PHYS-4220H-A: Electromagnetic Theory
2021FA - Peterborough Campus

Instructor:

Instructor: Aaron Slepkov
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Office Hours: Mondays AND Thursdays, 11 AM - Noon in my office and via Zoom. (Link will be provided at start of course)

Meeting Times:

We will have two 2-hour lectures per week in SC317.
Mondays: 15:00-16:50
Wednesdays: 10:00-11:50

Department:

Academic Administrative Assistant: Colleen Berrigan
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Description:

This course follows PHYS-3200Y. Starting from Maxwell's Equations, we develop the electromagnetic theory beyond static electric and magnetic systems to dynamic time varying systems. Topics covered are electromagnetic wave theory and propagation in vacuum and matter; waveguide theory; potentials, fields, and radiation.

Learning Outcomes:

[These learning objectives are a great checklist for exam/test review!!!]

By the end of the course, students are expected to be able to

1. write down, from "memory", Maxwell's Equations in differential form, both in vacuum and in (linear) media.
2. show how the continuity equation—an expression of charge conservation—is implicit in Maxwell's Equations.
3. compare the continuity equation and Poynting's Theorem in terms of conservation laws, and argue, by analogy, that the Poynting vector is an "energy density current" of sorts.
4. describe electromagnetic fields in linear media, including the presence of "displacement cur- rents", displacement field, D, and magnetic field H; and how they differ from fields E and B.
5. describe mathematically the energy density and total energy stored in electromagnetic fields, as well as the flow of energy.
6. write down, from "memory"—or better yet, derive—the (four) typical boundary conditions for the electric and magnetic field components parallel and perpendicular to an interface between linear media.
7. show how Maxwell's Equations suggest that electricity and magnetism are linked via the propagation of fields at the speed of light.
8. describe the procedure for using typical boundary conditions for electromagnetic fields to derive the Fresnel Equations for reflection and transmission in a dielectric interface in the case of incident-plane and orthogonal polarization.
9. Describe the presence or absence of "Brewster's angle" for reflection off a dielectric inter- face for transverse-E and transverse-B polarized light. Link this condition to the Fresnel Equations.
10. Generate the Transmission and Reflection coefficients from the Fresnel Equations, and sketch the transmitted and reflected power as a function of incident angle for transverse-E and transverse-B polarized light.
11. calculate/estimate reflection and transmission coefficients from the dielectric function of various materials.
12. describe how material (linear) conductivity can be included in Maxwell's Equations and how this inclusion subsequently leads to absorption.
13. apply boundary conditions to obtain reflection and transmission behaviour of metals and dielectrics
14. describe the meaning of "skin depth" and use this parameter to calculate electromagnetic attenuation in media.

15. describe the relative phase differences between the electric and magnetic field oscillations in nonconductive and conductive media. Estimate the magnitude of this phase difference as a function of the "quality" of conductor through which the fields propagate.
16. relate the real and imaginary components of the index of refraction (n and k) to the dielectric function.
17. show (or at the very least, describe) how dispersion arises in the dielectric function.
18. describe quantitatively and qualitatively the dielectric function (ϱ) of conductors and insulators.
19. apply boundary conditions in waveguides and cavities to obtain "modes"; use the obtained dispersion relations of such modes to describe the frequency progression of allowed waveguide modes.
20. describe the presence or absence of cut-off frequencies in various devices such as square channel and coaxial waveguides.
21. calculate "skin-depth" or attenuation behaviour of electromagnetic radiation in a conductive channel as a function of frequency and "waveguide" size.
22. describe the meaning and purpose of a "gauge transformation".
23. provide a specific example of a "gauge transformation" and its particular use/application.
24. explain the need for re-parametrizing scalar and vector potentials in "retarded-time".
25. relate the retarded-time formalism to the Lorenz Gauge
26. work with "retarded-time" as a parameter; including the necessary vector geometry and calculus.
27. describe the differences, both fundamental and functional, between near- (or induction) fields and radiation fields.
28. describe quantitatively and qualitatively radiation from oscillating electric and magnetic dipoles.
29. describe at least one outstanding paradox of radiation from accelerating charges (for example, with respect to causality).
30. link the history of the atomic model with the concept of radiation from accelerating charges.

Texts:

Required Text: *Introduction to Electrodynamics* (4th Ed. preferred) by David J. Griffiths. (Now from Cambridge Press)

Readings:

The course follows extremely closely the sequence of Chapters 8-11 in Griffiths. I highly recommend that every student read the relevant section in advance of every lecture. I'll take you through the derivations in the book, and highlight key ideas (and tricks/simplifications/hacks), but if you know where we are going, you might be able to enjoy the scenery better.

Assessments, Assignments and Tests:

There will be five homework assignments to be completed throughout the term, each due every two weeks on Thursdays at 11 AM (during office hours). Late assignments will receive a deduction of 20% (i.e. maximum score will be 80%), and will be due on the subsequent Monday at 11 AM (during office hours), after which late assignments will no longer be accepted, and will receive a score of zero.

There will be a series of (roughly 8 or 9) short quizzes at the start of some lectures. These quizzes will mostly retread some key results (or steps in a derivation) from the previous week's lectures, and are meant both to get students to review the lectures weekly and to highlight key findings and takeaways. I will inform the class in advance of each quiz. The lowest **two** quiz scores will be dropped to allow for the occasional absence, illness, or plain old befuddlement.

A 110-minute Midterm Test will be held in class on Monday, November 1st.

Grading:

- **Assignments** (4-5 in total, roughly bi-weekly): 35%
- Lecture **quizzes** (8-10 total, drop worst 2 scores): 15%
- **Midterm Test**: (In class, Nov. 3rd :) 20%
- **Final Exam**: (3-hours, cumulative): 30%

At least 25% of the term grade will be available by the drop date of Nov 9, 2021.

Schedule:

	Topic	Book Chapter
WEEK 1	Introduction and Maxwell's Equations	7.3
WEEK 2	conservation laws; Poynting's Theorem	8.1
WEEK 3	EM waves; waves in vacuum, energy and momentum;	9.1, 9.2
WEEK 4 & 5	waves in matter, transmission, reflection; absorption and dispersion	9.3, 9.4
WEEK 6 & 7	guided waves, resonant cavities	9.5

	Topic	Book Chapter
October 25-29	Reading Week: NO LECTURES	
NOV 3, 10:00-11:50	Mid-Term: In Class	
WEEK 8 & 9	scalar and vector potentials; gauge transformations	10.1
WEEK 9 &10	Retarded potentials from continuous distributions and moving point charges and fields from a moving point charge	10.2, 10.3
WEEK 10 & 11	Radiation from oscillating dipoles and from moving point charges	11.1, 11.2
WEEK 12	Review and Make-up time	

This schedule is somewhat tentative and may change to accommodate the needs of the class.

Course Guidelines:

Departmental Minimum Exam Achievement Policy: A wighted average of at least 40% must be obtained on the midterm and final exam in order to pass the course. If this condition is not met, a final grade not exceeding 45% (F) will be assigned, regardless of the mark calculated accorded to the posted grading scheme.

Late Policy: Late assignments will receive a deduction of 20% (i.e. maximum score will be 80%), and will be due exactly 4 days after the initial due time, after which late assignments will no longer be accepted, and will receive a score of zero.

University Policies:

Academic Integrity

Academic dishonesty, which includes plagiarism and cheating, is an extremely serious academic offence and carries penalties varying from failure on an assignment to expulsion from the University. Definitions, penalties, and procedures for dealing with plagiarism and cheating are set out in Trent University's *Academic Integrity Policy*. You have a responsibility to educate yourself – unfamiliarity with the policy is not an excuse. You are strongly encouraged to visit Trent's Academic Integrity website to learn more: www.trentu.ca/academicintegrity.

Access to Instruction

It is Trent University's intent to create an inclusive learning environment. If a student has a disability and documentation from a regulated health care practitioner and feels that they may need accommodations to succeed in a course, the student should contact the Student Accessibility Services Office (SAS) at the respective campus as soon as possible.

Sharing and Distribution of Course Content

Students in this class should be aware that classroom activities (lecture, seminars, labs, etc.) may be recorded for teaching and learning purposes. Any students with concerns about being recorded in a classroom context should speak with their professor. If a student shares or distributes course content in any way that breaches copyright legislation, privacy legislation, and/or this policy, the student will be subject to disciplinary actions under the Student Charter of Rights and Responsibilities or the relevant Academic Integrity Policy, at a minimum, and may be subject to legal consequences that are outside of the responsibility of the university. More details on sharing of course content are described in the policy found here: https://www.trentu.ca/artsci/sites/trentu.ca.artsci/files/documents/Policy%20on%20Sharing%20and%20Distribution%20of%20Course%20Content%202020-08-14.pdf

Student Absenteeism, Missed Tests and Examinations

Students are responsible for completing all course requirements, including attending classes and meeting assignment deadlines as specified on their syllabus.

Adjustments and deferrals to dates for participation, assignment submissions, tests, midterms and final examinations are not automatic. It is the student's responsibility to email their instructor immediately if they are unable to fulfill academic requirements.

Courses delivered remotely may involve student participation in scheduled (synchronous) classes via web-based platforms, such as Zoom. Students unable to participate (i.e., by video and/or audio) should email their instructors to request alternative arrangements for participation in these scheduled (synchronous) classes.

Students are required to be available for all tests, midterms and exams that are listed in their course syllabus and scheduled by their instructor or the Office of the Registrar. Depending on their program, the instructor or the chair/director may decide on alternative arrangements for exams and tests. Normally a doctor's note or supporting documentation is not required; however, when a student's success in the course or program is in jeopardy as determined by the instructor or chair/director, documentation may be requested.

Specific SAS accommodations can be implemented for students registered with Student Accessibility Services (SAS), but it is the responsibility of the student to make these arrangements in advance as per SAS guidelines, and to discuss accommodations of due dates with their instructors.

Students can notify the Office of the Registrar of their wish to observe cultural or religious holidays during scheduled examination periods by the deadline set in the Academic Calendar. Personal travel plans are not acceptable reasons for missing tests or exams.