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

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

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

(b) Replacing $m_p$ with $m_e$

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

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 $q = 7.00\ \mu\text{C}$.

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

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

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

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

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 $\pi r$, so $r = L/\pi$, and

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