Electromagnetism I

TECHNICAL DETAILS

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Office Hours: open-door policy; please feel free to stop by anytime.
Prerequisites: PHYS 2710, MATH 2210, 2250
Required Text: *Introduction to Electrodynamics* (Fourth Edition) by David J. Griffiths.
Credits: 3 credit hours
Lecture: Tu Th, Technology 122, 10:30 – 11:45 am
Course Website: on canvas.usu.edu

OVERVIEW

Subject matter. The theory of classical electrodynamics is a general framework for describing and explaining the interactions of charged particles and objects composed of charged particles via electric and magnetic fields. Generally, this means our overall goal is to solve the Maxwell equations,

$$\begin{aligned} \nabla \cdot \mathbf{E} &= \frac{\rho}{\epsilon_0}, \qquad & \nabla \cdot \mathbf{B} &= 0, \\ \nabla \times \mathbf{E} + \frac{\partial \mathbf{B}}{\partial t} &= 0, \qquad & \nabla \times \mathbf{B} - \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t} &= \mu_0 \mathbf{J}, \end{aligned} \tag{1}$$

for the electric field $\mathbf{E}(\mathbf{r}, t)$ and magnetic field $\mathbf{B}(\mathbf{r}, t)$ under a wide variety of physical situations. As Newton's second law is the starting point of solving dynamical problems in classical mechanics, these equations are the starting point for finding the fields **E** and **B**. In these equations the terms $\rho(\mathbf{r}, t)$ and $\mathbf{J}(\mathbf{r}, t)$ (respectively, the charge density and current density) are the sources of **E** and **B**.

In this course we shall cover two basic situations, which come under the headings electrostatics and magnetostatics. Electrostatics is the study of static electric fields produced by static charge distributions $\rho(\mathbf{r})$. Electrostatics also includes the interaction of matter with such electric fields. Analogously, magnetostatics is the study of static magnetic fields produced by steady-state current distributions $\mathbf{J}(r)$. Magnetostatics also includes the interaction of matter with such magnetic fields. As we shall see, these two topics parallel each other quite closely. Importantly, the ideas introduced in describing static fields lay the foundation for the study of dynamic electromagnetic fields, the general subject of the follow-on course, Electromagnetism II (PHYS 4600).

While you have already been exposed to electromagnetism in your introductory physics sequence, we shall now discuss this material at much higher conceptual and mathematical levels than you have previously encountered. At times, the word abstract may be an appropriate term to use. In many ways you are at the beginning of your foray into modern theoretical physics. Although it will likely take a lot of work to master this subject, I hope it will be fun!

COURSE GOALS
(Students should ...)

The goals for this course, while all intertwined to some extent, can be divided into three categories: (i) application of math techniques, (ii) development of physics ability, and (iii) practice of efficient study habits. Let's discuss each of these. *All of the goals listed below are critical to developing the ability to utilize physics in a professional setting.*

Application of Math Techniques

► **Vector calculus**. Students should become competent at applying the mathematics of vector calculus – divergence, curl, gradient, Laplacian, various 3D integrals, Stoke's theorem, and the divergence theorem – in Cartesian, cylindrical, and spherical-polar coordinates.

► **Limiting cases**. Student should become proficient at simplifying expressions in the limit where a particular parameter is either small or large, which often means utilizing Taylor-series expansion. This ability is essential for checking the validity (or at least the plausibility) of complicated mathematical expressions.

Development of Physics Ability

► **Overview of Time Independent E&M**. Students should develop a working overview of the subjects of electrostatics and magnetostatics, including cases involving material response to the fields.

► **Problem Analysis and Solution**. Students should develop the ability to assess what techniques are appropriate for a particular problem, and then be able to apply those techniques to the problem to find the solution.

► **Extracting Meaning from Equations**. Students should become proficient at gaining insight from the mathematical equations involved in any particular problem. *What are the equations telling you?*

► **Think as a Physicist**. Overall, students should develop the ability to approach, analyze, and solve problems in the manner that an expert (i.e., a professional physicist) does.

Practice of Efficient Study Habits

► **Assimilate Textual Material**. Students should develop the ability to internalize physics ideas and concepts from written material. The practices of (i) prereading and (ii) efficient note taking are two techniques for achieving this goal.

► **Timely Completion of Assignments**. To enable the most proficient assimilation of the material, students should develop the practice of completing assignments in a timely fashion. In this course this involves completing homework assignments shortly after the material has been introduced through the associated reading assignment and lecture.

SCHEDULE

The schedule for the lectures (and not coincidentally, the reading assignments) can be found in the table on the following page. In essence, we shall work our way through Chapters 2 - 6 of the text. As necessary, mathematical material from Chapter 1 will be included.

Table 1: Reading Assignments and Lecture Schedule

Week of	**Tuesday**	**Thursday**
Aug 26	[1] Electric field **E** / Coulomb's Law (Ch. 2: 59-65)	[2] Gauss' law (Ch. 2: 66-78)
Sept 2	[3] Scalar potential V (Ch. 2: 78-84)	[4] Scalar potential V / Boundary conditions (Ch. 2: 84-91)
Sep 9	[5] Work and energy (Ch. 2: 91-97)	[6] Conductors / Capacitance (Ch. 2: 97-102, 105-107)
Sep 16	Buffer / Review	**Exam I** (Ch. 2)
Sep 23	[7] Laplace's equation (Ch. 3: 113-124)	[8] Method of images (Ch. 3: 124-130)
Sep 30	[9] Separation of variables: Cartesian coordinates (Ch. 3: 130-140)	[10] Separation of variables: Spherical-polar coordinates (Ch. 3: 141-149)
Oct 7	[11] Multipole expansion / Electric dipole **p** (Ch. 3: 151-159)	[12] Polarization field **P** (Ch. 4: 167-179)
Oct 14	[13] Displacement field **D** / Linear response (Ch. 4: 181-189)	Fall Break
Oct 21	[14] Capacitors / Boundary-value problems (Ch. 4: 190-196)	[15] Energy / Clausius-Mossotti (Ch. 4: 197-202, Prob. 4.41)
Oct 28	Buffer / Review	**Exam II** (Ch. 3-4)
Nov 4	[16] Currents / Magnetic force (Ch. 5: 210-223)	[17] Biot-Savart law (Ch. 5: 223-229)
Nov 11	[18] Ampere's law (Ch. 5: 229-242)	[19] Vector potential **A** (Ch. 5: 243-248)
Nov 18	[20] Boundary conditions / Magnetic dipole **m** (Ch. 5: 249-255)	[21] Magnetic fields in matter / Magnetization field **M** (Ch. 6: 266-279)
Nov 25	[22] Auxiliary field **H** (Ch. 6: 279-287)	Thanksgiving Break
Dec 2	Buffer / Review	Study day
Dec 9	**Final Exam** (Chs. 5-6 / Comprehensive) 9:30 am – 11:20 pm	

READING QUIZZES

In order to encourage you to keep up with the material (and to make lectures more profitable), there are online reading quizzes, administered through Canvas. Generally, there is a quiz before each class period. Each quiz shall contain on the order of 5 questions, which are readily answerable after reading the associated material in the text. The primary deadline for each quiz is the **night before the associated lecture, at 1 AM**. For full credit, each quiz must be completed before the primary deadline. A secondary deadline occurs **24 hours** after the primary deadline. The scores on quizzes completed between these two deadlines are worth 50% of their full value. No quizzes may be completed after the secondary deadline.

HOMEWORK

Assignments. Each homework assignment is tied to the lecture with the same number (see schedule on previous page). **You should work through each assignment before the next lecture**, as this will help you (i) internalized the material and (ii) be ready for the upcoming class period. In order to prepare for the exams, it is strongly suggested you keep your solutions for all the problems together in one place, such as a three-ring binder.

Homework (assigned in the previous week) will be collected each Tuesday. Approximately 1/3 of the assigned problems will be graded. No late homework will be accepted.

For full credit the homework must be written up in complete sentences that **clearly indicate your thinking and your process of working out the problem**. Neatness counts, as the grader will not be inclined to assess sloppy work. Assessment will mostly be based on your completion of each problem.

Supplemental instruction / Recitations. A teaching assistant (TA) assigned to the course will lead regularly scheduled recitation sections. The TA will answer any question you have regarding course material, especially assigned homework problems. Take advantage of this resource!

COLLABORATION IS ENCOURAGED

I strongly encourage collaboration, which is an essential skill in science (and highly valued by employers!) Social interaction is critical to the success of all scientists – most good ideas grow out of discussions with colleagues. Essentially all scientists work as part of a research team. Find a partner or two with whom you can discuss the homework. However, it is also important that you *own* the material. **It is best to limit yourself to verbal help**; resist the impulse to take written information from others. This practice will ensure that you think things through independently after you get help. If you complete the homework but do poorly on exams, then you may be getting too much help. The point of the homework is not to just find the answer, but more importantly to understand the pathway that leads to the answer.

While collaboration is the rule in technical work, the evaluation of each individual also plays an important role. Exams will be done without help from others. The reading quizzes are to be done by yourself. Your homework solution should be your own.

EXAMS

There will be two midterm exams and a comprehensive final exam. The midterm exams shall take place during fourth and tenth weeks of the semester; see the schedule above. The comprehensive final exam is scheduled for **11:30 AM - 1:20 PM, Tuesday, December 11, 2018**.

HOW TO SUCCEED IN THIS COURSE

I firmly believe **anyone** can do well in this class if they adhere to the following guidelines.

- Before each class read the assigned sections in the text. Many students find it helpful to make an outline of the material as they read, highlighting important concepts and equations; notes should also include questions about material that is unclear. Follow up your reading by getting answers to your questions.
- Take the quiz immediately after reading the assigned material.
- Attend every lecture. And ask questions while you are there!
- Keep up with the homework. Schedule a regular time each week for each assignment.
- Work together and/or get help when necessary.
- Don't get behind. It's very hard to catch up.

These points can be summed up as follows:

do the **reading**, take the **quiz**, come to **lecture**, complete the **homework** ...
(lather, rinse, repeat,...)

GRADING

Scores on reading quizzes, homework, and exams contribute to your final grade. The percentage that each contributes is as follows.

- Reading quizzes 10%
- Homework assignments 15%
- First midterm exam 20%
- Second midterm exam 25%
- Final exam 30%

If the First Midterm Exam is your lowest scoring exam, then your exams shall be weighted as follows.

- First midterm exam 10%
- Second midterm exam 30%
- Final exam 35%

The grading scale is listed below. Expect final grades in the course to closely follow this scheme.

A $\geq$ 90%,	B $\geq$ 75%,	C $\geq$ 60%,
A$-$ $\geq$ 85%,	B$-$ $\geq$ 70%,	C$-$ $\geq$ 55%,
B+ $\geq$ 80%,	C+ $\geq$ 65%,	D $\geq$ 50%

Yes, there is no possibility for a D+ grade.

DISABILITY

USU welcomes students with disabilities. If you have, or suspect you may have, a physical, mental health, or learning disability that may require accommodations in this course, please contact the Disability Resource Center (DRC) as early in the semester as possible (University Inn 101, 435-797-2444, drc@usu.edu). All disability related accommodations must be approved by the DRC. Once approved, the DRC will coordinate with faculty to provide accommodations.

HONOR CODE

The honor code will be strictly enforced in this course. Any suspected violations of the honor code will be promptly reported to the honor system. For more information please visit http://studentconduct.usu.edu/studentcode/article6.

POSSIBLE CHANGES

The instructor reserves the right to modify, as deemed appropriate, any part of this syllabus.