Carleton University Department of Electronics

Fall 2025

ELEC3909: Electromagnetic Waves

Introduction

This course covers the fundamentals of electromagnetic wave behavior, starting with Maxwell's equations, which govern how electric and magnetic fields interact and propagate. It explores wave solutions in free space and materials, including polarization types (linear, circular, elliptical) and energy flow via the Poynting vector. In dielectrics and conductors, wave behavior differs, with conductors exhibiting attenuation described by skin depth. At boundaries, reflection and refraction occur, governed by Snell's law and Fresnel equations, with special cases like the Brewster angle. Standing waves result from interference between incident and reflected waves. Transmission lines are introduced with their voltage/current wave dynamics, highlighting impedance, matching, and the use of Smith charts for analysis. The course concludes with guided wave concepts, including slab waveguides that confine EM waves and support mode propagation.

Course Description and Requirements

Course Description:
Maxwell's equations and EM wave solutions. Polarization. Poynting vector. EM waves in dielectrics and conductors; skin depth. Reflection and refraction. Standing waves. Fresnel relations, Brewster angle. Transmission lines. Line termination, basic impedance matching and transformation. Smith charts. Introduction to guided waves; slab waveguide.
Includes: Experiential learning activity
Prerequisite(s): ELEC 3105 or permission of the Department

Lectures: three hours a week

Laboratory and problem analysis: problem analysis three hours alternate weeks

Instructor

Professor: Connor Kupchak
Email: connor.kupchak@carleton.ca
Course Webpage: on Brightspace

Textbook: Please include price of required books

1) M. Sadiku, "Elements of Electromagnetics", 6th or latest edition (recommended)

2) David J. Griffith, "Introduction to Electrodynamics", Pearson. (recommended)

Lecture Outline

In person, Tuesdays and Thursdays 11:35 am – 12:55 pm
3030 Nicoll Building

Laboratory and Problem Analysis Sessions

3 hours (alternate weeks) as per schedule and location posted on Brightspace.

Note 1: All sessions are mandatory, and attendance will be taken. Zero will be assigned for the corresponding lab reports in case of absence.

Note 2: All HFSS/lecture related questions must be posted on Brightspace forum only, to avoid repetitions and so that everyone benefits. In certain cases, questions can be emailed to me or the TAs

Notes for Labs

- There is total 6 software labs.
- All labs will be in MC6030 Computer Lab in Minto building. No Section switching is allowed.
- All lab reports must be prepared using Latex only using the templates provided and submitted as a pdf file, with suggested section headings and specified page limits. Latex template will be provided in advance.
- The prepared document must be electronically submitted on Brightspace within 2 weeks. Reports must be named according to the following format:

Lastname_Firstname_ELEC_3909_Summer_2025_Lab_#.pdf

Self-Declaration form and Deferred Term work

Students who claim illness, injury or other extraordinary circumstances beyond their control as a reason for missed term work are held responsible for immediately informing the instructor concerned and for submitting a self-declaration form no later than three (3) days after the date/deadline of term work including test/midterm, labs, assignments. Any alternate arrangements made with the instructor for submission of term work should be made as soon as possible but within 3 days of the missed due date. If this is not possible after discussion with the instructor, alternate arrangements must be made before the last day of classes in the term as published in the academic schedule.

Instructors can require (or not) the student to submit the self-declaration form. Include the following statement if you require the student to submit a completed self-declaration form:

> **Consult with the instructor no later then 3 days after any missed course work or midterm examination.**
>
> or
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> **Contact the instructor with the completed self-declaration form no later than 3 days after the date/deadline of term work including test/midterm, labs, assignments.**

Evaluation and Grading Scheme

The cumulative course grade will be determined as follows:

1 Final exam (During normal exam period): weight 50% but you need to pass the final exam with at least 50% to pass the course.

• The Final exam will be scheduled during examination period at the end of the Fall term. Rules for a missed final exam are covered in Carleton's undergraduate calendar.
• The final exam will be traditional 3 hour closed book format and in-person in campus.
• The final exam is exclusively for the purpose of evaluating student performance and will not be returned.
• Students who miss the final exam may be granted permission to write a deferred examination. See the Undergraduate Calendar for regulations on deferred examinations.

• **Final exams are for evaluation purpose and will not be returned to students.**

1 Midterm: 20% weight of the final grade (1 x 20%)

• Midterm will occur during the course lecture and will be in-person date TBD.
• Missing a Midterm without a valid medical certificate or reason will result in a mark of zero. In case of justified explanation, the midterm weight will be moved to the final exam.
• Midterm will be closed book but you will be permitted 1 page of notes double sided.
• No discussions between students allowed. Any evidence of discussions, cheating, or something similar, during both the final exams or Midterm, will have serious consequences.
• Students registered in their own lab sessions only will be allowed to attend the Midterm. No switching allowed.

6 Software Labs: 30% weight of the final grade (6 x 5%)

To pass the course you need:

1- Minimum term course grade of 50% AND

2- Minimum grade of 50% in final exam.

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a) Deferred Final Examinations

Students who are unable to write the final examination because of a serious illness/emergency or other circumstances beyond their control may apply for accommodation by contact the Registrar's office. Consult the Section 4.3 of the University Calendar (https://calendar.carleton.ca/undergrad/regulations/academicregulationsoftheuniversity/examinations/)

b) Additional requirement(s):

Please consult Section 5 of the undergraduate regulations (https://calendar.carleton.ca/undergrad/regulations/academicregulationsoftheuniversity/grading/)

The materials (including the course outline and any slides, posted notes, videos, labs, project,

assignments, quizzes, exams and solutions) created for this course and posted on this web site are intended for personal use and may not be reproduced or redistributed or posted on any web site without prior written permission from the instructor.

Students must review their assignment and quiz grades as soon as they are given back to them. Any marking concerns, and clarifications must first be directly addressed to the TA. In case, TA's clarifications are not sufficient, or students are not satisfied with their markings, they must bring this to my attention as soon as possible. I will treat such instances as an informal appeal and will review/re-mark the quizzes/assignments in question.

The instructor understands the benefits of AI use in learning and development. However, use of AI for the full generation of documents and text is not permitted. Students are required to disclose any AI use in their submitted use. Acceptable examples include: grammar and spelling checks, sentence clarity and obtaining deeper insight into course material that is justified by the student.

As our understanding of the uses of AI and its relationship to student work and academic integrity continue to evolve, students are required to discuss their use of AI in any circumstance not described here with the course instructor to ensure it supports the learning goals for the course.

c) Exam format and e-proctoring statement

Engineering Courses shall have on campus and proctored final examinations. The final exam may be in electronic format (ie. Student will write the exam on campus and use either their computer or a university-owned computer).

Learning Outcomes

Upon successful completion of this course, students will be able to:

- Understand and apply Maxwell's equations to analyze electromagnetic fields and wave propagation.
- Describe and identify different types of polarization in EM waves.
- Calculate and interpret the Poynting vector to determine power flow in EM fields.
- Analyze EM wave behavior in dielectrics and conductors, including the concept of skin depth.
- Apply Snell's law and Fresnel equations to problems involving reflection and refraction.
- Explain the formation of standing waves and conditions that cause them.
- Determine reflection coefficients and identify the Brewster angle for zero reflection.
- Analyze transmission lines, including voltage/current behavior and characteristic impedance.
- Design basic impedance matching networks to minimize reflections.
- Use the Smith chart to visualize and solve impedance matching and transformation problems.
- Understand guided wave propagation, including supported modes and cutoff conditions.

Graduate Attributes

The Canadian Engineering Accreditation Board requires graduates of undergraduate engineering programs to possess 12 attributes: Graduate-Attributes.pdf (engineerscanada.ca) or GA's. Courses in all four years of our programs evaluate students' progress towards acquiring these attributes. Aggregate data (typically, the data collected in all sections of a course during an academic year) is used for accreditation purposes and to guide improvements to programs. Some of the assessments used to measure GAs may also contribute to final grades; however, the GA measurements for individual students are not used to determine the student's year-to-year progression through the program or eligibility to graduate. Accreditation metrics are based on courses common to all students in a program.

This following list provides the GAs that will be measured in this course, along with the indicators that are intended to develop and assess these attributes.

Graduate Attribute and Level	Indicators or Area for Specialization	Methods used for Evaluation
1. 1.6E	Knowledge base: Discipline-specific concept DOE-3	Final Exam
2. 2.1	Problem analysis: Problem definition	Midterm Exam
3. 2.2	Problem analysis: Approach to the problem	Midterm Exam
4. 2.3	Problem analysis: Use of assumptions	Midterm Exam
5. 2.4	Problem analysis: Interpreting the solution – validity of results	Midterm Exam
6. 4.1	Design: Clear design goals	Computer Lab Reports
7. 4.2	Design: Detailed design specifications and requirements	Computer Lab Reports
8. 4.4	Design: Design solution(s)	Computer Lab Reports
9. 4.5	Design: Design implementation / task(s) definition	Computer Lab Reports
10. 4.6	Design: Alternate solutions(s) definition	Computer Lab Reports
11. 4.7	Design: Evaluation on engineering principles	Computer Lab Reports

Academic Integrity and Plagiarism

a) Please consult the Faculty of Engineering and Design information page about the Academic Integrity policy and our procedures: https://carleton.ca/engineering-design/current-students/fed-academic-integrity. Violations of the Academic Integrity Policy will result in the assignment of a penalty such as reduced grades, the assignment of an F in a course, a suspension or, expulsion.

b) One of the main objectives of the Academic Integrity Policy is to ensure that the work you submit is your own. As a result, it is important to write your own solutions when studying and preparing with other students and to avoid plagiarism in your submissions. The University Academic Integrity Policy defines plagiarism as "presenting, whether intentionally or not, the ideas, expression of ideas or work of others as one's own." This includes reproducing or paraphrasing portions of someone else's published or unpublished material, regardless of the source, and presenting these as one's own without proper citation or reference to the original source.

Examples of violations of the policy include, but are not limited to:

- Any submission prepared in whole or in part, by someone else;
- Using another's data or research findings without appropriate acknowledgment;

- Submitting a computer program developed in whole or in part by someone else, with or without modifications, as one's own;
- Failing to acknowledge sources of information through the use of proper citations when using another's work and/or failing to use quotations marks; and
- Unless explicitly permitted by the instructor in a specific course, the use of generative AI and similar tools to produce assessed content (such as text, code, equations, images, summaries, videos, etc.).

Academic Accommodations

You may need special arrangements to meet your academic obligations during the term. For an accommodation request the processes are as follows:

Pregnancy obligation: Contact us with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For accommodation regarding a formally-scheduled final exam, you must complete the Pregnancy Accommodation Form (click here).

Religious obligation: Contact us with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details click here.

Academic Accommodations for Students with Disabilities: The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or pmc@carleton.ca for a formal evaluation. If you are already registered with the PMC, contact your PMC coordinator to send us your Letter of Accommodation at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After requesting accommodation from PMC, contact us, if needed, to ensure that accommodation arrangements are made.

You should request your academic accommodations in the Ventus Student Portal, for each course at the beginning of every term. For in-term tests or midterms, please request accommodations at least two (2) weeks before the first test or midterm.

Please consult the PMC website for the deadline to request accommodations for formally-scheduled exams (if applicable).

Survivors of Sexual Violence: As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: https://carleton.ca/equity/sexual-assault-support-services

Accommodation for Student Activities: Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation will be provided to students who compete or perform at the national or international level. Contact us with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist: https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf