended process, subject to constraints which may be governed by standards or legislation to varying degrees depending upon the discipline. These constraints may also relate to economic, health, safety, environmental, societal or other interdisciplinary factors.

Graduate Attributes:
This course contributes to the development of the following attributes:

Graduating Attributes	**KB**	**PA**	**IN**	**DE**	**ET**	**IT**	**CS**	**PR**	**IE**	**EE**	**EP**	**LL**
Level	D	D	n/a	I	I	A	A	n/a	n/a	n/a	n/a	A

n/a = Not applicable; I = Introduced; D = Developed; A = Applied

KB - Knowledge Base for Engineering: Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.

PA - Problem Analysis: An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.

IN - Investigation: An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.

DE - Design: An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, economic, environmental, cultural and societal considerations.

ET - Use of Engineering Tools: An ability to create, select, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.

IT - Individual and Team Work: An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.

CS - Communication Skills: An ability to communicate complex engineering concepts within the profession and with society at large. Such abilities include reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.

PR - Professionalism: An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.

IE - Impact of Engineering on Society and the Environment: An ability to analyse social and environmental aspects of engineering activities. Such abilities include an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society; the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.

EE - Ethics and Equity: An ability to apply professional ethics, accountability, and equity
EP - Economics and Project Management: An ability to appropriately incorporate economics and business practices including project, risk and change management into the practice of engineering, and to understand their limitations.
LL - Life-Long Learning: An ability to identify and to address their own educational needs in a changing world, sufficiently to maintain their competence and contribute to the advancement of knowledge

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Course pre-requisite(s): MATH 262 and MATH 263 and (ECSE 353 or ECSE 354 or PHYS 242) or permission of the instructor.

Course Schedule (Day and Time of Class): 1 class/week: Friday 10:05 am – 12:55 pm

Location: Duff 321 @ Duff Medical Building, 3775 Rue University, Montréal, QC H3A 2B4

Course Instructor: Emily Porter

Email: emily.porter@mcgill.ca

Office location: ES1.1630 at the RI-MUHC (Block E)

Office hours for students: As posted on myCourses

Course Description: Introduction to concepts and characteristics of electromagnetic (EM) fields interacting with the body, from theory to practice. Electromagnetic properties of biological tissues, safety considerations, electrode- and antenna-based measurements, and existing and emerging medical technologies.

Course Overview: This course will provide a fundamental introduction into how EM fields interact with the body; followed by an application-oriented discussion of EM-based medical technologies of today and tomorrow, focusing primarily on low-power non-invasive and non-ionizing devices across the radio-frequency (RF) spectrum.

Starting with a brief overview of electromagnetic waves and of propagation and radiators, the course will then turn to the measurement of electromagnetic behaviours in electrode-based and antenna-based measurement technologies. Topics will include: the measurement and characterization of electrical and electromagnetic tissue properties, safe exposure considerations and limitations, and example sensing technologies and clinical applications.

Communication Plan: All updates related to the course will be posted on myCourses; please be sure to check for updates regularly. Office hours are open for all students by drop-in, no appointment is needed. Additional virtual or in person one-on-one meetings can be scheduled with Dr. Porter if needed. Please contact Dr. Porter through myCourses messaging for meeting requests or any other concerns/questions, she will aim to respond to all inquiries within 24 hours typically, and at most 48 hours (excluding weekends/holidays).

Learning Outcomes

LO1: Explain and apply fundamental principles of electromagnetic wave propagation and wave interactions with human tissues (KB-D (KB.7, KB.8), PA-D (PA.3));

LO2: Design and simulate computational models of electromagnetic wave interactions with tissues (KB-D (KB.8), PA-D (PA.4), ET-I (ET.1), IN-D (IN.2));

LO3: Differentiate between safe and unsafe operating characteristics of active bio-electromagnetic technologies (KB-D (KB.8), PA-D (PA.1));

LO4: Describe the operating principles of active non-ionizing bio-electromagnetics in applied clinical devices (CS-A (CS.3), LL-A (LL.4), IN-D (IN.1)).

LO5: Identify and investigate constraints of electromagnetic medical devices from various perspectives, including safety, cost, patient experience, and clinical need (CS-A (CS.1, CS.2, CS.3), LL-A (LL.4), IT-A (IT.1), DE-I (DE.1), IN-D (IN.2));

LO6: Identify and discuss challenges, opportunities, and potential new medical applications for active non-ionizing bio-electromagnetic technologies (CS-A (CS.1, CS.2, CS.3), IT-A (IT.1), IN-D (IN.2)).

Instructional Method

Lectures, team discussions and project work; student presentations.

Textbook

"Basic Introduction to Bio-Electromagnetics", 3rd ed., ed: James R. Nagel, Cynthia M. Furse, Douglas A. Christensen, Carl H. Durney, CRC Press (2019).

E-book available for free through McGill Library:
https://mcgill.on.worldcat.org/oclc/1054092750

Course Materials

Reading materials (consisting of selected original research papers and review articles), lecture slides, and assignments will be posted on McGill myCourses.

Course Content

Lecture	Date	Description and content	Projects Due	Assignment Due
1	Aug. 29	**First class** ***Introduction to EM waves and propagation:*** EM spectrum; allocations; Basic concepts (plane wave, wavefronts, polarization, power density, characteristic impedance, attenuation)		
2	Sept. 5	Radiation (reception, reciprocity, radio-transmission equation); Electromagnetic and electrical parameters		
3	Sept. 12	Passive vs. active measurements; Types of transmitters and receivers; Practical measurement considerations		#1
4	Sept. 19	***Electrode-based technologies:*** Low-frequency approximation; Electrical tissue properties and tissue property measurement techniques; Electrode measurements; electrode types and configurations		
5	Sept. 26	Example active measurement technologies: applications; clinical needs; operational characteristics; output data, images, and analysis: bio-impedance measurements; and electrical impedance tomography		#2
6	Oct. 3	Safety considerations; Challenges and future opportunities	Team Projects between Oct. 3 – Nov. 21	
7	Oct. 10	***Antenna-based technologies:*** *Wave behaviour at interfaces and dielectric scattering; Electromagnetic tissue properties and tissue property measurement techniques; Dosimetry and safety*		#3
	Oct. 17	No class; Reading week Oct. 14 - 17		
8	Oct. 24	Imaging: radar and tomography		

9	Oct. 31	Existing and emerging applications using radio-frequency (RF) waves: applications; clinical needs; operational characteristics; output data, images, and analysis: i. Technologies for general purposes (Electromagnetic tissue property estimation; Temperature measurement and monitoring)		#4
10	Nov. 7	ii. Wearable health monitoring (e.g. vital sign measurements; Hydration monitoring; Wound healing and infection; Post-anomaly monitoring)		
11	Nov. 14	iii. Screening and diagnostics, e.g.: 1. Bone health: Osteoporosis 2. Breast health: Breast cancer 3. Brain health: Stroke and traumatic brain injury 4. Signal processing considerations: noise reduction; decision-making; AI and machine learning		#5
12	Nov. 21	Continuation of topics from Nov. 14 class		
13	Nov. 28	**Last class** Challenges and future opportunities		
	Dec. 3		Individual Project due	

Summary of Deadlines:

Task	Deadline*
Assignment #1	Sept. 13
Assignment #2	Sept. 27
Assignment #3	Oct. 11
Assignment #4	Nov. 1
Assignment #5	Nov. 15
Team Project	Oct. 3 – Nov. 21 (depending on date selected)
Individual Project	Dec. 3

*All assignments due at 11:59pm.
(Except for Team Project oral presentation, which is presented in class.)

Assignments and Evaluations

Summary:

- Assignments 50%
- Team Project 20%
- Individual Final Project 20%
- Presence and Participation 10%

Details:

Assignments: Across the semester, there will be 5 assignments which account for a total of 50% of the overall course grade (10% per assignment). The assignments will generally each consist of five problems, incorporating problems that are theory-based, simulation-based, and/or application-oriented.

Assignments should be submitted on myCourses. Simulation files do not need to be uploaded; however your assignment submission should include screenshots of your simulation set-up and results. Responses to assignment questions should be concise and to the point, no more than 1-2 paragraphs of text per question would be expected. Supplementary diagrams, figures, or images, that support your response, are encouraged. Assignments will be assessed based on: technical accuracy of solutions (part marks for partial solutions and/or correct solution set-ups will be given) for theory and simulation-based problems; and demonstration of understanding, creativity, and clarity in responses to application-oriented discussion problems.

For homework assignments, late submissions will be subjected to a deduction of 15% per day late.

Projects: There will be two project-based components: a team project and an application-oriented individual final project.

In the team project, small groups of 2-3 students will each select a medical technology or application related to EM fields. The team must select two journal publications on the topic to read, review, and compare. The team will present their findings to the class.

Instructions to help you select a technology or application and to identify appropriate papers will be shared on myCourses.

The in-class presentations will be ~30 min long, followed by a period of questions and discussions. Presentation time slots will be offered at the beginning of the semester and teams can select their time slot based.

Each team must share their selected journal publications with the class on myCourses at least 1 week in advance of their presentation date. Additionally, the powerpoint slides must be submitted on myCourses by 11:59pm the night before the presentation day.

As this project involves an in-class presentation, late submissions will not be possible.

It is recommended that the presentation cover the following key topics (although you can be flexible with what format or order you present them in): need for the medical technology, how it fits in the current landscape of technologies, description of how it works, design requirements and constraints, comparison of set-up, methods, and results across studies, challenges and limitations.

The project will be evaluated based on: i) demonstration of understanding of clinical need for this technology (10%); ii) analysis and description of the literature providing the context for this medical technology (10%); iii) explaining how the technology works (30%); iv) discussion and comprehension of the methods and results (30%); vi) identification of constraints and challenges facing this technology (10%); and vii) responses during question and answer session (10%).

In the individual final project, due during the last week of classes, students will design, simulate, and analyze an antenna of their choosing, for a given clinical application scenario, and submit a report detailing the results.

A PDF report along with simulated design files will be submitted to myCourses. The report should be a maximum of 5 pages long and include supporting graphs, calculations, explanations, and discussions. The project will be graded on: i) report format, organization, clarity (5%); ii) antenna design and justification of examined characteristics (10%); iii) study of antenna parameters (55%); iv) discussion of validation of results (15%), v) discussion of challenges (10%); vi) presentation of results, graphs, and tables (5%). More details on each of these categories, including examples, will be provided in the project description which will be available on myCourses. Late submissions will be subjected to a deduction of 15% per day late.

Presence and participation: Presence during student-led presentations and active participation during discussions is an important part of learning in this course. In particular, attendance during student-led presentations contributes to 50% of this presence and participation score, where full marks are given for attending 100% of student-led presentations, and 0% if none of the presentations are attended. The other 50% of this presence and participation score is earned through asking questions during student-led presentations and/or contributing to discussion of the student-led presentations or group break-out discussions.

Electromagnetic (EM) simulation software: This course will involve EM simulations that allow us to design, model, understand, and analyze the behaviour of EM interactions with tissues. Access to the software, Ansys HFSS, will be provided to all students enrolled in the class.

McGill Policy Statements

Language of submission

In accord with McGill University's Charter of Students' Rights, students in this course have the right to submit in English or in French written work that is to be graded. This does not apply to courses in which acquiring proficiency in a language is one of the objectives. (Approved by Senate on 21 January 2009)

Conformément à la Charte des droits de l'étudiant de l'Université McGill, chaque étudiant a le droit de soumettre en français ou en anglais tout travail écrit devant être noté, sauf dans le cas des cours dont l'un des objets est la maîtrise d'une langue. (Énoncé approuvé par le Sénat le 21 janvier 2009)

Academic integrity

McGill University values academic integrity. Therefore, all students must understand the meaning and consequences of cheating, plagiarism and other academic offences under the Code of Student Conduct and Disciplinary Procedures (Approved by Senate on 29 January 2003) (See McGill's guide to academic honesty for more information).

L'université McGill attache une haute importance à l'honnêteté académique. Il incombe par conséquent à tous les étudiants de comprendre ce que l'on entend par tricherie, plagiat et autres infractions académiques, ainsi que les conséquences que peuvent avoir de telles actions, selon le Code de conduite de l'étudiant et procédures disciplinaires. (Énoncé approuvé par le Sénat le 29 janvier 2003) (pour de plus amples renseignements, veuillez consulter le guide pour l'honnêteté académique de McGill.)

Additional Statements

- Artificial Intelligence (AI) Tools: Students may make use of technology, including generative AI tools to contribute to and support their understanding of course materials. Students may further use such tools to aid in: i) phrasing responses or content in assignments or projects; ii) debugging simulation challenges; and iii) gaining deeper insight into the course topics. However, students are ultimately responsible for the work they submit.
- Assessment: The University Student Assessment Policy exists to ensure fair and equitable academic assessment for all students and to protect students from excessive workloads.
- Copyright: © Instructor-generated course materials (e.g., handouts, notes, summaries, exam questions) are protected by law and may not be copied or distributed in any form or in any medium without explicit permission of the instructor. Note that copyright

infringements can be subject to follow-up by the University under the Code of Student Conduct and Disciplinary Procedures.

- Intellectual property: To protect intellectual property e.g., course materials, student presentations, I ask for everyone's cooperation in ensuring that the materials are not reproduced or placed in the public domain. This means that each of you can use it for your own purposes, but you cannot allow others to use it by posting it online or giving it or selling it to others who may copy it and make it available. Thank you for your help with this.
- Extraordinary circumstances: In the event of extraordinary circumstances beyond the University's control, the content and/or evaluation scheme in this course is subject to change.
- Inclusive learning environment: As the instructor of this course, I endeavor to provide an inclusive learning environment. However, if you experience barriers to learning in this course, do not hesitate to discuss them with me and/or Student Accessibility and Achievement.
- Mercury course evaluations: Mercury course evaluations are one of the ways that McGill works towards maintaining and improving the quality of courses and the student's learning experience. You will be notified by e-mail when the evaluations are available. Please note that a minimum number of responses must be received for results to be available to students.
- Respect: The University is committed to maintaining teaching and learning spaces that are respectful and inclusive for all. To this end, offensive, violent, or harmful language arising in course contexts may be cause for disciplinary action.
- Wellness: Many students may face mental health challenges that can impact not only their academic success but also their ability to thrive in our campus community. Please reach out for support when you need it; wellness resources are available on campus, off campus, and online.