Physics 361 - Electromagnetic Theory (3 cr)

Session: Spring 2025
Instructor: Prof. John B. Buncher (he/him)
Office: South Engineering 317
Email: john.buncher@ndsu.edu
Office Hours: MTWTh 10 AM – 11 AM, or by appointment
Class Meetings: TTh 3:30 PM – 4:45 PM
Location: South Engineering 221
Final: Thurs, May 15, 2024, 10:30 AM – 12:30 PM
Prerequisites: Phys 252, Math 266

Course Materials

- The primary text for the course will be "Introduction to Electrodynamics", by David J. Griffiths, published by Cambridge University Press. Either the 5th Edition or 4th Edition of the text will work.

Course Description

From the NDSU Catalog Course Description: Electrostatics, magnetostatics, dielectrics, electric circuits, time varying electric and magnetic fields, electromagnetic induction, and application of Maxwell's equations.

I will assume that you have taken the introductory physics sequence and are familiar with the topics covered there, along with a basic understanding of differential and integral calculus. Additionally, you should have a basic knowledge of vectors and vector algebra. Any mathematical topics needed beyond these will be introduced/reviewed as necessary.

Course Objectives

The primary goal of this course is to provide the students with an more sophisticated understanding of electromagnetism and the associated mathematical tools that will aid them in their careers in any techcnical field. The students will further refine their conceptual understanding and problem-solving ability such that they can readily apply their knowledge to novel problems and situations. Specifically, students shall be able to:

- Translate between the physical description of a junior-level electromagnetism problem and the mathematical equation needed to solve it.
- Visualize the physical parameters of a problem, through plots and sketches.
- Justify and explain their thinking and/or approach to a problem or physical situation, in either written or oral form.
- Choose and apply the appropriate problem-solving technique for a given problem, including but not limited to: effective use of approximations, series expansions, exploiting symmetries, integration, and superposition.

- Check the validity and plausibility of a solution by examining limiting cases.

Feedback

If you have any concerns about the course or suggestions on how it may improve, please let me know! I am happy to consider and implement student suggestions, and I have had success implementing such suggestions in previous courses.

Course Standards

In this course we will use *standards-based grading*. This is different than the usual "points-based grading" that you are likely used to. A "standard" represents a core idea or skill you should learn in a junior-level E&M course, and is something that should stay with you past when you are "tested" on it.

You will be given multiple opportunities to demonstrate your *proficiency* with each standard. To be judged as proficient ("meeting the standard"), you'll need to show that you can solve a variety of problems related to that standard *largely correctly*, with no *fatal flaws* in your reasoning and process.

Throughout PHYS 361 you'll be given opportunities to show you are proficient with the following 19 Standards.

Explain how electric charges give rise to electric interactions

1. Represent charge distributions mathematically and calculate the amount of total charge in a system.
2. Represent the electric field created by a given charge distributions both diagrammatically and mathematically.

Explain and apply fundamental properties of the Electric Field

3. Describe and apply the relationships between charge density, Electric Field, Electric Potential, and work done by the Electric field.
4. Apply properties of the Electric Field and conductors at equilibrium to determine the electric field in and around charged and neutral conductors.
5. Apply Gauss's Law to find the Electric Field in cases of high symmetry.

Solve simple applications of Laplace's Equation

6. Explain how and apply the 1st and 2nd Uniqueness Theorems, with appropriate boundary conditions, to solve Laplace's equation.
7. Use the Method of Images to solve Laplace's equation, and explain which regions of space the solution applies to and why.

Apply Separation of Variables to Solve Laplace's Equation in multiple coordinate systems

8. Apply Separation of Variables to solve Laplace's Equations with appropriate boundary conditions in Cartesian Coordinates.
9. Apply Separation of Variables to solve Laplace's Equations with appropriate boundary conditions in Spherical Coordinates.

Understand the Connection between Electric Dipoles and Electric Fields in Matter

10. Apply the multipole expansion to approximate the Electric Potential (and thus the Electric Field), and be able to explain what each term means physically.
11. Explain how the dipole moment relates to Polarization and how this gives rise to bound charges and the Electric Fields they generate.
12. Explain the relationship between Polarization, Electric Field, and Electric Displacement, and use the Electric Displacement to calculate the Polarization and field.

Explain how electric currents give rise to magnetic interactions

13. Represent current distributions mathematically and calculate the amount of total current in a system.
14. Represent the magnetic field created by a given current distributions both diagrammatically and mathematically.

Explain and apply fundamental properties of the Magnetic Field

15. Apply Ampere's Law, along with symmetry arguments and applying appropriate boundary conditions, to determine the Magnetic field from a given current.
16. Understand how the constraints on the divergence of the Magnetic Field gives rise to the Vector Potential, and how to apply the relation between the Vector Potential and the Magnetic Flux.

Understand the Connection between Magnetic Dipoles and Magnetic Fields in Matter

17. Apply the multipole expansion to approximate the Vector Potential, which gives rise to the magnetic dipole.
18. Explain how the magnetic dipole moment relates to Magnetization and how this gives rise to bound currents and the Magnetic Fields they generate.
19. Explain the relationship between Magnetization, Magnetic Field, and "H", and use H to calculate the Magnetization and Magnetic field.

Grades

Final grades in the course will be determined according to the number of standards you are proficient with.

17-19 Standards: A	13-16 Standards: B	9-12 Standards: C	4-8 Standards: D	1-3 Standards: F

How do you *get* to proficiency with a standard? In short: preparation, participation, and practice.

Preparation

Prior to most classes you'll have assigned reading out of our textbook, and possibly an video to watch and think about or some problems to attempt. While I don't expect you to have mastered anything after just reading about it, it is important to complete this preparation so you are ready to participate in the class activities.

Participation (Classtime)

We will have a number of in-class activities in which you need to actively participate, rather than being a passive "receiver". This will include some typical lecture (where you being "active" means being engaged and asking questions), but also includes some shorter Conceptual Questions that we'll work on and discuss both individually and as a class, as well as In-Class Tutorials covering the basis of relevant standards.

Practice (Homework)

For each standard, you will be provided with a problem set to practice your skills in the relevant standards and to prepare you for the quiz. These are not graded, but you will receive feedback on them so you know what standards you need to improve on before the quiz. Additionally, turning in the homeworks *on time* is a *requirement* to be able to re-test on any standard.

When submitting your homework, you should pay attention to the following guidelines:

1. It should be neat and presentable.
2. It is to be written on loose-leaf, perforated, or plain paper (no notebook "frillies").
3. Each problem should be started on a separate page.
4. The pages must be stapled, with the staple in a position that does not obscure what you've written on any of the pages.
5. The pages should be in order (numbering helps with this!).
6. You must re-state the problem which you are attempting to solve, at least briefly.
7. Answers should be clearly labeled (boxed, highlighted, bold, etc.).

8. If you worked with anyone else on your assignment (which you are encouraged to do!), you must indicated key contributions that your other group members made.
9. You may also typeset your assignments using any program that you prefer (LaTeX, *Mathematica*, LibreOffice, Word, etc.), if you wish. If you decide to do this, make sure you are spening more time doing the *physics* than you are dealing with formatting issues!

Quizzes

Every few weeks you'll be given an in-class Quiz to work on independently. These are the opportunities to demonstrate proficiency with each standard. I have put tentative quiz dates in the schedule in this syllabus, but they may need to be adjusted. You will always have at least 1 week of notice prior to a quiz.

If you do not meet proficiency on any standard, that's okay! You are allowed up to two retakes for all Quizzes, *as long as you turned in the relevant homework assignments on time.*

Office Hours

See the front page for office hours. If you need to meet outside of those times, email me and we should be able to work something out. During office hours, we can discuss anything that you wish (homework, grading, concepts, exams, topics of interest, etc.) If there is something of a personal nature, it would be best to make a separate appointment.

Accommodations

Any students with disabilities or other special needs, who need special accommodations in this course, are invited to share these concerns or requests with the instructor and contact the Disability Services Office http://www.ndsu.edu/disabilityservices/ as soon as possible.

Course Policies

Attendance & Participation

You are expected to come prepared each day and to participate in the discussion and problem-solving. If you miss a class, it is your responsibility to get the missed notes (from a classmate) and any assignments given.

According to NDSU Policy 333 www.ndsu.edu/fileadmin/policy/333.pdf, attendance in classes is expected. Veterans and student service members with special circumstances or who are activated are encouraged to notify the instructor as soon as possible and are encouraged to provide Activation Orders.

On Academic Dishonesty

The academic community is operated on the basis of honesty, integrity, and fair play. NDSU Policy 335: Code of Academic Responsibility and Conduct applies to cases in which cheating, plagiarism, or other academic misconduct have occurred in an instructional context. Students found guilty of academic misconduct are subject to penalties, up to and possibly including suspension and/or expulsion. Student academic misconduct records are maintained by the Office of Registration and Records. Informational resources about academic honesty for students and instructional staff members can be found at www.ndsu.edu/academichonesty.

You are highly encouraged to work with your fellow students, and to seek out their assistance or the assistance of the instructor, in all of your studies. Working with another person is highly beneficial for both people when there is a healthy working relationship. However, whatever you turn in must be your own work and words. Copying someone else's work and turning it in as your own is a case of academic dishonesty. You are not permitted to collaborate with anyone else on exams.

If you have any questions about what constitutes academic dishonesty it is your responsibility to ask before the assignment is due.

Course Schedule

I intend to cover Chapters 1–7, roughly as follows. This is tentative, and the Quizzes are planned to be on the Thursday of each of the indicated weeks, but I might push this back depending on the progress made in the course.

	Week	Topic
1/13	1	Introduction, Coulomb's Law, & $\vec{\imath}$
1/20	2	Continuous Charge Distributions
1/27	3	Gauss's Law, $\nabla \cdot \vec{E}$, and $\nabla \times \vec{E}$ - **Quiz 1 (Standards 1 & 2)**
2/03	4	Electric Potential & Energy
2/10	5	Conductors in Electrostatics
2/17	6	Laplace's Equation, Earnshaw's Theorem, & Method of Images - **Quiz 2 (Standards 3, 4, & 5)**
2/24	7	Separation of Variables
3/03	8	Multipoles & Legendre Expansions **Quiz 3 - Standards 6 & 7**
3/10	9	No Class - Spring Break
3/17	10	Polarization - **Quiz 4 - Standards 8 & 9**
3/24	11	$\vec{D}$-field & Linear Dielectrics
3/31	12	Magnetic Forces & Current
4/07	13	Biot-Savart Law - **Quiz 5 - Standards 10, 11, & 12**
4/14	14	Ampere's Law
4/21	15	Vector Potential - **Quiz 6 - Standards 13, 14, 15, & 16**
4/28	16	Magnetization
5/05	17	Leftovers & Wrapping Up - **Quiz 7 - Standards 17, 18, & 19**
5/12	18	**Re-testing for Standards 17-19 only!**

Advice

Here are some helpful tips for success in the course, from my own personal experience and suggestions of other professors.

1. If you are having trouble, ask for help! Help is available through me via my office hours (or other appointment), other faculty in the department, and your fellow students.
2. When reading the text, be sure to read *critically*. That is, ask questions and take notes! If something is not clear, make a note of it so you can ask in class. You should also be working through steps done (or omitted) in class and the text. As a friend of mine once said "The exam will NOT ask if you agree with our solution, but will asked you to come up with your OWN solution."
3. This course will likely take a significantly greater amount of time than your previous courses, both in completing the homework and understanding the concepts. It is critical that you start your homework assignments as early as possible, as you may need a few days to solve the problem sets.
4. Don't work for more than a few hours on a problem if you're stuck! Switch to another problem (which may cause you to think about the troublesome one in a different way), and find assistance. That being said, do not despair if it is not obvious what to do after 5 minutes of thinking. These problems will require some extra thought.
5. Don't panic. Physics is hard. Like anything else worthwhile, it will take practice and perseverance to succeed, but the rewards are well worth it.