Chapter 5 Problem 92 †

Given

$E = 200\ N/C$

$K = 3.2 \times 10^{-16}\ J$

$q = 1.60 \times 10^{-19}\ C$

$m_e = 9.11 \times 10^{-31}\ kg$

$m_p = 1.67 \times 10^{-27}\ kg$

Solution

Find the distance and time needed for a proton and electron to reach the given kinetic energy.

The work-energy theorem states

$$\Delta K = W_{net}$$

Therefore, we only need to calculate the work on each particle. Since the electric field is the only force acting on the particles and the field is uniform, then the force on each charged particle is

$$F = qE$$

and the work is

$$W = Fx = qEx$$

Since the magnitude of the charge for both proton and electron are the same, the distance traveled by each of them is the same, only in opposite directions.

$$x = \frac{W}{qE} = \frac{3.2 \times 10^{-16}\ J}{(1.60 \times 10^{-19}\ C)(200\ N/C)}$$

$$x = 10.0\ m$$

The time for each particle is different since the mass of the proton is 1800x that of the electron. The acceleration of the electron is

$$a_e = \frac{F_e}{m_e} = \frac{qE}{m_e} = \frac{(1.60 \times 10^{-19}\ C)(200\ N/C)}{9.11 \times 10^{-31}\ kg}$$

$$a_e = 3.51 \times 10^{13}\ m/s^2$$

Using the third kinematic equation and starting with an initial velocity of zero, then

$$\Delta x = \tfrac{1}{2}at^2$$

Solving for time gives

$$t^2 = \frac{2\Delta x}{a}$$

$$t = \sqrt{\frac{2\Delta x}{a_e}} = \sqrt{\frac{2(10.0\ m)}{3.51 \times 10^{13}\ m/s^2}}$$

$$t = 7.55 \times 10^{-7}\ s$$

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†Problem from Univesity Physics by Ling, Sanny and Moebs (OpenStax)

It takes 0.755 μs for the electron to travel the 10.0 m. For the proton

$$a_p = \frac{F_p}{m_p} = \frac{qE}{m_p} = \frac{(1.60 \times 10^{-19}\ C)(200\ N/C)}{1.67 \times 10^{-27}\ kg}$$

$$a_e = 1.92 \times 10^{10}\ m/s^2$$

Solving for time gives

$$t = \sqrt{\frac{2\Delta x}{a_p}} = \sqrt{\frac{2(10.0\ m)}{1.92 \times 10^{10}\ m/s^2}}$$

$$t = 3.23 \times 10^{-5}\ s$$

It takes 32.3 μs for the proton to travel the 10.0 m.