Electrodynamics (PHYS 480) Fifth Guide

Fall 2014 v1.0

In **Chapter 5** we start on magnetic fields.[1] Griffiths begins the chapter with moving electric charges (why not magnets?) and the experimentally derived magnetostatic equations. The chapter then develops the key concepts of the Lorentz force, the Biot-Savart and Ampére laws, the vector potential and boundary conditions.

This material is much richer than the "more linear" electrostatics. Have fun!

Problems:

(1) 4.13
(2) 4.18 Use Gauss's law for the electric displacement to get started.
(3) 4.28 Use energy
(4) 5.2 Charged particle trajectories
(5) 5.4 Finding the magnetic force on a loop via " $I\ell \times B$".
(6) 5.6 Finding current densities
(7) 5.9 Use superposition
(8) 5.11 Putting the Biot-Savart integration to practice
(9) In the distant past you may have completed a magnetic field mapping lab. Removing the shrouds of the ancient past... you find data on the field as a function of distance away from the solenoid (length $L = 16.5 \pm .03$ cm and diameter $d = 1.5 \pm 0.2$ cm). See the supplied spreadsheet.
   (a) By using the result from the last problem, find the expression for the magnetic field in terms of the quantities you measured and the size of the solenoid, L and d (or a in David's diagram).
   (b) Using the values given, plot your theoretical expression. One way to do this is to enter your result into excel and plot the prediction as a new series on the same plot at your data. Include plenty of points so it is easy to see the shape of the prediction.
   (c) Does your theoretical result match your data? Submit a printout of your plot.
(10) 5.14 Ampére's law for a cylinder
(11) 5.22 Modifying Maxwell to incude monopoles

Notes on text:

- page 212 The key equation for the motion of charged particles. The examples on the next couple of pages are classic.
- page 223 Griffiths looses a great opportunity to get his "static/stationary" definitions precise. Let's fix this problem. The physics behind the full mathematical definition is this: A **stationary** system is time independent (when you know the solution at one time, you know it for all time). A **static** system is stationary *and* is invariant under time reversal (t goes to $-t$). With these definitions "stationary current" doesn't sound so strange at least to some ears. Can you think of a system which is stationary but not static?
- page 224, where did this monster, Eq. (5.32), come from? On the pronunciation on the name, think French.
- page 232 The familiar and important Ampére's law is derived from Biot-Savart.
- pages 236-7 Locally, the current sheet used in the solenoid of Example 5.9 is identical to the current sheet of Example 5.8. Why aren't the fields equivalent, i.e. Eq. (5.58) and Eq. (5.59)?
- page 243 The vector potential! A step closer to reality or a step away?

[1] If we were working through Maxwell's treatise on electrodynamics he would have us study electrostatics, magnetostatics, and electrodynamics *simultaneously*.

- page 251 Boundary conditions for **B** and **A**!
- page 252 Multipoles for **A**
- page 253 The magnetic dipole moment is introduced. Do you buy the argument? Study Eq. (1.108).

Other Curiosities:

- The Levitron! Discuss Earnshaw's theorem for magnetic fields, demonstrate the toy, and give a full discussion of the physics behind it.
- The Biot-Savart law from pronunciation to Ampére. It is also a bit embarrassing that the interaction between two current elements does not obey Newton's Third Law (see 5.49). (or is it?) References: Lyness *Contemp. Phys.* **4** (1963) 453. Peach and Shirely *Am. J. Phys.* **50** (1982) 410. Whitney *Am. J. Phys.* **56** (1988) 871.
- The vector potentials: Do they have physical meaning? Read the article *Am. J. Phys.* **64** (1996) 1361
- Present 5.41 and the Quantum Hall Effect (what was the discovery, why did it result in a Nobel Prize).
- Work out 5.58 and tell us more about the "finest achievement of QED."