Problem 25.1

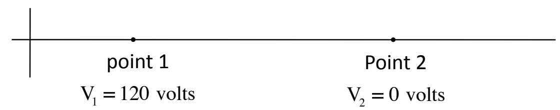
What happens to a proton and/or an electron that is accelerated through a potential difference? (Note that there are two ways to do a problem like this.)

OPTION 1:

a.) If a proton accelerates between the points, the amount of work W done on the proton (which is to say, the amount of energy the proton picks up) will be related to the potential difference ΔV (i.e., the change in the amount of *potential energy per unit charge available* between the points) times the charge *q*, or:

$$\begin{aligned} W &= q\Delta V \\ &= \left(1.6\text{x}10^{-19}\ \text{C}\right)\left(120\ \text{joules/C}\right) \\ &= 1.92\text{x}10^{-17}\ \text{joules} \end{aligned}$$

The sketch below identifies the points and the given information:



If the particle is a proton, it will accelerate (from rest) from point 1 to point 2 and we can use the work/energy theorem to write:

$$\begin{aligned} W_{net} &= \Delta KE \\ &= \frac{1}{2} m_{proton} v_2^2 - 0 \\ \Rightarrow\ v_2 &= \left(\frac{2W}{m_{proton}}\right)^{1/2} \\ \Rightarrow\ v_2 &= \left(\frac{2\left(1.92\text{x}10^{-17}\ \text{j}\right)}{\left(1.67\text{x}10^{-27}\ \text{kg}\right)}\right)^{1/2} \\ &= 1.52\text{x}10^{5}\ \text{m/s} \end{aligned}$$

b.) If the charge was an electron, the work/energy yields:

$$\begin{aligned} v_2 &= \left(\frac{2W}{m_{electron}}\right)^{1/2} \\ &= \left(\frac{2\left(1.92\text{x}10^{-17}\ \text{j}\right)}{\left(9.1\text{x}10^{-31}\ \text{kg}\right)}\right)^{1/2} \\ &= 6.49\text{x}10^{6}\ \text{m/s} \end{aligned}$$

OPTION 2:

a.) The voltage V at a point identifies the amount of *potential energy per unit charge (U/q) available* at the point whether there is a charge there to feel the effect or not. That means qV identifies the amount of potential energy U a charge q has when residing at the point.

A proton will accelerate from higher voltage to lower. If we assume that the initial point of the proton's acceleration has a voltage of V = 120 volts and the final point is zero, and if we assume the proton is initially at rest, we can use conservation of energy to write:

$$\sum KE_1 + \sum U_1 + \sum W_{ext} = \sum KE_2 + \sum U_2$$

$$0 + qV_1 + 0 = \frac{1}{2} m_{proton} v_2^2 + \cancel{qV_2}^{\,0}$$

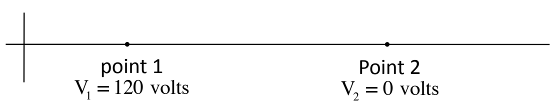
$$\Rightarrow\ v_2 = \left(\frac{2qV_1}{m_{proton}}\right)^{1/2}$$

$$\Rightarrow\ v_2 = \left(\frac{2\left(1.6\text{x}10^{-19}\text{C}\right)\left(120\text{V}\right)}{\left(1.67\text{x}10^{-27}\right)}\right)^{1/2}$$

$$\Rightarrow\ v_2 = 1.52\text{x}10^{5}\ \text{m/s}$$

OPTION 2:

b.) What makes the electron interesting is that electrons accelerate from lower to higher voltage, so it will go from the zero volt (i.e., the point identified as point 2) to the 120 volt point (the point identified as point 1). If we include the fact that the electron is *negative* in the calculation, we can write:



$$\sum KE_1 + \sum U_1 + \sum W_{ext} = \sum KE_2 + \sum U_2$$

$$0 + \cancel{qV_2}^{\,0} + 0 = \frac{1}{2} m_{electron} v_2^2 + qV_1$$

$$\Rightarrow\ v_2 = \left(\frac{-2qV_1}{m_{electron}}\right)^{1/2}$$

$$\Rightarrow\ v_2 = \left(\frac{-2\left(-1.6\text{x}10^{-19}\text{C}\right)\left(120\text{V}\right)}{\left(9.1\text{x}10^{-31}\right)}\right)^{1/2}$$

$$\Rightarrow\ v_2 = 6.49\text{x}10^{6}\ \text{m/s}$$

At least part of what is important to notice is that the sign of the charge must be included when determining a potential energy quantity using an electrical potential.

5.)