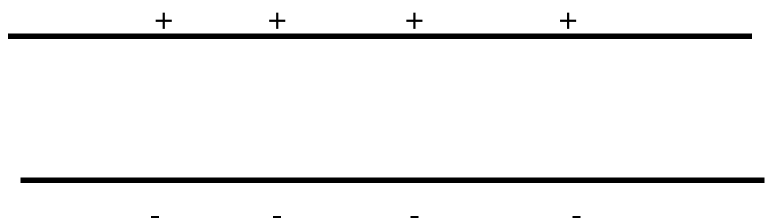
Physics 132
General Physics II
Grinnell College

Homework VIII.3

1. In this problem I will lead you through a classic example—what happens to a capacitor when you stick some stuff between the plates. Imagine that two parallel plates are charged to achieve a voltage difference V_o between the plates. They have area A and spacing d. The plates are then electrically isolated so that no charge can be added or taken away.



a. What is the electric field E_o between the plates in terms of V_o and d (and constants like ε_o)?

b. What is the total charge on the positive plate in terms of V_o, A, d and constants? (You may wish to recall $C=\varepsilon_o A/d$.)

c. A good conductor of thickness d/2 is placed in between the two plates, as shown.

Show where charges appear on the conducting slab in the middle.

d. What is the electric field in the conductor (this should be easy to answer!)?

e. How great is the charge density on the surface of the conductor relative to that on either of the plates? Why? (You may use infinite plane approximations for the surfaces.)

f. Given that the charge on the plates cannot change, what is the electric field in the regions between the plates, but above and below the conductor? (If you are stuck, Gauss's Law may help.)

g. Does the voltage difference of the plates change? Why or why not? If yes, what is it in terms of the old voltage difference V_o? (Don't forget $\Delta V=-\int E dx$.)

h. What then is the capacitance of this new configuration? Is it different from the original capacitance?

i. How about the electrical stored energy, using the formula U = (1/2) QV? What was it before, and what is it now?

2. A dipole consists of two charges with values of $\pm 10^{-10}$C, separated by 1 mm.

a) What is the dipole moment?

b) What is the maximum torque an electric field of 10^5 V/m can exert on this? Make sure to give your answer in Nm.

3. We can estimate the dipole moment of a strongly polar diatomic molecule by saying the charges are ±e (where e = 1.6 x 10^{-19} C) and the spacing is about one atom width, say 2x10^{-10} m. How large a derivative of E (dE/dx) is necessary to overcome gravity for this dipole? Say that the molecular weight of such a molecule is 18 (like water is). This makes the mass of this 18 times the proton mass, roughly. Is this dE/dx easily made in the laboratory? Explain.

4. Make a table of the radial/distance dependence of both fields and potentials due to each of the following: dipole, point charge, line charge, plane of charge. (For example, the field due to a point charge depends on $1/r^2$.)

5. You found that the electric potential due to a dipole oriented along the z axis is given by

$$V = \frac{p\cos(\theta)}{4\pi\varepsilon_o r^2} \quad .$$

a. What is the direction of the field along the x axis?

b. If we are on the x axis, a derivative with respect to z is the same as

$$\frac{d}{dz} = -\frac{1}{r}\frac{d}{d\theta} \quad .$$

Use this equivalence to calculate E_z along the x axis. This should agree with your result from Unit VII p. 20 in your activity guide.

6. Will an electric dipole that is initially at rest but is free to move and rotate be attracted to, repelled from, or unaffected by a point charge? Explain.