Course: PHYS 532
Term: Spring 2023
Room: GRB W211
Class: WF 2:00-3:15pm

INSTRUCTOR CONTACT INFORMATION

Instructor: Matthew G Baring
Office: Herman Brown 366
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Office Hours: Mon 4:00-5:30pm (Zoom) & Fri 12:00-1.30pm (HBH 310)

COURSE OBJECTIVES AND LEARNING OUTCOMES

Graduate level Classical Electrodynamics is a core offering on an array of concepts pertaining to one of the four fundamental forces of nature. It gathers together many of the concepts and techniques that are discovered in undergraduate electromagnetism courses, yet approaches them with a more sophisticated physical insight and more formal rigor. It serves as a focal point of Rice's Physics and Astronomy graduate curriculum, yet is an important pedagogy that will equip students whose interests range beyond physics to the chemistry and engineering disciplines. The material presented provides an excellent starting point for those interested in delving deeper into particular advanced subfields of physics, such as quantum mechanics, condensed matter physics, particle physics, plasma physics and also Einstein's theory of general relativity. For graduates, it also serves as a grounding for problems they might tackle in their research work.

Objectives: The goal is to provide students with a basic understanding of many of the important elements of electrodynamics, developing a working knowledge of the fields generated by charges, the motion of charges within them, and the radiation of electromagnetic waves. Much of the course is analytic in character and formal theory by necessity. Yet to maintain contact with contemporaneous computational methods as research tools, there will be occasional numerical components in the homeworks. There will also be sporadic examples from laboratory physics, space physics and astrophysics in the lectures to elucidate their content. Topics covered include the determination of electromagnetic fields from charges and their motion, the responses of charges to electromagnetic fields, Maxwell's field equations, the character of electromagnetic waves, time-dependent fields of moving charges, and the radiation of electromagnetic waves.

Students will learn how particular concepts can be applied to different physics disciplines. They will learn to assess how various of elements of electromagnetic theory are applicable to disparate subfields such as quantum theory and general relativity. Students will be taught to think logically and critically about what are reasonable assumptions in physical developments and what are not, and how to evaluate and check derived results. They will also be taught how to think "laterally" by connecting seemingly unrelated concepts to enhance understanding of a given problem or task. This will apply both to analysis methods and occasionally also in developing computational skills.

Learning Outcomes: By completing the course, students will be much better equipped to use electromagnetic concepts in their research, thereby enhancing the Rice graduate study experience. They will be in a position to assess posed problems, suggest algorithms for approaching analytic and computational tasks, test their ideas, and develop efficient strategies for reducing a problem to a tractable form, or an endpoint that will facilitate numerical evaluation. They will receive training in communicating their ideas, hypotheses and understanding of select issues to an ensemble of their peers. This is the essence of the research process: think critically, probe, discover, revise one's perspective and tell the broader community of the results and the path taken to get there, and where to go next. This is invaluable training for an array of professions and potential careers down the line, including industry, business and academia.

REQUIRED TEXTS AND MATERIALS

The Classical Theory of Fields, by L. D. Landau and E. M. Lifshitz (Fourth Revised English Edition, Pergamon Press or Butterworth & Heinemann). This is the second volume of the venerated Course of Theoretical Physics that should be on every practicing physicist's bookshelf.

We will structure the course around the Fourth Edition (1990) of this book: it is an essential supplement to the lectures as students will be required to read it. Notes for course material not contained therein will be provided, for example some content on tensors.

SUPPLEMENTARY SUPPORTING TEXTS

Classical Electrodynamics, by J. D. Jackson (Third edition, 1999, J. Wiley and Sons)
[This can serve as a reference on more experimental elements of electrodynamics.]

EXAMS AND PAPERS

The course assessment will consist of approximately six to seven problem sheets, cumulatively constituting 60% of the total grade. There will be one ***open-book, take-home*** **mid-term exam** during the semester that constitutes 15% of the grade, and an ***open-book, take-home*** **final exam** at the end of the semester, constituting the remaining 25% of the assessment.

GRADE POLICIES

All parts of the assessment will be graded on a curve, determined commensurately with the overall performance of past students who have taken this course at Rice.

Late homeworks will automatically receive a **5% reduction in credit**, unless an extension has been negotiated (see below) with Prof. Baring. Homeworks that are **4-7 days overdue** will be **reduced by 30%** in total credit. Beyond that timeframe, late homeworks will not be graded and score zero. This policy is because it is (i) not fair to other students to have the return of their homeworks in a timeframe that is delayed by inadvertent tardiness by any student, and (ii) it is not fair to impose logistical constraints on Prof. Baring and the course TA(s) in terms of grading.

Extensions of homework deadlines must be negotiated with Prof. Baring prior to the original deadline, with the student defining good cause for the extension. The negotiated deadline will substitute for the original one in terms of the aforementioned late penalties.

The final exam must be submitted electronically prior to the University-mandated deadline of 5pm on Tuesday, 2nd May, the end of Spring Semester, 2023. **Late submissions score zero.**

Exceptions to these late policies can occur for extenuating circumstances such as student illness, family illness or emergency. In such cases, it is the **student's responsibility to let Prof. Baring know** (ahead of time, if possible) what is going on so that he is not "in the dark." The student will need to (retroactively) document the circumstances.

CLASS ATTENDANCE

The purpose of the lectures is to impart knowledge distilled to its essentials on the subject matter of the course and in a manner more efficient than is afforded by merely reading textbooks and browsing Web sites; these important out-of-class learning paths are intended to supplement, not replace lectures. A central ingredient of this classroom forum is leveraging the extensive research experience and science connections of the Lecturer, *and this is best done by attending lectures*. The small average class size underpins an exceptional learning experience that sets Rice apart from many of its peer institutions. **Students should take advantage of this opportunity by habitually attending classes**; their learning curve will be enhanced by such dedication.

Classes will be given in dual delivery format. The live classes will be presented via Zoom so that students not able to be in the classroom can attend in real time as suits. The presentations will be recorded so that students may view them asynchronously, providing the ability to meet all the needs of students as circumstances vary during the semester.

ABSENCE POLICIES

Infrequent absences are not a problem. If a student is noted to be absent for an extended period of time, or frequently, the student must communicate with Prof. Baring the reasons of the absence(s). Such cases normally will degrade the learning for the student. Again, if there are extenuating circumstances such as student illness or family illness or emergency, accommodations will be made, and Prof. Baring should be informed. Otherwise, concerning any absence, it is the student's responsibility to acquire the pertinent notes/materials to guide their study accordingly. Prof. Baring is under no obligation to "re-lecture" such material during office hours.

IN-CLASSROOM TECHNOLOGIES

The learning environment for individuals and the entire class is optimized if it is not disrupted by cell phone activity. Use of cell phones to text or via another mode is distracting to the lecturer and shows inattention on the part of the perpetrator. Moreover it is rude to the lecturer, who invests considerable time in preparing lectures to facilitate the learning of the entire class, and to other students when a distracted moment arises. Dr. Baring **prohibits the use of cell phones in the lecture room**; if a student cannot wait until the conclusion of class to send a text or make a call, he/she/they should quickly excuse themselves, leave the room, and return only when finished and ready to concentrate on the lecture. Use of laptop computers to take notes is not intrusive and is acceptable to Dr. Baring; use of them to perform telecommunication functions such as Skyping and email is similarly not permitted. **Violations of these rules will lead to the student being asked to leave the classroom for the remainder of the lecture.**

RICE HONOR CODE

In this course, all students will be held to the standards of the Rice Honor Code, a code that you pledged to honor when you matriculated at this institution. If you are unfamiliar with the details of this code and how it is administered, you should consult the Honor System Handbook at http://honor.rice.edu/honor-system-handbook/. This handbook outlines the University's expectations for the integrity of your academic work, the procedures for resolving alleged violations of those expectations, and the rights and responsibilities of students and faculty members throughout the process.

The mid-term and final exam questions are not to be discussed at all with other students, faculty or graders, and are subject to the provisions of the Rice Honor Code. Please verify this by **writing the word pledge and your signature on each exam**. Questions specifically about exams should be directed only to Prof. Baring.

DISABILITY SUPPORT SERVICES

If you have a documented disability or other condition that may affect academic performance you should: 1) make sure this documentation is on file with Disability Support Services (Allen Center, Room 111 / adarice@rice.edu / x5841) to determine the accommodations you need; and 2) talk with Prof. Baring to discuss your accommodation needs *during the first two weeks of class*.

Any letter from DRC to the instructor requesting accommodations for the student should be delivered in the first three weeks of semester (either via email or hardcopy by campus mail or in person), so that Prof. Baring can plan accordingly.

TITLE IX RESPONSIBLE EMPLOYEE NOTIFICATION

Rice University cares about your wellbeing and safety. Rice encourages any student who has experienced an incident of harassment, pregnancy discrimination, gender discrimination or relationship, sexual, or other forms interpersonal violence to seek support through The SAFE Office. Students should be aware when seeking support on campus that most employees, including myself, as the Instructor, are required by Title IX to disclose all incidents of non-consensual interpersonal behaviors to Title IX professionals on campus who can act to support that student and meet their needs. For more information, please visit the http://safe.rice.edu/ webpage or email titleixsupport@rice.edu .

SYLLABUS

The detailed syllabus below gives the layout of the course material. For further information, such as scheduling, pointers to related chapters in the Required Text, etc., see the PHYS 532 course web pages at https://www.ruf.rice.edu/~baring/phys532/phys532_syllabus.html .

Foundations of Special Relativity

The Principle of Relativity
Spacetime Intervals
Proper time
The Lorentz Transformation
Transformation of Velocities
Vectors and Tensors in Spacetime
Four-velocity and Four-acceleration

Relativistic Dynamics

Lagrangian and Hamiltonian Mechanics
Relativistic Action for Free Particles
Momentum and Energy and their Lorentz Transformation
Angular Momentum
Relativistic Collisions and Decay

Charges in Electromagnetic Fields

Fields, Rigid Bodies, and Elementary Particles in Classical Electrodynamics
Action, Lagrangian and Hamiltonian
Equations of Motion
Invariance Properties and Gauges
Static Electromagnetic Fields
Particle Motion in Uniform Static Electromagnetic Fields
The Electromagnetic Field Tensor
Lorentz Transformation of the Electromagnetic Field

Electromagnetic Field Equations

The Homogeneous Maxwell Equations
Charge and Current Densities
The Action Integral for the Electromagnetic Field
The Inhomogeneous Maxwell Equations
Electromagnetic Energy
The Energy-Momentum Tensor
The Electromagnetic Energy-Momentum Tensor
The Generalized Poynting Theorem

Static Electromagnetic Fields

Static Electric Fields
Electrostatic Energy of a System of Charges
Electrostatic Multipole Moments
Charges in an External Electrostatic Field
Static Magnetic Fields
Magnetostatic Multipole Moments
Charges in an External Magnetostatic Field

Electromagnetic Waves

The Wave Equation and Electromagnetic Plane Waves
Electromagnetic Units
Monochromatic Plane Waves
The Relativistic Doppler Effect
Spectral Analysis
Group Velocity

Fields of Moving Charges

Field of a Uniformly Moving Charge
Potentials and Fields for Time-Dependent Sources
Potentials of a Moving Charge
Electromagnetic Field Of A Moving Charge

Radiation of Electromagnetic Waves

Radiation from a Slow Charge
Dipole Radiation from Slow Charges
Magnetic Dipole and Electric Quadrupole Radiation from Slow Charges
Radiation from a Fast Charge
Synchrotron Radiation
Radiation Damping
Radiation Scattering

Syllabus Change Policy

This syllabus is a general guide for the course and is subject to change without advanced notice. In practice, over the years it has served as an excellent model for the course content.