Electrodynamics (PHYS 480) Fourth Guide

Fall 2014 v1.0

We are now on the final topic on electrostatics, dielectric materials, i.e. those materials which become polarized when immersed in an electric field. Polarization is both a cause and an effect of electric fields - a property which makes them difficult both conceptually and at times "calculationally" (see e.g. problem 4.23). As Griffiths shows, clarification comes from identifying the chief aim of this study - finding the *macroscopic* fields - and distinguishing free and bound charges.

Griffiths' writing in this chapter is not as crisp as before. Many of the arguments are of a more "hand wavy" nature. In parts of the chapter this means that the reading goes faster, in other sections, we have to read closely. Purcell has a good discussion of dielectrics as well (Ch. 10 in the 3rd and 2nd edition).

Problems:

(1) 3.25 essentially a continuation of 3.24 and example 3.8
(2) 3.47 A neat result that we will use later.
(3) 3.52 We have done part (a) in class. Try part (b)
(4) A possible midterm question: A spherical surface of radius R is maintained at a potential of

$$V(r,\theta) = V_o \cos\theta$$

where V_o is a constant.
  (a) Write down expressions for the electric potential inside and outside the sphere.
  (b) Write down the boundary conditions and determine the potential in both regions.
  (c) Determine the electric field.
  (d) Determine the charge density on the surface.
  (e) What is the electric dipole moment of the sphere?

(5) 4.2 A refinement of the uniform polarized sphere calculation. Use Gaussian surface to find $\mathbf{E}$. (Thanks to Griffiths that he chose the wavefunction with $l = 0$!) Here's a useful integral

$$\int z^n e^{az} dz = \frac{e^{az}}{a^{n+1}} \left[(az)^n - n(az)^{n-1} + n(n-1)(az)^{n-2} + \cdots + (-1)^{n-1} n!(az) + (-1)^n n! \right].$$

When you expand, go to third order. Compute the value of $\alpha/4\pi\epsilon_o$ and compare this to the value given in Table 4.1.

(6) 4.5 Torques on dipoles
(7) 4.6 First find the field using a technique of last chapter then find the torque.
(8) 4.7 The energy of a dipole in an electric field
(9) 4.8 We'll be using this later.

Notes on text: Chapter 4

- page 169 Griffiths introduces a tensor to describe polarization. Why? How would you write this as a matrix?
- page 172 - the definition of polarization
- In pages 173 - 176The concept of a bound charge emerges. This is worth reading with more care than usual.
- page 173 The second paragraph is the **key** point of the notion of fields in matter. This is the notion of the spacetime average of the electric field.
- page 175-6 The electric displacement is introduced - important material.
- page 186 Boundary value problems revisited.
- page 190 Note the use of the image charge method.
- page 192 Nice explanation of the energy

- page 194 ”w” is ”a” in Figure 4.30
- page 195 A slightly mysterious derivation: How does the uniform, vertical field used in the derivation yield a horizontal force?

Material of note:

- Griffiths introduces a small zoo of new parameters, $\epsilon, \epsilon_r, \chi_e, \alpha, P, \rho_b, \sigma_b$. Put these in a pattern which is easy to understand.
- A more careful derivation of the force on a dielectric (Section 4.4.4): Read the article by Margulies [*Am.J. Phys.* **52** (1984) 515].