Spring 2017

Electrodynamics

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

Unlike Classical and Quantum Mechanics which mainly 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>, P&A 1144, 505-277-1508.
- **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**: Josh Martin <josh86@unm.edu>.
- **TA's office hour**: 2:00 — 3:00 PM on Wednesday, P&A Lobby.
- **Lecture hours**: 11:00 AM — 12:15 PM on Monday and Wednesday, P&A 5.
- **Problem session** (PHYC551.055): 5:30 — 6:45 PM on Wednesday, P&A 184.
- **Textbook**: *Modern Electrodynamics* by Andrew Zangwill (Cambridge, ISBN 978-0521896979).
- **Course homepage/repository**: UNM Learn <https://learn.unm.edu>.
- **Communication**: Class news and notices will be sent through UNM Learn 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

- One semester of undergraduate Modern Physics (PHYC330, especially the part on special relativity).
- Two semesters of undergraduate Electricity and Magnetism (PHYC405/406). If you have taken only one semester of undergraduate E&M, you are strongly encouraged to take PHYC406 first.
- One semester of Methods of Theoretical Physics (PHYC466).
- Passing the preliminary exam on undergraduate E&M. If you have not passed this exam, you may encounter a very steep learning curve.

Pedagogy

The goal of our graduate program is to equip 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 Electromagnetism* by Jerrold Franklin — This book is out of print, and it does not contain all the subjects that I will cover. But it is easier to read than many other graduate textbooks and uses the "right" (i.e. Gaussian) units.
   - *Classical Electrodynamics* by John D. Jackson — A classical graduate textbook used by most physics departments. Not an easy read.
   - *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 grasp mathematical skills only 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 after discussing with other people. 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, or to write everything down on the cheatsheet, which has no use if you do not know how to use it. My suggestion is to spend time pondering on and playing with the key equations until you can truly understand the physical concepts behind these equations. These equations and concepts are usually the starting point in solving a problem. You also need to keep some math tricks in you memory which may be used repeatedly in this course. To encourage you along this direction there will be several unannounced 10-minute, 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 his 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. His 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 35% + 5% (bonus)** Please turn in EVERY homework even if you cannot finish it. The solution to each assignment will be posted in UNM Learn after the assignments have been collected. There will be NO MAKEUP HOMEWORK.
2. **Exams 20% + 20% + 25%** Two midterms will be held during the **problem sessions on 2/15 and 3/29**. The final exam will be comprehensive and be held at **10 am – 12 pm on 5/10**. 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		1/16	MARTIN LUTHER KING JR. DAY	
	1	1/18	Electric field	1.2-3, 1.4.2, 1.5, 2.1.1, 2.2.1-2
2	2	1/23	Scalar potential	1.9, 3.1-3, 3.4.1-2, 3.5
	3	1/25	Electric energy and stress	3.6-7
3	4	1/30	Electric multipoles	4.1-2, 4.4
	5	2/1	Dielectric matter	6.1-2, 6.3.1, 6.4-5, 6.7, 6.8.4-5
4	6	2/6	Magnetic field	2.1.2-3, 2.2.3, 10.1-3
	7	2/8	Vector potential	10.5, 11.1-2
5	8	2/13	Magnetic matter	13.1-3, 13.5-6
	9	2/15	Magnetic force	12.1-2, 12.4-5, 13.8.5
6	10	2/20	Magnetic energy	9.7.1-2, 12.6-7, 13.7, 1.4.5, 14.3-4
	11	2/22	Maxwell's equations	2.2, 2.4, 14.1-2, 15.4
7	12	2/27	Momentum conservation	15.5
	13	3/1	Plane waves	16.3-4, 17.1-2
8	14	3/6	Reflection and refraction	17.3
	15	3/8	Waves in conductor	17.3.6-7, 17.6
9		3/13	SPRING BREAK	
		3/15	SPRING BREAK	
10	16	3/20	Drude model	18.4, 18.5.1-3
	17	3/22	Lorentz model	18.5.5, 18.6.1

WK	LEC	DATE	TOPIC	CHAPTER
11	18	3/27	Kramers-Krönig relations	18.2-3, 18.7
	19	3/29	Retarded potentials	20.1-3
12	20	4/3	Time-varying dipole	20.4
	21	4/5	Radiation fields — Time domain	20.5
13	22	4/10	Radiation fields — Frequency domain	20.5.6, 20.6
	23	4/12	Multipole radiation	20.7
14	24	4/17	Thomson scattering	21.1-3
	25	4/19	Rayleigh scattering and Born approximation	21.4, 21.6.1
15	26	4/24	Lorentz transformation	1.7-8, 15.2, 22.1-4
	27	4/26	Space-time and four-vectors	
16	28	5/1	Lorentz covariant quantities	
	29	5/3	Relativistic electrodynamics	
17		5/10	FINAL EXAM	