

Physics 3040: Electromagnetism (Normal)

Unit of Study Outline 2010

Lecturer: A/Prof Zdenka Kuncic (Room 415, A28, zdenka.kuncic@sydney.edu.au)

Textbook and reference books

The textbook is *Introduction to Electrodynamics (Third Edition)* by David J. Griffiths. All students will be expected to have access to a copy. It can be bought from the Co-Op book shop, and there are also copies on closed reserve¹ in the Physics library. Note that Griffiths may also be helpful as a reference book for the Physics Honours course on “Advanced Electromagnetic Theory.”

There are many other suitable books on electromagnetism. One of the best is *The Feynman Lectures on Physics*, Volume 2, by Feynman, Leighton & Sands. A few copies are held on closed reserve in the Physics Library, while Fisher Undergraduate Library has many copies that can be borrowed for one week.

We will always follow the notation in Griffiths, but be aware of differences in other books. For example, Griffiths uses V for electric potential, whereas Feynman uses ϕ .

Lectures

There will be 19 lectures in weeks 1–10 of Semester 1. Lectures will be in Lecture Theatre 5 each Wednesday at 1pm and Friday at 12noon. The week-by-week timetable can be found on the Senior Physics Web site (www.physics.usyd.edu.au/current/sphys/timetable_weekly_1.shtml).

Assessment

There will be one final exam, worth 75% of your total assessment for this unit. The remaining 25% is made up by two assignments. A formula sheet will be made available with the exam. The assignments should be done individually and handed in to the Student Support Office. Make sure you identify your course as PHYS 3040.

Assignment 1 is due by 5pm on Friday 16-Apr-2010 (Week 6)

Assignment 2 is due by 5pm on Friday 28-May-2010 (Week 12)

COURSE OUTLINE

This course develops the classical theory of electromagnetism, one of the cornerstones of physics. It builds on courses in Junior and Intermediate Physics, which introduced Maxwell’s equations in their integral form. In this course we will develop the equations in differential form, using the power of vector calculus. The main application will be to electromagnetic waves, including the interaction of waves with matter through reflection and absorption. These have application in fields such as optics, plasma physics and astrophysics. This course lays the foundation for more advanced treatments, such as a full description of the origin of electromagnetic radiation. The course content is defined in terms of the textbook. However, the material may not necessarily be covered in the same order as in the textbook.

Note that there are Maths prerequisites for this unit. They are MATH 2061 or 2961 (Linear Mathematics/Algebra and Vector Calculus) or MATH 2067 (Differential Equations and Vector Calculus for Engineers). Whilst a brief revision of vector calculus may be given in the first lecture, it will thereafter be treated as assumed knowledge. Students who require further revision of vector calculus are referred to Chapter 1 of the textbook.

¹Books on closed reserve can be borrowed for two hours, or overnight provided they are returned by 10am the next day.

Chapter 1: Vector Analysis

- this chapter should be read for mathematical background, and will be referred to as needed
- Omit: Section 1.5 (The Dirac delta function)

Chapter 2: Electrostatics

- Section 2.1: Coulomb's law, principle of superposition, definition of electric field, continuous charge distributions
- Section 2.2: field lines, flux, Gauss's Law in integral and differential form (omit Section 2.2.2)
- Section 2.3: electric potential, boundary conditions
- Section 2.4: work and energy in electrostatics
- Section 2.5: conductors, capacitors

Chapter 4: Electric fields in matter

- Not explicitly examinable (mostly revision, but with differential forms)

Chapter 5: Magnetostatics

- Section 5.1: magnetic forces, currents
- Section 5.2: Biot-Savart Law
- Section 5.3: divergence and curl, Ampere's law
- Section 5.4: Magnetic vector potential (\mathbf{A})

Chapter 6: Magnetic fields in matter

- Not explicitly examinable (mostly revision, but with differential forms)

Chapter 7: Electrodynamics

- Sections 7.1 and 7.2 not examinable (mostly revision, but with differential forms)
- Section 7.3 (Maxwell's equations)

Chapter 8: Conservation Laws

- main results (omit full derivations): conservation of charge (Eq. 8.4), Poynting vector (Eq. 8.10), energy (Eq. 8.13), momentum (Eq. 8.30)
- omit Section 8.2.2 (Maxwell's Stress Tensor) and Section 8.2.4 (Angular momentum)

Chapter 9: Electromagnetic Waves

- Section 9.1: waves in one dimension, exponential notation
- Section 9.2: electromagnetic waves in vacuum, exponential notation, energy and momentum
- Section 9.3: electromagnetic waves in matter, reflection and transmission (non-examinable)

LECTURE-BY-LECTURE OUTLINE

Lecture 1

- course overview and rationale
- revision of differential vector calculus (Secs. 1.2, 1.3.3, 1.3.4, 1.3.5, 1.6)

Lecture 2

- electrostatics - Ch. 2
- Coulomb's law (Sec. 2.1)
- Prob. 2.7

Lecture 3

- divergence & curl of electrostatic fields (Sec. 2.2)
- Gauss's law in integral form (Sec. 2.2.3)
- Prob. 2.11
- Gauss's law in differential form
- Prob. 2.9

Lecture 4

- Gauss's law (cont.)
- Ex. 2.4 – Gaussian pillbox
- Prob. 2.15
- curl of \mathbf{E} (Sec. 2.2.4)

Lecture 5

- Prob. 2.20
- electric potential (Sec. 2.3)
- Ex. 2.6
- Prob. 2.23
- Poisson & Laplace eqns (Sec. 2.3.3)
- summary of ρ , \mathbf{E} , V in electrostatics

Lecture 6

- work & energy in electrostatics (Sec. 2.4)
- Prob. 2.32

Lecture 7

- conductors (Sec. 2.5)
- induced charges (Sec. 2.5.2)
- Prob. 2.36
- force on a conductor (Sec. 2.5.3)

Lecture 8

- capacitors (Sec. 2.5.4)
- Ex. 2.10
- magnetostatics – Ch. 5
- magnetic forces (Sec. 5.1.2)

Lecture 9

- Prob. 5.1
- currents (Sec. 5.1.3)
- Ex. 5.3
- surface & volume current densities

Lecture 10

- charge continuity eqn
- Biot-Savart law (Sec. 5.2)
- Ex. 5.5, 5.6

Lecture 11

- divergence & curl of \mathbf{B} (Sec. 5.3)
- Ampere's law in integral form
- Ampere's law in differential form
- Ex. 5.7, 5.9, 5.10

Lecture 12

- Prob. 5.14
- magnetic vector potential (Sec. 5.4)
- summary of magnetostatics

Lecture 13

- Faraday's experiments (Sec. 7.2)
- electrodynamics – Ch. 7
- Maxwell's eqns (Sec. 7.3)

Lecture 14

- Ampere's law
- Prob. 7.31
- conservation laws – Ch. 8
- continuity eqn (Sec. 8.1.1)

Lecture 15

- Poynting's theorem (Sec. 8.1.2)
- Ohm's law
- momentum conservation (Sec. 8.2.3)

Lecture 16

- EM waves – Ch. 9
- plane wave solutions
- Ex. 9.2

Lecture 17

- energy & momentum in EM waves (Sec. 9.2.3)
- Maxwell's eqns in matter (Sec. 7.3.5)
- EM waves in matter (Sec. 9.3) – non-examinable
- propagation in linear media (Sec. 9.3.1) – non-examinable

Lecture 18

- reflection & transmission at normal incidence (Sec. 9.3.2) – non-examinable

Lecture 19

- reflection & transmission at oblique incidence (Sec. 9.3.3) – non-examinable