**UNIVERSITY OF MISSISSIPPI**
Department of Physics and Astronomy
Grad Electromagnetism II (Phys. 722) — Prof. Leo C. Stein — Fall 2024

**Grad Electromagnetism II Syllabus**

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| Class schedule: | MWF 0900–0950, Lewis 109 |
| Office hours: | TBD |
| Course website: | https://duetosymmetry.com/teaching |
| Professor: | Leo C. Stein (he/him; you can call me "Leo" or "Dr. Stein") |
| Email: | ⟨lcstein@go.olemiss.edu⟩ |
| Office: | 205 Lewis Hall |

Accessing homeworks/exams will be through Blackboard. If you are in this course and do not have access to the virtual classroom, email Leo ASAP!

## Course goals and learning outcome

This is the second half of a standard course on electromagnetism in the graduate curriculum for physics.

Key concepts (time permitting): • cavities and waveguides, • magnetohydrodynamics, • special relativity and index gymnastics, • covariant and potential formulation of electromagnetism, • Lagrangian formulation of electromagnetism, • Noether's theorem and conservation laws, • partial wave decomposition, • diffraction and scattering theory .

Goals: Understanding of electro- and magneto- statics and dynamics; relevance to physical systems; strengthen tools of vector/tensor calculus; applying multivariate/tensor calculus and special mathematical tools (e.g. Green's functions and the multipole expansion). These goals are to enhance students' mathematical reasoning, critical thinking, and analytical reasoning.

## Texts

There is no required textbook for this course. However, for your own studies and reference, I recommend getting a standard text. There are lots of options, e.g.

- Schwinger et al., *Classical Electrodynamics*.
- Jackson, *Classical Electrodynamics*.

I list some additional references:

- Wald, *Advanced Classical Electromagnetism*. Better treatment of point particles, the self-force, and some other topics than most texts.
- Griffiths, *Introduction to Electrodynamics*. An undergraduate textbook but very easy to follow.
- Thorne and Blandford, *Modern Classical Physics*. Very comprehensive (∼1500 pages) covering much more than electrodynamics. Includes intro to magnetohydrodynamics and plasma physics. PDFs of pre-publication notes currently available at http://www.pmaweb.caltech.edu/Courses/ph136/yr2012/.
- Sturrock, *Plasma Physics*. Specialist text, but starts from scratch and I found it easy to follow.
- PDFs available online from Russell Herman (UNC Wilmington); David Tong (Cambridge); Philip Nelson (UPenn); Richard Fitzpatrick (UT Austin); Alan Guth (MIT)

## Evaluation

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| Grade type: | Letter grade A–F |
| Grade ranges: | (subject to change)<br>• A: 88% and up<br>• B: 75–87%<br>• C: 65–74%<br>• D: 55–64%<br>• F: <55% |
| Grade breakdown: | (subject to change)<br>• 50% Homework<br>• 20% Midterm<br>• 30% Final |

## Homework, tests, and final exam

Homework assignments will be announced via the course web site, and they must be turned in by midnight on the due date. Late homework will be penalized 20% per day (exceptions and extensions permitted with good cause). Homeworks and exams may be physically handed in, or submitted as PDFs or JPGs via the course web site. Homework must be easy to read: please clearly write down your name and the problem set number, do not use a red pen. The midterm and final exam will be open-book and open-notes, and a calculator will be permitted.

## Attendance

There is no strict attendance requirement, but you are strongly advised to attend class. Attendance has a strong correlation with performance. I recommend that you read the book sections in advance and come ready to participate. If you miss an exam or cannot turn in homework, please inform me beforehand and get a doctor's note if applicable. Absences from tests count as zeros, unless they are justified. If you must be absent during a test for a University sponsored event, you must discuss this with me before the test date.

## Disability Access and Inclusion

The University of Mississippi is committed to the creation of inclusive learning environments for all students. If there are aspects of the instruction or design of this course that result in barriers to your full inclusion and participation, or to accurate assessment of your achievement, please contact the course instructor as soon as possible. Barriers may include, but are not necessarily limited to, timed exams and in-class assignments, difficulty with the acquisition of lecture content, inaccessible web content, and the use of non-captioned or non-transcribed video and audio files. If you are approved through SDS, you must log in to your Rebel Access portal at https://sds.olemiss.edu to request approved accommodations. If you are NOT approved through SDS, you must contact Student Disability Services at 662-915-7128 so the office can: 1) determine your eligibility for accommodations, 2) disseminate to your instructors a Faculty Notification Letter, 3) facilitate the removal of barriers, and 4) ensure you have equal access to the same opportunities for success that are available to all students.

## Academic Integrity

Violations of the University's policy of academic integrity will result in a failing grade and other disciplinary actions. A student with a documented case of plagiarism or cheating in this course will receive a failing grade for the course and may face disciplinary action by the University, including expulsion.

In particular, do not turn in problem set solutions copied from online or a solutions manual. Copying solutions does nothing to enhance your learning. If I see this then you will get an automatic 0 for the problem set. It if happens more than once I will report it to the chair of the department.

## Use of Generative Artificial Intelligence

Generative AI refers to technologies like ChatGPT or similar tools, that can draw on a large corpus of training data to create new written, visual, or audio content. The point of education is not just to correctly answer problems, but to deeply understand a topic for yourself. If you feel that generative AI helps you think for yourself and more deeply understand the material we are learning, I am not going to stop you from using it. Copying output from generative AI still constitutes plagiarism, and there is no guarantee that the tool is responding correctly (it is just like autocompletion). I therefore discourage you from using tools like OpenAI's ChatGPT, Google's Gemini, Microsoft's Copilot, Anthropic's Claude, etc.

## Other

If a change in the syllabus becomes necessary during the semester, it will be discussed in class and then posted on the course website. The course website will also contain up-to-date information on the class schedule, homework assignments, and complementary material.

## Schedule (subject to change)

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| M | Aug | 26 | Lecture 01: | Admin. Lightning review of EM I |
| W | Aug | 28 | Lecture 02: | Review of EM I; Starting dispersion relations |
| F | Aug | 30 | Lecture 03: | Dispersion relations |
| M | Sep | 02 | | Labor Day – Holiday |
| W | Sep | 04 | Lecture 04: | Waveguides |
| F | Sep | 06 | Lecture 05: | Waveguides; Magnetohydrodynamic waves |
| M | Sep | 09 | Lecture 06: | Magnetohydrodynamic waves |
| W | Sep | 11 | Lecture 07: | Dipole radiation |
| F | Sep | 13 | Lecture 08: | Radiative multipole expansion |
| M | Sep | 16 | Lecture 09: | Radiative multipole expansion |
| W | Sep | 18 | Lecture 10: | Vector spherical harmonics |
| F | Sep | 20 | Lecture 11: | Radiation using vector spherical harmonics |
| M | Sep | 23 | Lecture 12: | Special relativity |
| W | Sep | 25 | Lecture 13: | Lorentz vectors, tensors, velocity, momentum, force |
| F | Sep | 27 | Lecture 14: | Special relativistic kinematics |
| M | Sep | 30 | Lecture 15: | Maxwell's eqs. and Lorentz force law in 4d language |
| W | Oct | 02 | Lecture 16: | Potential formulation, gauge invariance |
| F | Oct | 04 | Lecture 17: | Lagrangian formulation of electrodynamics |
| M | Oct | 07 | Lecture 18: | Densities, fluxes, conservation laws |
| W | Oct | 09 | Lecture 19: | Symmetries and Noether's theorem |
| F | Oct | 11 | Lecture 20: | Energy-momentum-stress tensor |
| M | Oct | 14 | Lecture 21: | Radiation from arbitrary relativistic motion |
| W | Oct | 16 | Lecture 22: | Angular, spectral distribution of energy |
| F | Oct | 18 | Lecture 23: | Radiation spectrum from circular motion |
| M | Oct | 21 | Lecture 24: | Synchrotron sources |
| W | Oct | 23 | Lecture 25: | Synchrotron sources |
| F | Oct | 25 | Lecture 26: | Beginning scattering |
| M | Oct | 28 | Lecture 27: | Beginning scattering |
| W | Oct | 30 | Lecture 28: | Born approximation |
| F | Nov | 01 | Lecture 29: | Partial wave expansion |
| M | Nov | 04 | Lecture 30: | Partial wave expansion |
| W | Nov | 06 | Lecture 31: | Diffraction |
| F | Nov | 08 | Lecture 32: | Diffraction |
| M | Nov | 11 | Lecture 33: | Diffraction |
| W | Nov | 13 | Lecture 34: | Optical theorem |
| F | Nov | 15 | Lecture 35: | Thomson scattering |
| M | Nov | 18 | Lecture 36: | Radiation from collisions |
| W | Nov | 20 | Lecture 37: | Bremsstrahlung |
| F | Nov | 22 | Lecture 38: | Bremsstrahlung |
| | | | | Nov 23–Dec 01 Thanksgiving Holidays |
| M | Dec | 02 | Lecture 39: | Radiation-reaction self-force |
| W | Dec | 04 | Lecture 40: | Abraham-Dirac-Lorentz self-force |
| F | Dec | 06 | Lecture 41: | Hamiltonian formulation |
| | | | | Dec 09–13 Final exams |

*=Leo has another responsibility (e.g. travel). So far, this schedule is just a suggested order. Please let me know about any holidays that I should be aware of (e.g. Eid, Yom Kippur, etc.).