PHYS 4392
Fall 2014
TE Coan
Due: 26 Sep '14 6:00 PM

Homework 4

1. A parallel plate capacitor is charged to a potential V and then disconnected from the charging circuit. How much work W is done by slowly separating the plates from d to d'? You can assume the plates are circular and ignore edge effects.

2. Show that the total work W required to assemble a uniform sphere of radius R with uniform charge density ρ is

$$W = \frac{3}{5}(\frac{Q^2}{4\pi\epsilon_0 R}),$$

where Q is the total charge carried by the sphere. Hint: Consider adding a thin layer of charge at a time until you build up the radius to R and think about how the total work required to charge a capacitor was calculated. You may remember a similar problem constructing a spherical mass from classical mechanics.

3. A charged conductor has a small-diameter hole in a region where the surface charge density is σ. Show that the magnitude E of the electric field in the hole close to the surface of the conductor is $\sigma/2\epsilon_0$.

4. A positive point charge is located at some position in space. Sketch the electric field lines and equipotential surfaces surrounding the charge.

5. An air-filled capacitor is made from two long concentric metal cylinders. The outer cylinder has a radius of 1 cm. Although you will not need it for your final answer, call the charge per unit length on each conductor λ. (One cylinder is positively charged and the other is negatively charged.) Call the magnitude of the breakdown electric field in air E_b. You saw E_b in action with both the tesla coil lighting up the fluorescent bulb and the Jacob's ladder. The sparks were due to the applied electric field exceeding the breakdown electric field limit in air.

(a.) What choice of radius for the inner conductor will allow a maximum potential difference between the the conductors before breakdown of the air? What is the maximum potential difference V_{max} between the conductors in this case? Call the inner radius R_1 and the outer radius R_2.

(b.) What choice of radius for the inner conductor will allow a maximum energy to be stored in the capacitor before the breakdown of the air? Again, what is the maximum

potential difference V_{max} between the conductors in this case? Use the same notation for the radii as above.

(c.) Calculate V_{max} for both conditions for a breakdown electric field in air of $E = 3 \times 10^6\,\mathrm{V/m}$.

6. A conducting sphere of radius R carrying a total charge Q is cut in half. What is the magnitude F of the force that must be used to keep the halves together?