Assignment 7
PHGN361

Homework due March 24

1. Manipulate the interactive simulation found at

   http://www.falstad.com/emstatic/

   by choosing Setup: dielectric 1 from the pull down menu. Reduce the resolution to the lowest possible. Note that the length of the vectors is not shown by the length of the arrows but rather by the color of the arrows.

   Answer the following questions: (1) Why is the direction of E not radially away from the point charge? (2) Looking at the interactive simulation, what can you say about the surface bound charge? (3) What is the physical significance of the dipole moment per unit volume along the normal?

2. Create a generic problem solving method for finding E in dielectrics for which Gauss's law, written in terms of D, yields a useful result. Demonstrate this method step by step using an example that is not a parallel plate capacitor geometry.

3. Find the force you must exert to extract a dielectric, which almost completely fills a parallel plate capacitor, in the direction parallel to the plates. Let the dielectric be pulled half way out of the capacitor.

4. Achilles wants to catch a tortoise which is a distance D_0 away. Achilles moves at speed $V_{Achilles}$ while the tortoise moves at speed $V_{Achilles}/10$. Zeno argues that by the time Achilles gets to position D_0 the tortoise has moved to position D_1. When Achilles reaches D_1 the tortoise has moved ahead of Achilles to position D_2. This argument continues forever and so Achilles will never reach the tortoise. Explain using equations why Achilles either catches or does not catch the tortoise.

5. An op-amp is an amplifier with feedback. The input signal, V_{in} is first amplified to an output voltage $V_{out} = AV_{in}$ where A is the gain of the amplifier. Now this output is modified by feeding back to the input the output voltage. Let the output be added or subtracted with the input signal before going back through the amplifier. What is the equation that describes this process for positive and for negative feedback. Try to write it down without looking up the answer. Solve the equation for ratio V_{out}/V_{in}. For small A write this expression as series expansion (perturbation series)in A.

6. A hydrogen atom is a distance d away from another hydrogen atom when it acquires a dipole moment (another atom just bounced off it) $\vec{p}_0$ along the direction between the atoms. Derive the first three terms in the series approximation for the actual dipole moment this hydrogen atom acquires. Under what conditions does this perturbation series not converge?

7. Charges q are placed randomly at only 5 of the 20 vertices of a dodecahedron

   (http://en.wikipedia.org/wiki/Dodecahedron).

   This simple model of a charged virus is then placed near a sharp metal tip of a scanning probe microscope. Model this tip by a point charge. Using the simplest technique, outline the principle and method (including differential equations and how they will be solved) for determining how this virus moves due to the point charge.

8. Read section 5.1.

9. Problem 5.6