Workshop Module 1

1. A long conducting cylinder of length L and radius R_1 carrying a total charge $Q > 0$ is surrounded by a conducting cylindrical shell of total charge $-2Q$ and radius R_2.

   (a) What is the appropriate Gaussian surface to use for calculating the electric fields in this system? WHY?

   (b) What are the regions of space that should be considered separately in order to calculate the electric fields in the system? WHY?

   (c) Calculate the electric fields in all space inside and surrounding this system.

2. A conducting spherical shell with inner radius R_1 and outer radius R_2 has a positive charge of magnitude $2Q$ ($Q > 0$) distributed evenly in its interior. The total charge on the shell is $-3Q$, and it is insulated from its surroundings.

   (a) What is the appropriate Gaussian surface to use for calculating the electric fields in this system? WHY?

   (b) What are the regions of space that should be considered separately in order to calculate the electric fields in the system? WHY?

   (c) Where does the charge reside on the conductor?

   (d) Calculate the electric fields in all space inside and surrounding this system.

   (e) Graph the electric field as a function of the radius.

   (f) How would this problem change if the charge distributed in the interior had a volume charge density given by $\rho(r) = Q\frac{A}{r^2}$, where A is a constant with units of m^{-1}?

3. A small sphere with a mass of $3.20g$ hangs by a thread between two parallel vertical plates $6.00cm$ apart. The charge on the sphere is $q = 7 \times 10^{-6}C$. What potential difference between the plates will cause the thread to assume an angle of 20.0° with the vertical.

4. If the electric field is zero in a region of space, which of the following is always true:

   (a) the potential is zero

   (b) the potential is constant

   (c) the potential is negative

   (d) the potential depends on the size of the region of space

5. Run the MIT TEAL applet for capacitors at `http://web.mit.edu/8.02t/www/802TEAL3D/visualizations/electrostatics/capacitor/capacitor.htm`. Right after the simulation starts, pause it. In the default setup, each conducting plate has 12 charges inside, and they are randomly bouncing around to start with. Draw what your guesses are for the equipotential lines (roughly), and then click the "equipotential" button. It will draw the actual equipotentials for you.

   (a) How did your guesses compare? What is different, what is the same?

   (b) What will the charges do if you let the simulation run for a while? How will they be arranged?

   (c) What do you expect the equipotential lines will look like after this?

   (d) Let the simulaton run until the charges settle down. How did your second set of predictions compare with the result?

6. Reset the simulation to run again, but this time increase the number of charges and decrease their magnitude. For example, 30 charges of charge 3 instead of 12 of charge 5. You can try different numbers to see what happens if you want.

   (a) Repeat the steps from number 5, but concentrate on what the increased number of charges of smaller magnitude will change.

   (b) Once you've seen the result, explain what the limit of an actual conductor containing $\mathcal{O}\left(6 \times 10^{23}\right)$ electrons each with a tiny charge would look like. Why? How does this compare to the idealized cases we study in our problems?