ELECTROMAGNETIC THEORY II

Phys 312 Spring 2025

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Office Hours:	M 9 – 10am, T 2 – 3pm, W 2 – 3pm, Th 9am – 10am, F 1 – 2pm
Class Meetings:	TTh 11:00am – 12:15pm, WS 366
Course Website:	Phys 312 Website, Spring 2025
Required Text:	D. J. Griffiths, *Introduction to Electrodynamics,* 5^{th} ed, Cambridge University Press (2024).
Prerequisites:	Phys 311

Overview

The classical theory of electromagnetism is completely described by Maxwell's equations and the Lorentz force law. Maxwell's equations specify how charge distributions produce electric and magnetic fields and the Lorentz force law describes the forces that these exert on charges.

Physics 311 focused on methods for determining fields for stationary charge and current distributions. However, many charge and current distributions are not of this type. Yet Maxwell's equations are still valid here. Physics 312 will concentrate on applying Maxwell's equations to such situations. This will include some of the greatest triumphs of 19^{th} century physics: the existence and properties of electromagnetic waves and the production of electromagnetic waves by moving charges. Additionally Physics 312 will present methods for relating electromagnetic fields for different inertial observers and will connect this to special relativity. Various other topics from electromagnetism, that were omitted from Phys 311, will also be covered.

Physics 312 assumes a solid understanding of electromagnetism from Physics 311 as well as fluency with the associated mathematics.

The course covers:

1. Electric fields in matter, polarization, dielectrics.
2. Magnetic fields in matter, magnetization.
3. Maxwell's equations, boundary conditions, conservation laws.
4. Electromagnetic waves.
5. Potential formulation of electromagnetism.

6. Fields produced by a moving point charge.
7. Electromagnetic radiation.
8. Electromagnetism and relativity.

Assignments

An undergraduate student should expect to spend on this course a minimum of two hours outside the classroom for every hour in the classroom. The outside hours may vary depending on the number of credit hours or type of course. More details are available from the faculty member or department office and in CMU's Curriculum Policies and Procedures Manual.

1. **Homework:** There will typically be one homework assignment per class meeting. This will be due by 5pm on the date indicated on the assignment. Late homework will be subject to a penalty of at least a 2% reduction in maximum grade for each hour that the work is late. It is in your best interests to work by yourself on the homework problems but collaboration is acceptable. You can discuss the broad outlines of problem solutions with your colleagues but must write your final solutions independently. You are also encouraged to consult me for help with homework problems.

Exams and Quizzes

1. **Class Exams:** There will be two exams during class on the following days:

   Exam 1: February 25, 2025
   Exam 2: April 3, 2025

   Exams will be closed book and closed notes although you will be able to bring a formula sheet. Calculators will be allowed.

2. **Final Exam:** There will be a final exam at **10:00 am on Tuesday May 13, 2025**. The final will consist of a single exam done outside of class. Students will have two hours to complete the exam and submit it electronically.

Grades

Individual assignments and exams will be graded using suitable scales. In general, to get full credit (100%) for a problem your solution must be correct with complete explanations and calculations. Partial credit will be given for incomplete or partly correct solutions. No credit (0%) will be given for problems not attempted, assignments not turned in or quizzes and exams missed without good reason.

The numerical grades for each component will be totaled and a final numerical grade will be computed according to the following distribution.

Homework	40%
Class Exams	30%
Final Exam	30%

The following final numerical scores will guarantee letter grades:

90%	A
80%	B
70%	C
60%	D

Policies

1. **Helpful Resources:** The Tutorial Learning & Writing Center (TLC) is a *free* academic service for all CMU students. Tutors are available in Houston Hall 113 on a walk-in basis for many courses. Check out the Tutorial Learning & Writing Center website or call 970-248-1392 with any questions.

   In coordination with Educational Access Services, reasonable accommodations will be provided for qualified students with disabilities. Students should contact Educational Access Services at 970-248-1856 or Houston Hall 108 as soon as possible. Please visit Educational Access Services for additional information.

2. **Withdrawals:** There are several ways to drop this course. The deadline for dropping without penalty is **February 5, 2025.** Please consult the CMU academic calendar and catalog for more details about adding and dropping courses.

3. **Attendance:** Attendance policies are described in the Maverick Guide. You are expected to attend all the class meetings. In case of an absence due to illness, another emergency, or a conflicting CMU-sanctioned event, you must be able to produce the appropriate documentation from someone other than you that attests to the conflict or absence. If you miss more than half of the class meetings in the first week of the semester, you will be dropped from the course. If you miss a class or lab for a *documented* valid reason, turn in any assignments due within two business days after the end of the documented absence period.

   The dates of the class exams and final exam are set at the beginning of the semester and these have priority over any other events. If you have an event that conflicts with these **and** that was scheduled before the start of the semester, you must notify the instructor about this prior to **Friday, January 24, 2025**, provide documentation from someone other than you that attests to the event and I will arrange an alternative test time. If you notify the instructor about a conflict after **Friday, January 24, 2025**, the possibility of taking the test at an alternative time will depend on the nature of the conflict (e.g. illness, CMU athletic events, other emergencies). In this case you must explain the nature of the conflict to the instructor, provide documentation from

someone other than you that attests to the conflict and the instructor will decide whether the absence warrants an alternative testing time or arrangement. Alternative testing times will be decided by the instructor.

4. **Academic integrity:** You are expected to present your own work in assignments, exams and quizzes. Fabrication of data, plagiarism, and copying from anyone else, particularly in closed book exams, are serious violation of academic norms. CMU has extensive policies on these matters and penalties for infringement can be severe. For more details, consult the academic integrity policies in the Maverick Guide.

   You are prohibited from using sources which provide solutions to homework assignment or exam problems. Websites which allow students to solicit solutions for homework problems will be monitored regularly for solutions to problems that have been written and produced by the course instructor or any other CMU faculty. Students who are discovered to have submitted any assignment or exam problem to any such service or have used any such service to obtain or view solutions to any assignment or exam problem will receive zero credit for that entire assignment and the instructor will submit a Report of Academic Dishonesty with the Office of Academic Affairs. Additional penalties may be levied in such cases.

Student Learning Outcomes

Upon completion of this course, a student should be able to:

1. Translate between verbal and mathematical descriptions of physical situations and apply mathematical reasoning, using vectors and vector calculus, to analyze these situations.
2. Determine electromagnetic fields, polarization, and magnetization in linear matter.
3. Compute the Poynting vector and apply it to energy flow in electromagnetism.
4. Derive electromagnetic wave equations from Maxwell's equations.
5. Determine basic properties and reflection and transmission of electromagnetic waves from Maxwell's equations.
6. Use the potential formalism to determine potentials and fields for non-stationary sources.
7. Determine the energy radiated by source charges and currents.

This course contributes to the fulfillment the following program learning objectives for the BS in Physics degree. A student will have demonstrated the ability to:

1. Show fluency with the major fields of physics (classical mechanics, electromagnetism, statistical physics and quantum theory).
2. Use mathematical representations to analyze physical scenarios. This requires translating back and forth between physical and mathematical problems and using appropriate mathematics to aid in the analysis of the scenario.

Schedule

The following schedule is tentative, except for the dates of the class exams.

Week	Dates	Topic
1	1/21 – 1/23	Review of electrostatics, polarization, electric displacement (Ch. 4.1 – 4.3).
2	1/28 – 1/30	Electric displacement, dielectrics, magnetic dipoles (Ch. 4.3 – 4.4).
3	2/4 – 2/6	Magnetization, magnetic fields in matter (Ch. 6.1 – 6.4).
4	2/11 – 2/13	Maxwell's equations in matter, boundary conditions, energy in electromagnetism (Ch. 7.3, 8.1).
5	2/18 – 2/20	Waves in one dimension (Ch. 9.1).
6	2/25	**Exam I**.
6	2/27	Reflection and transmission of waves (Ch. 9.1).
7	3/4 – 3/6	Polarization, Electromagnetic waves (Ch. 9.1 – 9.3).
8	3/11 – 3/13	Reflection and transmission of EM waves (Ch. 9.3).
9	3/25 – 3/27	Potential formulation of electromagnetism (Ch. 10.1).
10	4/1	Potentials produced by point charges (Ch 10.2 – 10.3).
10	4/3	**Exam II**.
11	4/8 – 4/10	Moving point charges, Liénard-Wiechert potentials (Ch 10.3).
12	4/15 – 4/17	Fields of a moving point charge, radiation (Ch 10.3, 11.1 – 11.2).
13	4/22 – 4/24	Special relativity (Ch 12.1 – 12.2).
14	4/29 – 5/1	Special relativity, relativistic electrodynamics (Ch 12.2 – 12.3).
15	5/6 – 5/8	Relativistic electromagnetism (Ch 12.2 – 12.3).