Electrodynamics (PHYS 480) Eighth Guide

Fall 2014 v1.0

This week we'll be finishing up the intro to field dynamics, discussing inductance, and likely starting on Chapter 8.

Chapter 8 is short in pages but full of new concepts and intriguing problems. In it you will find angular momentum of fields, the Maxwell stress tensor, field energy, energy flux density, and a quirk in linear momentum. All of these are central subjects to the study of electrodynamics and, in fact, any field theory.

The following week we'll have an in-class mid-term on Chapters 1-6. There will be no problems due that week.

Problems of note:

(1) 7.8 Flux for non-uniform B

(2) **Theft with no moving parts!** By stringing wire loops alongside large transmission lines some ingenious ranchers generated power - a practice that has been legally ruled to be theft. The scene is sketched below. The power line carries 60 Hz alternating current with an amplitude of

$$I_o = 10 \text{ kA } (I = I_o \sin(\omega t).$$

(a) As in the last problem show that the magnetic flux through a rectangular loop of length ℓ, width w, and distance away from the wire a is

$$\Phi_B = \frac{\mu_o I}{2\pi} \left[\ln(a+w) - \ln(a)\right] \ell$$

(b) If one wishes to run normal 120 V equipment then a peak voltage of 170 V is required. What should the length ℓ of the loop be?

(c) If the equipment has an equivalent resistance of 5.0 Ω, what is the power consumption?

(d) If the power company normally charges 13 cents per kWh, what is the monetary value of the energy stolen each day?

(e) Without visually inspecting the transmission lines, how could the power company detect the crime?

(3) 7.9 This can be addressed in one sentence.

(4) 7.11 Eddy currents! Expect an exponential piece.

(5) 7.15 What does the quasistatic approximation allow you to do?

(6) 7.18 The snipped wire referred to earlier

(7) 7.22 This checks the mutual inductance relation in one example. You can find the magnetic fields in Chapter 5.

Notes on text:

- page 356 Griffiths rederives the conservation of charge and the continuity equation. Recall how we derived it at the beginning of the semester.
- page 357-8 We'll work through this derivation of Poynting's Theorem. These are the sorts of "vector gymnastics" that we need to be able to use.
- page 360 The electromagnetic force does not follow Newton's third law! The result, that fields carry momentum, is one of the central themes of this chapter.
- pages 362-364 Stress tensor! This is a long derivation but one we will work through. Write down the full matrix for the stress tensor.
- pages 367 The stress energy tensor as a momentum flux density

- page 370 Field angular momentum is a new and key element which is a source of many fun problems such as Example 8.4. It is worth spending some time with this example and the related problems to gain an understanding of the concept.