Physics 4B: Problem Set 4 Electric Potential and Energy

1. A negative charge, -q, has a mass, m, and an initial velocity, v, but is infinitely far away from a fixed large positive charge of +Q and radius R such that if the negative charge continued at constant velocity it would miss the center of the fixed charge by a perpendicular amount b. But because of the Coulomb attraction between the two charges the incoming negative charge is deviated from its straight line course and attracted to the fixed charge and approaches it. Find the closest distance the negative charge gets to the positive one.

2. With what initial speed should a positive charge, +q, of mass *m* be given such that if starting infinitely far away from a fixed positively charged nucleus, +Q, of radius R, the positive charge is *just* able to get the surface of the positive charge. You should be able to do the problem using energy with a system just being the approaching charge and then the system being both charges.

3. Charges $+Q_1$ and $–Q_2$ are held fixed from one another by a distance of d. Find the work done by an external applied force to move a –q from a distance d outside the negative charge (along a line joining the two fixed charges) to a point directly in between the two fixed charges without changing the kinetic energy of the cha rge, -q.

4. Three equal charges of equal mass are held fixed forming an equilateral triangle. Two of the three are released while the third is held fixed. Find the speed of one of the released charges when it is infinitely far away. Do this problem using energy methods with as many valid systems as are possible.

5. A dielectric sphere of total charge Q and radius R is uniformly charged. Because of Coulomb repulsion the sphere completely explodes. Find the maximum energy released after all the sphere's mass is infinitely far away.

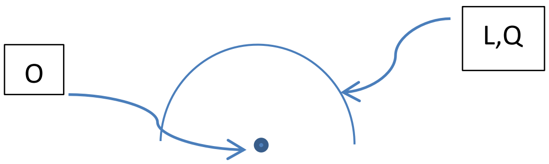
6. Two conducting spheres of radius R_1 and R_2 are some distance apart from one another and held fixed. Sphere one initially has a charge Q_{1i} and the second sphere is initially uncharged. The two spheres are then connected by a long thin wire without changing their positions. After a sufficient time, find the final charge on each sphere and the potential of each sphere relative to a zero potential at infinity.

7. Consider two conducting parallel infinite flat plates of equal charge density but opposite sign (e.g. a charged capacitor). Let the plates be separated by a distance d. Let the left plate be at the origin (x = 0) in the z-y plane and be defined to be the zero potential. Find the potential of the right plate. Find the potential as a function of x within the three regions of space that involve this configuration of charge.

8. Consider a uniformly charged dielectric sphere of radius R and total charge Q. Let the zero potential be defined at the surface of the sphere. Find the potential of the sphere at its center.

9. Four identical particles, each of charge q and mass m are released from rest at the vertices of a square of side L. How fast is each particle moving when their distance from the center of the square doubles?

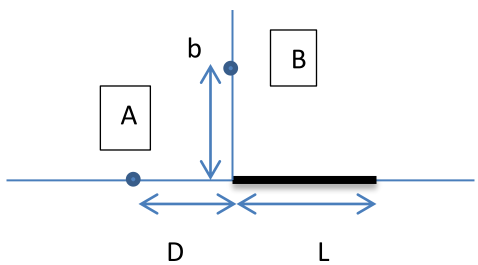
10. A uniformly charged insulating rod of length L is bent into a semicircle as shown. The rod has a total charge of Q. Find the electric potential at O, the center of the semicircle. You may assume that the electric potential at infinity is zero.



11. A rod of length L lies along the x axis with its left end at the origin. It has a uniform charge density λ. Calculate:

a. The electric potential at point $A = (x = -d, y = 0)$.

b. The electric potential at point $B = (0, b)$ as shown.



12. A conducting sphere with radius r_a is suspended concentrically at the center of another hollow, conducting, spherical shell with radius r_b. There is charge $+q$ on the inner sphere and charge $-q$ on the outer spherical shell.

a. Calculate the electric potential V(r) everywhere in space. That is, for $r < r_a$, $r_a < r < r_b$ and for $r > r_b$. Take $V = 0$ at infinity.

b. Show that the potential of the inner sphere with respect to the outer is $V_{ab} = \frac{q}{4\pi\epsilon}\left(\frac{1}{r_a} - \frac{1}{r_b}\right)$

c. Use the result from part a to show that the electric field at any point between the spheres has magnitude $E(r) = \frac{V_{ab}}{\left(\frac{1}{r_a} - \frac{1}{r_b}\right)}\frac{1}{r^2}$

14. A disk with radius *R* has uniform surface charge density σ.

a. By regarding the disk as a series of thin concentric rings, calculate the electric potential V at a point on the disk's axis a distance x from the center of the disk. Assume that the potential is zero at infinity.

b. Calculate - $\frac{\partial V}{\partial x}$