

$$\partial_{\mu} F^{\mu\nu} = \frac{4\pi}{c} j^{\nu}$$

Unlike Classical and Quantum Mechanics which look at systems of a few particles, or Statistical Mechanics which investigates ensembles of a large number of particles at finite temperatures, in Electrodynamics we study the classical electromagnetic field that permeates space. This subject is of great importance to physicists because all modern physics experiments rely on electromagnetism in one way or another, and because the theory of electromagnetism is the doorway to the understanding of the fundamental forces in nature.

In this one-semester graduate course we will review the important concepts of electromagnetism which students have learned in undergraduate courses. But more importantly, our goal is to deepen students' understanding of electrodynamics and to acquaint them with the physical concepts and mathematical skills which will benefit their future career.

General Information

- **Instructor:** Dr. Huaiyu Mike Duan <duan@unm.edu>, PAIS 3212.
- **Instructor's office hour:** You are welcome to drop by and discuss physics with me whenever my door is open. You may also send me a email to make an appointment.
- **TA:** TBA.
- **TA's office hour:** TBA.
- **Lecture hours:** 12:30 – 1:45 PM on Tuesday and Thursday, PAIS 1160.
- **Problem session (PHYS 551.001):** 10:00 – 10:50 AM on Friday, PAIS 1160.
- **Textbook:** *Modern Electrodynamics* by Andrew Zangwill (Cambridge, ISBN 978-0521896979).
- **Course homepage/repository:** UNM Canvas <<https://canvas.unm.edu>>.
- **Communication:** Class news and notices will be sent through UNM Canvas to (most likely) your UNM email address, i.e. <your_unm_net_id@unm.edu>. Please check your UNM mailbox regularly during the week or set up autoforwarding to your favorite email account.

Prerequisites

Students who have not taken the following courses may encounter a steep learning curve.

- Undergraduate Modern Physics (PHYS 330, especially the part on special relativity).
- Undergraduate Electricity and Magnetism (PHYS 405 & 406). If you have taken only one semester of undergraduate E&M, you are strongly encouraged to take PHYS 406 first.
- Methods of Theoretical Physics I (PHYS 466).

Pedagogy

The goal of our graduate program is to equip the students with the skills of a successful physicist who can learn by reading the literature and who can find and work on interesting problems to which no one knows the solutions yet. Therefore, it is very important that you cultivate a good habit of self-studying.

1. **Textbook and supplementary materials.** Study of the textbook and supplementary materials should be the PRIMARY way for you to develop understanding of the course material. The instructor will provide skeleton lecture notes to guide your reading. It is of great importance that you READ the corresponding sections of the textbook and supplemental materials BEFORE you work on homework problems. Here are a few reference books that you may also find useful:

- *Classical Electrodynamics* by John D. Jackson A classical graduate textbook used by many physics departments.
- *Introduction to Electrodynamics* by David J. Griffiths A popular undergraduate textbook used in many physics departments including ours. You may want to consult it or your favorite undergraduate E&M textbook if other books are difficult for you.

2. **Problems.** The best way to learn a subject is by practicing. This is especially true for Electrodynamics because this subject is very “math-heavy”. You can acquire the mathematical skills through solving problems: the examples in the textbook, reference books, supplemental materials and lectures, and the problems in problem sessions, homework, and textbooks. You are encouraged to discuss these problems with the instructor, TA and your fellow students if you have trouble solving them by yourself, but you must work out the homework problems THOROUGHLY and INDEPENDENTLY afterwards. One of the ways to improve your understanding of the homework is to consult the solutions which the instructor has spent many hours to prepare. You may gain a deeper or alternative understanding of the problems by reading the solutions even if you have solved the problems successfully.

3. **Quizzes.** Many students find their mind completely blank when they encounter a “new” problem, especially during an exam, even though they have worked hard. The way out is not to memorize everything, which is impossible (for most people), or to write everything down on the cheatsheet, which is of no use if you do not know how to use it. My suggestion is that you spend time pondering on and playing with the key equations until you understand the physical concepts behind these equations. These equations and concepts are usually the starting point of solving a problem. You also need to keep some math tricks in your memory which may be used repeatedly in this course. To encourage you along this direction, there will be several unannounced short in-class quizzes focusing on the basic concepts and frequently used formulas. Some students may fail the course because they have developed an unhealthy habit of spending little time studying except before exams. These quizzes will check if you are on the right track and alert you before it is too late.

4. **Instructor.** The role of the instructor is to give their unique perspective on the subject, which is not necessarily the same as that of the textbook, and to provide timely help and to clarify confusions. Their job is best achieved when you are not shy to ask questions in and after class. There is NO DUMB QUESTION! There may be times that we have to continue the discussion in small groups after the class if the questions are relevant to only a few students.

Grades

1. **Homework 40%** Please turn in EVERY homework even if you cannot finish it. The solution to each assignment will be posted in UNM Canvas after the assignments have been collected. NO LATE homework will be accepted unless the student has a very good reason and has contacted the instructor before the solution is posted.
2. **Exams 20% + 20% + 20%** The first two exams will be held during the **problem sessions on 2/21 and 4/4**, respectively. The last exam will be held during the finals week. All exams will be closed-book but you may carry a letter-sized double-sided information sheet.
3. **Quizzes 5% (bonus)** There will be NO MAKEUP QUIZ.
4. **Final letter grades** can be: A+ (≥ 100), A (95.0–99.9), A- (90.0–94.9), B+ (85.0–89.9), B (80.0–84.9), B- (75.0–79.9), C+ (70.0–74.9), C (65.0–69.9), C- (60.0–64.9), F (< 60).
5. **Problem session:** You will receive Credit for the problem session as long as you register and show up for more than 60% of the time.

Preliminary Schedule

Here is a preliminary schedule of this course. The actual schedule may be different.

WK	LEC	DATE	TOPIC	CHAPTER
1	1	1/17	Electric field	3.1-2
	2	1/19	Divergence theorem and Helmholtz theorem	1.4.2, 1.9, 3.3-4
2	3	1/24	Electrostatic energy	3.5-6
	4	1/26	Electrostatic force and perfect conductor	3.7, 5
3	5	1/31	Electric multipoles (I)	4.1-2, 4.4
	6	2/2	Electric multipoles (II)	4.4-7, 6.1-3
4	7	2/7	Dielectric matter	6.4-8
	8	2/9	Real conductor and steady current	5.7, 9.1-3, 9.5-7
5	9	2/14	Magnetic field (I)	10.1-3, 10.5
	10	2/16	Magnetic field (II)	11.1-3, 12.1-2
6		2/21	EXAM 1	
	11	2/23	Magnetic field (III)	12.3-7
7	12	2/28	Magnetic matter (I)	13
	13	3/2	Magnetic matter (II)	13
8	14	3/7	Quasi-static fields (I)	14.1-12
	15	3/9	Quasi-static fields (II)	14.1-12
9		3/14	SPRING BREAK	
		3/16	SPRING BREAK	
10	16	3/21	Electromagnetic potentials and conservation laws	15.1-5
	17	3/23	Electromagnetic waves (I)	16.1-3, 16.5
11	18	3/28	Electromagnetic waves (II)	1.6, 16.4, 17.1-2
	19	3/30	Reflection and refraction	17.3
12		4/4	EXAM 2	15.3, 20.1-3
	20	4/6	Dispersive media	17.2.2, 17.6, 18.1-2
13	21	4/11	Drude model	18.4, 18.5.1-3
	22	4/13	Lorentz model and Kramers-Krönig relations	18.5, 18.7
14	23	4/18	Retarded potentials	15.3, 20.1-5
	24	4/20	Multipole radiation	20.7
15	25	4/25	Scattering (I)	21.1-4
	26	4/27	Scattering (II)	21.6-7
16	27	5/2	Lorentz covariant electrodynamics (I)	1.7-8, 15.2, 22.1-7
	28	5/4	Lorentz covariant electrodynamics (II)	1.7-8, 15.2, 22.1-7
17			EXAM 3	