Physics 2555
Advanced Classical Electricity and Magnetism
Winter/Spring 2020 (2204)

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Office Hours: Tuesdays 2:30 – 3:30 pm, Thursdays 11 am – noon
Help Session, 105 Allen Hall: Fridays 2:00 – 3:00 pm

Text: *Classical Electrodynamics* (Third Edition) by J.D. Jackson.

The Course: Physics 2555 is the **four**-credit graduate core course in classical electricity and magnetism. The intent is to cover selected material in Jackson, Chapters 1-12, 14, and possibly other topics from the later chapters, if time permits. Topics will include: electrostatics, magneto-statics, time varying fields, electromagnetic waves, waveguides, antennas, special relativity and radiation from moving charges. Required mathematical background is covered in Physics 2373.

Course Objectives: The student will be able to:

- State Maxwell's Equations, constitutive relations, boundary conditions, and a variety of other important concepts, results and facts about classical electromagnetism (see list of topics at end of syllabus) in both mathematical form and conceptually.
- Apply important methods of mathematical physics to solve problems in classical electromagnetism (once again, see list), and be able to interpret the results conceptually.
- Pass the classical electromagnetism component of the comprehensive exam for admission to candidacy for the Ph.D.

Lectures: Mondays and Fridays 10:00 – 10:50 am, Wednesdays 9:00 – 10:50 am, 106 Allen Hall.

Homework: Homework problems will be assigned weekly. Much of the learning in this course takes place by doing the problems. It is important to do the homework problems on time and not fall behind. You are allowed to work with others on the homework if you find this helpful, but your solutions should be your own. Cite any assistance, whether from books or people. Do not consult solutions available on the internet. Late homework will not be graded, particularly if it is so late that the solution has been made available and the set has already been graded.

Exams and Grading: There will be two "in-term" exams, scheduled for Friday, February 14, and Friday, March 27, and a comprehensive final exam, scheduled for Wednesday, April 22. The "in-term" exams will each count 100 points. The final exam will be worth approximately 150 points. The homework will contribute 150 points. If clicker questions are used, these class participation points will count for 10 or 20 points under "homework". The course total will be about 500 points. Your numerical score will be converted to a letter grade.

Help Session: I will hold a weekly help/question/discussion session if there is interest and if we can determine a mutually agreeable time slot.

Reserve Books: A list of books on classical electrodynamics and related topics appears on the back of this sheet. Some of these books are on reserve in the Engineering Library in Benedum Hall. If you want a book placed on reserve, let me know.

Courseweb Site: I will use a Courseweb site to post announcements, lecture notes, problem assignments, homework solution sets, etc.

Student Opinion of Teaching Surveys:

Students in this class will be asked to complete a *Student Opinion of Teaching Survey*. Surveys will be sent via Pitt email and appear on your CourseWeb landing page during the last three weeks of class meeting days. Your responses are anonymous. Please take time to thoughtfully respond, your feedback is important to me. Read more about *Student Opinion of Teaching Surveys*.

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.

Disability Resources:

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.

Copyright Notice:

Course 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.

Statement on Classroom Recording:

To ensure the free and open discussion of ideas, students may not record classroom lectures, discussion and/or activities without the advance written permission of the instructor, and any such recording properly approved in advance can be used solely for the student's own private use.

Inclusivity Statement:

Code of Conduct:

Communication is key to a productive learning environment, and we can maintain productive communication by exhibiting respect for one another. The success of the course for yourself and others depends on all of our commitment to behavior that demonstrates respect for differences, understanding towards others and a willingness to listen and learn. For these reasons,

it is unacceptable to harass, discriminate against, or abuse anyone because of race, ethnicity, gender, disability, religious affiliation, sexual orientation, or age. If you witness or are subject to such harassment, please report it to the instructor or to the Office of Diversity and Inclusion: https://www.diversity.pitt.edu/ .

Title IX:

Legal text: "No person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving Federal financial assistance."

As a professor I am a mandatory reporter, and I am required to report violations of Title IX that I observe or am made aware of to the Title IX office https://www.titleix.pitt.edu/ . Title IX violations include, but are not limited to, sexual harassment, sexual violence and verbal or sexual abuse. Within the classroom, behavior in violation might appear as: suggestive jokes or innuendos, inappropriate touching, and unwanted sexual behavior or advances, but my capacity and obligation to report does not end at the classroom.

Physics 2555
Books
Winter/Spring 2015 (2164)
R.P. Devaty

Reserve Books

1. *Classical Electrodynamics* (3rd Edition) by John David Jackson
2. *Modern Electrodynamics* by Andrew Zangwill
3. *Classical Electricity and Magnetism* by Wolfgang K.H. Panofsky and Melba Phillips
4. *Introduction to Electrodynamics* (4th Edition) by David J. Griffiths
5. *The Classical Theory of Fields* by L.D. Landau and E.M. Lifshitz
6. *Electrodynamics of Continuous Media* by L.D. Landau and E.M. Lifshitz

Others

1. *Electrodynamics* by Fulvio Melia
2. *The Classical Electromagnetic Field* by Leonard Eyges
3. *The Feynman Lectures on Physics* (Vol. II) by R.P. Feynman
4. *Principles of Optics* by M. Born and E. Wolf
5. *Electromagnetic Theory* by J.A. Stratton (available on-line through PittCat)
6. *Static and Dynamic Electricity* by W.R. Smythe
7. *Foundations of Electromagnetic Theory* by J.R. Reitz, F.J. Milford and R.W. Christy
8. *Classical Electrodynamics* by Julian Schwinger, L.L. DeRaad, Jr., K.A. Milton and W. Tsai
9. *Optical Properties of Solids*, by Frederick Wooten

Mathematics and Tables

1. *Methods of Theoretical Physics* by P.M. Morse and H. Feshbach
2. *Table of Integrals, Series and Products* by I.S. Gradshteyn and I.M. Ryzhik
3. *Handbook of Mathematical Functions with Formulas, Graphs, and Mathematical Tables* by M. Abramowitz and I.A. Stegun (available on-line through PittCat)

Physics 2555
Winter/Spring 2020 (2204)
List of Topics

Electrostatics (Topics 2, 4 and 5 were covered in Physics 2573)

1. Review Coulomb's Law, concept of electric field and Gauss' Law
2. Poisson's and Laplace's equations, Green's theorem, uniqueness theorem, solutions with Dirichlet and Neumann boundary conditions
3. Electrostatic potential energy, energy density, capacitance
4. Green's functions in one, two and three dimensions for parallel plates, cylinders and spheres; method of images
5. Solutions of Laplace's equation in two and three dimensions utilizing Fourier series, spherical harmonics and Bessel functions, i.e., solving Laplace's equation in rectangular, spherical and cylindrical coordinates
6. Multipole expansion, macroscopic media, dielectrics. Electrostatics problems with dielectrics. Polarization and energy with dielectrics present. Molecular origin of polarization.

Magnetostatics

1. Review basic equations of magnetism including Biot-Savart and Ampere's Lawa.
2. Vector potential, magnetic induction for a circular loop, localized current distributions, magnetic moment, force and torque, energy of localized current distributions.
3. Macroscopic equations and magnetic materials, boundary conditions on **B** and **H**, methods of solving boundary value problems in magnetostatics.

Time Varying Fields and Plane Waves

1. Faraday's Law, energy in a magnetic field and inductance, Maxwell's displacement current and Maxwell's equations
2. Quasi-static fields and skin depth
3. Vector and scalar potentials, gauge transformations and gauges, wave equation, development of Green's function for wave equation and solution of wave equation
4. Poynting's theorem, conservation of energy and momentum for a system of charged particles and electromagnetic fields, Maxwell's stress tensor
5. Plane waves, linear, circular and elliptical polarization, reflection and refraction of electromagnetic waves at a plane interface between dielectrics
6. Frequency dispersion characteristics of dielectrics, conductors and plasmas. Waves in conducting or dissipative medium.
7. Superposition of waves, group velocity, spreading of a pulse.
8. Causality in the connection between **D** and **E**, Kramers-Kronig relations.

Wave Guides and Resonant Cavities

1. Fields at the surface and within conductors
2. Cylindrical cavities and wave guides
3. Modes in wave guides, energy flow and attenuation in wave guides
4. Resonance and power loss in conducting cavities

Radiation

1. Nonrelativistic treatment of simple radiating systems including electric dipole and magnetic dipole radiation from a localized oscillating source.
2. Center fed linear antenna, half wave and full wave antennas.
3. Scattering at long wavelengths, Rayleigh scattering (blue sky), optical theorem

Relativity

1. Lorentz transformations and basic kinematic results of special relativity, addition of velocities, four vectors, relativistic energy and momentum of a particle
2. Invariance of electric charge, covariance of electrodynamics, transformation of electromagnetic field, covariant notation
3. Lagrangian and Hamiltonian for a relativistic charged particle in an external electromagnetic field, Lagrangian for the electromagnetic field
4. Motion of a charged particle in uniform static electric and/or magnetic field

Radiation from Moving Charges

1. Development of the Lienard-Wiechert potentials and fields using the Green' function solutions of the wave equation. Include discussion of the Heavyside and Feynman fields if this wasn't done earlier.
2. Power radiated by an accelerated charge, the Larmor formula, and the more general relativistic results for linearly accelerated and circularly accelerated charges
3. Frequency spectrum and angular distribution of radiation from accelerated charged particles, synchrotron radiation
4. Thomson scattering