PHYS 2555: Advanced Electricity and Magnetism
Spring 2024 (2244)

Course Info:

- Instructor: **Pranava Teja Surukuchi**; 417 Allen Hall; surukuchi@pitt.edu; T/Th: 3-4 PM
- Grader: **William Musk**
- Meeting times: **Monday and Friday 10:00–10:50 AM, Wednesday 9:00–10:50 AM**
- Location: All classes will be held in person in **106 Allen Hall**

Course Description:

This is a graduate-level four-credit core course on electromagnetism. We will discuss the static and dynamic nature and properties of electromagnetic fields. The list of topics to be covered in the course is listed at the end of this document.

The course will be taught in the traditional blackboard and chalk format. We will explore a range of topics in the class. Students are encouraged to review the lecture notes on their own time after the lecture. However, the notes are concise, so to gain a deeper understanding of the course material, it is recommended to consult the suggested textbooks for extended explanations.

Textbooks and Notes:

There are no official textbooks for the course but the following resources are suggested for reference:

- **Fulvio Melia**; Electrodynamics: Covers most (but not all) of the topics we discuss; relatively easy to follow; however the content is very concise and there are no exercises or practice problems
- **John David Jackson**; Classical Electrodynamics: The go-to book for graduate E&M; very comprehensive; extensive exercises; not always straightforward to follow; uses SI units (as opposed to the Gaussian units that we will use is this course) for half of the book

Notes on the topics discussed will be provided (through Canvas) after each lecture.

Prerequisites:

A graduate-level mathematics background is needed for the course. You are expected to know the following key topics (this is a non-exhaustive list):

- Vector calculus in n-dimensional orthogonal (Cartesian and curvilinear) coordinate systems: Gauss's theorem, Stokes's theorem, etc.,
- Key concepts in partial differential equations: Green's functions, boundary conditions, etc.,
- Special and generalized functions: Bessel functions, Legendre polynomials, spherical harmonics, Dirac-delta functions, etc.,
- Series expansion (Taylor, Fourier series, etc.,) and the relevant techniques such as Fourier analysis

The Mathematical Methods course (PHYS 2373) provides good training in these concepts.

Course Objectives:

Upon completion of the course, students are expected to:

- Gain a detailed understanding of Maxwell's equations and the constitutive relationships both conceptually and mathematically,
- Analyze the symmetries, choose a convenient coordinate system, define appropriate boundary conditions, and systematically analyze the problem at hand,
- Use Green's function approach and/or orthogonal decomposition to solve partial differential equations in electricity and magnetism,
- Analyze the problems involving the propagation of waves and their energy and momentum transport in free space, dielectric media, waveguides, and resonant cavities,
- Develop intuition for kinematics and invariances in special relativity and apply Lorentz transformations and Minkowski formalism to electromagnetic quantities,
- Analyze the emission and scattering of electromagnetic radiation of point charges moving at relativistic speeds,

Homework:

A significant portion of learning in the course occurs through solving the homework problems. Homework sets are assigned each week on Friday and are collected the next week on Friday. Late homework will not be graded, especially if the solutions are posted. I encourage you to discuss with me ahead of time any extenuating circumstances that would prevent you from submitting your homework by the due date. The homework with the lowest score will be dropped. We will use Canvas as the primary source for sharing homework problem sets and solutions.

You are encouraged to form study groups with the other members of the class. You can discuss the homework problems with the study group, but you are required to submit your own solutions.

Some homework problems will be discussed in the class after they have been graded and returned. I will occasionally ask a student to discuss their solution on the blackboard. This will provide an opportunity for you to learn from each other and also enable you to practice your presentation skills.

Exams and Grading:

There will be one mid-term and one final exam. The dates for these exams are TBD but will be announced several weeks in advance. The final grade will be determined based on

- Homework: 35%
- Mid-term exam: 25%
- Final exam: 35%
- Class participation: 5%

Policies and Statements

Academic Integrity

Students in this course will be expected to comply with the University of Pittsburgh's Policy on Academic Integrity. Any student suspected of violating this obligation for any reason during the semester will be required to participate in the procedural process, initiated at the instructor level, as outlined in the University Guidelines on Academic Integrity. This may include, but is not limited to, the confiscation of the examination of any individual suspected of violating University Policy. Furthermore, no student may bring any unauthorized materials to an exam, including dictionaries and programmable calculators.

To learn more about Academic Integrity, visit the Academic Integrity Guide for an overview of the topic. For hands- on practice, complete the Academic Integrity Modules.

Disability Services

If you have a disability for which you are or may be requesting an accommodation, you are encouraged to contact both your instructor and Disability Resources and Services (DRS), 140 William Pitt Union, (412) 648-7890, drsrecep@pitt.edu, (412) 228-5347 for P3 ASL users, as early as possible in the term. DRS will verify your disability and determine reasonable accommodations for this course.

Accessibility

The Canvas LMS platform was built using the most modern HTML and CSS technologies, and is committed to W3C's Web Accessibility Initiative and Section 508 guidelines. Specific details regarding individual feature compliance are documented and updated regularly.

Copyright Notice

These materials may be protected by copyright. United States copyright law, 17 USC section 101, et seq., in addition to University policy and procedures, prohibit unauthorized duplication or retransmission of course materials.

See Library of Congress Copyright Office and the University Copyright Policy.

Equity, Diversity, and Inclusion

The University of Pittsburgh does not tolerate any form of discrimination, harassment, or retaliation based on disability, race, color, religion, national origin, ancestry, genetic information, marital status, familial status, sex, age, sexual orientation, veteran status or gender identity or other factors as stated in the University's Title IX policy. The University is committed to taking prompt action to end a hostile environment that interferes with the University's mission. For more information about policies, procedures, and practices, visit the Civil Rights & Title IX Compliance web page.

I ask that everyone in the class strive to help ensure that other members of this class can learn in a supportive and respectful environment. If there are instances of the aforementioned issues, please contact the Title IX Coordinator, by calling (412) 648-7860, or e-mailing titleixcoordinator@pitt.edu. Reports can also be filed online. You may also choose to report this to a faculty/staff member; they are required to communicate this to the University's Office of Diversity and Inclusion. If you wish to maintain complete confidentiality, you may also contact the University Counseling Center (412) 648-7930.

Religious Observances

The observance of religious holidays (activities observed by a religious group of which a student is a member) and cultural practices are an important reflection of diversity. As your instructor, I am committed to providing equivalent educational opportunities to students of all belief systems. At the beginning of the semester, you should review the course requirements to identify foreseeable conflicts with assignments, exams, or other required attendance. If at all possible, please contact me (your course coordinator/s) within the first two weeks of the first class meeting to allow time for us to discuss and make fair and reasonable adjustments to the schedule and/or tasks.

Sexual Misconduct, Required Reporting, and Title IX

If you are experiencing sexual assault, sexual harassment, domestic violence, and stalking, please report it to me and I will connect you to University resources to support you.

University faculty and staff members are required to report all instances of sexual misconduct, including harassment and sexual violence to the Office of Civil Rights and Title IX. When a report is made, individuals can expect to be contacted by the Title IX Office with information about support resources and options related to safety, accommodations, process, and policy. I encourage you to use the services and resources that may be most helpful to you.

As your professor, I am required to report any incidents of sexual misconduct that are directly reported to me. You can also report directly to Office of Civil Rights and Title IX: (412) 648-7860 (M-F; 8:30am-5:00pm) or via the Pitt Concern Connection at: Make A Report

An important exception to the reporting requirement exists for academic work. Disclosures about sexual misconduct that are shared as a relevant part of an academic project, classroom discussion, or course assignment, are not required to be disclosed to the University's Title IX office.

If you wish to make a confidential report, Pitt encourages you to reach out to these resources:

- The University Counseling Center: (412) 648-7930 (8:30 A.M. TO 5 P.M. M-F) and (412) 648-7856 (AFTER BUSINESS HOURS)
- Pittsburgh Action Against Rape (community resource): 1(866) 363-7273 (24/7)

If you have an immediate safety concern, please contact the University of Pittsburgh Police, (412) 624-2121

Any form of sexual harassment or violence will not be excused or tolerated at the University of Pittsburgh.

For additional information, please visit the full syllabus statement on the Office of Diversity, Equity, and Inclusion webpage.

Your Well-being Matters

College/Graduate school can be an exciting and challenging time for students. Taking time to maintain your well-being and seek appropriate support can help you achieve your goals and lead a fulfilling life. It can be helpful to remember that we all benefit from assistance and guidance at times, and there are many resources available to support your well-being while you are at Pitt. You are encouraged to visit Thrive@Pitt to learn more about well-being and the many campus resources available to help you thrive.

If you or anyone you know experiences overwhelming academic stress, persistent difficult feelings and/or challenging life events, you are strongly encouraged to seek support. In addition to reaching out to friends and loved ones, consider connecting with a faculty member you trust for assistance connecting to helpful resources.

The University Counseling Center is also here for you. You can call (412) 648-7930 at any time to connect with a clinician. If you or someone you know is feeling suicidal, please call the University Counseling Center at any time at (412) 648-7930. You can also contact Resolve Crisis Network at (888) 796-8226. If the situation is life threatening, call Pitt Police at (412) 624-2121 or dial 911.

Course Content

We will try to cover most (if not all) of these topics

1. Basics and foundations:
    - Intro to E&M and Maxwell's equations
    - A very brief reminder of some math we will use in the class
    - Units
2. Electrostatics:
    - Introduction to electrostatics including potential
    - Green's function methods including the method of images and effects of boundaries
    - Expansions in orthonormal functions in Cartesian and curvilinear coordinate systems
    - Electrostatic energy
    - Multipole expansion and localized charge distribution in external fields
    - Electrostatics in media
3. Magnetostatics:
    - Introduction including potential
    - Multipole expansion
    - Magnetostatics in media
4. Time-dependent fields:
    - Introduction: Potentials and gauges
    - Conservation laws and transformation properties
    - Free electromagnetic waves; includes polarization, reflection, refraction etc.
    - Time harmonic fields in matter and the response of dielectrics on these fields
    - Transmission and storage of radiation including waveguides and resonant cavities
    - Solutions of the inhomogeneous wave equations
    - Radiation from localized sources and moving charges
5. The special theory of relativity and electromagnetism:
    - The formalism of special relativity
    - Mathematical structure of four-dimensional spacetime
    - Relativistic mechanics
    - Covariant Maxwell equations
    - Stress-energy tensor and conservation laws
    - Lagrangian formulation of electrodynamics
    - Radiation from relativistic sources