Answer Question #65291 – Physics – Electric Circuit

An electron is fired horizontally with an initial velocity of 4.2×10^6 m/s between a pair of horizontal plates. The plates are separated by a distance of 1.20 mm and are charged to have a potential difference of 120 V, with the bottom plate being at the higher potential. If the electron is midway between the plates when it is fired, how far from its entry point will it strike the bottom plate? You may ignore the acceleration due to gravity in this problem so that the force on the electron is entirely due to electrostatics (but think about why this assumption is OK!).

Solution. Find the electric force acting on the electron and gravity. Electric force is equal to $F_e = \frac{qV}{d}$, where $q = 1.6 \cdot 10^{-19} C$ – the charge of the electron; $V = 120V$ – potential difference; $d = 1.2 \cdot 10^{-3} m$ – the distance between the plates.

$F_e = \frac{1.6 \cdot 10^{-19} \cdot 120}{1.2 \cdot 10^{-3}} = 1.6 \cdot 10^{-14} N$

The force of gravity for the electron $F = m_e g$, where $m_e = 9.1 \cdot 10^{-31} kg$, $g = 9.8 \frac{m}{s^2}$ – gravitational acceleration. Hence $F = 9.1 \cdot 10^{-31} \cdot 9.8 = 8.918 \cdot 10^{-30} N$.

Since $F = 8.918 \cdot 10^{-30} \ll F_e = 1.6 \cdot 10^{-14} N$ we may ignore the acceleration due to gravity in this problem. Hence the acceleration mode of action on the electron according to the second Newton's law

$a = \frac{F_e}{m_e} = \frac{1.6 \cdot 10^{-14}}{9.1 \cdot 10^{-31}} \approx 1.76 \cdot 10^{16} \frac{m}{s^2}$.

Consider separately the motion of an electron in the horizontal and vertical direction. In horizontal direction the electron moves with constant speed $v = 4.2 \times 10^6 \frac{m}{s}$. In the vertical direction the electron moves uniformly accelerated with acceleration $a = 1.76 \cdot 10^{11}$ and zero initial velocity.

Let in the horizontal direction of the electron flying distance L and in the vertical direction $\frac{d}{2} = 0.6 \cdot 10^{-3} m$.

Using the laws of mechanics we can write the system of equations

$\begin{cases} L = vt \\ \frac{d}{2} = \frac{at^2}{2} \end{cases}$, where t – time. $\rightarrow t = \sqrt{\frac{d}{a}}$. Hence

$L = 4.2 \cdot 10^6 \cdot \sqrt{\frac{1.2 \cdot 10^{-3}}{1.76 \cdot 10^{16}}} \approx 0.0011 m = 1.1 mm$

Answer. $1.1 mm$.