Homework 3

Chapter 20

Problem 1. *(a) Calculate the speed of a proton that is accelerated from rest through a potential difference of $\Delta V = 120$ V. (b) Calculate the speed of an electron that is accelerated through the same potential difference.*

(a) Conserving energy

$$E_0 = \frac{1}{2} m_p v^2 = E_1 = e\Delta V \tag{1}$$

$$v = \sqrt{\frac{2e\Delta V}{m_p}} = \sqrt{\frac{2 \cdot 1.60 \cdot 10^{-19}\ \text{C} \cdot 120\ \text{V}}{1.67 \cdot 10^{-27}\ \text{kg}}} = 152\ \text{km/s} \tag{2}$$

(b) Replacing m_p with m_e

$$v = \sqrt{\frac{2e\Delta V}{m_e}} = \sqrt{\frac{2 \cdot 1.60 \cdot 10^{-19}\ \text{C} \cdot 120\ \text{V}}{9.11 \cdot 10^{-31}\ \text{kg}}} = 6.49\ \text{Mm/s} \tag{3}$$

Problem 11. *The three charges in Figure P20.11 are at the vertices of an isosceles triangle. Calculate the electric potential at the midpoint of the base, taking $q = 7.00\ \mu C$.*

$$V = k_e \left(\frac{-q}{1.00\ \text{cm}} + \frac{-q}{1.00\ \text{cm}} + \frac{q}{\sqrt{4.00^2 - 1.00^2}\ \text{cm}} \right) \cdot \frac{100\ \text{cm}}{1\ \text{m}} = -11.0\ \text{MV} \tag{4}$$

Problem 27. *A uniformly charged insulating rod of length $L = 14.0$ cm is bent to form a semicircle. The rod has a total charge of $Q = -7.50\ \mu C$. Find the electric potential at the center of the semicircle* 0.

As in problem 2, we'll sum over all the charge bits, but in this case our bits are infinitesimal, so our sum is technically an integral. Defining the charge density $\lambda = Q/L$ we have

$$V = \int_0^L k_e \frac{\lambda dL}{r} = k_e \frac{\lambda}{r} \int_0^L dL = k_e \frac{Q}{r} \tag{5}$$

The same as for a point charge Q! This is because electric potential is a scalar, and all the charges are the same distance from O. It doesn't matter if they are all gathered together at one point, or smeared out in a semicircle, spherical shell, or whatever, as long as they are all the same distance r from O.

We still need to find r, but we know that the arc length of a semicircle is πr, so $r = L/\pi$, and

$$V = k_e \frac{\pi Q}{L} = 8.99 \cdot 10^9\ \text{N m}^2/\text{C}^2 \frac{\pi \cdot (-7.50 \cdot 10^{-6}\ \text{C})}{0.140\ \text{m}} = -1.51\ \text{MV} \tag{6}$$