Electrodynamics (PHYS 480) Tenth Guide

Fall 2014 v1.0

There's still time to nudge our direction at the end of the course towards some favorite material but if I don't hear anything this is what we will do: We will finish Chapter 9 the week after break, going very lightly over wave guides. Then we'll set up what we need for radiation (Chapter 11). This means that we would not return to special relativity.

Chapter 10 is devoted to setting up the technologies that will be necessary in our work on radiation (Chapter 11). Specifically: Maxwell's equations are re-expressed in terms of the potential; we see that there is some gauge freedom in how the potential is expressed; and the general solutions are derived for potential and fields. In the presentation of these topics, there is some heavy algebra to get through. Griffiths indicates (and see notes on text) where alternate derivations and physical arguments can be found.

Reading:

Problems of note:

(1) 8.9 A spherical version of the field angular momentum example we did
(2) 8.13 Induced current and the flow of power through the fields
(3) 8.37 A (flawed) classical model of the electron. Start with your solution to problem 5.37 on the Sixth guide.
(4) 9.9 Working with the new wave notation
(5) 9.13 Working out the stress-momentum tensor for monochromatic plane waves.

Notes on text:

- page 403 Don't get lost in the algebra. Go for the big picture, i.e. what are the BC's? how are they applied? and what is the result?
- page 405 This derivation might seem a bit slippery. We'll spend some time with it in class. Nonetheless it is amazing how easy it is to derive the laws of geometric optics. It all seems to drop out from the "continuity condition" of Eq. 9.93. Neat! When are the laws valid?
- page 408 "More BC's $\equiv$ More Results" in this case Fresnel's equations and Brewster's angle.
- page 412 There is a key conceptual step in going from Eq. (9.118) to Eq. (9.121). When is it valid?
- page 414 We have new equations and a new wave number. The usefulness is easy to see in the damping exponential factors in Eq. (9.127). The skin depth is a key property of conductors.
- page 417 Griffiths packs a lot into section 9.4.3 and we ought to keep our hats on. Look for the big picture.
- page 425 Wave guides are another whole topic unto themselves. When I taught this course at Swarthmore – "Lo, those many years ago!" – this was a hot field, at least in application. Due to the expected demand for internet speed and bandwidth during the .com bubble in 1999, one company that made fiber optic components saw its stock jump 430 % (!) (Yes I did have some but no, I didn't sell it at the peak.)
- pages 436-7 An important derivation, especially Eq. 10.3 (This relation indicates that, roughly, "$\mathbf{E}$ is the canonical momentum of $\mathbf{A}$")
- page 439-40 Here begins a entirely new concept for physics – one that has caused no end of delight and frustration. The Nobel Prize in 2007 was awarded to 't Hooft and Veltman who showed that (nonabelian) gauge theories are renormalizable. For more on what is "gauge" see the reading in Lee's book.

Additional cool stuff:

- Gauge principle of Weyl: There is a short, wonderful, but not fully fleshed out, discussion of gauge in Lee Smolin's "The Life of the Cosmos" starting on page 51.
- The Belot article and the ontological significance of the fields and the potentials. This will involve a discussion of the Aharonov-Bohm effect.

Resources:

- Lee Smolin *The Life of the Cosmos* This is a relatively high level popular science book which has some uncommonly good pieces on 20th century physics.
- Gordan Belot, "Understanding Electromagnetism" *Brit. J. Phil. Sci.* **49** (1998) 531-555. A more formal continuation on the "reality" of the fields and potentials of electrodynamics. This article introduces some wonderful techniques very briefly e.g. Hamiltonian flows on phase space. These are then used in the discussion of the fields.
- Heald and Marion, *Classical Electromagentic Radiation*