Homework 14 for September 19 2008
Due 8AM on September 23 2008
Physics 221 with Professor Jeff Terry

1. How much work is done in moving Avogadro's number of electrons from an initial point where the electric potential is 9.00V to a point where the potential is -5.00V? (Assume that the potential is measured from a common reference point.)

$\Delta V = -14.0 \text{ V}$ and $Q = -N_A e = -\left(6.02 \times 10^{23}\right)\left(1.60 \times 10^{-19}\right) = -9.63 \times 10^4 \text{ C}$

$\Delta V = \dfrac{W}{Q}$, so $W = Q\Delta V = \left(-9.63 \times 10^4 \text{ C}\right)\left(-14.0 \text{ J/C}\right) = \boxed{1.35 \text{ MJ}}$

2. Calculate the speed of (a) a proton and (b) an electron when accelerated from rest through a potential difference of 120 V.

Energy of the proton-field system is conserved as the proton moves from high to low potential, which can be defined for this problem as moving from 120 V down to 0 V.

$K_i + U_i + \Delta E_{\text{mech}} = K_f + U_f$ $\quad 0 + qV + 0 = \frac{1}{2}mv_p^2 + 0$

$$\left(1.60 \times 10^{-19} \text{ C}\right)\left(120 \text{ V}\right)\left(\frac{1 \text{ J}}{1 \text{ V} \cdot \text{C}}\right) = \frac{1}{2}\left(1.67 \times 10^{-27} \text{ kg}\right)v_p^2$$

$$v_p = \boxed{1.52 \times 10^5 \text{ m/s}}$$

The electron will gain speed in moving the other way,

from $V_i = 0$ to $V_f = 120 \text{ V}$: $\quad K_i + U_i + \Delta E_{\text{mech}} = K_f + U_f$

$$0 + 0 + 0 = \frac{1}{2}mv_e^2 + qV$$

$$0 = \frac{1}{2}\left(9.11 \times 10^{-31} \text{ kg}\right)v_e^2 + \left(-1.60 \times 10^{-19} \text{ C}\right)\left(120 \text{ J/C}\right)$$

$$v_e = \boxed{6.49 \times 10^6 \text{ m/s}}$$

3. An electron has an initial speed of $3.70*10^6$ m/s* which is reduced to $1.40*10^5$ m/s when it has traveled 2.00 cm. Calculate the potential difference between its initial and final position.

$$\Delta U = -\frac{1}{2}m\left(v_f^2 - v_i^2\right) = -\frac{1}{2}\left(9.11\times10^{-31}\text{ kg}\right)\left[\left(1.40\times10^{5}\text{ m/s}\right)^2 - \left(3.70\times10^{6}\text{ m/s}\right)^2\right] = 6.23\times10^{-18}\text{ J}$$

$$\Delta U = q\Delta V: \qquad +6.23\times10^{-18} = \left(-1.60\times10^{-19}\right)\Delta V$$

$$\Delta V = \boxed{-38.9\text{ V. The origin is at highest potential.}}$$

4. At a certain distance from a point charge, the magnitude of the electric field is 500 V/m and the electric potential is -3.00 kV. What is the distance to the charge and what is the magnitude of the charge?

(a)

$$E = \frac{|Q|}{4\pi\epsilon_0 r^2}$$

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

$$r = \frac{|V|}{|E|} = \frac{3\,000\text{ V}}{500\text{ V/m}} = \boxed{6.00\text{ m}}$$

(b)

$$V = -3\,000\text{ V} = \frac{Q}{4\pi\epsilon_0(6.00\text{ m})}$$

$$Q = \frac{-3\,000\text{ V}}{\left(8.99\times10^{9}\text{ V}\cdot\text{m/C}\right)}(6.00\text{ m}) = \boxed{-2.00\ \mu\text{C}}$$