Physics 111 Homework Solutions Collected on Friday 1/16/15

Tuesday, January 13, 2015

Chapter 15

Questions

- None

Multiple-Choice

- None

Problems

- None

Wednesday, January 14, 2015

Chapter 15

Questions

15.5 $\frac{V}{m} = \frac{J}{Cm} = \frac{Nm}{Cm} = \frac{N}{C}$

15.8 They are always perpendicular since if there were a component of the electric field parallel to the equipotential surface then work would be done moving a charge around the equipotential surface. This cannot be the case since the work done in moving a charge around the equipotential surface has to be zero. The only way for this to happen is to have no component of the electric field parallel to the equipotential surface, but rather only perpendicular.

15.11 Suppose that the electric field points along the positive x-axis. If the dipole is oriented so that the negative charge is to the left of the positive charge then the dipole is in a stable equilibrium, for if the charge is displaced slightly off of the axis then the dipole will experience a torque that will return to the dipole to its original configuration. However if the dipole is oriented so that the negative charge is on the right of the positive charge then the dipole is in an unstable equilibrium. Here if the dipole is displaced slightly it will experience a net torque and this torque will rotate the dipole so that the negative charge is on the left of the positive charge.

Multiple-Choice

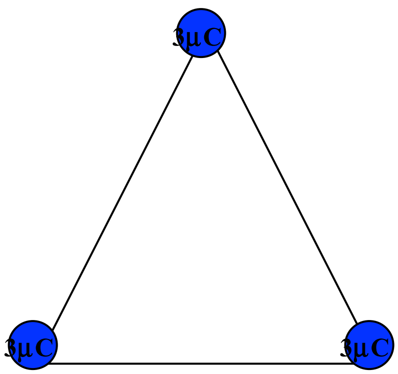
15.2 B
15.4 A
15.5 B
15.6 A
15.7 D

15.8 D

Problems

15.1 The equilateral triangle is given as shown. The potential energy is given by the equation $PE_{1,2} = \frac{kQ_1Q_2}{r}$. Substituting the values given, we find the

$$PE_{total} = 3 \times PE_{1,2} = 3 \times \frac{\left(9\times10^{9}\ \frac{\text{Nm}^2}{\text{C}^2}\right)\left(3\times10^{-6}\text{C}\right)^2}{0.05\text{m}} = 4.86\text{J}.$$



15.2 Bringing each charge Q in one at a time from very far away and assuming that $L = 1.0m$:

i. the first charge is brought in for free since it feels no forces

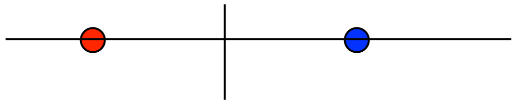
ii. the second charge requires $W = -\frac{kQ}{L} = -0.9J$

iii. the next charge interacts with both of the previous and so the additional work is $W = -\frac{kQ}{L} - \frac{kQ}{\sqrt{L^2+L^2}}$ = -1.54 J, where the denominator in the second term is the diagonal distance between charges 1 and 3

iv. the last charge costs an additional $W = -\frac{kQ}{L} - \frac{kQ}{\sqrt{L^2+L^2}} - \frac{kQ}{L}$ = -2.44 J

The total work to assemble all 4 charges is then -4.88 J

15.3



a. $V = \sum \frac{kQ}{r}$ and since equal and opposite charges are equally distant from the observation point at the origin, the two terms add up to zero – remember these are just + and – numbers, not vectors

b. The electric fields from each charge do not cancel, but both point in the same direction (to the left) since the force from both charges on a positive test charge at the origin is to the left. Adding these up gives $E = 2\frac{kQ}{x^2}$, where Q = 10 μC and x = 0.1 m, so E = 1.8 x 10^7 N/C, pointing to the left.

c. Since the potential at the origin is V = 0, as it is at infinity (very far away), then there is no change in V for the third charge and therefore no net work is required.

Repeating for two positive charges:

a. $V = \frac{2kQ}{r} = 1.8 \times 10^6 V$;

b. In this case E = 0 since the E fields from each charge point in opposite directions and now cancel;

c. The net work required is QΔV = -18 J or 18J by an external force.

15.4 The relation between electric field and electric potential

a. To calculate the potential at any position x, knowing the other position and potential we use the general relation
$$E = -\frac{\Delta V}{\Delta x} \to 10\tfrac{V}{m} = -\frac{\left(V_f - (-15V)\right)}{10m - 0m} \to V_f = -115V.$$

b. The potential is zero at infinity and also at a distance x given by
$$E = -\frac{\Delta V}{\Delta x} \to 10\tfrac{V}{m} = -\frac{(0-15)V}{x_f - 0m} \to x = -1.5m.$$

15.11 The energy is related to the charge transferred and the potential difference. We have $W = q\Delta V \to \Delta V = \frac{W}{q} = \frac{30 \times 10^6 J}{5C} = 6 \times 10^6 V = 6MV$.

15.24 Rutherford Backscattering Spectrometry

a. The electrostatic repulsion due to the two positive nuclei did work bringing the alpha particle to rest. The alpha particle loses its kinetic energy in favor of potential energy as it comes to rest at the quoted distance. Thus we have

$$\Delta KE + \Delta PE = \left(KE_f - KE_i\right) + \left(PE_f - PE_i\right) = 0 \rightarrow KE_i = PE_f$$

$$KE_i = \frac{kQ_{Au}Q_\alpha}{r} = \frac{9\times10^9 \frac{Nm^2}{C^2}\left(79e\times\frac{1.6\times10^{-19}C}{1e}\right)\left(2e\times\frac{1.6\times10^{-19}C}{1e}\right)}{9.23\times10^{-15}m} = 3.9\times10^{-12}J$$

b. The work done accelerating the alpha particle changed its kinetic energy. Thus

$$W = \Delta KE = q\Delta V \rightarrow \Delta V = \frac{W}{q} = \frac{3.9\times10^{-12}J}{2e\times\frac{1.6\times10^{-19}C}{1e}} = 1.2\times10^7 V = 12MV$$

c. The work done is $3.9\text{x}10^{-12}$J.

d. The electrostatic repulsion due to the two positive nuclei did work bringing the alpha particle to rest. The alpha particle loses its kinetic energy in favor of potential energy as it comes to rest at the quoted distance. Thus we have

$$\Delta KE + \Delta PE = \left(KE_f - KE_i\right) + \left(PE_f - PE_i\right) = 0 \rightarrow KE_i = PE_f$$

$$KE_i = 3.3\times10^6 eV\times\frac{1.6\times10^{-19}C}{1e} = 5.28\times10^{-13}J$$

$$\rightarrow 5.28\times10^{-13}J = \frac{kQ_{Au}Q_\alpha}{r} = \frac{9\times10^9 \frac{Nm^2}{C^2}\left(79e\times\frac{1.6\times10^{-19}C}{1e}\right)\left(2e\times\frac{1.6\times10^{-19}C}{1e}\right)}{r}$$

$$\therefore r = 6.9\times10^{-14}m$$