PROBLEMS

1. Determine the vel. and k.E of an e^- accelerated through a potential of 3kv.

Sol. The electron is assumed to be starting from rest position

$V_A = 0$

So final velocity, $v = \sqrt{\frac{2eV}{m}}$ where 'e' is charge of e^- (magnitude)

V is P.D.

M is mass of e-

$$v = \sqrt{\frac{2\times1.602\times10^{-19}\times3\times10^{3}}{9.1\times10^{-31}}}$$

$$= 3.247\times10^{7}\, m/\sec$$

$$k.E = eV$$

$$= 1.602\times10-^{19}\times3\times10^{3}\, J$$

$$= 4.806\times10^{-16}\, J$$

But $1eV == 1.602\times10-^{19}\ J$ Here eV is electron volts.

$$? = 4.806\times10^{-16}\, J$$

$$k.E = 3\times10^{3}\, eV$$

Energy :

Energy is defined as capacity to do work Joule is unit of enrgy. As this Joule is large unit for electronic applications. So joules are converted into ergs by multiplying a factor of

$$10^{-7} = 1J = 10^{7}\, egs$$

But even these ergs also largen units for electronic devices, this ergs (energy) is converted into eV (electron volts)

i.e., $1eV = 1.602\times10^{-19}\, J$

If an electron falls through a potential of 1V its K.E. is increased by decrease in P.E.

Relation between electric field intensity and potential :

If electric filed is uniform, then

Potential $V = -\int_{x_0}^{x} \varepsilon_x d_x \quad - \quad (1)$

$$= -\varepsilon_x (x - x_0)$$

Where 'V' is P.D. between the two conduction plates fo a parallel palte capacitor.

Then $\varepsilon_x = \frac{V}{x - x_0}$

$$= \frac{-V}{d}$$

$\because d = x - x_0$ *i.e.,* distance between two plates

$$\therefore \varepsilon_x = \frac{-V}{d}$$

Hence units of ε_x are volt/meter

If electric filed is varies w.r.t distance then ε_x is obtained by differentiating the eqn(1)

$$\therefore \varepsilon_x = \frac{dV}{dx}$$

$$\Rightarrow \varepsilon_x = \frac{-dV}{dx}$$

This is the electric filed intensity if filed varies w.r.t distance

This is –ve sign indicates that electric filed directed from higher potential to region of lower potential.

i.e. ε is directed from +ve plate to –ve palte.

Problem:

1. An e^- starts at rest on one plate of parallel plate capacitor whose plates are fakjs apart. The applied voltage is zero at the instant e^- is released ε it increases linearly from 0 to 10V in 0.1microsecond.

(i) where will be at end of this time.

(ii) with what speed will the e- strikes the +ve plate.

Sol. From the given data we can infer that

Distance between two plates $d = 5cm = 5 \times 10^{-2} m$

Applied voltage is ramp voltage (i.e. increases linearly)

At time T potential is V

Time t Potential is Vt

$$\therefore V_t = \frac{t}{T} \times V$$

Relation between the ε, V & d is given by

$$\varepsilon = \frac{-V}{d} = \frac{V_t}{d} = \frac{\frac{Vt}{T}}{d} = \frac{Vt}{Td}$$

$$= \frac{10 \times t}{5 \times 10^{-2} \times 0.1 \times 10^{-6}}$$

$$= 2 \times 10^9 t \ V/m$$

$$an = \frac{e\varepsilon_x}{m} = 1.759 \times 10^{11} \times 2 \times 10^9 t$$

$$= 3.518 \times 10^{20} tm/S^2$$

$$dv_x = \int a_x dt$$

$$v_x = \int a_x dt = 3.518 \times 10^{20} \int tdt$$

$$= 3.518 \times 10^{20} \frac{t^2}{2}$$

$$= 1.759 \times 10^{20} .t^2$$

(a) If $t = 50\,\text{nsec} \Rightarrow v_x = 1.759 \times 10^{20} \left(50 \times 10^{-8}\right)^2$

$$= 1.759 \times 25 \times 10^4$$

$$= 4.3975 \times 10^5 m/\sec$$

(b) $d_x = \int v_x dt = 1.759 \times 10^{20} \int t^2 dt = \frac{1.759 \times 10^{20}}{3} \cdot t^3$

At $t = 50$ nsec $\Rightarrow d_x = \frac{1.759}{3} \times 10^{20} \times 125 \times 10 - 24m$

$$= 0.5863 \times 125 \times 10^{-4}$$

$$= 73.2875 \times 10^{-4} m$$

$$= 0.732 cm$$

To find the speed with which it strikes the +ve plate we have to calculate the time taken to strike the +ve palte.

From (ii) $x = 5.87 \times 10^{19} t^3$

$x = 5cm \Rightarrow t = ?$

$5 \times 10^{-2} = 5.87 \times 10^{19} t^3$

$$t^3 = \frac{5 \times 10^{-2}}{5.87 \times 10^{19}}$$

$$t = \left(\frac{5 \times 10^{-2}}{5.87 \times 10^{19}} \right)^{\frac{1}{3}}$$

$= 9.96 \times 10 - 8 \sec$

Velocity,
$$\begin{aligned} v_x &= 1.759 \times 10^{20} t^2 \\ &= 1.759 \times 10^{20} \times \left(9.46 \times 10^{-8}\right)^2 \\ &= 1.759 \times 10^4 \times 9.46 \times 9.46 \\ &= 1.589 \times 10^6 m/\sec \end{aligned}$$

Two-dimensional motion:

Effect of electric filed on an electron when paltes are parallel to the plane Suppose an electron enters to the region b/w the two parallel plates which are parallel to plate with an initial velocity v_{0x} in the positive x-direction. Here the electric field between the two plates is uniform where $d < l$ and ε is in –ve y-direction.

Initial conditions :

$\lambda t\ t = 0$ $\quad v_{0x} = v_x \quad x = 0$ (small & negligible = x_0)

$v_y = 0 \Rightarrow y = 0$

$v_z = 0 \Rightarrow z = 0$

Z-direction :

Since there is no force along z-direction acceleration in that direction is zero.

Vel. in z-direction is constant but initial vel. along z-direction is asumed to be zero. So this zero is constant so there is no electron motion along z-direction

X-direction :

Since there is no electric filed intensity along x-direction acceleration along x-axis is zero. So vel. in x-axis constant.

$\therefore$ Since initial vel. is v_{0x} it will continues

$$\therefore v_x = v_{0x}$$
$$\frac{dx}{dt} = v_{0x}$$
$$x = \int_0^t v_{ox} dt = v_{ox} t + C_1$$

Put t=0 in above expression

$$\Rightarrow C_1 = x = x_0 = 0$$
$$\therefore x = v_{0x}.tx_0$$
$$x = v_{0x} \qquad - \qquad (1)$$

Y-direction

As electric filed intensity is acting along –y-axis there is a force component towards +Ve y-axis. So, acceleration is constant along y-direction i.e., vel. is increasing at constant rate towards y-direction (Vy).

$$ay = \frac{dV_y}{dt} = cons\tan t \qquad \because \varepsilon \text{ is constant}$$

By integrating

$$\int a_y dt = \int v_y$$
$$\Rightarrow v_y = \int_0^t a_y dt = a_y t + C_2$$

Put t = 0 in above expression

$$v_y = C_2$$

From initial conditions

At $t = 0, \quad v_y = 0$

$$\Rightarrow C_2 = 0$$
$$v_y = a_y \cdot t \qquad - \qquad (2)$$
$$But \qquad v_y = \frac{dy}{dt} = a_y \cdot t$$

By integrating

$$y = \int_0^t a_y \cdot t dt$$

$$= a_y \cdot \frac{t^2}{2} + C_3$$

Put $t = 0, \quad y = C_3$

From initial conditions at $t = 0, y = 0$

$$\therefore y = a_y \cdot \frac{t^2}{2} \qquad - \qquad (3)$$

But $a_y = \frac{-e\varepsilon}{m}$

$$\varepsilon_y = \frac{-V_d}{d} \qquad\qquad ma_y = e\varepsilon_y$$

$$a_y = \frac{e\varepsilon_y}{m}$$

Where Vd is potential applied between two plates and d is distance between two plates.

$$v_y = \frac{eV_d}{md} \qquad - \qquad (4)$$

The above equations indicates that in region between two plates electron accelerated upwards (towards +ve y-axis). The vel. component v_y is varying from point to point where vel. component v_x remains constant.

The path of electron w.r.t 0(0, 0) is determined by combining the effect of motion along y-directions. This is obtained by combining eq(1) and eq(3) and eliminating ‘t’.

Eq(1) $x = v_{0x} t \qquad \Rightarrow t = \frac{x}{v_{0x}}$

Eq(3) $y = a_y \cdot \frac{t^2}{2}$

$$y = \frac{a_y}{2} \cdot \frac{x^2}{v_{ox} 2} = \left(\frac{\frac{1}{2} a_y}{v_{ox}{}^2} \right) x^2 \qquad - \qquad (3)$$

This equation shown that particle moves in a parabolic path with the region between the plates.