Electricity and Magnetism I

PHYS 405

Instructor Info

Prof. Francis-Yan Cyr-Racine

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Course Info

Prereq: A good foundation in classical mechanics and vector calculus; PHYS 366

Tues & Thurs

1-2:15pm

PAIS 1140/Zoom

Course Website

Office Hours

Tues & Thurs

Tues: 3-4pm; Thurs: 10-11am

Zoom

TA Info

Ali Kazemi

Thursdays 3:30-4:30pm

Zoom

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Why Electromagnetism?

While electric and magnetic phenomena have been known to mankind for millennia, the theory of electricity and magnetism was put on rigorous mathematical footing only in the 1800s. The work of Maxwell and others showed that electric and magnetic phenomena are two sides of the same coin, hence providing the first example that apparently distinct forces could be unified into a single theory. This breakthrough had a huge impact on the evolution of physics and continue to shape how we think about fundamental interactions in our world. Together with gravity, electromagnetism is the most important force shaping our everyday life. From the colors we see, the textures we feel and the bio-chemical reactions going on inside our bodies, to the precise electronic circuits powering our phones and computers, electromagnetic forces play a huge role in making the world around us works. As such, a good understanding of classical electromagnetism is key to explore a plethora of other phenomena, including more complex forces such as the weak and strong nuclear force. Many of the concepts introduced in this class can be applied to other physical contexts, making this course a central pillar of a physicist academic career.

Overview

The goal of this class is to introduce the subject of classical electromagnetism at the advanced undergraduate level. Classical electromagnetism (EM) is fundamentally a local theory of vector fields and its proper treatment requires methods of vector analysis and differential equations. We will briefly review these mathematical concepts in the first few lectures of the class. In this class, we will entirely focus on static (time-independent) fields interacting with charges at rest or in steady motion. In this case, the electric and magnetic fields decouple from one another so they can be treated independently. Such independent treatment of electrostatics and magnetostatics is the central content of this class. A sizable fraction of this class will be spent computing the electric field and potential created by a static distribution of charges. We will also discuss how the electric field behaves within conductors and insulators. The second part of the class will be spent computing magnetic field resulting from static currents, including how the magnetic field behaves in the presence of insulating matter. Time-dependent electric and magnetic fields created by moving charges and nonsteady currents will be covered in the next Electricity and Magnetism course, PHYS 406.

About Me

I am a practicing theoretical cosmologist/astrophysicist with a keen interest about dark matter and the physics of the early Universe.

Material

Required Text

Griffiths, D. J. *Introduction to Electrodynamics*. 4th Edition. Cambridge University Press. 2017. (ISBN: 978-1108420419)

Useful Reference

Purcell, E. M. and Morin, D. J. *Electricity and Magnetism*. 3rd Edition. Cambridge University Press. 2013. (ISBN: 978-1107014022)

Grading Scheme

20%	Your 10 best homework assignments (out of 11).
50%	2 Midterm Exams (25% each)
30%	Final Exam

FAQs

? What are the most important things I need to do to succeed in this class?

! It's quite simple: Call in to every class, register and attend the PHYS 415 problem sessions, and attempt every homework assignments.

? Is this a "hard" class?

! This may be the most mathematically advanced class you have taken so far. Getting the right answers will require that you rigorously follow the rules of vector calculus. But understanding the physical picture beyond the math is even more important (and it can often save you a lot of algebra!).

? My vector calculus is rusty. What should I do?

! Take a deep breath. Relax. You probably already master more vector calculus than you can remember. In any case, we'll start the course with a brief review. Remember, this is a physics class, not a math class.

? Will we cover how magnets work?

! Absolutely! We will see how tiny currents at the atomic levels can lead to macroscopic magnetic field, such as those of fridge magnets.

Class Format

This will be an hybrid online/in-person class held at the regular times outlined above. Depending of the COVID situation and whether students are comfortable coming to class, I will consider meeting face-to-face. The default format will be online; if you don't hear from me about coming to class in person, assume that the class will take place online.

In terms of the actual format for the class itself, it will consist of a mix of lecturing and active problem solving by the students in small (virtual) groups. It is very important that you attend every class. Students will be asked often to share their solutions (or their group's solution) with the rest of the class. The lectures will be recorded and posted on Learn, in case you want to re-watch some parts.

Homework Assignment

There will be 11 homework assignments spread out over the course of the semester. They will be due every 7-10 days. They will be posted on the course webpage/UNM Learn. Homeworks are to be submitted online on UNM Learn using the appropriate link provided there. Homework assignments submitted up to 24 hours after they are due will be accepted, but with a 25% penalty. Homework submitted after 24 hours will not be graded. It is very important that you attempt every assignment as they will help you make sure you are staying on top of the class material.

While I strongly encourage you to discuss the homework assignments with your classmates, the work you hand in must be entirely yours.

PHYS 415: Problems in Electricity and Magnetism I

This is a very important adjunct to the main lecture class, taking place every Fridays from 9 to 9:50am online. It will provide you additional practice with solving problems beyond the homework assignments and self study. Furthermore, the class will also give you a valuable opportunity to bring to my attention your difficulties with any concepts covered in the lecture class so I can address them in a group setting. The problem sheets would be posted on the course webpage on the Wednesday before the problem class. The corresponding solutions will be posted after the problem class. You will receive credit for the problems class as long as you register and show up for more than 10 sessions. Even if you don't register for the class, I encourage you to attend anyway, just to get the extra practice.

Learning Goals

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

- Compute the electric field and electric potential for simple static charge distributions and boundary conditions.
- Compute the energy contained in a given electric field configuration.
- Explain the behavior of the electric field and potential in the presence of a conductor.
- Compute charges induced on a conductor when the latter is placed in an external electric field.
- Explain the behavior of the electric field and potential in the presence of a dielectric.
- Compute the bound and surface charges induced in a dielectric material when placed in an external electric field.
- Compute the electric potential a large distance away from an arbitrary charge distribution using the multipole expansion.
- Compute the magnetic field and vector potential for a steady current.
- Explain the behavior of the magnetic field and vector potential in the presence of matter.
- Explain the difference between a diamagnet, a paramagnet, and a ferromagnet.
- Compute the bound and surface currents induced in an object placed in an external magnetic field.
- Write down and explain the physical meaning of Maxwell's equations for electrostatics and magnetostatics.

Academic Integrity

Each student is expected to maintain the highest standards of honesty and integrity in academic and professional matters. The University reserves the right to take disciplinary action, up to and including dismissal, against any student who is found guilty of academic dishonesty or otherwise fails to meet the standards. Any student judged to have engaged in academic dishonesty in course work may receive a reduced or failing grade for the work in question and/or for the course. Academic dishonesty includes, but is not limited to, dishonesty in quizzes, tests, or assignments; claiming credit for work not done or done by others; hindering the academic work of other students; misrepresenting academic or professional qualifications within or without the University; and nondisclosure or misrepresentation in filling out applications or other University records.

Diversity and Inclusivity Statement

I consider this classroom to be a place where you will be treated with respect, and I welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, ability - and other visible and non-visible differences. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class.

Citizenship and/or Immigration Status: All students are welcome in this class regardless of citizenship, residency, or immigration status. Your professor will respect your privacy if you choose to disclose your status. UNM as an institution has made a core commitment to the success of all our students, including members of our undocumented community. The Administration's welcome is found on our website.

A Note About Sexual Violence and Sexual Misconduct: As a UNM faculty member, I am required to inform the Title IX Coordinator at the Office of Equal Opportunity of any report I receive of gender discrimination which includes sexual harassment, sexual misconduct, and/or sexual violence. You can read the full campus policy regarding sexual misconduct. If you have experienced sexual violence or sexual misconduct, please ask a faculty or staff member for help or contact LOBORESPECT.

Accommodations for Students with Disabilities

In accordance with University Policy 2310 and the Americans with Disabilities Act (ADA), academic accommodations may be made for any student who notifies the instructor of the need for an accommodation. It is imperative that you take the initiative to bring such needs to the instructor's attention, as I am not legally permitted to inquire. Students who may require assistance in emergency evacuations should contact the instructor as to the most appropriate procedures to follow. Contact Accessibility Resource Center at (505) 277-3506 for additional information.

If you need an accommodation based on how course requirement interact with the impact of a disability, you should contact me to arrange an appointment as soon as possible. At the appointment we can discuss the course format and requirements, anticipate the need for adjustments and explore potential accommodations. I rely on the Accessibility Resource Center for assistance in developing strategies and verifying accommodation needs. If you have not previously contacted them I encourage you to do so.

Respect the UNM Community by Preserving Health

You have the ability to prevent the spread of COVID-19 and to preserve the health of fellow students, your instructor, staff and the community by following UNM health protocols. The UNM Provost Administrative Directive on Mandatory Student Face Covering and Symptom Reporting of July 9, 2020 requires that all students on UNM-Main and UNM branch campuses wear face masks in the face-to-face classroom and on campus unless they have a specific mask accommodation (confidentially documented with the Accessibility Resource Center). UNM Provost Administrative Directive is consistent with Governor Lujan Grisham's Public Health Emergency Order, as amended, and the Public Health Order of the New Mexico Health Secretary. It also requires daily participation in symptom screening through covidscreen, which will be sent via UNM e-mail.

Acceptable masks and mask wearing in class: A two-layer mask that covers the nose and mouth and that is cleaned regularly is acceptable. A face shield is not sufficient protection. It is vital that you wear your mask correctly, covering your nose and mouth. Removing your mask for an extended period to eat or drink in class violates the Provost Administrative Directive and endangers others.

Mask Wearing Accommodation: Individuals with a documented disability or diagnosis may seek accommodation with the UNM Accessibility Resource Center (ARC). Individuals do not need to reveal private information to an instructor. ARC will require documentation of health requirements, which will be kept confidential. The instructor will be informed only of any need for accommodation.

Consequences of not wearing a mask properly: Unless you have an ARC-approved accommodation, if you don't wear a mask, or if you do not wear a mask properly by covering your nose and mouth, you will be asked to leave class. If you fail to wear a mask properly on more than one occasions, you can expect to be dropped from the class. If you insist on remaining in

the classroom while not wearing a mask (without an ARC-determined accommodation), class will be dismissed for the day to protect others and you will be dropped from the class immediately.

This class may move to remote delivery at any time to preserve the health and safety of the students, instructor and community. Please check the course webpage regularly for updates about our class and please check the Bringing Back the Pack website regularly for general UNM updates.

Tentative Class Schedule

MODULE 1: Review of vector calculus		
Week 1	Vectors, vector products, Einstein summation convention, multivariate functions, gradient operator and its fundamental theorem, divergence of vector fields, divergence theorem	Griffiths Ch. 1.1-1.3
Week 2	Curl of vector fields, Stoke's theorem, second derivatives, spherical and cylindrical coordinates, Dirac delta function, Helmholtz decomposition	Griffiths Ch. 1.2-1.6
MODULE 2: Electric field		
Week 3	Electric charge, Coulomb law, electric field, field lines, Gauss's law	Griffiths Ch. 2.1-2.2
Week 4	Electric potential, work done to move charges, energy of charge distribution	Griffiths Ch. 2.3-2.4
Week 5	Electrostatic energy and review of material covered so far 02/18: Midterm #1	
Week 6	Conductors, boundary conditions, induced charges, capacitors	Griffiths Chs. 2.3, 2.5
Week 7	Laplace's equation for the electric potential, uniqueness theorem, method of images, Direct solutions to Laplace's equation in cartesian coordinates	Griffiths Ch. 3.1-3.3
Week 8	Direct solutions to Laplace's equation in spherical and cylindrical coordinates	Griffiths Ch. 3.3
Week 9	Spring Break	
Week 10	The multiple expansion for the electric potential, electric dipole	Griffiths Ch. 3.4
Week 11	Review of Chapter 3, dielectrics and polarization 04/01: Midterm #2	Griffiths Ch. 4.1
Week 12	Electric field inside a dielectric, bound charges, electric displacement field, linear dielectrics	Griffiths Ch. 4.2-4.4
MODULE 3: Magnetic field		
Week 13	Origin of magnetism, the Lorentz force, Biot-Savart law	Griffiths Ch. 5.1-5.2
Week 14	Magnetic field from steady currents, the curl and divergence of the magnetic field, Ampère's law, vector potential	Griffiths Ch. 5.2-5.4

Week 15	Multiple expansion of the vector potential, magnetic dipole, diamagnets and paramagnets, magnetization, bound currents	Griffiths Chs. 5.5, 6.1-6.2
Week 16	Magnetic field in matter, the H field, magnetic susceptibility and permeability, ferromagnetism	Griffiths Ch. 6.3-6.4
Week 17	Final exam	