PHY 202 Homework 2

Due Friday, January 31 at SE 316 at 5:30 PM.

1. In class, we talked about Kepler's three laws. In fact, it is rather difficult to prove Kepler's third law for the general case of an elliptical orbit. Fortunately, the case of a circular orbit is a bit easier.

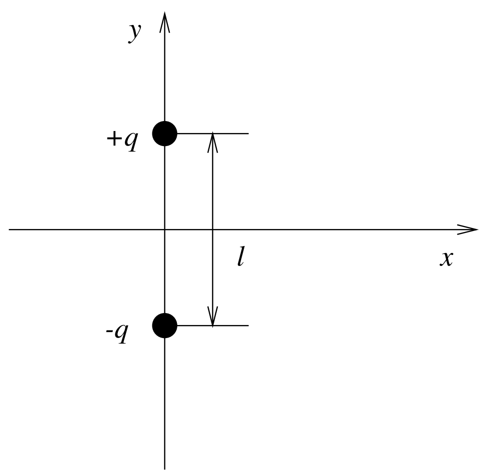
   (a) Derive Kepler's third law for a planet moving in a circular orbit around the sun. Since the sun is much more massive than any planet, we can assume—to a good approximation—that the sun stays at a fixed point. In particular, find an expression for the constant in Kepler's third law in terms of the mass of the sun and G.

   (b) Now, do the same thing for an electron moving in a circular orbit around a proton (the Hydrogen atom).

   (c) If the radius of the electron's orbit is equal to the "Bohr radius," what is the period of its orbit? You will have to look up value of the Bohr radius in your textbook.

   Incidentally, the motion of an electron at this radius is governed by quantum mechanics. It doesn't really "move in a circular orbit." Instead, its motion is described by "orbitals." You may have learned about orbitals in your chemistry class: 1S, 2S, 2P, *et cetera*.

2. Consider a dipole placed at the origin of the coordinate system:



   (a) Find the electric field $\mathbf{E}$ along the y-axis.

   (b) Find how $\mathbf{E}$ behaves in the "far field" limit $y \gg l$ along the y-axis.

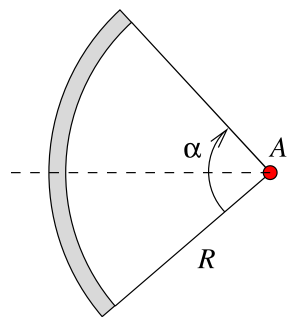
   (c) Look up "electric field lines" in your textbook. Use a half of a page to sketch a nice big picture of the electric field lines of a dipole.

3. Consider a uniform electric field in the $\hat{x}$-direction: $\mathbf{E} = E_x\hat{x}$. An electron is shot out of a gun in the $\hat{y}$ direction with initial velocity $\mathbf{v} = v_0\hat{y}$. Find an

expression for the subsequent motion of the electron. Draw a graph showing the path of the electron; express the shape of the curve as a function y vs. x. In this problem, you can ignore the force of gravity.

4. The electric dipole moment of a sodium fluoride molecule is $2.72 \cdot 10^{-29}\,\mathrm{C} \cdot \mathrm{m}$. Assuming, for simplicity, that each atom is singly ionized, how far apart are the two molecules. (The experimental value is $1.93 \cdot 10^{-10}\,\mathrm{m}$.)

5. I have a glass rod that is bent into the shape of an arc.



   I rub the rod with a silk cloth, creating a uniform charge per unit length λ along the rod.

   (a) What are the symmetries of this system?

   (b) What do these symmetries imply about the electric field at point A?

   (c) Use Coulomb's law and integrate over the rod to find the electric field at point A. (Hint: Don't confuse the integration limits with your integration variable).

6. Calculate the amount of work needed to put a charge Q on the surface of a metal sphere of radius R. The strategy for solving this problem is to find how much work it takes for one to bring in a small charge dq from infinity to the surface of the sphere. Then one integrates over many such charges until the total charge on the sphere is equal to Q.