Electricity and Magnetism I

PHYS 405

Instructor Info

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Course Info

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

Mon, Wed & Fri

11-11:50pm

PAIS 1140

Course Website

Office Hours

Mon & Wed

3-4pm

PAIS 3214

TA Info

Loc Ngo

Fri 8:30-9:30am

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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 as we encounter them throughout this course. 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

10%	Attendance/Class participation
25%	9 homework assignments
40%	2 Midterm Exams (20% each)
25%	Final Exam

FAQs

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

! It's quite simple: Come 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

The class will consist of a mix of lecturing and active problem solving by the students in small groups. It is very important that you attend every class, and 10% of the final grade is tied to class attendance and active participation in class activities. Students will be asked often to share their solutions (or their group's solution) with the rest of the class.

Homework Assignment

There will be 9 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. Homeworks are to be submitted in class on the due date. *Late Homework assignments will be accepted but with a 25% penalty for each day past the deadline.* So a homework handed-in within 24 hrs of the deadline will carry a 25% penalty, one handed-in within 48 hrs will carry a 50% penalty, as so on. *Let me know if you are planning on submitting your homework late such that I can delay the posting of the solutions.* Once the solutions are posted, assignments will no longer be accepted. 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 Wednesday from 12 to 12:50pm in PAIS 1140. 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 Tuesday 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.

Tentative Class Schedule

MODULE 1: Electric field

Week 1	Electromagnetism as a classical field theory, electric field, point charge, Coulomb law, field lines, principle of superposition, continuous charge distribution	Griffiths Ch. 2.1
Week 2	Electric flux, Gauss's law, gradient operator, Dirac delta function, divergence theorem	Griffiths Ch. 2.2
Week 3	Curl of the electric field, Stokes' theorem, electric potential, Poisson equation	Griffiths Ch. 2.3
Week 4	Boundary conditions, 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 02/16: Midterm #1	
Week 6	Conductors, induced charges, capacitors	Griffiths Ch. 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, force and torque on dipole	Griffiths Chs. 3.4, 4.1
Week 11	Dielectrics, polarization, electric field inside a dielectric, bound charges, electric displacement field, Boundary conditions	Griffiths Ch. 4.1-4.3
Week 12	Linear dielectrics, energy in dielectric systems 04/06: Midterm #2	Griffiths Ch. 4.4

MODULE 2: 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	

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

UNM Administrative Mandate on Required Vaccinations

UNM requires COVID-19 vaccination and a booster for all students, faculty, and staff, or an approved exemption (see UNM Administrative Mandate on Required Vaccinations). Proof of vaccination and booster, or a medical, religious, or online remote exemption, must be uploaded to the UNM vaccination verification site. Failure to provide this proof may result in a registration hold and/or disenrollment for students and disciplinary action for UNM employees.

Booster Requirement: Individuals who received their second dose of a Pfizer or Moderna vaccine on or before June 15, 2021, or their single dose of a Johnson & Johnson vaccine on or before October 15, 2021, must provide documentation of receipt of a booster dose no later than January 17, 2022.

Individuals who received their second dose of a Pfizer or Moderna vaccine after June 15, 2021 or who received their single dose of Johnson & Johnson after November 15, 2021 must provide documentation of receipt of a booster within four weeks of eligibility, according to the criteria provided by the FDA (6 months after completing an initial two-dose Moderna vaccine, 5 months after completing the Pfizer sequence, and 2 months after receiving a one-dose Johnson and Johnson vaccine).

International students: Consult with the Global Education Office.

Exemptions: Individuals who cannot yet obtain a booster due to illness should request a medical, religious, or online remote exemption (which may have an end date) and upload this to the vaccination verification site.

Medical and religious exemptions validated in Fall 2021 (see your email confirmation) are also valid for Spring 2022 unless an end date was specified in the granting of a limited medical exemption. Students must apply for a remote online exemption every semester.

UNM Requirement on Masking in Indoor Spaces

All students, staff, and instructors are required to wear face masks in indoor classes, labs, studios and meetings on UNM campuses, see the masking requirement. Students who do not wear a mask indoors on UNM campuses can expect to be asked to leave the classroom and to be dropped from a class if failure to wear a mask occurs more than once in that class. Students and employees who do not wear a mask in classrooms and other indoor public spaces on UNM campuses are subject to disciplinary actions. Medical/health grade masks are the best protection against the omicron variant and these masks should be used, rather than cloth.

COVID-19 Symptoms and Positive Test Results

Please do not come to a UNM campus if you are experiencing symptoms of illness, or have received a positive COVID-19 test (even if you have no symptoms). Contact your instructors and let them know that you should not come to class due to symptoms or diagnosis. Students who need support addressing a health or personal event or crisis can find it at the Lobo Respect Advocacy Center.