33761: Electrodynamics I

Fall 2020

Instructor: Prof. Riccardo Penco

Schedule: Mon, Wed, Fri 10:40-11:30am; Mon 5:20-6:10pm

Office Hours: on zoom, by appointment

Email: `rpenco@cmu.edu`

Zoom link: click here.

Canvas login: click here

Slack workspace: click here (link expires on Sep 17).

Course Description

This course is the first semester 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 a 12-unit course. This means that the you should be spending on average 12 hours/week on this course (4 hours lectures + 8 hours studying and solving homework problems). If you find yourself spending consistently more time than that, please come see me to discuss alternative learning strategies.

Format and Tools

The format of this course is remote-only. Throughout the semester we will rely on three main services:

1. **Zoom:** Lectures and recitations will be held over **zoom**, and can be accessed live using this link. CMU has a campus-wide zoom license: you can download and install it by following these instructions. Lectures will also be recorded for the benefit of those that cannot attend live because on a (very) different time zone. See the *Assessments* and *Course Policies* sections for additional information about attendance.

2. **Canvas:** the login page for Canvas is here. On the canvas page for this course, you will be able to:
    - find a copy of this syllabus;
    - download weekly homework assignments, and upload your solutions;
    - view recordings of lectures and recitations;
    - access your grades.
3. **Slack:** one of the potential downsides of not having in-person classes is that it might be more difficult to create a collaborative environment and start conversations that normally would occur spontaneously. To try to compensate for this, I've created a Slack workspace, which you can join using this link. This workspace contains different channels to discuss and ask questions about lectures, homework, exams, and everything else related to this course. I will also post all announcements here. You can access Slack within a web browser, or download a stand-alone app here. Slack is quickly becoming commonplace in large scientific collaborations as well as in the private sector, so it's good to become familiar with it.

Don't worry if you are not yet familiar with one or more of these tools: the first homework set will be a tutorial that introduces you to the basic features of all these tools. For now, just download and install zoom to make sure that you can attend the first lecture.

Learning Objectives

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

- Derive basic results of (special) relativistic kinematics and dynamics.
- Find static solutions to Maxwell's equations in cartesian, spherical and cylindrical coordinates.
- Use the multipole expansion to find approximate asymptotic solutions.
- Solve Maxwell's equations inside simple continuum media.
- Describe the properties of wave solutions to Maxwell's equations.
- Describe the propagation of waves within continuous media.
- Calculate the power radiated by a localized, oscillating source.

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. In a normal year, I would have placed a few copies on reserve at the Sorrells Engineering and Science Library (Wean 4400). Unfortunately, a digital version of this textbook doesn't exist, and since all CMU libraries are closed until further notice due to COVID, I couldn't place physical copies on reserve. There are however 3 scanned copies that can be accessed digitally via the Controlled Digital Lending Program—you can search for them in the library catalog the same way you would any other book. In the meantime, if you plan to rent or purchase a copy of Jackson, please be aware that the 1st and 2nd editions use a different system of units (electrostatic units) compared to the 3rd edition (SI units). As such, some additional "mental gymnastics" will 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 in digital format to seek alternative viewpoints on the subject (see however the "Academic Integrity" section of this syllabus for what is considered a permissible use of these sources). I myself may occasionally rely on other textbooks to complement the material found in Jackson.

Course Plan

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

- Experimental foundations of electrodynamics; Maxwell's equations in vacuum (week 1).
- Global and local symmetries of Maxwell's equations; electromagnetic potentials (week 2).
- Special relativity (week 3)
- Electrostatics; Poisson and Laplace equations; boundary conditions; conductors; methods of images (weeks 4-5)
- Solutions of Poisson and Laplace equations in cartesian, spherical and cylindrical coordinates; Legendre polynomials; spherical harmonics; Bessel functions (weeks 5-7)
- Magnetostatics (week 7)
- Multipole expansions (week 8-9)
- Maxwell's equations in continuous media (weeks 9-11)
- Conservation of energy and momentum (week 11)
- Wave solutions (week 12-14)
- Radiation (weeks 14-15)

Assessments

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

Attendance and Participation (10%): This is a small class, and thus there will be plenty of chances for you to participate, *e.g.* by asking and answering questions. 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 on the quality and not the quantity of your contributions. Participation also includes helping your classmates when they have questions, and interactions on Slack count towards participation. 10% of your grade might not seem like much, but it's the difference between an **A** grade and a **B** grade at the end of the semester.

Final Exam (20%): This will be a take-home, cumulative exam. It will start at 9am and end at 9pm, on a date between Dec 14 and Dec 21 to be determined by the registrar's office. The actual exam should take only a few hours to complete, but I am giving you 12 hours to ensure that time pressure is not a factor. During the exam, you are allowed to consult your notes, Jackson, and past homework sets, but you cannot use other books nor (duh!) google the answers.

Homework (30%): Each Monday morning I will assign a set of homework problems, which will be due the following Monday by the end of the day (unless there is a midterm that week, in which case there might be some more flexibility). I will not assign new homework sets during the weeks when midterms are scheduled to ensure that you have extra time to prepare for the exams. Homework assignments will be posted on canvas, where you will also be able to upload your solutions. You can just scan your handwritten solutions with your phone (let me know if you need suggestions about scanning apps), no need to type up your solutions (although you are welcome to do so if you prefer it). There will be a total of 12 homework assignments. At the end of the semester I will drop the lowest score. When working on your homework, you are welcome to discuss the problems with your colleagues (see however the "Academic Integrity" section for important disclaimers). You are also allowed (but not required) to use software such as Mathematica and/or Matlab to deal for instance with integrals involving special functions. Both Mathematica and Matlab are available for free to all CMU students, and come with extensive documentation. Homework problems will be challenging, so please make sure to start working on them early as late homework will not be accepted.

Midterm Exams (40%): We will have 3 midterm exams on the following dates:

- Fri, Sep 25
- Wed, Oct 21
- Fri, Nov 20

These will be 2-hour, take-home exams, which you can take anytime between 9am and 9pm on the day of the exam. Exams are due 2 hour after the start time, whenever that happens to be for you. As for the final, during the midterms you are allowed to consult your notes,

Jackson, and past homework sets but, but you cannot use other books nor google the answers..

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%

The lowest passing grade for this class is **B-**.

Course Policies

Technology in class. For obvious reasons, technology will be an integral part of this course. However, I suggest you turn off your cellphone and computer notifications during class, and 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.

Zoom etiquette. During lectures and recitations, feel free to jump in during the lecture and interrupt if you have any question. However, please mute your microphone when you are not speaking to avoid background noises from interfering with the lectures. If possible, please consider keeping your camera on: studying and working from home can be an isolating experience, and it's nice to see some friendly familiar faces every now and then :)

Attendance. You are expected to attend lectures and recitations live on zoom unless you happen to be on a very different time zone. If you are unable to attend live, please get in touch with me.

How to get in touch. Please post any general questions you may have about the course or the material in the appropriate channel on Slack. If they are directed at me please add the tag "@Riccardo Penco". If instead they are directed at everyone, add the tag "@channel". Chances are that your fellow classmates might have a similar question, or regardless benefit from reading the answer. By having these conversations on Slack we can make sure that we are always all on the same page. For more private questions, please contact me by email. Regardless of the mode of communication, 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 also on zoom, and 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...), (2) expected duration, and (3) a couple of time windows (during Mon-Fri, 9am-6pm) 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

Make-up Exams and Late Work. There are no make-up exams and late work will not be accepted, except in case of documented medical emergencies or particular learning accommodations.

Re-grade policy. If you would like me to review a graded assignment (homework or exam), please submit a request by email within one week from the day it has been returned to you. Your email should state clearly the reason why you are requesting a re-grade. Exceptions to this policy may apply to the final exam due to the university deadline for submitting final grades. Please be aware that your grade could end up increasing or decreasing as a result.

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).

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. This is especially true given the current circumstances. 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/).