33762: Electrodynamics II

Spring 2019

Instructor: Prof. Riccardo Penco

Schedule: Mon, Wed, Fri 10:30-11:20am

Class Room: Wean 6327

Office Hours: by appointment

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Course Description

This course is the second part in a two-semester series on Electromagnetism for graduate students. Electromagnetism is a foundational subject, and mastering its main concepts, techniques, and results will prove to be valuable for your research in high energy physics, astrophysics, condensed matter physics, or engineering. For a detailed list of topics covered, see the "Course Plan" section.

This is 12-unit course. This means that the you should be spending on average 12 hours/week on this course (3 hours lectures + 9 hours studying the material). If you find yourself spending consistently more time than that, please come see me to discuss alternative learning strategies.

Learning Objectives

By the end of this course, you should be able to:

- use Green's functions to solve the Poisson and wave equations.
- explain the physical origin of the following physical phenomena:
    1. Cyclotron radiation
    2. Syncrothron radiation
    3. Cherenkov radiation
    4. Transition radiation
    5. Bremsstrahlung
    6. Radiation reaction

7. Landau damping
8. Debye screening

- explain the difference between the following types of scattering:

1. Thomson scattering
2. Compton scattering
3. Rayleigh scattering
4. Rutherford scattering

- explain the properties and origin of the following collective excitations:

1. Alfven waves
2. plasma oscillations

- synthesize and present new material in a classroom setting.

Resources

Learning electromagnetism from Jackson's textbook has been a rite of passage for many generations of physics graduate students. We will continue this tradition, and mainly use the 3rd edition of the book *Classical Electrodynamics* by J.D. Jackson. However, we will do so by following a somewhat unorthodox path through the book. More on that in the next section.

This textbook is not required, but if you would like to own an electromagnetism textbook for future reference, you certainly can't go wrong with Jackson. The library also owns several copies of all three editions. If you plan to borrow or purchase one of the older editions, please be aware that they use a different system of units (electrostatic me units) compared to the 3rd edition (SI units). As such, some additional "mental gymnastics" may be needed to translate the equations in this book to the ones you will encounter in class.

During the semester, you are welcome to explore all electromagnetism textbooks that the library has to offer to seek alternative viewpoints on the subject. I myself may occasionally rely on other textbooks to complement the material found in Jackson. A few textbooks that I recommend in particular are:

- *Modern Electrodynamics*, Zangwill
- *Classical Electromagnetism*, Franklin
- *The Classical Theory of Fields*, Landau & Lifshitz
- *Electrodynamics of Continuous Media*, Landau & Lifshitz
- *Introduction to Electrodynamics*, Griffiths

Course Plan

Here is a rough breakdown of the topics we will discuss in this course, together with an estimated timeline:

- Green's functions (weeks 1-3)
- Radiation emitted by a point-like charge (weeks 4-5)
- Scattering of light (weeks 6-7)
- Scattering of charged particles; Cherenkov and transition radiation (weeks 8-11)
- Bremsstrahlung and radiation reaction (weeks 12-13)
- Magnetohydrodynamics and plasma physics (weeks 14-15)

For more details, see the attached schedule of lectures.

Assessments

Your final grade for this course will be determined based on a variety of factors (the relative weight is in parentheses):

Attendance (10%): The material will be challenging, and showing up to class will be particularly important to remain engaged with the material and not fall behind.

Participation (20%): This is a small class, and therefore it will have the flavor of a reading course. Lectures will hopefully be more like a conversation, and there will be plenty of chances for you to participate. While doing so, please be mindful of your classmates and allow everyone the same opportunity to contribute to the class. Your participation grade will be based mostly on the quality rather than the quantity of your contributions.

Final Exam (30%): In lieu of a written final exam, you will prepare by yourself and deliver a 50-minute lecture on a topic of your choice that is relevant for this class but wasn't covered during the semester. Your lecture will be scheduled at a mutually agreed time between May 6 and May 14. Possible topics include (but are not limited to):

- Lagrangian formulation of E&M and coupling to point-particles (J12.1, J12.7)
- Photon mass and superconductivity (J12.8, J12.9)
- Frequency dispersion of dielectrics, conductors and plasmas (J7.5)
- Group velocity and arrival of signal in a dispersive medium (J7.8, J7.11)
- Thomas precession (J11.8, J11.11)
- Causality and Kramers-Kronig relations (J7.10)
- Optical theorem (J10.11)

I have added the relevant sections in Jackson in parentheses to give you a sense of the expected range and depth of the material to be covered. You are however welcome to use any source you'd like to prepare your lecture. You may also choose to discuss a topic that is relevant for this class but is not listed above. In this case, however, please come talk to me to make sure that the topic you choose is at an appropriate level of difficulty. Regardless, you should let me know the topic you plan lecture on no later than April 26, 2019.

In-class Presentations (40%): in lieu of homework problems, you will co-teach 10 lectures throughout the semester, as shown in the attached schedule of lectures. You can choose how to subdivide the lectures amongst yourselves in a fair manner based on your preference and time constraints. You can even choose to share lectures. However, you are expected to teach the same amount as your colleagues, and you are not allowed to teach more than two consecutive lectures by yourself. You are welcome to meet with me prior to your lecture if you need help with the material to be covered. The material will be challenging, so don't wait until the last minute to prepare your lecture!

At the end of the semester, all your scores will be combined in the proportions shown above to determine your final grade based on the following grading scale:

A: 100-90% **B:** 89-80% **C:** 79-70% **D:** 69-60%

Course Policies

Email policy. The best way to contact me is by email. I will do my best to reply in a timely manner. This means that you can expect to receive a reply within 24 hours during the week, possibly 48 hours during the weekend.

Office Hours. Office hours are by appointment only. If you would like to schedule a meeting, please send me an email including (1) the topics you would like to discuss (*e.g.* electric dipole radiation, Problem 2 on this week's homework, etc...), and (2) a couple of time windows (during Mon-Fri, 9am-5pm) that work for you.

Learning Accommodations. If you need special accommodations for this course, please contact the Office of Disability Resources at 412-268-6121 or `access@andrew.cmu.edu`. Once you have obtained an accommodation letter from this office, please contact me as early as possible in the semester so that we can set up an appointment to privately discuss your needs. I will make every effort to provide you with any reasonable accommodation you may need. You can learn more about CMU's official policy for student accommodation here:

`https://www.cmu.edu/disability-resources/policies-guidelines/index.html`

Academic Integrity. You are allowed to work in groups on the homework problems. However, the solutions you turn in for grading should be your own work and reflect your own understanding of the material. In particular, while you are welcome to consult other electromagnetism books to further your understanding of the subject, looking for solutions to homework or exam problems in other textbooks or online amounts to cheating. Copying

someone else's work, whether from a book or from a colleague, is considered plagiarism and will be sanctioned according to CMU's policy. For more information about CMU's policy on academic integrity, please see

`https://www.cmu.edu/policies/student-and-student-life/academic-integrity.html`

Diversity, Inclusion and Harassment. This class is a safe learning environment where diversity is valued and any form of harassment will not be tolerated. Please feel free to reach out to me if you feel that these values are not being respected. However, you should be aware that the university requires me to report any serious incident that is disclosed to me, regardless of whether it took place on- or off-campus. While I am unable to promise confidentiality, I can assure you that I will handle any situation with discretion. You can also report any unethical behavior you witness on campus directly to the CMU Ethics Reporting Hotline (`www.reportit.net`, Username: tartans, Password: plaid).

Technology in the Classroom. Technology is welcome in the classroom as long at it enhances your learning experience. For instance, you are welcome to take notes on your tablet or laptop if you find it more convenient. Cellphones instead should be at least on silent mode during lectures, and must be completely turned off during exams. I strongly caution you against multitasking while in class. Lectures will be fast-paced, and it is likely that you will miss something important—at the very least some participation points—while checking your email or surfing the web.

Food and Drinks. You are welcome to bring beverages in the classroom, but you are responsible for cleaning up any spillage that may occur. However, food is not permitted.

Take care of yourself

Being a Ph.D. student can be a very fulfilling but also very demanding experience. One of the most valuable skills you should aim to learn while in graduate school is the ability to deal with a heavy workload without compromising your well-being. Please make sure to take care of yourself and carve out enough time during the week to eat well, have enough sleep and do things you enjoy outside physics. In the long run, this will make you more likely to succeed here at CMU.

If at any point during the semester you feel overwhelmed, please know that it is normal and make sure to reach out to people you'd feel comfortable talking with. These may include not only your friends and family, but also your fellow graduate students, your instructors, other faculty members, as well as resources on campus such as Counseling and Psychological Services (CaPS) (see `https://www.cmu.edu/counseling/`).