



Padalsalai's Telegram Groups!

(தலைப்பிற்கு கீழே உள்ள லிங்கை கிளிக் செய்து குழுவில் இணையவும்!)

- Padalsalai's NEWS - Group
https://t.me/joinchat/NIfCqVRBNj9hhV4wu6_NqA
- Padalsalai's Channel - Group
<https://t.me/padasalaichannel>
- Lesson Plan - Group
<https://t.me/joinchat/NIfCqVWwo5iL-21gpzrXLw>
- 12th Standard - Group
https://t.me/Padalsalai_12th
- 11th Standard - Group
https://t.me/Padalsalai_11th
- 10th Standard - Group
https://t.me/Padalsalai_10th
- 9th Standard - Group
https://t.me/Padalsalai_9th
- 6th to 8th Standard - Group
https://t.me/Padalsalai_6to8
- 1st to 5th Standard - Group
https://t.me/Padalsalai_1to5
- TET - Group
https://t.me/Padalsalai_TET
- PGTRB - Group
https://t.me/Padalsalai_PGTRB
- TNPSC - Group
https://t.me/Padalsalai_TNPSC

1. ELECTROSTATICS

1. Given:- $q = 50 \text{ nC} = 50 \times 10^{-9} \text{ C}$

Solution:- $n = ?$, $e^- = 1.6 \times 10^{-19} \text{ C}$

$$n = \frac{q}{e} = \frac{50 \times 10^{-9}}{1.6 \times 10^{-19}}$$

$$n = \frac{50 \times 10^{-9}}{1.6 \times 10^{-19}} = \frac{25 \times 10^0}{8 \times 10^{-1}}$$

$$n = 3.125 \times 10^{11} \text{ electrons.}$$

$$n = 31.25 \times 10^{10} \text{ electrons //$$

2. Given:- $n = 10^{28}$, $r = 1 \text{ m}$, $m = 60 \text{ kg}$

$$n' = 1\% \text{ of } 10^{28} = \frac{1}{100} \times 10^{28} = 10^{26}$$

$$n \text{ also has } 1\% e^- \Rightarrow n = 10^{26}$$

Solution:- (i) $F_e = \frac{1}{4\pi\epsilon_0} \frac{q q'}{r^2}$

$$q = ne = 10^{26} \times 1.6 \times 10^{-19} = 1.6 \times 10^7 \text{ C}$$

$$q' = n'e = 10^{26} \times 1.6 \times 10^{-19} = 1.6 \times 10^7 \text{ C}$$

$$\therefore F_e = \frac{9 \times 10^9 \times 1.6 \times 10^7 \times 1.6 \times 10^7}{1^2}$$

$$F_e = 9 \times 2.56 \times 10^{23}$$

$$F_e = 23.04 \times 10^{23} \text{ N}$$

$$\therefore \boxed{F_e = 23 \times 10^{23} \text{ N}}$$

(ii) weight, $w = mg = 60 \times 9.8$

$$\boxed{w = 588 \text{ N}}$$

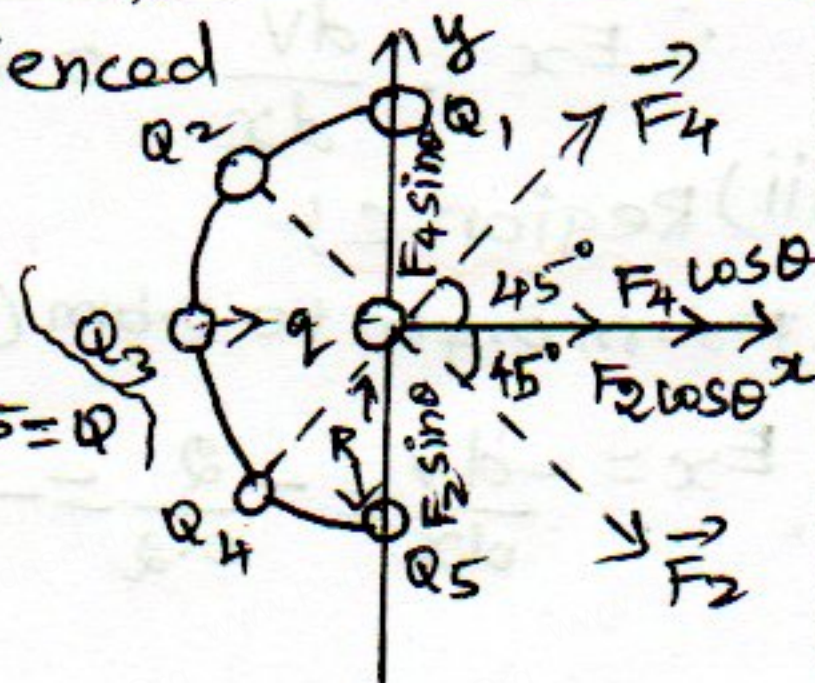
$$\therefore \frac{F_e}{w} = \frac{23 \times 10^{21}}{588}$$

$$\therefore F_e/w = 3.9 \times 10^{21} //$$

3. Force experienced by $q = ?$

Solution:-

$$Q_1 = Q_2 = Q_3 = Q_4 = Q_5 = q$$



* Forces acting on q due to Q_1 and Q_5 are equal and opposite. Hence $\vec{F}_1$ & $\vec{F}_5$ get cancelled. Net force is zero.

* Forces acting on q due to Q_2 ($\vec{F}_2$) and Q_4 ($\vec{F}_4$) is resolved into two components.

* $F_2 \sin \theta$ and $F_4 \sin \theta$ are equal in magnitude but opposite in direction, get cancelled.

* $F_2 \cos \theta$ and $F_4 \cos \theta$ are horizontal components acts in same direction, gets added.

* Force acting on q due to Q_3 is $\vec{F}_3$.

$\therefore$ Total force acting on q is

$$\vec{F} = \vec{F}_3 + F_2 \cos \theta \hat{i} + F_4 \cos \theta \hat{i}$$

$$\vec{F} = \frac{k q Q}{r^2} \hat{i} + \frac{k q Q}{r^2} \cos 45^\circ \hat{i} + \frac{k q Q}{r^2} \cos 45^\circ \hat{i}$$

$$= \frac{k q Q}{r^2} \left[1 + \frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}} \right]$$

$$= \frac{k q Q}{r^2} \left[1 + \frac{2}{\sqrt{2}} \right] = \frac{k q Q}{r^2} \left[1 + \sqrt{2} \right]$$

$$\therefore \boxed{\vec{F} = \frac{1}{4\pi\epsilon_0} \frac{q Q}{r^2} [1 + \sqrt{2}] \hat{i} \text{ N}} \quad \left(k = \frac{1}{4\pi\epsilon_0} \right)$$

4. Given:- $m_E = 5.9 \times 10^{24} \text{ kg}$

(i) $q = ?$ $m_M = 7.9 \times 10^{22} \text{ kg}$

(ii) If $r = r/2$, $q = ?$

Solution:- (a) $F_e = F_g$

$$\frac{1}{4\pi\epsilon_0} \frac{q \cdot q}{r^2} = \frac{G M_E M_M}{r^2}$$

$$9 \times 10^9 \times q^2 = 6.67 \times 10^{-11} \times 5.9 \times 10^{24} \times 7.9 \times 10^{22}$$

$$q^2 = \frac{6.67 \times 5.9 \times 7.9 \times 10^{35}}{9 \times 10^9}$$

$$q = \sqrt{\frac{6.67 \times 5.9 \times 7.9 \times 10^{26}}{9}}$$

$$q = 10^3 \sqrt{\frac{6.67 \times 5.9 \times 7.9}{9}} = 0.7692 \times 1.5384 \times 10^3 = 1.18 \times 10^3 \text{ C}$$

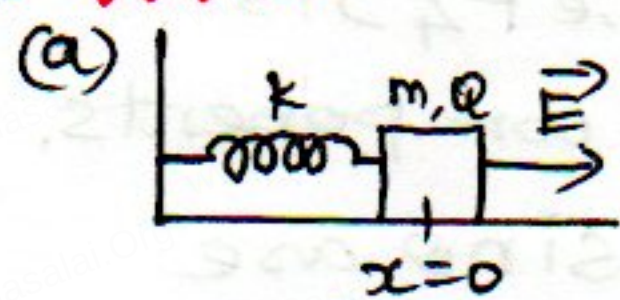
(2)

$$\therefore q = 5.87 \times 10^{13} \text{ C}$$

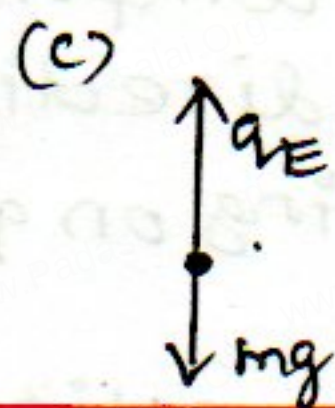
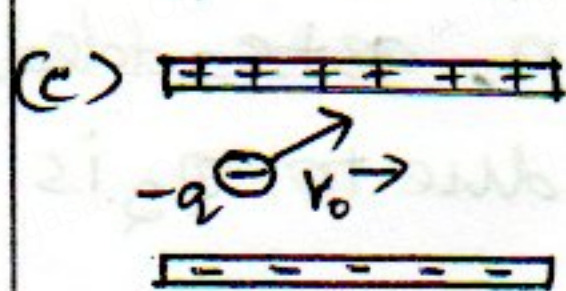
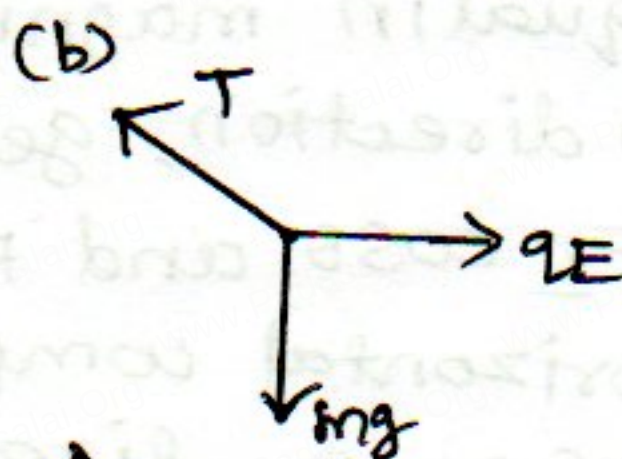
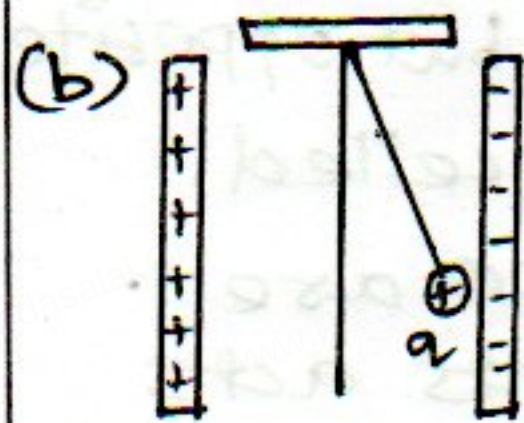
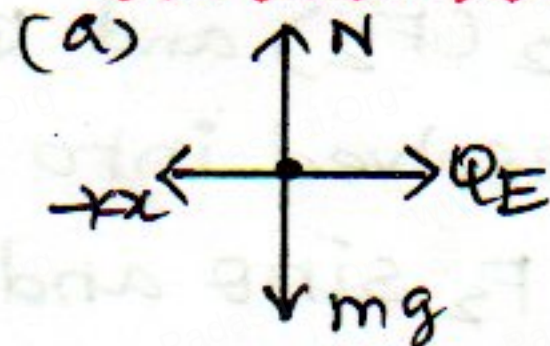
$$(ii) Kq^2 = G M_E M_m$$

If $r = r/2 \therefore$ The charge 'q' will not change.

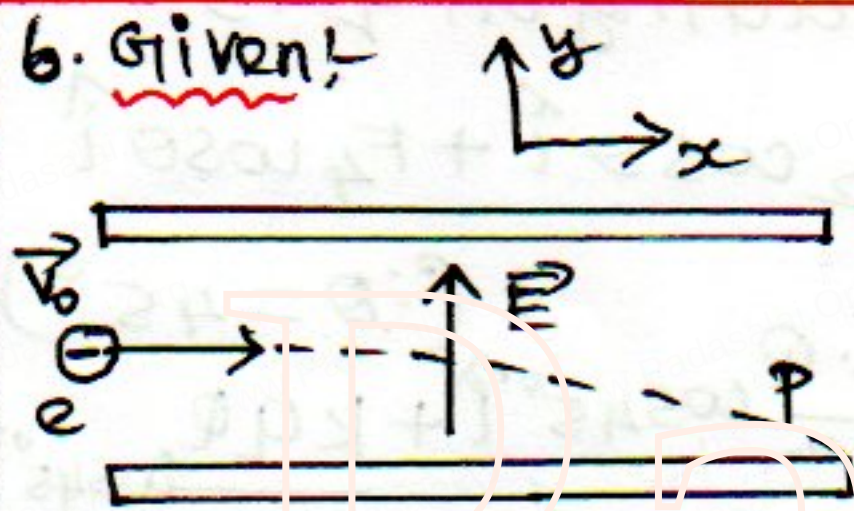
5. Given:-



Free body diagram



6. Given:-



$$\vec{a} = ?$$

$$\vec{v} = ?$$

$$\vec{r} = ?$$

Solution:- (i) $F = ma, a = \frac{F}{m}$

$\therefore$ Force experienced by e^- (F) = eE

$\therefore$ acceleration, $\vec{a} = \frac{eE}{m} (-\hat{j}) = -\frac{eE}{m} \hat{j}$

(ii) Velocity ($\vec{v}$):-

$$\vec{v} = \vec{u} + \vec{a}t, \vec{u} = v_0 \hat{i}, \vec{a} = -\frac{eE}{m} \hat{j}$$

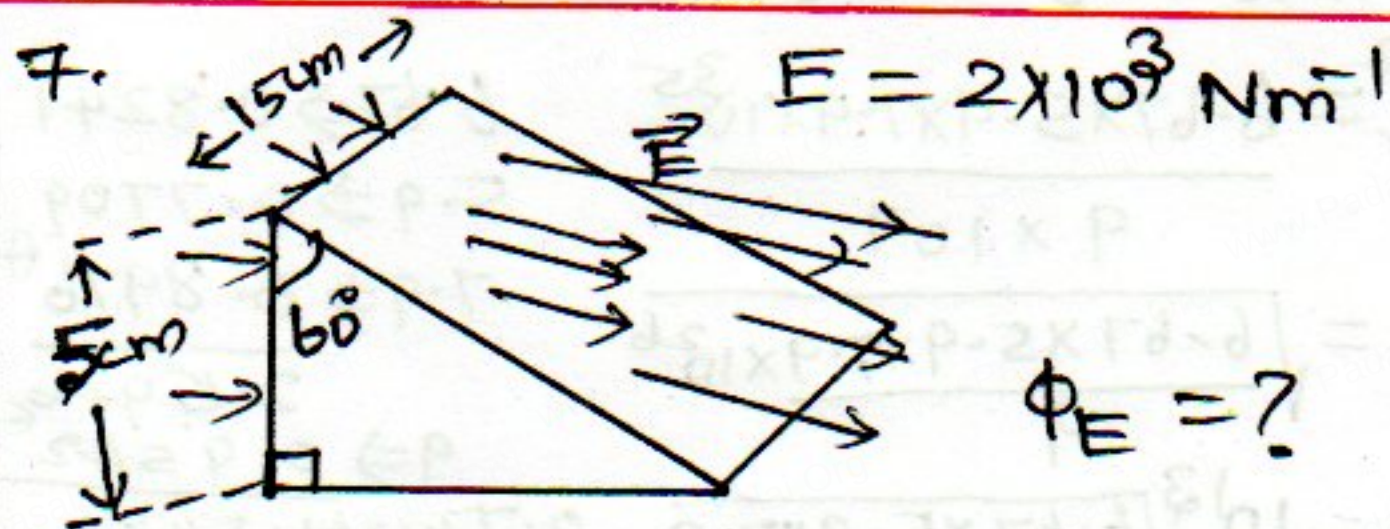
$$\vec{v} = v_0 \hat{i} - \frac{eE}{m} t \hat{j}$$

(iii) Position vector ($\vec{r}$):-

$$\vec{r} = \vec{u}t + \frac{1}{2} \vec{a}t^2$$

$$\vec{r} = v_0 \hat{i} + \frac{1}{2} \left(-\frac{eE}{m} \hat{j} \right) t^2$$

$$\vec{r} = v_0 \hat{i} - \frac{1}{2} \frac{eE}{m} t^2 \hat{j}$$



(a) Vertical rectangle surface

$$\Phi_E = EA \cos \theta, A = 15 \text{ m} \times 5 \text{ m}$$

$$\Phi_E = 2 \times 10^3 \times 75 \times 10^{-4} \times \cos 0^\circ$$

$$= 150 \times 10^{-1}$$

$$\Phi_E = 15 \text{ Nm}^2 \text{ C}^{-1}$$

(b) Slanted surface:-

$$\Phi_E = EA \cos \theta$$

Area of the slanted surface,

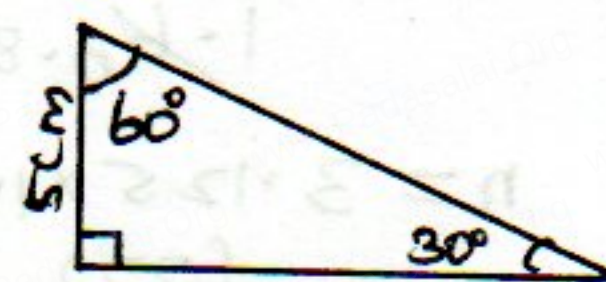
$$A = 15 \times 10^{-2} \times 10 \times 10^{-2} \text{ m}^2 \quad \sin \theta = \frac{\text{opposite}}{\text{hyp}}$$

$$A = 150 \times 10^{-4} \text{ m}^2$$

$$\Phi_E = 2 \times 10^3 \times 150 \times 10^{-4} \times \cos 60^\circ$$

$$\Phi_E = \frac{150}{300} \times 10^{-1} \times \frac{1}{2}$$

$$\Phi_E = 15 \text{ Nm}^2 \text{ C}^{-1}$$



$$\sin 30^\circ = \frac{5 \times 10^{-2}}{\text{hyp}}$$

$$\text{hyp} = \frac{5 \times 10^{-2}}{\sin 30^\circ}$$

$$\therefore \text{hyp} = 10 \times 10^{-2} \text{ m}$$

(c) Entire surface:-

Inward flux = outward flux

$$\Phi_E = 0$$

$\therefore$ Net flux is zero.

8. Given:-

$$E_x = ?$$

(i) Region A:-

$$E_x = -\frac{dV}{dx}$$

From 0 to 0.2m

Slope is -ve.

$$\therefore E_x = -\left(-\frac{dV}{dx}\right) = \frac{dV}{dx} = \frac{3}{0.2} = 15 \text{ Vm}^{-1}$$

(ii) Region B:-

From 0.2m to 0.4m, potential is constant.

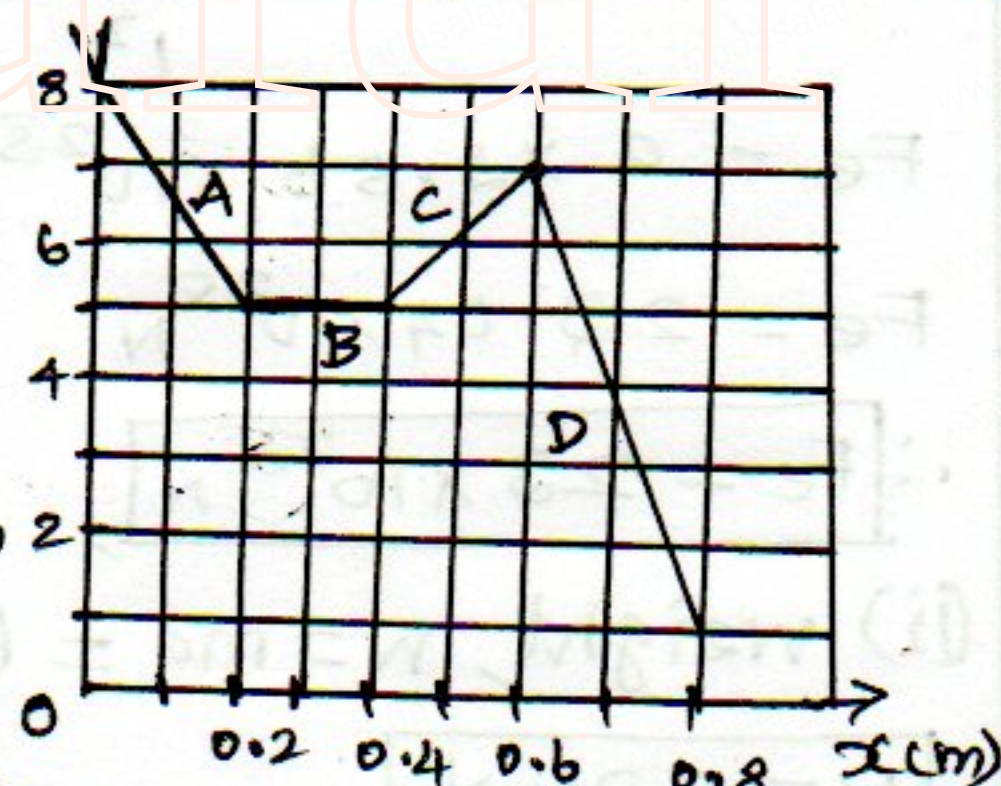
$$V = 5 \text{ V},$$

$$\therefore E_x = -\frac{dV}{dx} = 0 \quad \therefore (V = \text{constant})$$

(iii) Region C:-

From 0.4m to 0.6m (Slope is +ve)

$$E_x = -\frac{dV}{dx} = -\frac{2}{0.2} = -10 \text{ Vm}^{-1}$$



(iv) Region D:- From 0.6m to 0.8m

Slope is negative.

$$E_x = -\left(\frac{dv}{dx}\right) = \frac{dv}{dx} = \frac{6}{0.2} = 30 \text{ Vm}^{-1}$$

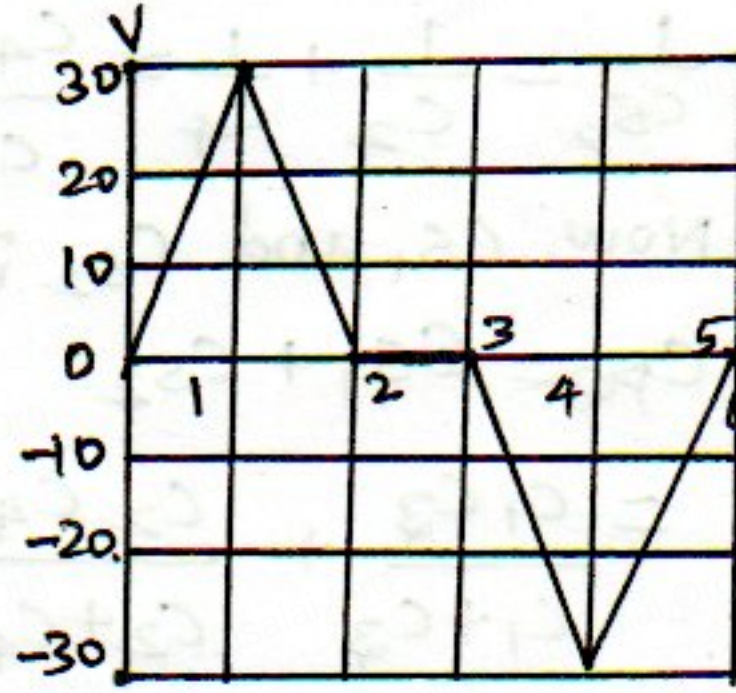
II. For Figure (b):-

(i) From 0 to 1m

Slope is +ve.

$$E_x = -\frac{dv}{dx} = \frac{-30}{1}$$

$$E_x = -30 \text{ Vm}^{-1}$$



(ii) From 1 to 2m Slope is negative.

$$E_x = -\left(\frac{dv}{dx}\right) = \frac{dv}{dx} = \frac{30}{1} = 30 \text{ Vm}^{-1}$$

(iii) From 2 to 3m, $V=0$.

$$\therefore E_x = -\frac{dv}{dx} = 0.$$

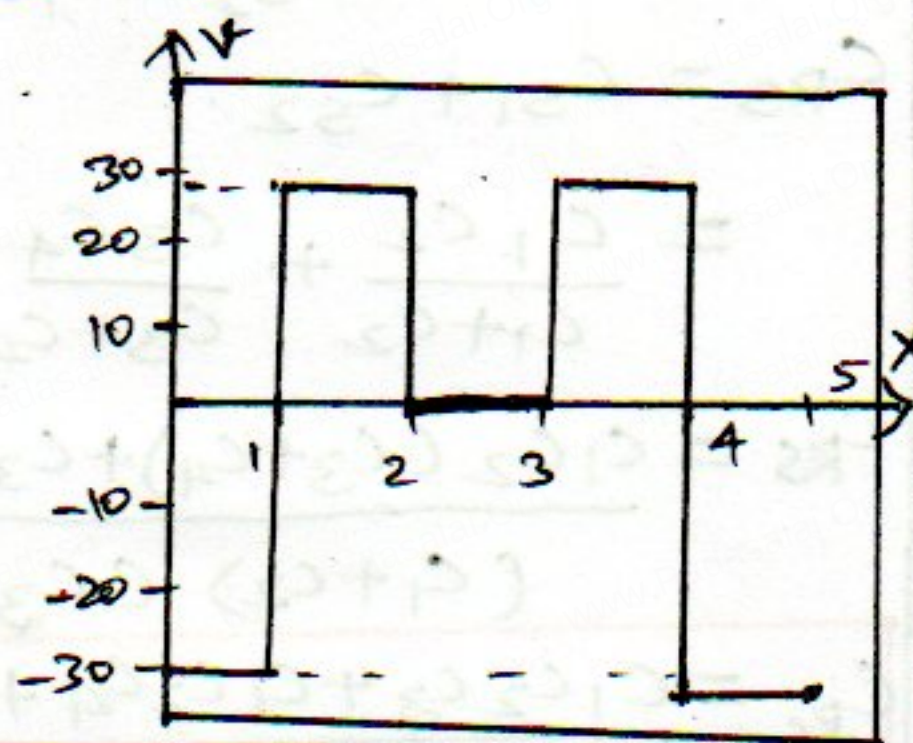
(iv) From 3 to 4m, slope is -ve

$$E_x = -\left(\frac{dv}{dx}\right) = \frac{dv}{dx} = \frac{30}{1} = 30 \text{ Vm}^{-1}$$

(v) From 4 to 5m, slope is +ve.

$$E_x = -\frac{dv}{dx} = \frac{-30}{1} = -30 \text{ Vm}^{-1}$$

Electric field as a function of 'x' diagram for 'b' is



9. Given:- $E = 3 \times 10^6 \text{ Vm}^{-1}$, $d = 0.6 \text{ mm}$

Solution:- $V = ?$

$$d = 6 \times 10^{-4} \text{ m}$$

(a) Potential difference, $V = Ed$

$$V = 3 \times 10^6 \times 6 \times 10^{-4} = 18 \times 10^2 \text{ volt}$$

(b) $V \propto d$

$$\therefore V = 1800 \text{ volt}$$

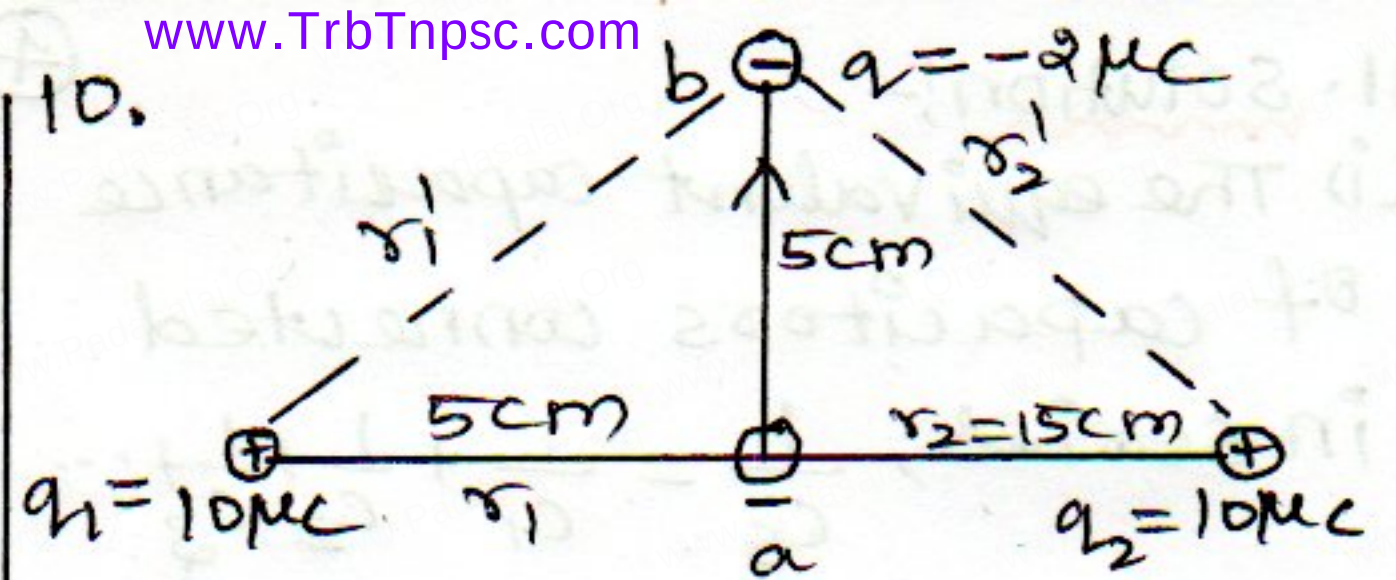
If gap increases, then potential also will increase.

(c) If $d = 1 \text{ mm}$, $V = Ed$

$$V = 3 \times 10^6 \times 1 \times 10^{-3} = 3 \times 10^3 \text{ V} = 3000 \text{ V}$$

③

10.



Given:-

$$q_1 = q_2 = 10 \mu\text{C},$$

$$r_1 = 5 \text{ cm}, r_2 = 15 \text{ cm}, q = -2 \mu\text{C}$$

$$r_1' = \sqrt{5^2 + 5^2} = \sqrt{50} = 5\sqrt{2} \text{ cm}$$

$$r_2' = \sqrt{15^2 + 5^2} = \sqrt{250} = \sqrt{25 \times 10} = 5\sqrt{10} \text{ cm}$$

$\therefore$ change in P.E $\Delta U = ?$

Solution:-

(i) Initial potential energy (U_i)

when $-2 \mu\text{C}$ charge at 'a'

$$U_i = \frac{1}{4\pi\epsilon_0} \frac{q_1 q}{r_1} + \frac{1}{4\pi\epsilon_0} \frac{q_2 q}{r_2}$$

$$= \frac{q q_1}{4\pi\epsilon_0} \left[\frac{1}{r_1} + \frac{1}{r_2} \right] \quad [q_1 = q_2]$$

$$U_i = 9 \times 10^9 \times (-2 \times 10^{-6}) \times 10 \times 10^{-6} \times \left[\frac{1}{5} + \frac{1}{15} \right]$$

$$= -\frac{18 \times 10^{-2}}{5 \times 10^{-2}} \times \frac{4}{15} \times \frac{1}{10} = -\frac{24}{5}$$

$$U_i = -4.8 \text{ J}$$

(ii) Final potential energy (U_f)

when a point charge ($-2 \mu\text{C}$) moved to 'b'

$$U_f = \frac{1}{4\pi\epsilon_0} \frac{q_1 q}{r_1'} + \frac{1}{4\pi\epsilon_0} \frac{q_2 q}{r_2'}$$

$$= \frac{q q_1}{4\pi\epsilon_0} \left[\frac{1}{r_1'} + \frac{1}{r_2'} \right] \quad (\because q_1 = q_2)$$

$$= 9 \times 10^9 \times (-2 \times 10^{-6}) \times 10 \times 10^{-6} \times \left[\frac{1}{5\sqrt{2}} + \frac{1}{5\sqrt{10}} \right]$$

$$= -\frac{18 \times 10^{-2}}{5 \times 10^{-2}} \times \left[\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{10}} \right]$$

$$= -3.6 \times \left[\frac{\sqrt{2}}{\sqrt{2} \times \sqrt{2}} + \frac{\sqrt{10}}{\sqrt{10} \times \sqrt{10}} \right]$$

$$= -3.6 \times \left[\frac{1.414}{2} + \frac{3.16}{10} \right]$$

$$= -3.6 \times [0.707 + 0.316]$$

$$= -3.6 \times 1.023$$

$$U_f = -3.683 \text{ J}$$

$$\therefore \text{change in Potential energy } \Delta U = U_f - U_i = -3.683 - (-4.8)$$

$$\therefore \Delta U = 1.12 \text{ J}$$

$$= 1.117 \text{ J}$$

$$\frac{4.800}{3.683} = 1.117$$

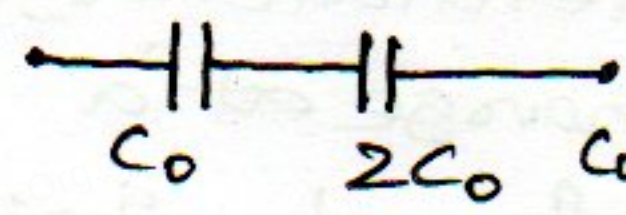
11. Solution:-

(i) The equivalent capacitance of capacitors connected in series, $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$
 + the equivalent capacitance in capacitors connected in parallel, $C_p = C_1 + C_2 + C_3 + \dots$

Figure (a):-

+ C_0 and C_0 in parallel,

$$\therefore C_p = C_0 + C_0 = 2C_0$$



$2C_0$ and $2C_0$ in series,

$$\frac{1}{C_s} = \frac{1}{C_0} + \frac{1}{2C_0} = \frac{2+1}{2C_0} = \frac{3}{2C_0}$$

$$\therefore C_s = \frac{2C_0}{3}$$

Figure (b):-

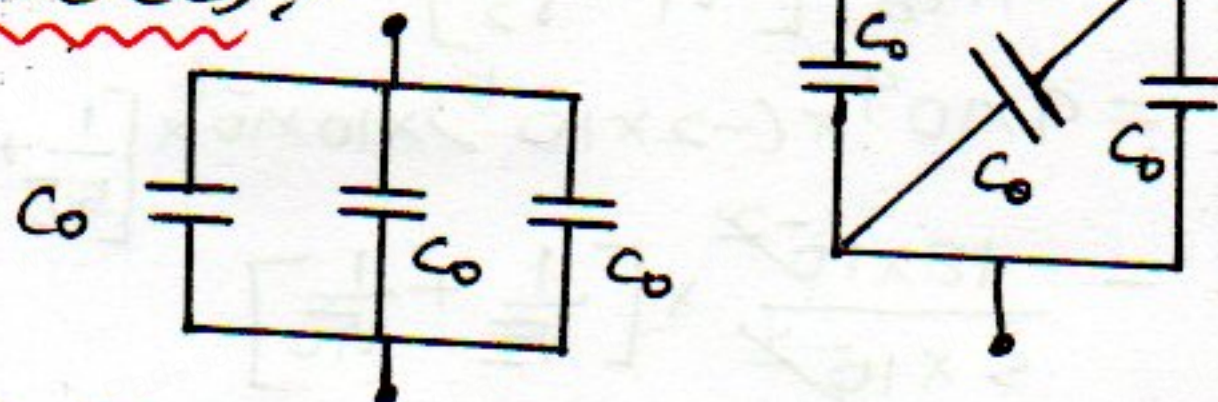
+ C_0 and C_0 in parallel,

$$C_p = C_0 + C_0 = 2C_0$$

Now, $2C_0$ and $2C_0$ are in series

$$\frac{1}{C_s} = \frac{1}{2C_0} + \frac{1}{2C_0} = \frac{2}{2C_0} = \frac{1}{C_0}$$

$$\therefore C_s = C_0$$

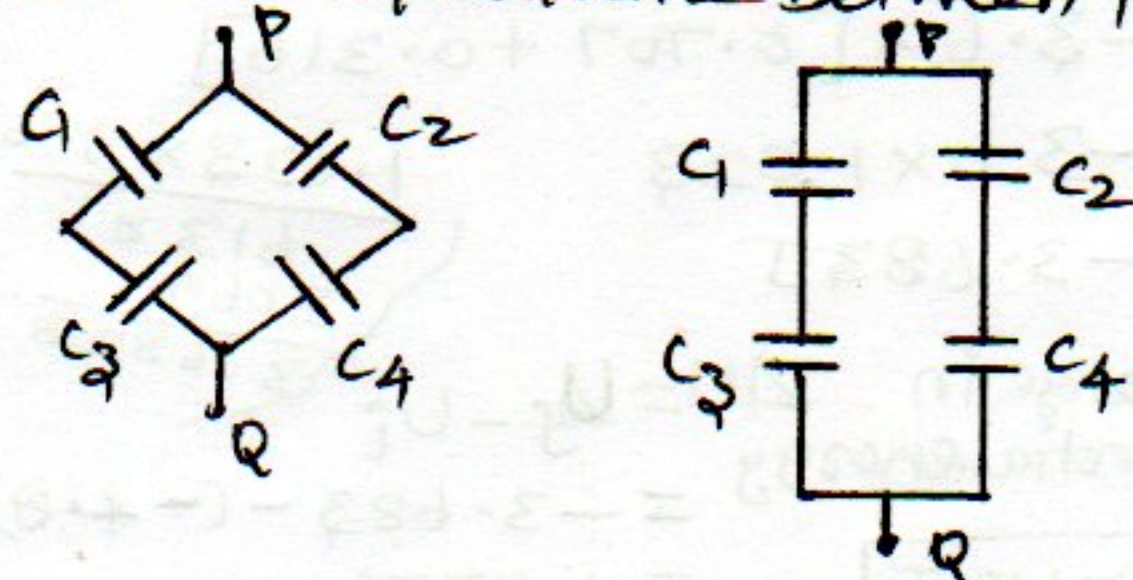
Figure (c):-

Now C_0 , C_0 and C_0 are in parallel,

$$C_p = C_0 + C_0 + C_0 \therefore C_p = 3C_0$$

Figure (d):-

Equivalent capacitance between P and Q



④

Now C_1 and C_3 in series,

$$\frac{1}{C_{s1}} = \frac{1}{C_1} + \frac{1}{C_3} = \frac{C_3 + C_1}{C_1 C_3} ; C_{s1} = \frac{C_1 C_3}{C_1 + C_3}$$

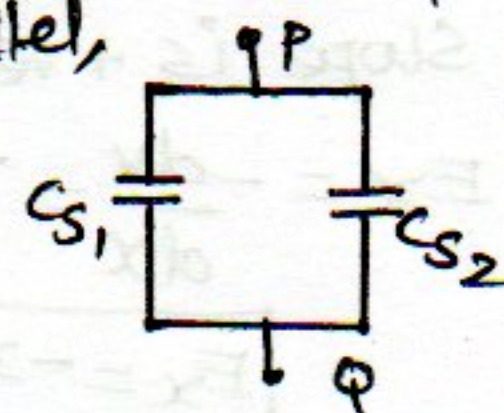
C_2 and C_4 in series,

$$\frac{1}{C_{s2}} = \frac{1}{C_2} + \frac{1}{C_4} = \frac{C_4 + C_2}{C_2 C_4} ; C_{s2} = \frac{C_2 C_4}{C_2 + C_4}$$

Now, C_{s1} and C_{s2} in parallel,

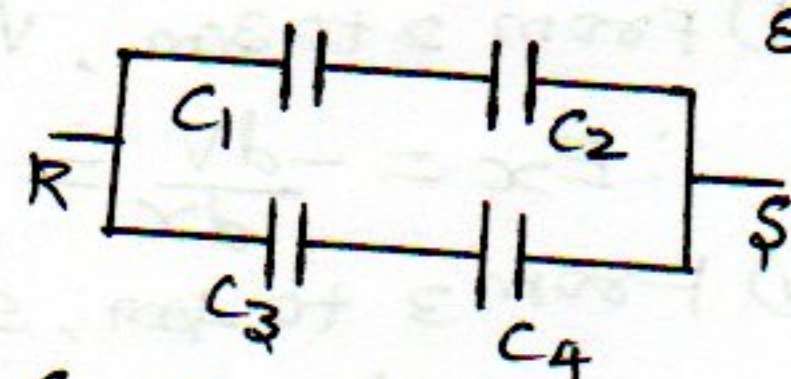
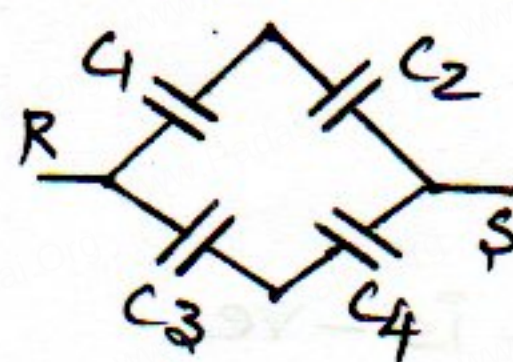
$$C_{PQ} = C_{s1} + C_{s2}$$

$$= \frac{C_1 C_3}{C_1 + C_3} + \frac{C_2 C_4}{C_2 + C_4}$$



$$C_{PQ} = \frac{C_1 C_3 (C_2 + C_4) + C_2 C_4 (C_1 + C_3)}{(C_1 + C_3) (C_2 + C_4)}$$

+ Equivalent capacitance between R and S



Now C_1 , C_2 are in series

$$\frac{1}{C_{s1}} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{C_2 + C_1}{C_1 C_2} ; C_{s1} = \frac{C_1 C_2}{C_1 + C_2}$$

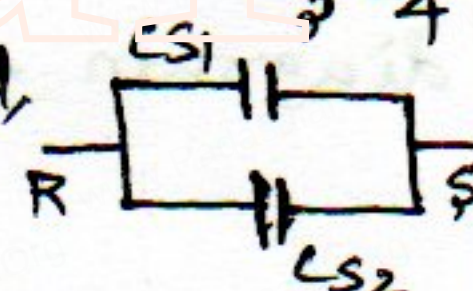
C_3 and C_4 in series,

$$\frac{1}{C_{s2}} = \frac{1}{C_3} + \frac{1}{C_4} = \frac{C_4 + C_3}{C_3 C_4} \Rightarrow C_{s2} = \frac{C_3 C_4}{C_3 + C_4}$$

Now, C_{s1} and C_{s2} in parallel,

$$C_{RS} = C_{s1} + C_{s2}$$

$$= \frac{C_1 C_2}{C_1 + C_2} + \frac{C_3 C_4}{C_3 + C_4}$$



$$C_{RS} = \frac{C_1 C_2 (C_3 + C_4) + C_3 C_4 (C_1 + C_2)}{(C_1 + C_2) (C_3 + C_4)}$$

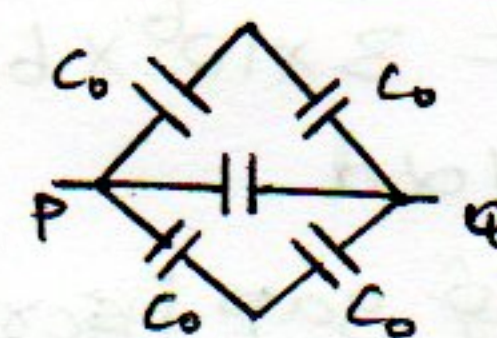
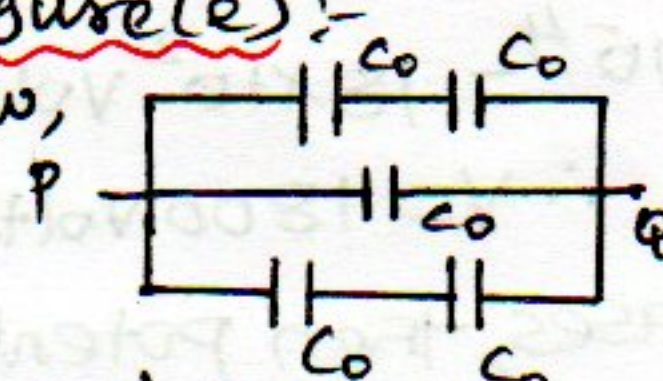
$$C_{RS} = \frac{C_1 C_2 C_3 + C_1 C_2 C_4 + C_1 C_3 C_4 + C_2 C_3 C_4}{(C_1 + C_2) (C_3 + C_4)}$$

and

$$C_{PQ} = \frac{C_1 C_2 C_3 + C_1 C_3 C_4 + C_1 C_2 C_4 + C_2 C_3 C_4}{(C_1 + C_3) (C_2 + C_4)}$$

Figure (e):-

Now,



C_0 and C_0 in series,

$$\frac{1}{C_{s1}} = \frac{1}{C_0} + \frac{1}{C_0} = \frac{2}{C_0} ; C_{s1} = \frac{C_0}{2}$$

$$\frac{1}{C_{s2}} = \frac{1}{C_0} + \frac{1}{C_0} = \frac{2}{C_0} ; C_{s2} = \frac{C_0}{2}$$

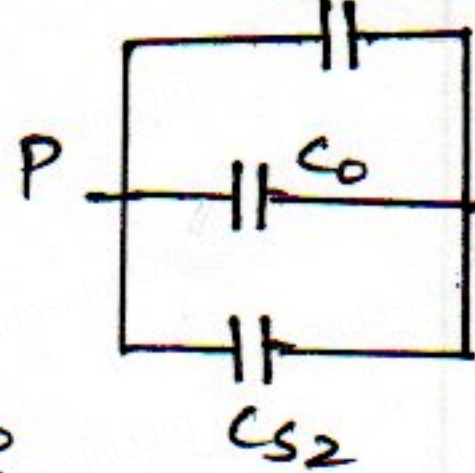
Now, C_{s1} , C_0 and C_{s2} in parallel

$$C_p = C_{s1} + C_0 + C_{s2}$$

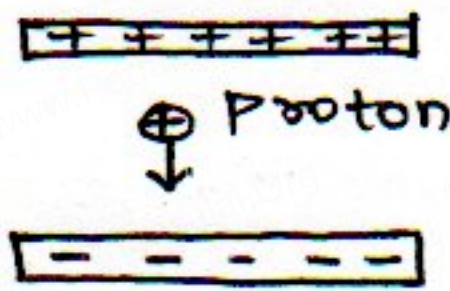
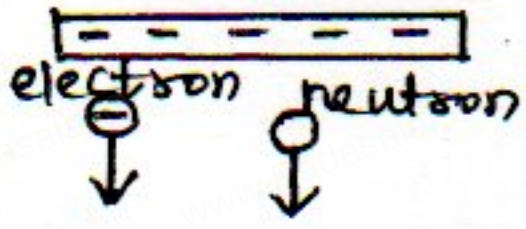
$$= \frac{C_0}{2} + C_0 + \frac{C_0}{2}$$

$$C_p = \frac{C_0 + 2C_0 + C_0}{2} = \frac{4C_0}{2}$$

$$\therefore \boxed{C_p = 2C_0}$$



12. Given:- $m_p = 1.6 \times 10^{-27} \text{ kg}$, $m_e = 9.1 \times 10^{-31} \text{ kg}$, $g = 10 \text{ ms}^{-2}$



Solution:- $h = 1 \text{ mm} = 1 \times 10^{-3} \text{ m}$, $V = 5 \text{ volt}$.

(i) Time of flight (t_e) $\therefore E = \frac{V}{h} = \frac{5}{10^3} = 5 \times 10^3 \text{ NC}^{-1}$

For electron, $S = ut + \frac{1}{2} at^2$

$$S = h, u = 0, a = \frac{F}{m} = \frac{eE}{m}, t = t_e$$

$$\text{Now, } h = 0 + \frac{1}{2} \left(\frac{eE}{m_e} \right) t_e^2 = \frac{1}{2} \left(\frac{eE}{m_e} \right) t_e^2$$

$$t_e = \sqrt{\frac{2m_e h}{eE}} = \sqrt{\frac{2 \times 9.1 \times 10^{-31} \times 1 \times 10^{-3}}{1.6 \times 10^{-19} \times 5 \times 10^3}}$$

$$t_e = \sqrt{\frac{18.2 \times 10^{-34}}{8 \times 10^{-16}}} = \frac{10^{-9}}{2} \sqrt{9.1}$$

$$t_e = \frac{1.5 \times 10^{-9}}{2} = 1.5 \times 10^{-9} \text{ s. } (\because \sqrt{9.1} \approx 3)$$

$$\therefore \boxed{t_e = 1.5 \text{ ns}}$$

(ii) Time of flight for proton (t_p):-

$$S = ut + \frac{1}{2} at^2; S = h, u = 0, t = t_p$$

$$h = 0 + \frac{1}{2} \left(\frac{eE}{m_p} \right) t_p^2 \quad a = \frac{eE}{m_p}$$

$$\therefore t_p = \sqrt{\frac{2m_p h}{eE}} = \sqrt{\frac{2 \times 1.6 \times 10^{-27} \times 1 \times 10^{-3}}{1.6 \times 10^{-19} \times 5 \times 10^3}}$$

$$t_p = \sqrt{0.4 \times 10^{-14}} = 10^{-7} \sqrt{0.4} \quad \left\{ \frac{1}{2} \log 0.4 \approx 1.602 \right\}$$

$$\therefore t_p = 6.3 \times 10^{-8} \times 10^{-1} = 6.3 \times 10^{-9} \text{ s. } \left\{ \begin{array}{l} \text{Antilog} \\ \log 6.3 \approx 0.8010 \\ 6.324 \times 10^{-1} \end{array} \right.$$

$$\therefore \boxed{t_p = 6.3 \text{ ns}}$$

(iii) Time of flight for neutron (t_n):-

$$\therefore t_n = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \times 1 \times 10^{-3}}{10}} \quad S = ut + \frac{1}{2} at^2$$

$$t_n = 10^{-2} \sqrt{2} = 1.414 \times 10^{-2} \text{ s. } u = 0, a = g$$

$$\therefore \boxed{t_n = 14.14 \text{ ms}} \quad S = h, t = t_n$$

$$\therefore t_e < t_p < t_n$$

$\therefore$ electrons will reach the bottom first.

13. Given:- $E = 3 \times 10^6 \text{ Vm}^{-1}$; $d = 1000 \text{ m}$, $V = ?$, $U = ?$, $q = 25 \text{ C}$

Solution:-

(i) Electric potential difference, $V = Ed$

$$V = 3 \times 10^6 \times 1000 = 3 \times 10^9 \text{ Volt}$$

(ii) Electrostatic potential energy (U):

$$U = V \times q = 3 \times 10^9 \times 25 = 75 \times 10^9 \text{ J}$$

14. Solution:- $V = 9 \text{ V}$

$$C_a = 8 \mu\text{F}, C_b = 6 \mu\text{F}$$

$$C_c = 2 \mu\text{F}, C_d = 8 \mu\text{F}$$

* C_b and C_c in parallel,

$$C_{bc} = C_b + C_c = 6 + 2 = 8 \mu\text{F}$$

* Potential difference in each capacitor:-

$$\therefore V_a = \frac{V}{3} = \frac{9}{3} = 3 \text{ Volt}$$

$$V_b = \frac{V}{3} = \frac{9}{3} = 3 \text{ Volt}$$

$$V_c = \frac{V}{3} = \frac{9}{3} = 3 \text{ Volt}$$

$$V_d = \frac{V}{3} = \frac{9}{3} = 3 \text{ Volt}$$

* Charge on each capacitor.

$$q_a = C_a V_a = 8 \times 10^{-6} \times 3 = 24 \times 10^{-6} \text{ C}$$

$$q_b = C_b V_b = 6 \times 10^{-6} \times 3 \quad \therefore \boxed{q_a = 24 \mu\text{C}}$$

$$q_b = 18 \times 10^{-6} \text{ C}, \quad \boxed{q_b = 18 \mu\text{C}}$$

$$q_c = C_c V_c = 2 \times 10^{-6} \times 3 = 6 \times 10^{-6} \text{ C}, \quad \boxed{q_c = 6 \mu\text{C}}$$

$$q_d = C_d V_d = 8 \times 10^{-6} \times 3 = 24 \times 10^{-6} \text{ C}, \quad \boxed{q_d = 24 \mu\text{C}}$$

* Energy stored in each capacitor

$$U_a = \frac{1}{2} C_a V_a^2 = \frac{1}{2} \times 8 \times 10^{-6} \times (3)^2 = 36 \times 10^{-6} \text{ J}$$

$$U_b = \frac{1}{2} C_b V_b^2 = \frac{1}{2} \times 6 \times 10^{-6} \times (3)^2 = 27 \times 10^{-6} \text{ J}, \quad \boxed{U_a = 36 \mu\text{J}}$$

$$U_c = \frac{1}{2} C_c V_c^2 = \frac{1}{2} \times 2 \times 10^{-6} \times (3)^2 = 9 \times 10^{-6} \text{ J}, \quad \boxed{U_b = 27 \mu\text{J}}$$

$$U_d = \frac{1}{2} C_d V_d^2 = \frac{1}{2} \times 8 \times 10^{-6} \times (3)^2 = 36 \times 10^{-6} \text{ J}, \quad \boxed{U_c = 9 \mu\text{J}}$$

$$U_d = 36 \times 10^{-6} \text{ J}, \quad \boxed{U_d = 36 \mu\text{J}}$$

15. Capacitor 'P'

(i) Capacitance of a parallel plate capacitor,

$$C = \frac{\epsilon_0 A}{d}$$

* with dielectric, $C = \frac{\epsilon_r \epsilon_0 A}{d}$

In capacitor 'P': C_1 and C_2 Parallel, $C_P = C_1 + C_2$

$$C_1 = \frac{\epsilon_0 A}{d}; \text{ here } A = A/2$$

$$C_1 = \frac{\epsilon_0 (A/2)}{d} = \frac{\epsilon_0 A}{2d}$$

$$\therefore C_2 = \frac{\epsilon_r \epsilon_0 (A/2)}{d} = \frac{\epsilon_r \epsilon_0 A}{2d}$$

$$\therefore C_P = \frac{\epsilon_0 A}{2d} + \frac{\epsilon_r \epsilon_0 A}{2d}$$

$$\therefore C_P = \frac{\epsilon_0 A}{2d} (1 + \epsilon_r)$$

In capacitor 'Q':

Now, $A = A$, $d = d/2$

C_1, C_2 are in series,

$$\frac{1}{C_Q} = \frac{1}{C_1} + \frac{1}{C_2}; C_1 = \frac{\epsilon_r \epsilon_0 A}{d/2}$$

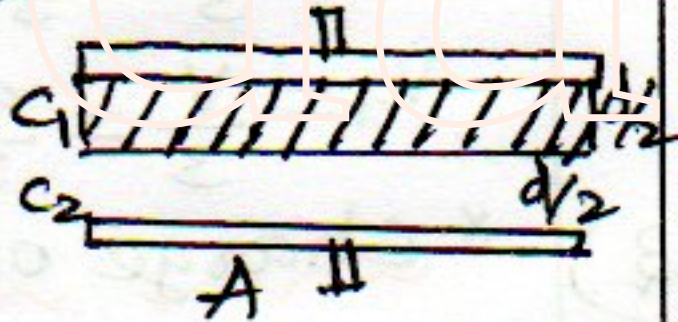
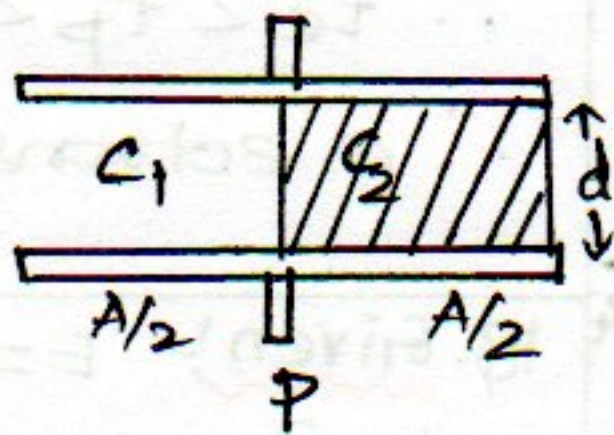
$$C_2 = \frac{\epsilon_0 A}{d/2} = \frac{2\epsilon_0 A}{d}, C_1 = \frac{2\epsilon_r \epsilon_0 A}{d}$$

$$\therefore \frac{1}{C_Q} = \frac{d}{2\epsilon_r \epsilon_0 A} + \frac{d}{2\epsilon_0 A}$$

$$= \frac{d}{2\epsilon_0 A} \left[\frac{1}{\epsilon_r} + 1 \right]$$

$$\frac{1}{C_Q} = \frac{d}{2\epsilon_0 A} \left[\frac{1 + \epsilon_r}{\epsilon_r} \right]$$

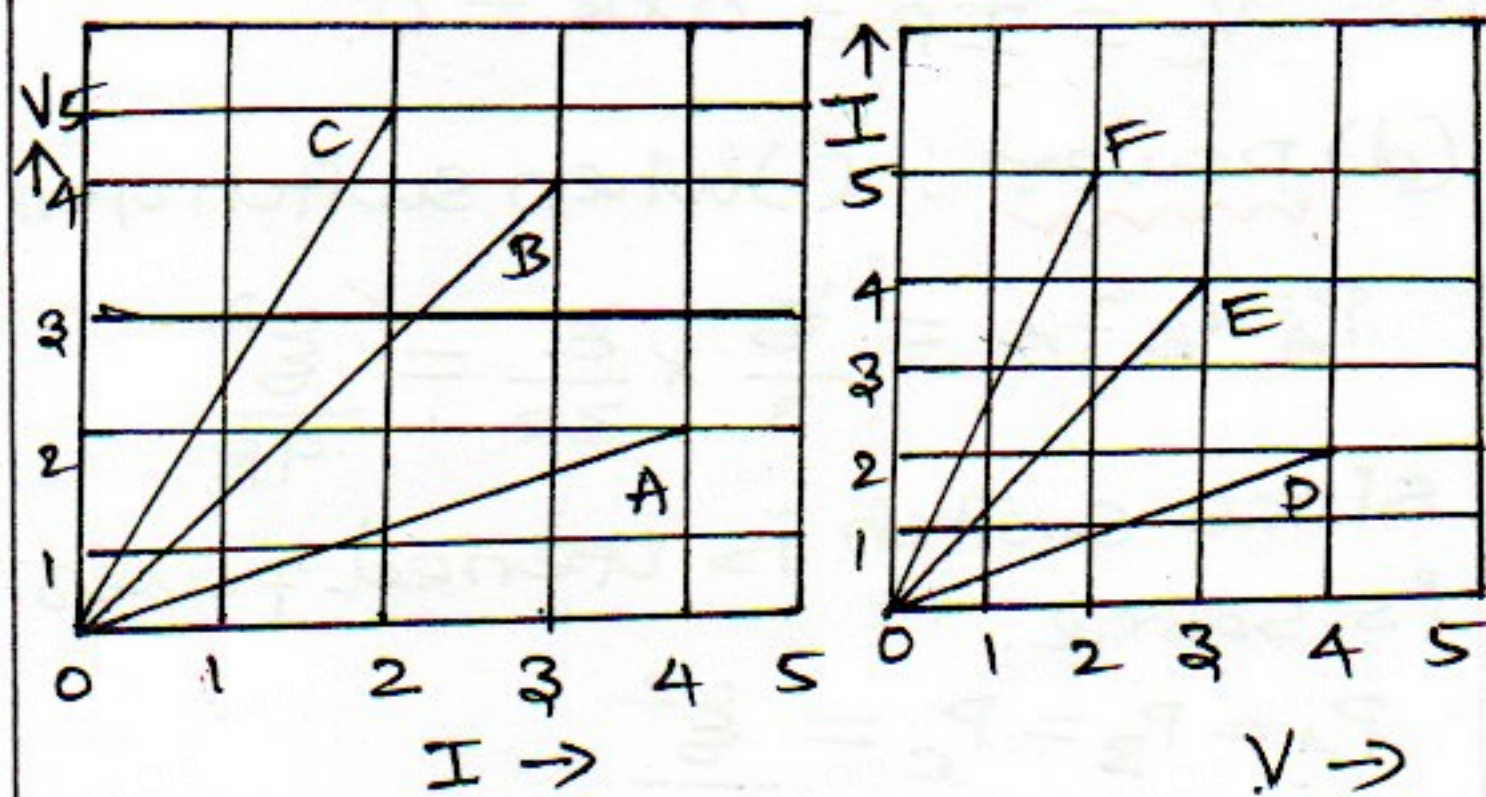
$$\therefore C_Q = \frac{2\epsilon_0 A}{d} \left[\frac{\epsilon_r}{1 + \epsilon_r} \right]$$



B.AROKIAARAJ, M.Sc., B.Ed.,
PGT in Physics, Neyveli TS.
Cell : 9487380576, 8667656700

2. CURRENT ELECTRICITY

1. Given:-



$R_{\text{least}} = ?$; $R_{\text{max}} = ?$

Solution:- According to ohm's law
 $V = IR$, $R = \frac{V}{I}$

Graph 1:-

For A:- slope = $R_A = \frac{\Delta V}{\Delta I} = \frac{2}{4} = 0.5 \Omega$

For B:- slope = $R_B = \frac{\Delta V}{\Delta I} = \frac{4}{3} = 1.33 \Omega$

For C:- slope = $R_C = \frac{\Delta V}{\Delta I} = \frac{5}{2} = 2.5 \Omega$

Graph 2:-

For D:- $R_D = \frac{1}{\text{slope}} = \frac{\Delta V}{\Delta I} = \frac{4}{2} = 2 \Omega$

For E:- $R_E = \frac{1}{\text{slope}} = \frac{\Delta V}{\Delta I} = \frac{3}{4} = 0.75 \Omega$

For F:- $R_F = \frac{1}{\text{slope}} = \frac{\Delta V}{\Delta I} = \frac{2}{5} = 0.4 \Omega$

$\therefore$ Least Resistance, $R_F = 0.4 \Omega$

Maximum Resistance, $R_C = 2.5 \Omega$

2. Given:- $W = 10^9 \text{ J}$, $V = 5 \times 10^7 \text{ Volt}$
 $t = 0.2 \text{ s} = 2 \times 10^{-1} \text{ s}$, $q = ?$, $I = ?$, $P = ?$

Solution:-

(i) Total amount of charge transferred

$$W = Vq$$

$$q = \frac{W}{V} = \frac{10^9}{5 \times 10^7} = 0.2 \times 10^2 = 20 \text{ C}$$

(ii) Current in the lightning bolt,

$$I = \frac{q}{t} = \frac{20}{2 \times 10^{-1}} = 100 \text{ A}$$

(iii) Power delivered in 0.2 second

$$P = VI = 5 \times 10^7 \times 10^2 = 5 \times 10^9 \text{ W}$$

$$\boxed{P = 5 \text{ GW}}$$

3. Given:- $A = 10^{-6} \text{ m}^2$, $I = 5 \text{ A}$,
 $n = 8 \times 10^{28}$, $J = ?$, $V_d = ?$

Solution:-

$$(i) J = \frac{I}{A} = \frac{5}{10^{-6}} = 5 \times 10^6 \text{ A m}^{-2}$$

$$(ii) J = nev_d$$

$$V_d = \frac{J}{ne} = \frac{5 \times 10^6}{8 \times 10^{28} \times 1.6 \times 10^{-19}}$$

$$V_d = \frac{10^{-3}}{6.4} = 1.56 \times 10^{-4} \text{ m s}^{-1}$$

$$10^{-3} \Rightarrow 3.0000$$

$$6.4 \Rightarrow 0.8062$$

$$\frac{3.0000}{0.8062} = 3.71938$$

$$1.563 \times 10^{-4}$$

4. Given:- $R_0 = 10 \Omega$, $T_0 = 0^\circ \text{C}$

$R_{100} = ?$, $T = 100^\circ \text{C}$

Solution:-

$$\alpha = 0.004 / ^\circ \text{C}$$

$$R_t = R_0 (1 + \alpha (T - T_0))$$

$$R_{100} = 10 [1 + 0.004 \times 100]$$

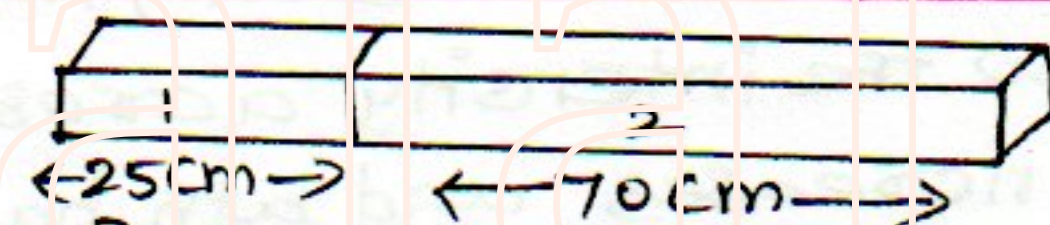
$$= 10 [1 + 0.4] = 10 \times 1.4$$

$$\boxed{R_{100} = 14 \Omega}$$

$\therefore$ As temperature increases, the resistance of wire also increases

5.

Given:-



$$P_1 = 4 \times 10^{-3} \Omega \text{ m}, l_1 = 25 \text{ cm}$$

$$P_2 = 5 \times 10^{-3} \Omega \text{ m}, l_2 = 70 \text{ cm}, R_s = ?$$

Side length = 3 mm, Area = $(3 \times 10^{-3} \text{ m})^2$

Solution:-

$$\text{Area, } A = 9 \times 10^{-6} \text{ m}^2$$

$$\therefore R_s = R_1 + R_2 \rightarrow (i)$$

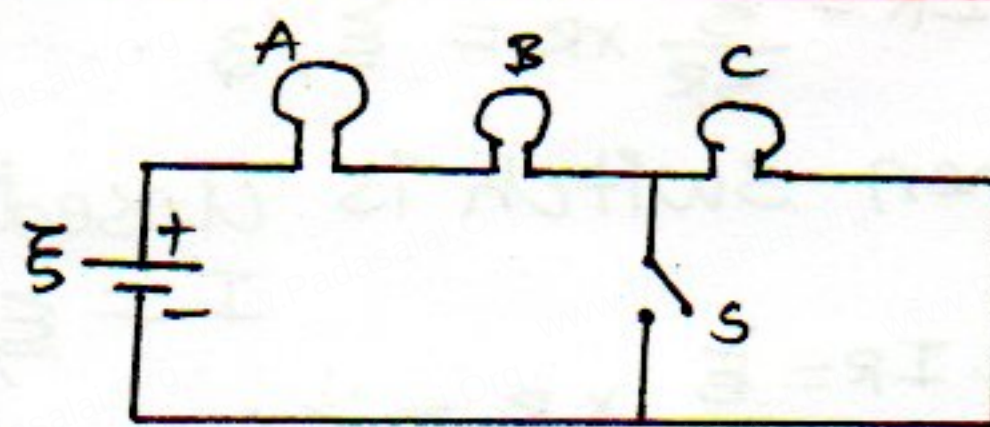
$$R_1 = \frac{P_1 l_1}{A} = \frac{4 \times 10^{-3} \times 25 \times 10^{-2}}{9 \times 10^{-6}} = \frac{1000}{9} \Omega$$

$$R_2 = \frac{P_2 l_2}{A} = \frac{5 \times 10^{-3} \times 70 \times 10^{-2}}{9 \times 10^{-6}} = \frac{3500}{9} \Omega$$

$$\Rightarrow R_s = \frac{1000}{9} + \frac{3500}{9} = \frac{4500}{9} = 500 \Omega$$

$$\therefore \text{Resistance, } \boxed{R_s = 500 \Omega}$$

6.



Suddenly, the switch is closed.

(a) Current in the circuit in which S is open and closed.

According to Ohm's law, $V = IR$
 $\mathcal{E} = V$.

$$R_1 = R_2 = R_3 = R$$

Three lamps are connected in series

$$R_s = R_1 + R_2 + R_3 = R + R + R = 3R$$

When switch is open,

$$I = \frac{V}{R_s} = \frac{\mathcal{E}}{3R}$$

When switch is closed, then no current flows through lamp 'c'

$$I = \mathcal{E}/2R$$

(b) Intensities of A, B, C:-

(i) When switch is open.

Three lamps are in series combination. So there is no change in intensity. So all bulbs having equal intensities.

(ii) When switch is closed

Bulbs A and B only in series. So the intensity across A and B increases and both having equal intensities.

* The bulb 'c' is in parallel, hence no current flows through it. So the bulb 'c' will not glow.

(c) Voltage:-

(i) When switch is open.

In series combination, current will be same. $I = \mathcal{E}/3R$

$$V_A = IR = \frac{\mathcal{E}}{3R} \times R = \mathcal{E}/3$$

$$V_B = IR = \frac{\mathcal{E}}{3R} \times R = \mathcal{E}/3$$

$$V_C = IR = \frac{\mathcal{E}}{3R} \times R = \mathcal{E}/3$$

(ii) When switch is closed,

$$\therefore V_A = IR = \frac{\mathcal{E}}{2R} \times R = \mathcal{E}/2$$

$$V_B = IR = \frac{\mathcal{E}}{2R} \times R = \mathcal{E}/2$$

(8) Bulb 'c' is in parallel

$$\therefore I = 0$$

$$V_c = IR = 0 \times R = 0$$

(d) Power:- (i) When switch open,

$$P_A = V_A I_A = \frac{\mathcal{E}}{3} \times \frac{\mathcal{E}}{3R} = \frac{\mathcal{E}^2}{9R}$$

Since switch is opened, power is same.

$$P_A = P_B = P_C = \frac{\mathcal{E}^2}{9R}$$

(ii) When switch is closed:-

$$P_A = V_A I_A$$

$$I = \frac{\mathcal{E}}{2R}$$

$$P_A = \frac{\mathcal{E}}{2} \times \frac{\mathcal{E}}{2R} = \frac{\mathcal{E}^2}{4R}$$

$$P_B = V_B I_B = \frac{\mathcal{E}}{2} \times \frac{\mathcal{E}}{2R} = \frac{\mathcal{E}^2}{4R}$$

Bulb 'c' is in parallel,

$$V_c = 0 \quad I_c = 0$$

$$\therefore P_c = V_c I_c$$

$$P_c = 0 \times 0 = 0$$

$\therefore$ Total power will increase.

7) $dq = ?$

$t = 0s, t = 2s, t = 5s$

Solution:-

(i) At $t = 0$.

$$I = \frac{dq}{dt}; dq = I \cdot dt = 10 \times 0 = 0$$

$$\therefore \boxed{dq = 0}$$

(ii) At $t = 2s$,

$$dq = I \times dt = 5 \times 2 = 10C$$

$$\boxed{dq = 10C}$$

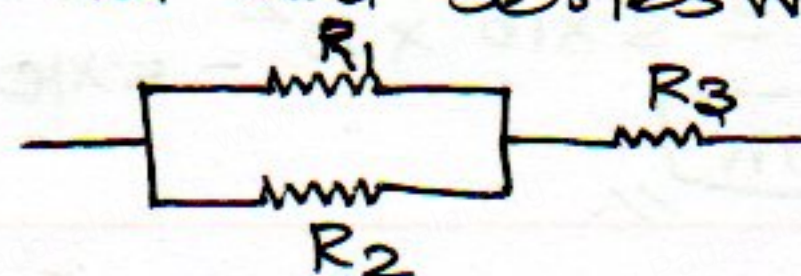
(iii) At $t = 5s$,

$$dq = I \times dt = 0 \times 5 = 0 \quad \boxed{dq = 0}$$

8. Resistance required, $R = 150\Omega$

$$R_1 = 220\Omega, R_2 = 79\Omega, R_3 = 92\Omega$$

For getting 150Ω as a resultant value, R_1 and R_2 will connect in parallel and series with R_3 .



R_1 and R_2 are connected in parallel, $R_p = \frac{R_1 R_2}{R_1 + R_2} = \frac{220 \times 79}{220 + 79}$

$$R_p = \frac{17380}{299}$$

$$17380 \Rightarrow 4.2400$$

$$299 \Rightarrow 2.4757$$

$$\text{Antilog } 1.7643$$

$$R_p = 58.2$$

Now, R_p and R_3 are in series, $58.2 \leq 5.812 \times 10^1$

$$\frac{R_p}{58.2} \quad \frac{R_3}{92.2}$$

$\therefore R_3, R_p$ are in series,

$$R_s = R_p + R_3 = 58 + 92 = 150 \Omega$$

$$\therefore R_s = 150 \Omega$$

$\therefore$ Parallel combination of 220Ω and 79Ω in series with 92Ω

9. Given:- $I_1 = 0.9 \text{ A}$, $R_1 = 2 \Omega$, $I_2 = 0.3 \text{ A}$, $R_2 = 7 \Omega$, $r = ?$

Solution:-

$$I_1 = \frac{\xi}{R_1 + r}, \xi = I_1 (R_1 + r) \rightarrow (1)$$

$$I_2 = \frac{\xi}{R_2 + r}, \xi = I_2 (R_2 + r) \rightarrow (2)$$

$$\text{From (1) \& (2)} \Rightarrow I_1 (R_1 + r) = I_2 (R_2 + r)$$

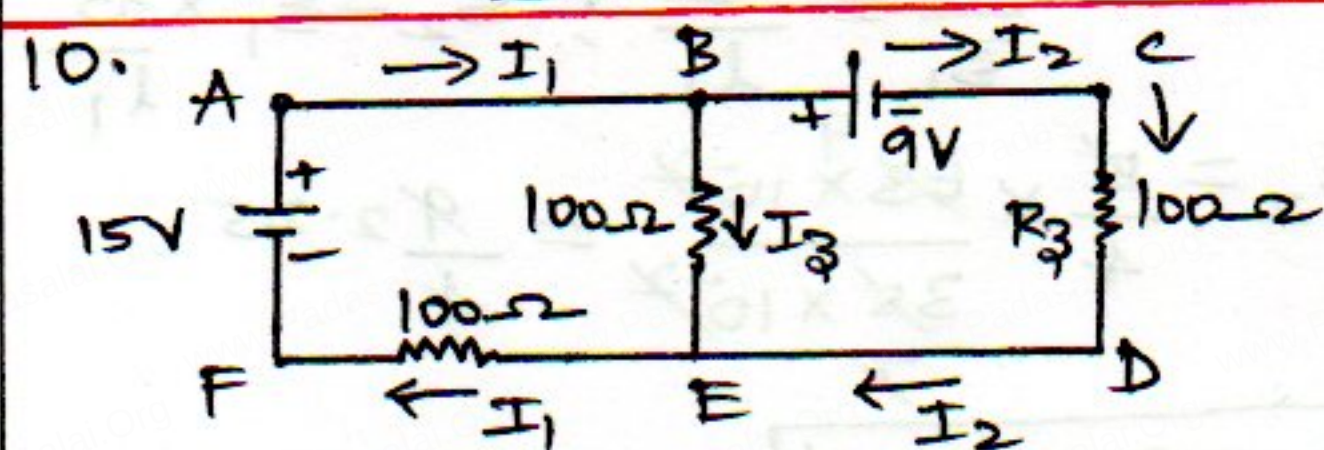
$$I_1 R_1 + I_1 r = I_2 R_2 + I_2 r$$

$$r [I_1 - I_2] = I_2 R_2 - I_1 R_1$$

$$r = \frac{I_2 R_2 - I_1 R_1}{I_1 - I_2} = \frac{0.3 \times 7 - 0.9 \times 2}{0.9 - 0.3}$$

$$r = \frac{2.1 - 1.8}{0.6} = \frac{0.3}{0.6} = 0.5 \Omega$$

$$\therefore r = 0.5 \Omega$$



$$I_1 = ?, I_2 = ?, I_3 = ?$$

Solution:- Apply Kirchhoff's current rule at junction B,

$$I_1 - I_2 - I_3 = 0, I_3 = I_1 - I_2 \rightarrow (1)$$

Apply Kirchhoff's voltage rule for closed path ABEFA,

$$100 I_1 + 100 I_3 = 15$$

$$100 I_1 + 100 (I_1 - I_2) = 15$$

$$100 I_1 + 100 I_1 - 100 I_2 = 15$$

(9)

$$200 I_1 - 100 I_2 = 15 \rightarrow (2)$$

Apply Kirchhoff's voltage rule for closed path BCDEB,

$$100 I_2 - 100 I_3 = -9$$

$$100 I_2 - 100 (I_1 - I_2) = -9$$

$$100 I_2 - 100 I_1 + 100 I_2 = -9$$

$$200 I_2 - 100 I_1 = -9$$

$$-100 I_1 + 200 I_2 = -9 \rightarrow (3)$$

$$(2) \Rightarrow 200 I_1 - 100 I_2 = 15$$

$$(3) \times 2 \Rightarrow -200 I_1 + 400 I_2 = -18 \quad (4)$$

$$300 I_2 = -3$$

$$I_2 = \frac{-1}{100} = -1 \times 10^{-2} \Rightarrow I_2 = -0.01 \text{ A}$$

$$(2) \Rightarrow 200 I_1 - 100 \times \frac{-1}{100} = 15$$

$$200 I_1 + 1 = 15, 200 I_1 = 14$$

$$I_1 = 0.07 \text{ A}$$

$$I_1 = 7/100$$

$$\therefore (1) \Rightarrow I_3 = I_1 - I_2 = 0.07 - (-0.01)$$

$$\therefore I_3 = 0.08 \text{ A}$$

11. Given:- $j = 4 \text{ m}$, resistance, $r = 20 \Omega$, $E = ?$, $\xi = 4 \text{ V}$, $r' = 2980 \Omega$

Solution:- Effective resistance for two resistors in series combination

$$R_s = r + r' = 20 + 2980 \Omega$$

$$R_s = 3000 \Omega$$

$$\therefore I = \xi / R = \frac{4}{3000} \text{ A}$$

$\therefore$ Potential drop across the wire,

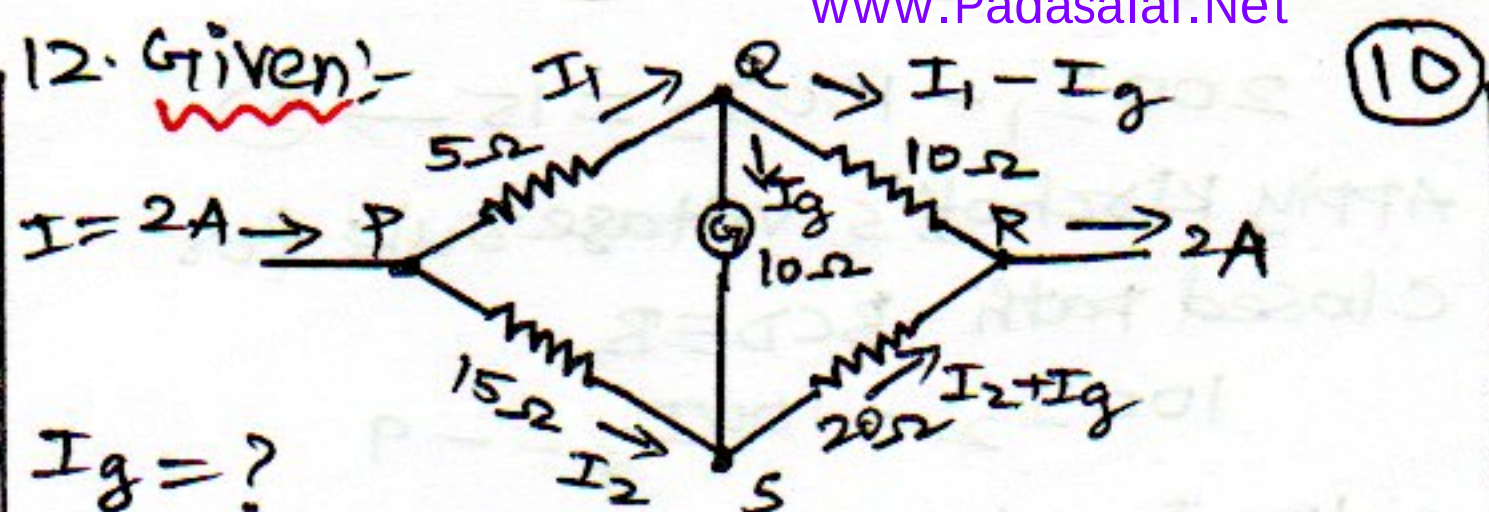
$$V = I r = \frac{4}{3000} \times 20 = \frac{4}{150} \text{ volt}$$

$\therefore$ Potential gradient, $E = \frac{V}{l} = \frac{4}{150} \times \frac{1}{4}$

$$E = \frac{1}{15 \times 10} = \frac{10 \times 10^{-2}}{15} = 0.66 \times 10^{-2} \text{ Vm}^{-1}$$

$$E = 0.66 \times 10^{-2} \text{ Vm}^{-1}$$

$$15 \left| \begin{array}{r} 0.66 \\ 100 \\ 90 \\ \hline 90 \\ 10 \end{array} \right|$$



$I_g = ?$

Solution:- Apply Kirchhoff's current rule at junction P, $I - I_1 - I_2 = 0$.

$$I - I_1 = I_2 \rightarrow (1)$$

Apply Kirchhoff's voltage rule for closed path PQSP, $5I_1 + 10I_g - 15I_2 = 0$.

From (1) $\Rightarrow 5I_1 + 10I_g - 15(I - I_1) = 0$.

$$5I_1 + 10I_g - 15I + 15I_1 = 0,$$

$$I = 2A, \therefore 20I_1 + 10I_g - 15 \times 2 = 0.$$

$$20I_1 + 10I_g = 30 \rightarrow (2)$$

Apply Kirchhoff's voltage rule for closed path QRSP,

$$10(I_1 - I_g) - 20(I_2 + I_g) - 10I_g = 0$$

$$10I_1 - 10I_g - 20I_2 - 20I_g - 10I_g = 0.$$

From (1) $\Rightarrow 10I_1 - 40I_g - 20(I - I_1) = 0$.

$$10I_1 - 40I_g - 20I + 20I_1 = 0.$$

$$I = 2A, \therefore 30I_1 - 40I_g - 20 \times 2 = 0$$

$$30I_1 - 40I_g = 40 \rightarrow (3)$$

$$(2) \times 3 \Rightarrow 60I_1 + 30I_g = 90$$

$$(3) \times 2 \Rightarrow 60I_1 - 80I_g = 80$$

$$110I_g = 10$$

$$I_g = \frac{1}{11} A$$

13.

$I = ?$

Solution:-

$$R_1 = 4\Omega, R_2 = 6\Omega,$$

$R_3 = 12\Omega$ are connected in parallel,

$$\therefore \frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{4} + \frac{1}{6} + \frac{1}{12} = \frac{3+2+1}{12}$$

$$\therefore R_p = 2\Omega$$

$$\frac{1}{R_p} = \frac{6}{12} \Omega$$

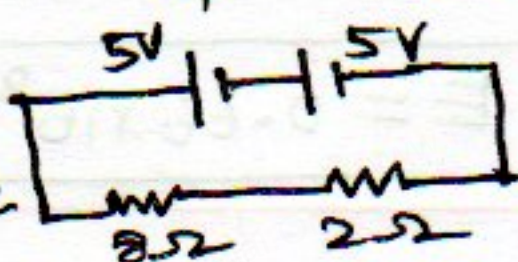
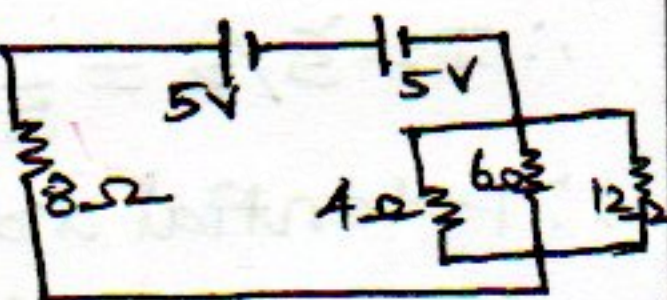
Now, 8Ω and 2Ω resistors are in series,

$$\therefore R_s = R + R_p = 8 + 2$$

$$R_s = 10\Omega.$$

$\therefore$ Two cells are connected in series,

$$\therefore E = E_1 + E_2 = 5 + 5 = 10 \text{ Volt.}$$



(10)

$\therefore$ current drawn from each cell,

$$I = \frac{E}{R_s} = \frac{10}{10} = 1 A$$

$\therefore$ potential difference through 8Ω resistor is, $V = IR$

$$V = 1 \times 8 = 8 \text{ volt.}$$

$\therefore$ Potential through 2Ω (net resistance in parallel),

$$V = IR = 1 \times 2 = 2 \text{ volt.}$$

(i) Current through 8Ω resistor,

$$I = \frac{V}{R} = \frac{8}{8} = 1 A ; \boxed{I = 1 A}$$

(ii) Current through $4\Omega, 6\Omega, 12\Omega$, $V = 2 \text{ Volt.}$

$$R = 4\Omega, I = \frac{V}{R} = \frac{2}{4} = 0.5 A //$$

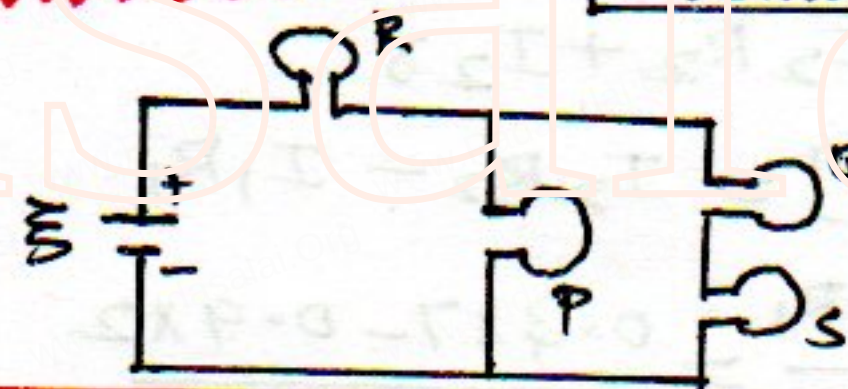
$$R = 6\Omega, I = \frac{2}{6} = 0.33 A //$$

$$R = 12\Omega, I = \frac{2}{12} = 0.166 A //$$

14.

	P	Q	R	S
P removed	x	ON	ON	ON
Q removed	ON	x	ON	OFF
R removed	off	off	x	off
S removed	on	off	on	x

Solution:-



15. Given:- $E_1 = 1.25V, E_2 = ? E = \frac{5}{4}V$
 $l_1 = 35 \times 10^{-2}m, l_2 = 63 \times 10^{-2}m.$

Solution:-

$$\frac{E_2}{E_1} = \frac{l_2}{l_1} ; E_2 = E_1 \times \frac{l_2}{l_1}$$

$$E_2 = \frac{5}{4} \times \frac{63 \times 10^{-2}}{35 \times 10^{-2}} = \frac{9 \times 2.25}{4}$$

$$\boxed{E_2 = 2.25 \text{ Volt}}$$

B.AROKIAARAJ, M.Sc., B.Ed.,
PGT in Physics, Neyveli TS.
Cell : 9487380576, 8667656700

(11)

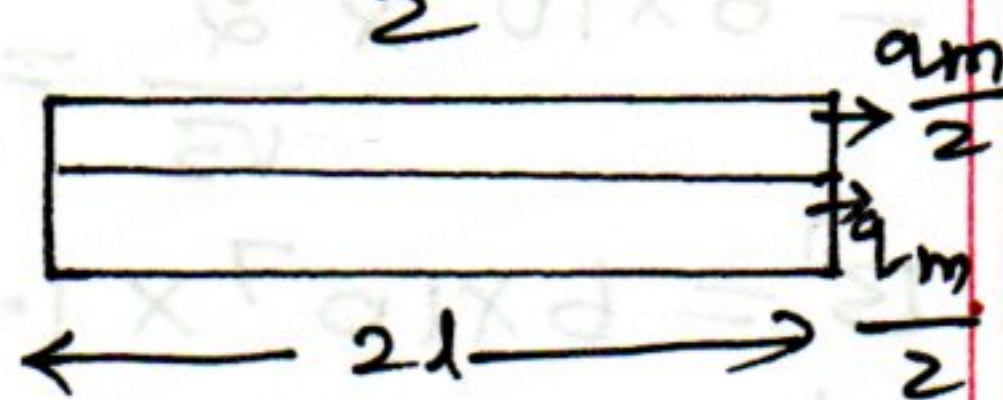
3. Magnetism and magnetic effects of electric current.

1. A bar magnet of magnetic moment $\vec{P}_m$. When a bar magnet first cut in two pieces along the axis, their magnetic moment is $\vec{P}_m' = \frac{\vec{P}_m}{2}$

$$\vec{P}_m' = q_m' \times 2l$$

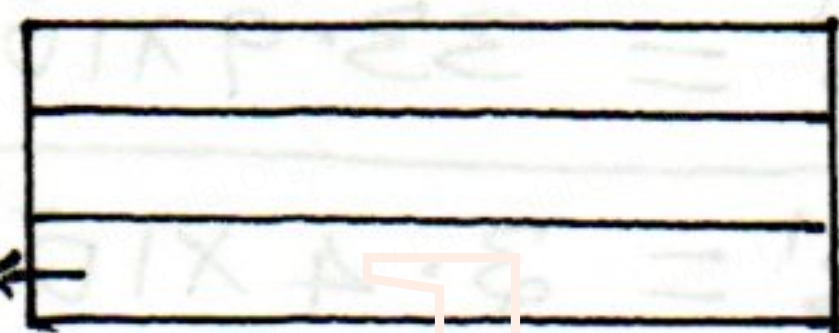
$$\vec{P}_m' = \frac{q_m}{2} \times 2l$$

$$\vec{P}_m' = \frac{\vec{P}_m}{2}$$



$$\therefore \vec{P}_m = q_m \times 2l$$

* Each piece is further cut into pieces.



$$\vec{P}_m'' = q_m'' \times 2l = \frac{q_m}{4} \times 2l$$

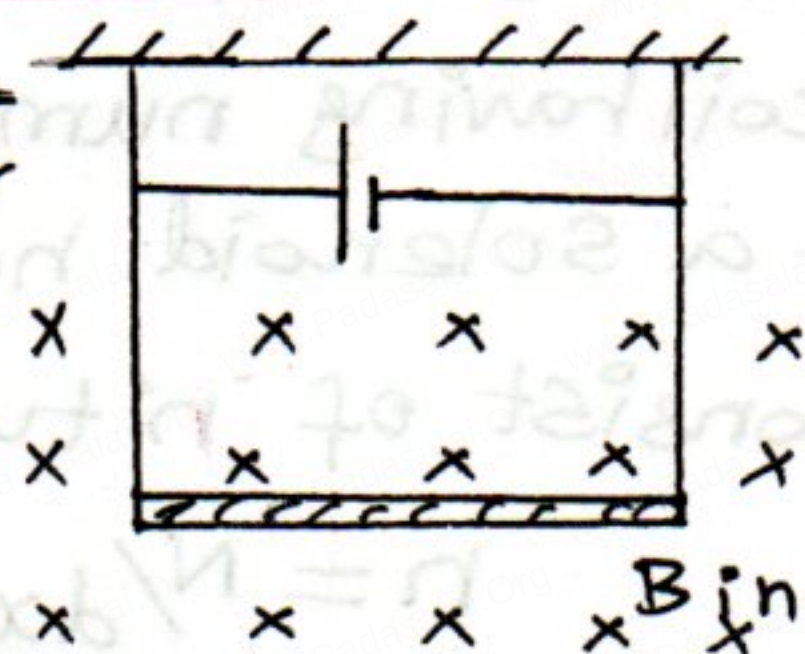
$$\vec{P}_m'' = \frac{\vec{P}_m}{4}$$

2. magnetic field, $B = 1T$

Downward force,

$$F = mg$$

Linear mass density



$$= \frac{m}{l} = 0.2 \times 10^{-3} \text{ kg m}^{-1}$$

$$m = \text{Linear mass density} \times l$$

$$m = 0.2 \times 10^{-3} \times l \quad (\because g = 10 \text{ m s}^{-2})$$

$$F = mg = 0.2 \times 10^{-3} \times l \times 10$$

$$F = 2 \times 10^{-3} l \rightarrow (1)$$

$$F = BIL = 1 \times I \times l \rightarrow (2)$$

This is upward magnetic force acting on the wire.

From (1) and (2)

$$I \times l = 2 \times 10^{-3} l; \quad \boxed{I = 2 \text{ mA}}$$

3. cross-sectional area of coil,

$$A = 0.1 \times (10^{-2} \text{ m})^2$$

$$A = 0.1 \text{ cm}^2$$

$$A = 0.1 \times 10^{-4} \text{ m}^2$$

$$n = 10^{28} \text{ m}^{-3}$$

$$B = 0.2 \text{ T}, I = 3 \text{ A}$$

$\therefore$ Angle between the magnetic field and normal to the coil, $\theta = 0^\circ$

(a) Total torque on the coil,

$$\tau = ABIn \sin \theta$$

$$= 0.1 \times 10^{-4} \times 0.2 \times 3 \times \sin 0^\circ$$

$$\boxed{\tau = 0}$$

$$(\because \sin 0^\circ = 0)$$

(b) Total force on the coil,

$$F = BIL \sin \theta$$

$$F = 0.2 \times 3 \times l \times \sin 0^\circ$$

$$\boxed{F = 0}$$

(c) Average force:

$$F = q v_d B, \text{ drift velocity,}$$

$$v_d = \frac{I}{n e A}$$

$$\therefore F = q \times \frac{I}{n e A} \times B$$

$$(\because q = e)$$

$$F = \frac{I B}{n A} = \frac{3 \times 0.2}{10^{28} \times 0.1 \times 10^{-4}}$$

$$F = 6 \times 10^{-24} \text{ N}, F = 0.6 \times 10^{-23} \text{ N}$$

4. $B = 0.8 \text{ T}, \theta = 30^\circ, \tau = 0.2 \text{ Nm}$

Solution! (i) $\tau = P_m B \sin \theta$

$$P_m = \frac{\tau}{B \sin \theta} = \frac{0.2}{0.8 \times \sin 30^\circ} = \frac{1}{4 \times \frac{1}{2}}$$

$$\boxed{P_m = 0.5 \text{ Am}^2}$$

(ii) In stable configuration work done by an applied force,

$$U_i = -P_m B \cos \theta$$



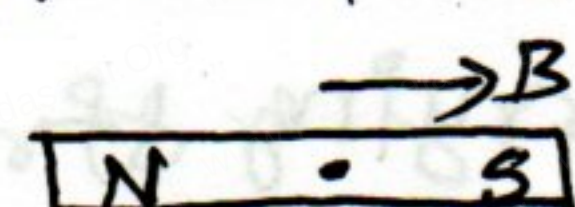
$$U_i = -P_m B \cos 0^\circ$$

$$\theta = 0^\circ, \cos 0^\circ = 1$$

$$U_i = -P_m B$$

(ii) In unstable configuration work done by an applied force,

$$U_f = -P_m B \cos \theta$$



$$U_f = -P_m B \cos 180^\circ$$

$$\theta = 180^\circ$$

$$U_f = P_m B$$

$$\cos 180^\circ = -1$$

Work done by applied magnetic field, $W = U_f - U_i$

$$= P_m B - (-P_m B)$$

$$W = 2 P_m B$$

$$W = 2 \times 0.5 \times 0.8$$

$$W = 0.8 \text{ J}$$

5.

Mass of the sphere, (m)

$$m = 100 \text{ g} = 100 \times 10^{-3} \text{ kg}$$

$$\text{Radius, } R = 20 \text{ cm} = 20 \times 10^{-2} \text{ m}$$

Number of turns, $n = 5$

uniform magnetic field, $B = 0.5 \text{ T}$
 $I = ?$ $B = \frac{1}{2} \text{ T}$

Solution:- At equilibrium,

$$f_s R - P_m B \sin \theta = 0.$$

$$f_s R = P_m B \sin \theta$$

$$mgR = N I A B$$

$$\theta = 90^\circ \quad \left[\begin{array}{l} P_m = I A, \\ \text{for } n \text{ turns} \\ P_m = N \times I A \end{array} \right]$$

$$I = \frac{mgR}{NBA} = \frac{mgR}{NB \times \pi R^2} = \frac{mg}{NB \cdot \pi R}$$

$$I = \frac{100 \times 10^{-3} \times 10}{5 \times \frac{1}{2} \times \pi \times 20 \times 10^{-2}}$$

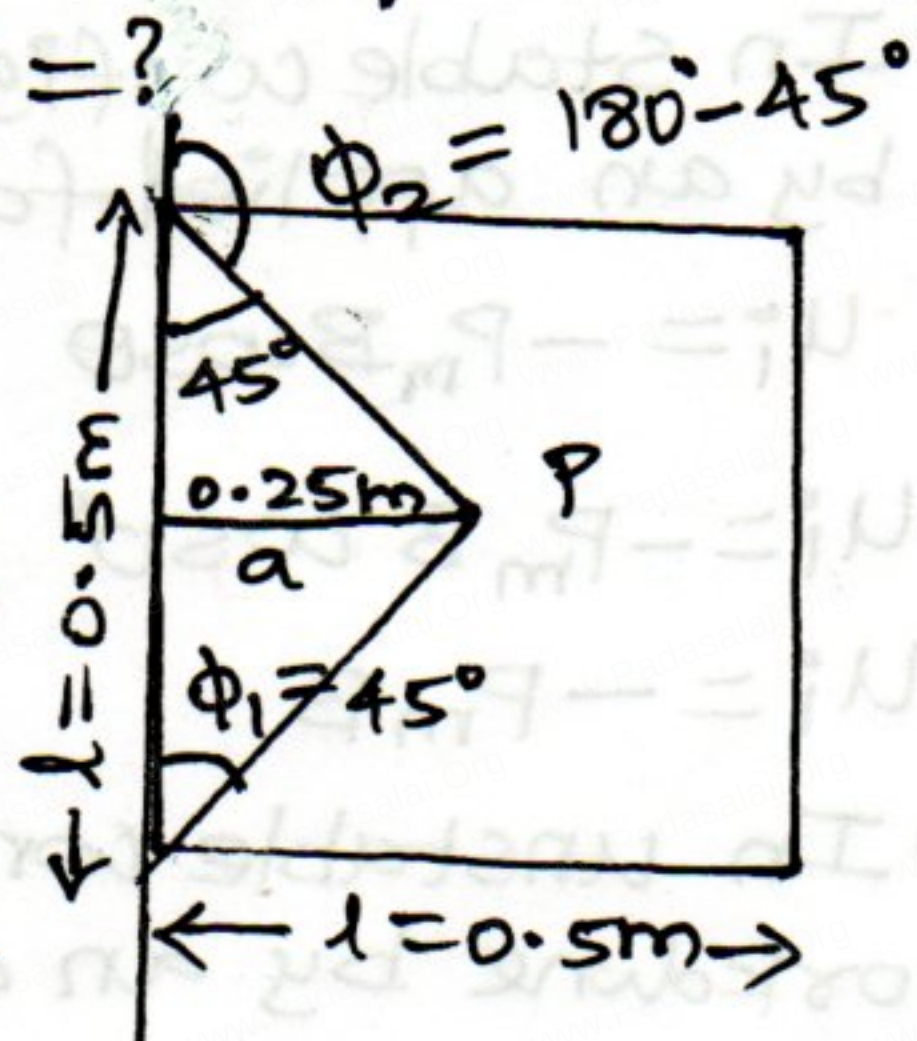
$$I = \frac{20 \times 10^{-1}}{\pi}, \quad \boxed{I = \frac{2}{\pi} \text{ A}}$$

b. $I = 1.5 \text{ A}$, length of each loop $l = 50 \text{ cm} = 0.5 \text{ m}$
 Magnetic field at the centre of current carrying square loop,

$$B' = ?$$

Solution:-

According to Biot-Savart law, Magnetic field due to a current carrying straight wire,



$$\textcircled{2} B' = \frac{\mu_0 I}{4\pi a} [\cos \phi_1 - \cos \phi_2]$$

$$= \frac{4\pi \times 10^{-7} \times 1.5}{4\pi \times 0.25} [\cos 45^\circ - \cos (180^\circ - 45^\circ)]$$

$$= 6 \times 10^{-7} [\cos 45^\circ + \cos 45^\circ]$$

$$= 6 \times 10^{-7} \times \left[\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}} \right] [\cos (180^\circ - \theta) = -\cos \theta]$$

$$= 6 \times 10^{-7} \times \frac{2}{\sqrt{2}} = 6 \times 10^{-7} \times \frac{\sqrt{2} \times \sqrt{2}}{\sqrt{2}}$$

$$B' = 6 \times 10^{-7} \times 1.414$$

$$B' = 8.484 \times 10^{-7} \text{ T}$$

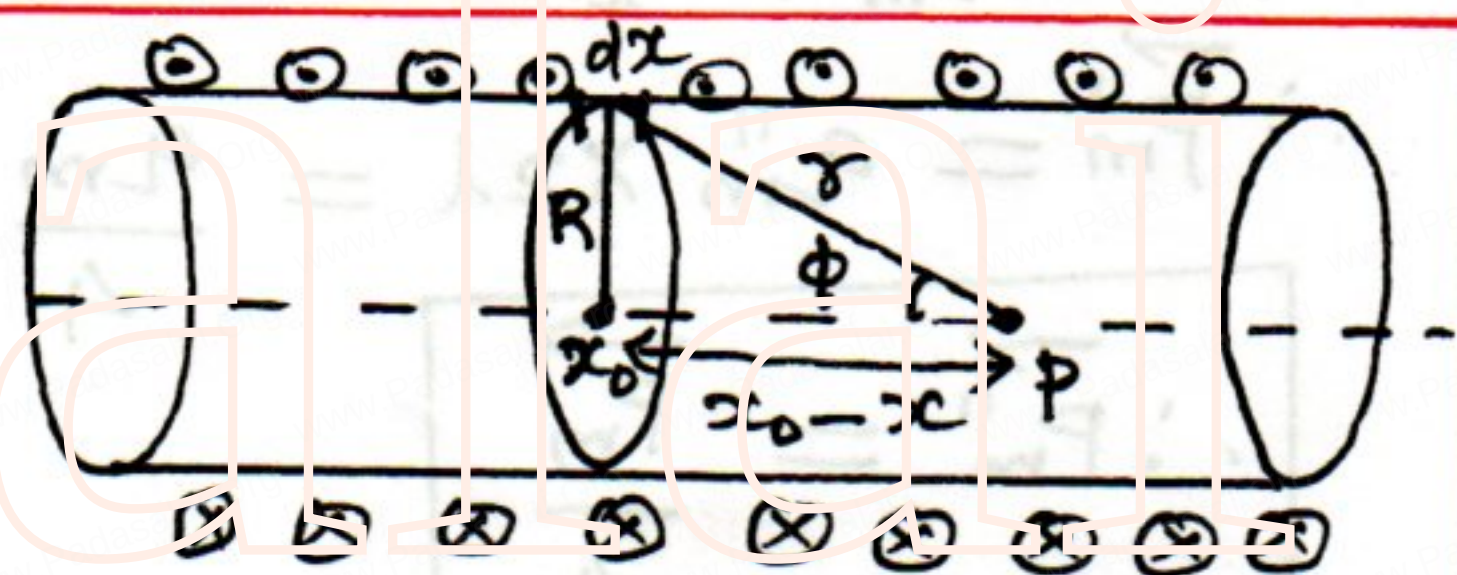
$\therefore$ For four sides,

$$B' = 4 \times 8.484 \times 10^{-7}$$

$$B' = 33.9 \times 10^{-7} = 3.39 \times 10^{-7}$$

$$\boxed{B' = 3.4 \times 10^{-7} \text{ T}}$$

6.



* A Solenoid is a long cylindrical coil having number of circular turns.
 * a solenoid having radius 'R' consist of 'n' turns per unit length
 $n = N/dx$; $N = ndx$

* Let 'P' be the point at a distance x_0 from the origin of the solenoid.
 * 'dx' be the current carrying element, 'r' distance from point P.
 $r^2 = R^2 + (x_0 - x)^2$; $r = \sqrt{R^2 + (x_0 - x)^2}$

The magnetic field due to current carrying circular coil at any point along the axis is $dB = \frac{\mu_0 I R^2}{2r^3} N$
 where, $N = ndx$

$$\therefore dB = \frac{\mu_0 n I R^2 dx}{2r^3} \rightarrow \textcircled{1}$$

$$\sin \phi = \frac{R}{r} ; r = \frac{R}{\sin \phi} = R \operatorname{cosec} \phi$$

$$\therefore r = R \operatorname{cosec} \phi \rightarrow (2)$$

$$\tan \phi = \frac{R}{x_0 - x} ; x_0 - x = \frac{R}{\tan \phi} = R \cot \phi$$

$$\frac{d(x_0 - x)}{d\phi} = \frac{d(R \cot \phi)}{d\phi}$$

$$\frac{dx}{d\phi} = -R \operatorname{cosec}^2 \phi \quad \left(\text{Here } x_0 \text{ is constant} \right)$$

$$\therefore dx = -R \operatorname{cosec}^2 \phi \cdot d\phi \rightarrow (3)$$

From (2) & (3), Eqn (1) becomes,

$$dB = \frac{\mu_0 n I}{2} \times \frac{R \operatorname{cosec}^2 \phi d\phi}{R \operatorname{cosec}^2 \phi}$$

$$dB = \frac{\mu_0 n I}{2} \sin \phi d\phi \quad \left[\sin \phi = \frac{1}{\operatorname{cosec} \phi} \right]$$

Now, total magnetic field can be obtained by integrating ϕ_1 to ϕ_2

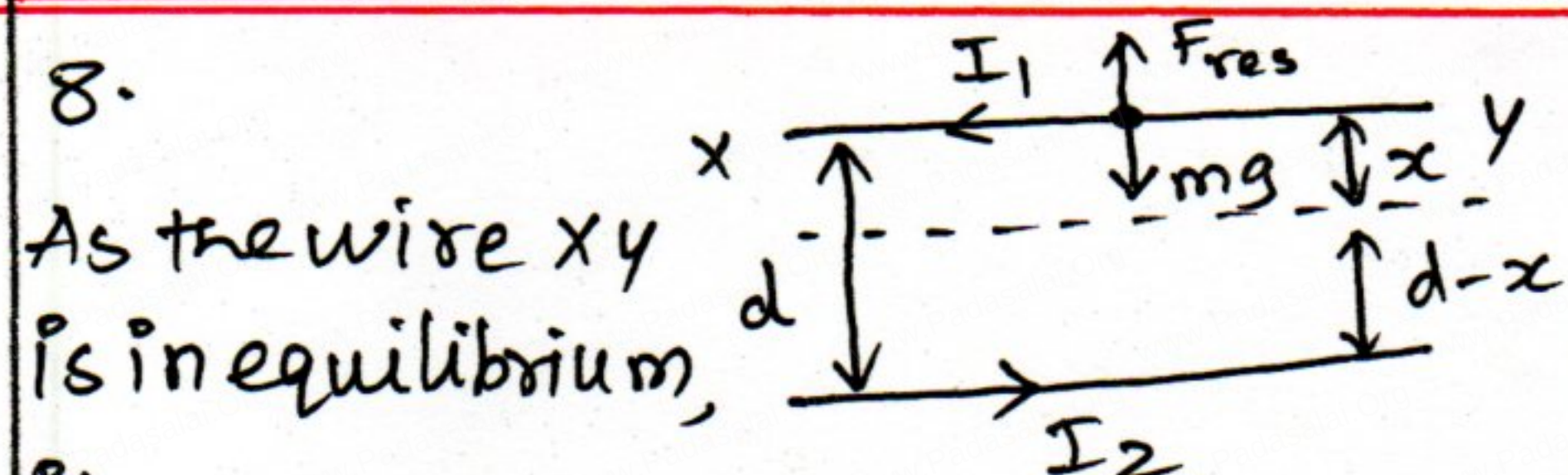
$$\int dB = \int_{\phi_1}^{\phi_2} \frac{\mu_0 n I}{2} \sin \phi d\phi$$

$$B = \frac{\mu_0 n I}{2} [-\cos \phi]_{\phi_1}^{\phi_2}$$

$$= \frac{\mu_0 n I}{2} [-\cos \phi_2 + \cos \phi_1]$$

$$B = \frac{\mu_0 n I}{2} [\cos \phi_1 - \cos \phi_2]$$

8.



As the wire xy is in equilibrium, it experiences an upward magnetic force which balances its weight acting downward (mg).

Let m and l be the mass and length of xy . I_1 and I_2 be currents in xy and PQ . ' d ' be the distance between xy and PQ at equilibrium.

(13): Force on current carrying wire xy due to PQ is

$$F = \frac{\mu_0}{2\pi} \frac{I_1 I_2 l}{d} ; F = mg$$

$$\therefore \frac{\mu_0}{2\pi} \frac{I_1 I_2 l}{d} = mg ; \frac{\mu_0 I_1 I_2 l}{2\pi} = mgd \rightarrow (1)$$

Let xy be depressed down a small distance x , the restoring (upward) force acting on xy is

$$F_{res} = - \left[\frac{\mu_0}{2\pi} \frac{I_1 I_2 l}{(d-x)} - mg \right] \rightarrow (2)$$

(-ve sign indicates that restoring force is acting opposite to displacement (x))
Using Eqn (1), Eqn (2) becomes,

$$F_{res} = - \left[\frac{mgd}{d-x} - mg \right]$$

$$F_{res} = -mg \left[\frac{d}{d-x} - 1 \right] = -mg \left[\frac{d - d + x}{d-x} \right]$$

$$\therefore F_{res} = - \frac{mgx}{d-x} \quad (d \gg x, \text{ hence } x \text{ can be neglected})$$

$$\therefore F_{res} = - \frac{mg}{d} x \quad (\because F = ma)$$

$$\therefore \text{acceleration, } a = - \frac{g}{d} x$$

$$\text{In SHM, } a = -\omega^2 x, \therefore \omega^2 = \frac{g}{d}$$

Since acceleration is proportional to displacement x and oppositely directed, the wire xy on being released, would execute SHM. Its time period is $T = \frac{2\pi}{\omega}$

$$\therefore T = 2\pi \sqrt{\frac{d}{g}}$$

B. AROKIA RAJ, M.Sc., B.Ed.,
PGT in Physics, Neyveli TS.
Cell : 9487380576, 8667656700

(14)

4. Electromagnetic Induction and Alternating current.

1. Given:- cross-sectional Area

$$A = 30 \times 10^2 \times 30 \times 10^2 \text{ m}^2$$

$$A = 900 \times 10^4 = 9 \times 10^6 \text{ m}^2$$

$B = 0.4 \text{ T}$, plane inclined to the field, $\theta = 30^\circ$

$$\therefore \theta = 90^\circ - 30^\circ = 60^\circ$$

$$N = 500 \text{ turns}, \phi_B = ?$$

Solution:-

$$\phi_B = NBA \cos \theta = 500 \times 0.4 \times 9 \times 10^6 \times \cos 60^\circ$$

$$\phi_B = 5 \times 10^2 \times 4 \times 10^1 \times 9 \times 10^6 \times \frac{1}{2}$$

$$\phi_B = 10 \times 10^1 \times 9, \quad \boxed{\phi_B = 9 \text{ Wb}}$$

2. Given:-

$$d\phi = 4 \text{ mWb}$$

change in magnetic flux, $d\phi = 4 \times 10^{-3} \text{ Wb}$

" time, $dt = 0.4 \text{ s} = 4 \times 10^{-1} \text{ s}$

$$E = ?$$

Solution:-

Magnitude of induced

$$\text{emf, } E = \frac{d\phi}{dt} = \frac{4 \times 10^{-3}}{4 \times 10^{-1}} = 10 \times 10^{-2} \text{ V}$$

$$\boxed{E = 10 \text{ mV}}$$

3. Given:- $\phi_B = (2t^3 + 4t^2 + 8t + 8) \text{ Wb}$

$$R = 5 \Omega, t = 3 \text{ s}$$

$$i = ?$$

$$\text{Solution:- } E = \frac{d\phi_B}{dt}$$

$$E = \frac{d}{dt} (2t^3 + 4t^2 + 8t + 8)$$

$$E = (6t^2 + 8t + 8)$$

$$t = 3 \text{ s}, E = 6 \times (3)^2 + 8 \times 3 + 8$$

$$E = 6 \times 9 + 24 + 8$$

$$E = 54 + 32 = 86 \text{ V}$$

$$\therefore \text{Induced current, } i = \frac{E}{R} = \frac{86}{5}$$

$$\boxed{i = 17.2 \text{ A}}$$

$$\frac{17.2}{5} = 3.44$$

4. Given:- radius, $r = 0.02 \text{ m}$
 $r = 2 \times 10^{-2} \text{ m}$

$$B_1 = 8000 \text{ T}, B_2 = 2000 \text{ T},$$

$$dt = 6 \text{ s}, E = 44 \text{ Volt.}$$

$$\theta = 0^\circ, N = ?$$

$$\text{Solution:- } E = \frac{d\phi_B}{dt}$$

$$E = \frac{NA(B_1 - B_2)}{t} \times \cos \theta$$

$$A = \pi r^2 = 3.14 \times (2 \times 10^{-2})^2$$

$$E = 44 \text{ Volt}, \theta = 0^\circ$$

$$\therefore 44 = \frac{N \times 3.14 \times 4 \times 10^{-4} \times \cos 0^\circ \times (8000 - 2000)}{6}$$

$$11 = \frac{N \times 3.14 \times 10^{-4} \times 1 \times 6000}{6}$$

$$11 = N \times 3.14 \times 10^{-1}$$

$$N = \frac{110}{3.14} = \frac{11 \times 10}{32/7} = 5 \times 7 = 35$$

$$\boxed{N = 35 \text{ turns}}$$

5. Given:- $A = 6 \text{ cm}^2 = 6 \times 10^{-4} \text{ m}^2$

$$N = 3500 = 35 \times 10^2 \text{ turns}, B = 0.4 \text{ T}$$

$$\theta_1 = 0^\circ, \theta_2 = 180^\circ, B = 4 \times 10^{-1} \text{ T}$$

$$t = 1 \text{ s}, R = 35 \Omega, q = ?$$

Solution:-

$$E = \frac{-d\phi}{dt} = \frac{NBA(\cos \theta_1 - \cos \theta_2)}{t}$$

(only considering magnitude)

$$E = \frac{35 \times 10^2 \times 4 \times 10^{-1} \times 6 \times 10^{-4} (\cos 0^\circ - \cos 180^\circ)}{1}$$

$$E = \frac{840 \times 10^{-3} \times (1 + 1)}{1} = 1680 \times 10^{-3} \text{ V}$$

$$i = \frac{E}{R} = \frac{1680 \times 10^{-3}}{35} = 48 \times 10^{-3} \text{ A}$$

$$q = it, \therefore \text{charge, } q = 48 \times 10^{-3} \times 1$$

$$q = 48 \times 10^{-3} \text{ C}, \quad \boxed{q = 48 \text{ mC}}$$

6. Given:- Induced current, $I = 2.5 \text{ mA}$
Resistance, $R = 100 \Omega$, $\frac{d\phi_B}{dt} = ?$

Solution:- $\frac{d\phi_B}{dt} = E$, $E = IR$

$$\frac{d\phi_B}{dt} = 2.5 \times 10^{-3} \times 100 = 250 \times 10^{-3}$$

$\therefore$ Rate of change of flux, $\frac{d\phi}{dt} = 250 \text{ mwb/s}$

7. Given:- $l = 0.4 \text{ m}$, $B = 4 \times 10^{-3} \text{ T}$
 $E = 0.02 \text{ V} = 2 \times 10^{-2} \text{ V}$, $\omega = ?$

$$\therefore \text{Area, } A = \pi r^2 = 3.14 \times (0.4)^2$$

Solution:- $E = NBA\omega \sin \theta$

$$[N=1, \theta=90^\circ, \sin 90^\circ=1]$$

$$\omega = \frac{E}{NBA \sin \theta} = \frac{2 \times 10^{-2}}{1 \times 4 \times 10^{-3} \times 3.14 \times (0.4)^2 \times \sin 90^\circ}$$

$$\omega = \frac{1.05}{2 \times 3.14 \times 0.16 \times 1}$$

$\omega = 9.95 \text{ revolutions per second.}$

$$\omega = 9.95 \text{ rps}$$

$$\log 5 \Rightarrow 0.6990$$

$$3.14 \Rightarrow 0.4969$$

$$0.16 \Rightarrow 1.2041$$

$$1.7010$$

$$0.6990$$

$$\text{Antilog } 1.7010 \Rightarrow 50.1189$$

$$9.954 \times 10^0 \approx 9.95$$

8. Given:- $l = 1 \text{ m}$, $B = 4 \times 10^{-5} \text{ T}$
Area, $A = \pi r^2 = 3.14 \times (1)^2 = 3.14 \text{ m}^2$
emf, $E = 31.4 \text{ mV} = 31.4 \times 10^{-3} \text{ V}$

$$\omega = ? \quad E = 3.14 \times 10^{-2} \text{ V.}$$

Solution:- $E = NBA\omega \sin \theta$

$$\omega = \frac{E}{NBA \sin \theta}, [N=1, \theta=90^\circ, \sin 90^\circ=1]$$

$$\omega = \frac{3.14 \times 10^{-2}}{1 \times 4 \times 10^{-5} \times 3.14 \times \sin 90^\circ}$$

$$\omega = \frac{1000}{4 \times 1} = 250 \text{ revolutions/s}$$

$$\omega = 250 \text{ rps}$$

9. $N = 4000 \text{ turns}$, $l = 2 \text{ m}$,
diameter, $d = 0.04 \text{ m}$, $r = 0.02 \text{ m}$
 $L = ?$, $A = \pi r^2$ $r = 2 \times 10^{-2} \text{ m}$

Solution:- $L = \mu_0 n^2 A l$, $n = \frac{N}{l}$

$$L = \frac{\mu_0 N^2 A}{l} = \frac{4\pi \times 10^{-7} \times (4000)^2 \times 3.14 \times (2 \times 10^{-2})^2}{2}$$

$$L = 2 \times 3.14 \times 10^{-7} \times 16 \times 10^6 \times 3.14 \times 4 \times 10^{-4}$$

$$L = 3.14 \times 3.14 \times 128 \times 10^{-5}$$

$$L = 1262.02 \times 10^{-5} \text{ H}$$

$$L = 12.62 \times 10^{-3} \text{ H}$$

$$L = 12.62 \text{ mH}$$

$$\begin{array}{r} 3.14 \Rightarrow 0.4969 \\ 3.14 \Rightarrow 0.4969 \\ 128 \Rightarrow 2.1072 \\ \hline \text{Antilog } 4.1010 \\ 1.262 \times 10^3 \end{array}$$

10. Given:- $N = 200 = 2 \times 10^2 \text{ turns}$,
 $I = 4 \text{ A}$, $\phi_B = 6 \times 10^{-5} \text{ wb}$, $U_B = ?$

Solution:-

$$U_B = \frac{1}{2} L I^2; \quad L I = N \phi_B, \quad L = N \phi_B / I$$

$$= \frac{1}{2} \times \frac{N \phi_B}{I} \times I^2 = \frac{1}{2} N \phi_B \times I$$

$$U_B = \frac{1}{2} \times 2 \times 10^2 \times 6 \times 10^{-5} \times 4$$

$$U_B = 24 \times 10^{-3} \text{ J}$$

$$\therefore U_B = 0.024 \text{ J}$$

11. Given:- $l = 50 \text{ cm} = 5 \times 10^{-1} \text{ m}$.

$$n = 400 \text{ turns per cm} = \frac{400}{10^{-2}} = 4 \times 10^4 \text{ turns}$$

diameter, $d = 0.04 \text{ m}$, radius, $r = 0.02 \text{ m}$.

$$\therefore \text{Area, } A = \pi r^2 = 3.14 \times (2 \times 10^{-2})^2 = 3.14 \times 4 \times 10^{-4} \text{ m}^2$$

$$A = 3.14 \times 4 \times 10^{-4} \text{ m}^2 = 12.56 \times 10^{-4} \text{ m}^2$$

$$\phi_B = ?$$

$$I = 1 \text{ A}$$

Solution:-

$$\phi_B = L I, \quad L = \mu_0 n^2 A l$$

$$\phi_B = \mu_0 n^2 A l \times I$$

$$= 4\pi \times 10^{-7} \times (4 \times 10^4)^2 \times 12.56 \times 10^{-4} \times 5 \times 10^{-1} \times 1$$

$$= 12.56 \times 10^{-12} \times 16 \times 10^8 \times 12.56 \times 5$$

$$= 12.56 \times 12.56 \times 80 \times 10^{-4}$$

$$= 1.262 \times 10^4 \times 10^{-4} \text{ wb}$$

$$\phi_B = 1.262 \text{ wb}$$

$$\begin{array}{r} 12.56 \Rightarrow 1.0990 \\ 12.56 \Rightarrow 1.0990 \\ 80 \Rightarrow 1.9031 \\ \hline \text{Antilog } 4.1011 \\ 1.262 \times 10^4 \end{array}$$

Then, the total flux linked with the coil, $N\phi_B = LI$.

$$N = n\lambda = \frac{400}{10^{-2}} \times 5 \times 10^{-1} = 2 \times 10^4 \text{ turns}$$

$$2 \times 10^4 \phi_B = 1.262 \times 10^{-4}$$

$$\therefore \phi_B = 0.631 \times 10^{-4} \text{ wb}$$

12. $N = 200 \text{ turns}$, $I = 0.4 \text{ A} = 4 \times 10^{-1}$

$$\phi_B = 4 \text{ mwb} \Rightarrow 4 \times 10^{-3} \text{ wb}, L = ?$$

Solution:- $N\phi_B = LI$, $L = \frac{N\phi_B}{I}$

$$\therefore L = \frac{200 \times 4 \times 10^{-3}}{4 \times 10^{-1}} \Rightarrow \boxed{L = 2 \text{ H}}$$

13. $\lambda = 80 \text{ cm} = 8 \times 10^{-1}$, $A = 5 \text{ cm}^2$

$$M = ?$$

$$N_1 = 1200 \text{ turns}, A = 5 \times 10^{-4} \text{ m}^2$$

$$N_1 = 12 \times 10^2, N_2 = 400 = 4 \times 10^2$$

Solution:- $M = \frac{\mu_0 N_1 N_2 A}{\lambda}$

$$M = \mu_0 n_1 n_2 A \lambda, \quad n_1 = \frac{N_1}{\lambda}, \quad n_2 = \frac{N_2}{\lambda}$$

$$\therefore M = \frac{4\pi \times 10^{-7} \times 12 \times 10^2 \times 4 \times 10^2 \times 5 \times 10^{-4}}{2 \times 8 \times 10^{-1}}$$

$$= 4 \times 3.14 \times 30 \times 10^{-6}$$

$$= 12.56 \times 3 \times 10^{-5}$$

$$M = 37.68 \times 10^{-5} \text{ H}$$

$$\therefore M = 0.3768 \times 10^{-3} \text{ H}$$

$$\therefore \boxed{M = 0.38 \text{ mH}}$$

14. $N_1 = \frac{400}{10^{-2}} = 400 \times 10^2 = 4 \times 10^4$

$$N_2 = 100 \Rightarrow 10^2, A = 4 \text{ cm}^2 = 4 \times 10^{-4} \text{ m}^2$$

$$I = 2 \text{ A}, t = 0.04 \text{ s} \Rightarrow 4 \times 10^{-2} \text{ s}$$

$$E = ?$$

Solution:- $E = -M \frac{dI}{dt} \rightarrow (1)$

$$M = \frac{\mu_0 n_1 n_2 A \lambda}{1} = \frac{\mu_0 N_1 N_2 A}{\lambda}$$

$$n_1 = \frac{N_1}{\lambda}, \quad n_2 = \frac{N_2}{\lambda}$$

(16) $M = \frac{4\pi \times 10^{-7} \times 4 \times 10^4 \times 10^2 \times 4 \times 10^{-4}}{1}$

$$= 4 \times 3.14 \times 16 \times 10^{-5} = 12.56 \times 16 \times 10^{-5}$$

$$M = 200.96 \times 10^{-5}, \quad M = 2 \times 10^{-3} \text{ H}$$

$$\therefore \boxed{M = 2 \text{ mH}}$$

$\therefore$ magnitude of emf, $E = M \frac{dI}{dt}$

$$E = 2 \times 10^{-3} \times \frac{2}{2 \times 10^{-2}} = 10^{-1} \text{ V}$$

$$\boxed{E = 0.1 \text{ V}}$$

15. $N_2 = 200$, $r = 2 \times 10^{-2} \text{ m}$, $A = \pi r^2$

$$N_1 = 90 \text{ turns/cm} = \frac{90}{10^{-2}} = 90 \times 10^2, \quad M = ?$$

Solution:-

$$M = \frac{\mu_0 N_1 N_2 A}{\lambda} \Rightarrow \frac{4\pi \times 10^{-7} \times 9 \times 10^3 \times 2 \times 10^2}{3.14 \times (2 \times 10^{-2})^2}$$

$$A = \pi r^2 = 3.14 \times (2 \times 10^{-2})^2$$

$$M = 4 \times 3.14 \times 18 \times 3.14 \times 4 \times 10^{-4} \times 10^2$$

$$= 12.56 \times 18 \times 12.56 \times 10^{-6}$$

$$M = 2.84 \times 10^{-3} \text{ H}$$

$$\boxed{M = 2.84 \text{ mH}}$$

$$12.56 \Rightarrow 1.0990$$

$$12.56 \Rightarrow 1.0990 (+)$$

$$18 \Rightarrow 1.2553$$

$$\text{Anti-log } 3.4533$$

$$2.84 \times 10^{-3}$$

16. Given:- $\mu_r = 900 = 9 \times 10^2$, $\lambda = 0.04 \text{ m}$

$$\text{Area, } A = 4 \text{ cm}^2 = 4 \times 10^{-4} \text{ m}^2, \quad \lambda = 4 \times 10^{-2} \text{ m}$$

$$N_1 = 200 = 2 \times 10^2 \text{ turns}, \quad N_2 = 800 = 8 \times 10^2$$

$$dI = I_2 - I_1 = 8 - 2 = 6 \text{ A}, \quad t = 0.04 \text{ s}$$

$$I_1 = 2 \text{ A}, \quad I_2 = 8 \text{ A}, \quad E_2 = ? \quad t = 4 \times 10^{-2} \text{ s}$$

Solution:-

The induced emf in solenoid 2 is

$$E_2 = -M \frac{dI}{dt}, \quad M = \frac{\mu_0 \mu_r N_1 N_2 A}{\lambda}$$

$$M = \frac{4\pi \times 10^{-7} \times 2 \times 10^2 \times 8 \times 10^2 \times 4 \times 10^{-4}}{4 \times 10^{-2}} \times 9 \times 10^2$$

$$= 4 \times 3.14 \times 16 \times 9 \times 10^{-3} / 12.56 \Rightarrow 1.0990$$

$$= 12.56 \times 144 \times 10^{-3} / 144 \Rightarrow 2.1584 (+)$$

$$M = 1.81 \times 10^{-3} \times 10^3$$

$$\boxed{M = 1.81 \text{ H}}$$

$$\text{Anti-log } 3.2574$$

$$1.809 \times 10^3$$

$$1.81 \times 10^3$$

$$\therefore E_2 = -M \frac{dI}{dt} = -1.81 \times 1.5 \times 10^{-2}$$

$$E_2 = -2.715 \times 10^{-2} \text{ V}$$

$$E_2 = -271.5 \text{ V}$$

$\therefore$ magnitude of emf

$$E = 271.5 \text{ V}$$

17. Given: $V_p = 220 \text{ V}$, $V_s = 11 \text{ V}$,
output power $= V_s I_s = 88 \text{ W}$
Solution: $k = ?$, $I_p = ?$

(i) Transformer Ratio $(k) = \frac{V_s}{V_p} = \frac{I_p}{I_s}$

$$k = \frac{1}{20}$$

(ii) $V_s I_s = 88$, $k \times I_s = 88$
 $I_s = 8 \text{ A}$,

$$\frac{I_p}{I_s} = \frac{V_s}{V_p}; I_p = \frac{V_s}{V_p} \times I_s$$

$$I_p = \frac{1}{220} \times 8^2 = 0.4 \text{ A}$$

$$\therefore I_p = 0.4 \text{ A} \quad (\text{or})$$

$$\frac{I_p}{I_s} = k; I_p = k \times I_s = \frac{1}{20} \times 8$$

$$I_p = 0.4 \text{ A}$$

18. Given: $V_p = 200 \text{ V}$, $V_s = 120 \text{ V}$,
 $\eta = 90\% = \frac{90}{100}$, $R_s = 40 \Omega$, $I_p = ?$

Solution: $V_s = I_s R_s$

$$I_s = \frac{V_s}{R_s} = \frac{120}{40} = 3 \text{ A}, \quad \therefore I_s = 3 \text{ A}$$

$$\therefore \eta = \frac{V_s I_s}{V_p I_p}; \frac{90}{100} = \frac{120 \times 3}{200 \times I_p}$$

$$I_p = 2 \text{ A}$$

19. Given: $N_p = 300$, $R_p = 0.82 \Omega$,
 $N_s = 1200$, $R_s = 6.2 \Omega$, $V_p = ?$, $V_s = 1600 \text{ V}$
output power $= V_s I_s = 32 \text{ kW} = 32 \times 10^3 \text{ W}$

$$I_p^2 R_p = ?$$

$$\eta = 80\%$$

$$I_s^2 R_s = ?$$

$$\eta = \frac{80}{100}$$

Solution: (i) $\frac{V_p}{V_s} = \frac{N_p}{N_s}$

$$V_p = \frac{N_p}{N_s} \times V_s = \frac{300}{1200} \times 1600; V_p = 400 \text{ V}$$

(ii) output power, $V_s I_s = 32 \times 10^3 \text{ W}$

$$I_s = \frac{32 \times 10^3}{1600} = 20 \text{ A}, \quad I_s = 20 \text{ A}$$

(iii) $\eta = \frac{V_s I_s}{V_p I_p}; \frac{80}{100} = \frac{1600 \times 20}{400 \times I_p}$

$$\therefore I_p = 100 \text{ A}$$

$\therefore$ Power loss in primary coil $= I_p^2 R_p$

$$\therefore I_p^2 R_p = (100)^2 \times 0.82 = 8200 \text{ W}$$

$$I_p^2 R_p = 8.2 \text{ kW} = 8.2 \times 10^3 \text{ W}$$

Power loss in secondary coil,

$$I_s^2 R_p = (20)^2 \times 6.2 = 4 \times 10^2 \times 6.2$$

$$= 24.8 \times 10^2$$

$$= 2.48 \times 10^3 \text{ W}$$

$$\therefore I_s^2 R_p = 2.48 \text{ kW}$$

20. $\theta = 60^\circ$, $i = ?$, $I_{\text{av}} = ?$, $I_{\text{rms}} = ?$

Solution:

$$I_m = 20 \text{ A}$$

(i) Instantaneous current, $i = I_m \sin \omega t$

$$\theta = \omega t, \quad i = 20 \sin 60^\circ = \frac{10 \times \sqrt{3}}{2}$$

$$i = 10 \times 1.732 = 17.32 \text{ A}$$

(ii) $I_{\text{average}} = \frac{2I_m}{\pi} = \frac{2 \times 20}{3.14}$

$$I_{\text{av}} = \frac{40}{3.14} = 1.275 \times 10^1$$

$$\therefore I_{\text{av}} = 12.75 \text{ A}$$

(iii) $I_{\text{rms}} = \frac{I_m}{\sqrt{2}} = 0.707 I_m = 0.707 \times 20$

$$I_{\text{rms}} = 14.14 \text{ A}$$

B. AROKIA RAJ, M.Sc., B.Ed.,
PGT in Physics, Neyveli TS.
Cell : 9487380576, 8667656700

5. ELECTRO MAGNETIC WAVES1. Given:- conduction current, $I_c = 5A$ Solution:- $I_d = ?$

Electric flux, $\phi_E = \frac{q}{\epsilon_0}$

$$\therefore I_d = \epsilon_0 \cdot \frac{d\phi_E}{dt} = \epsilon_0 \cdot \frac{d}{dt} \left(\frac{q}{\epsilon_0} \right)$$

$$I_d = \frac{dq}{dt} = \frac{d(I_c t)}{dt} \quad \begin{cases} I_c = q/t \\ q = I_c t \end{cases}$$

$$\therefore I_d = I_c \frac{dt}{dt}$$

$$\therefore I_d = I_c = 5A$$

2. Given:- $L = 1\text{mH} = 10^{-6}\text{H}$, $C = 1\text{MF} = 10^{-6}\text{F}$, $\lambda = ?$ Solution:-Wavelength of EM wave, $\lambda = \frac{c}{f}$

$$f = \frac{1}{2\pi\sqrt{LC}} \quad \begin{matrix} \text{Speed of light,} \\ c = 3 \times 10^8 \text{ ms}^{-1} \end{matrix}$$

$$\therefore \text{frequency, } f = \frac{1}{2 \times 3.14 \sqrt{10^{-6} \times 10^{-6}}}$$
$$f = \frac{1}{6.28 \times 10^{-6}} = \frac{10^6}{6.28} \text{ Hz}$$

$$\therefore \lambda = \frac{c}{f} = \frac{3 \times 10^8 \times 6.28}{10^6} = 18.84 \times 10^2$$

$$\therefore \lambda = 18.84 \times 10^2 \text{ m}$$

3. Given:- $t = 10^{-6}\text{s}$, Power = $60 \times 10^{-3}\text{W}$ momentum, $P = ?$ Solution:- Final momentum, $p = \frac{U}{c}$ Energy, $U = \text{power} \times \text{time}$ $c \Rightarrow \text{speed of light} = 3 \times 10^8 \text{ ms}^{-1}$

$$\therefore \text{Momentum, } p = \frac{60 \times 10^{-3} \times 10^{-6}}{3 \times 10^8}$$

$$P = 20 \times 10^{-17} \text{ kg ms}^{-1}$$

4. Given:- $f = 10^{10} \text{ Hz}$, $B_0 = 10^{-5} \text{ T}$, $\lambda = ?$ - Expression for $\vec{E} = ?$ $c = 3 \times 10^8 \text{ ms}^{-1}$ (speed of light).Solution:- (i) Wavelength, $\lambda = \frac{c}{f}$ (18)

$$\lambda = \frac{3 \times 10^8 \text{ ms}^{-1}}{10^{10} \text{ s}^{-1}} = 3 \times 10^{-2} \text{ m}; \quad \lambda = 3 \times 10^{-2} \text{ m}$$

(ii) Amplitude of oscillating electric field,

$$E_0 = c B_0 = 3 \times 10^8 \times 10^{-5} = 3 \times 10^3 \text{ NC}^{-1}$$

Expression for Electric field in EM wave, $E = E_0 \sin(kx - \omega t)$.

$$k = \frac{2\pi}{\lambda} = \frac{2 \times 3.14}{3 \times 10^{-2}} = \frac{6.28 \times 10^2}{3} = 2.09 \times 10^2$$

$$\omega = 2\pi f = 2 \times 3.14 \times 10^{10} = 6.28 \times 10^{10}$$

$$\vec{E} = 3 \times 10^3 \sin(2.09 \times 10^2 x - 6.28 \times 10^{10} t) \hat{i}$$

(unit $\Rightarrow \text{NC}^{-1} \hat{i} \leftarrow \text{NC}^{-1}$)

5. Given:- relative permeability, $\mu_r = 1.0$
relative permittivity of the medium, $\epsilon_r = 2.25$ Solution:- $v = ?$

Speed of Electromagnetic wave

in vacuum (or) Free space, $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$ $\therefore$ Speed of EM wave in medium, $v = \frac{1}{\sqrt{\mu \epsilon}}$

$$\mu = \mu_0 \mu_r, \quad \epsilon = \epsilon_0 \epsilon_r$$

$$\therefore v = \frac{1}{\sqrt{\mu_0 \mu_r \times \epsilon_0 \epsilon_r}} = \frac{c}{\sqrt{\mu_r \epsilon_r}} = \frac{3 \times 10^8}{\sqrt{1 \times 2.25}}$$

$$v = \frac{3 \times 10^8}{1.5} = 2 \times 10^8 \text{ ms}^{-1}$$

$$\therefore v = 2 \times 10^8 \text{ ms}^{-1}$$

B.AROKIA RAJ, M.Sc., B.Ed.,
PGT in Physics, Neyveli TS.
Cell : 9487380576, 8667656700

PLUS TWO

PHYSICS

VOLUME-2 (PROBLEMS SOLUTION)

UNIT-6

OPTICS

1. Given:- focal length, $f=20\text{cm}$
 object distance, $u=?$
 magnification, $m=4$

Solution:-

Using Len's equation

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\text{magnification, } m = \frac{v}{u}$$

$$4 = \frac{v}{u} ; v = 4u$$

$$\frac{1}{4u} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1-4}{4u} = \frac{1}{f} ; \frac{-3}{4u} = \frac{1}{f}$$

$$\therefore u = \frac{-3f}{4} = \frac{-3 \times 20\text{cm}}{4}$$

$$\therefore \boxed{u = -15\text{cm}}$$

2. Given:- magnification, $m=30$

$f_e = 5\text{cm}$, least distance of distinct vision, $D=25\text{cm}$

magnification due to objective, $m_o=?$

Solution:-

total magnification in near

point is $m = m_o m_e$

$$\therefore m_e = \left(1 + \frac{D}{f_e}\right) = \left(1 + \frac{25}{5}\right)$$

$$\therefore m_e = 6$$

$$\therefore m_o = \frac{m}{m_e} = \frac{30}{6}, \boxed{m_o = 5}$$

3. Given:- concave mirror of focal length, $f = -20\text{cm}$, image, $v = -3u$,

Two possible distance of the object $u=?$

Solution:- (i) For real image, magnification, $m = -3$, $m = \frac{v}{u}$
 $\therefore -3 = \frac{v}{u} ; v = 3u$

Using mirror equation

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

$$\frac{1}{-20} = \frac{1}{3u} + \frac{1}{u} \quad u = -26.67\text{cm}$$

$$\frac{1}{-20} = \frac{4}{3u} ; \therefore \boxed{u = -\frac{80}{3}\text{cm}}$$

(ii) For virtual image,

$$m = +3, +3 = \frac{v}{u}$$

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \quad \therefore v = -3u$$

$$\frac{1}{-20} = \frac{1}{-3u} + \frac{1}{u} ; \frac{1}{-20} = \frac{2}{3u}$$

$$\therefore \boxed{u = -\frac{40}{3}\text{cm}}, u = -13.33\text{cm}$$

4. Given:- depth, $d = 80\text{cm}$
 Area, $A=?$ $d = 8 \times 10^{-1}\text{m}$
 $n = 1.33 = \frac{4}{3}$

Solution:-

Area of the surface, $A = \pi R^2$

Radius of illumination, $R = \frac{d}{\sqrt{n^2 - 1}}$

squaring on both sides

$$R^2 = d^2 / n^2 - 1$$

$$\therefore R^2 = \frac{(8 \times 10^{-1})^2}{(4/3)^2 - 1} = \frac{64 \times 10^{-2}}{\frac{16}{9} - 1}$$

$$R^2 = \frac{64 \times 10^{-2} \times 9}{7} = \frac{576 \times 10^{-2}}{7}$$

$$\begin{array}{r} 82.2 \\ 7 \overline{) 576} \\ \underline{56} \\ 16 \\ \underline{14} \\ 20 \end{array}$$

$$\therefore R^2 = 82.28 \times 10^{-2}$$

$$R^2 = 0.8228 \text{ m}^2$$

$$\therefore \text{Area, } A = \pi R^2 = 3.14 \times 0.823$$

$$\therefore A = 2.6 \text{ m}^2$$

$$\log 3.14 \Rightarrow 0.4969$$

$$0.823 \Rightarrow 0.9154$$

$$\text{Antilog } 0.4123$$

$$2.6 \approx 2.584 \times 10^0$$

5. Given:-

$n_g = n_2 = 1.5$, Power $P = \frac{1}{f} = +5 \text{ D}$
For divergent lens
 $f = 100 \text{ cm} = 1 \text{ m}$, $n = ?$

Solution:-

Using lens makers formula,

$$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1 \right) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$5 = \left(\frac{1.5}{1} - 1 \right) \left[\frac{1}{R_1} - \frac{1}{R_2} \right]$$

$$5 = 0.5 \left(\frac{1}{R_1} - \frac{1}{R_2} \right) \rightarrow \textcircled{1}$$

$$\therefore f = 100 \text{ cm} = 1 \text{ m}$$

$$-1 = \left(\frac{1.5}{n_1} - 1 \right) \left[\frac{1}{R_1} - \frac{1}{R_2} \right] \rightarrow \textcircled{2}$$

$$\frac{5}{-1} = \frac{0.5}{\left(\frac{1.5}{n_1} - 1 \right)} \quad \left| \quad \frac{7.5}{n_1} = 4.5 \right.$$

$$5 \times \left(\frac{1.5}{n_1} - 1 \right) = -0.5 \quad \left| \quad n_1 = \frac{7.5}{4.5} \right.$$

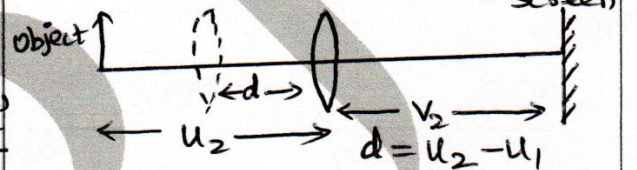
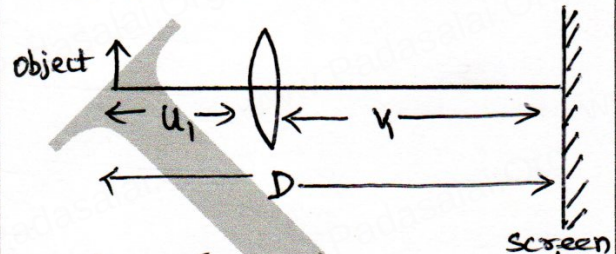
$$\frac{7.5}{n_1} - 5 = -0.5 \quad \left| \quad n_1 = \frac{7.5 \times 10}{4.5 \times 10} \right.$$

$$n_1 = \frac{75}{45} = \frac{5}{3}$$

$$n_1 = n ; \quad \boxed{n = 5/3}$$

6. Solution:-

Conjugate foci method



$$u_1 = -u, \quad v_1 = D - u_1 = D + u$$

$$\text{using lens law, } \frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f}$$

$$\frac{1}{D - u} - \frac{1}{-u} = \frac{1}{f}$$

$$\frac{-u - D + u}{-(D - u)u} = \frac{1}{f}$$

$$\frac{-D}{-Du + u^2} = \frac{1}{f}$$

$$-Df = -Du + u^2$$

$$u^2 - Du + Df = 0$$

using quadratic eqn

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$a = 1; \quad b = -D, \quad c = Df, \quad x = u$$

$$u = \frac{D \pm \sqrt{D^2 - 4Df}}{2}$$

$$\therefore u_1 = \frac{D + \sqrt{D^2 - 4Df}}{2}, u_2 = \frac{D - \sqrt{D^2 - 4Df}}{2}$$

$$\therefore d = u_2 - u_1$$

$$d = \frac{D - \sqrt{D^2 - 4Df}}{2} - \frac{D + \sqrt{D^2 - 4Df}}{2}$$

$$d = \frac{D}{2} - \frac{\sqrt{D^2 - 4Df}}{2} - \frac{D}{2} - \frac{\sqrt{D^2 - 4Df}}{2}$$

$$d = - \frac{2\sqrt{D^2 - 4Df}}{2}$$

squaring on both sides,

$$d^2 = D^2 - 4Df$$

$$4Df = D^2 - d^2$$

$$f = \frac{D^2 - d^2}{4D}$$

7. Given:- $\lambda = 600 \text{ nm}$

$$d = 1 \text{ mm}, \lambda = 600 \times 10^{-9} \text{ m} = 6 \times 10^{-7} \text{ m}$$

$$d = 1 \times 10^{-3} \text{ m}, D = 2 \text{ m}, y = ?$$

Solution:-

(Distance between the first dark fringe on either side of the central bright fringe is also called width of central maximum)

$$\therefore 2y = 2 \frac{D \lambda}{d}$$

$$2y = \frac{2 \times 2 \times 6 \times 10^{-7}}{1 \times 10^{-3}}$$

$$2y = 24 \times 10^{-4} \text{ m}$$

$$\therefore 2y = 2.4 \times 10^{-3} \text{ m}$$

$$\therefore 2y = 2.4 \text{ mm}$$

8. Given:- $d = 2 \text{ mm} = 2 \times 10^{-3} \text{ m}$

$$\lambda_0 = 750 \text{ nm} = 750 \times 10^{-9} \text{ m}, D = 2 \text{ m}$$

$$\lambda = 900 \text{ nm} = 9 \times 10^{-7} \text{ m}$$

$$y_n = ?$$

Solution:-

* n^{th} order of bright fringe (1) coincides with $(n+1)^{\text{th}}$ order of bright fringe (2)

$$\therefore y_n = n \frac{D \lambda}{d}$$

$$n \lambda \frac{D}{d} = (n+1) \lambda_0 \frac{D}{d}$$

$$\frac{\lambda}{\lambda_0} = \frac{n+1}{n}, \frac{\lambda}{\lambda_0} = 1 + \frac{1}{n}$$

$$\frac{6 \times 10^{-7}}{7.5 \times 10^{-7}} - 1 = \frac{1}{n}, \frac{1}{n} = \frac{1}{5}$$

$$\therefore n = 5$$

$$\therefore y_n = \frac{5 \times 9 \times 10^{-7}}{2 \times 10^{-3}} = 4.5 \times 10^{-4} \text{ m}$$

$$y_n = 4.5 \text{ mm}$$

9. Given:- $n_1 = 62$ fringes.

$$\lambda_1 = 5893 \text{ \AA}, \lambda_2 = 4359 \text{ \AA}$$

$$n_2 = ?$$

Solution:-

$$y_n = n \frac{\lambda D}{d}$$

$$n_1 \lambda_1 = n_2 \lambda_2$$

$$n_2 = \frac{n_1 \lambda_1}{\lambda_2} = \frac{62 \times 5893 \text{ \AA}}{4359 \text{ \AA}}$$

$$n_2 = 84 \text{ fringes}$$

$$\begin{array}{r}
 \log 62 \Rightarrow 1.7924 \\
 5893 \Rightarrow 3.7703^{(+)} \\
 \underline{5.5627} \\
 4359 \Rightarrow 3.6394^{(-)} \\
 \underline{1.9233} \\
 \text{Antilog } 3.381 \times 10^1 \\
 8.4 \times 10^1
 \end{array}$$

10. Given:- $m = 100, f_o = 0.5 \text{ cm}$
 $f_e = ?$ $L = 6.5 \text{ cm}$
Solution:- $D = 25 \text{ cm}$.

Since the image is formed at infinity, the real image produced by the objective lens should be lie on the focus of the eyepiece.

$$\therefore v_o + f_e = 6.5 \text{ cm} \rightarrow (1)$$

$\therefore$ The magnifying power for normal focusing is $m = \frac{v_o}{u_o} \times \frac{D}{f_e}$

$$m = - \left[1 - \frac{v_o}{f_o} \right] \frac{D}{f_e}$$

$$100 = - \left[1 - \frac{v_o}{0.5} \right] \times \frac{25}{f_e}$$

$$100 = - \frac{25}{f_e} + \frac{25 v_o}{0.5 f_e}$$

$$100 = \frac{-25 + 50 v_o}{f_e}$$

$$100 f_e = -25 + 50 v_o$$

$$50 v_o - 100 f_e = 25 \text{ cm}$$

$$\div 25 \Rightarrow 2 v_o - 4 f_e = 1 \text{ cm} \rightarrow (2)$$

Solving the eqns (1) & (2)

$$2 \times 1 \Rightarrow 2 v_o + 2 f_e = 1 \text{ cm}$$

$$\rightarrow \cancel{2 v_o} + 4 f_e = 1 \text{ cm}$$

$$\cancel{4 f_e} = \cancel{1} \text{ cm}$$

$$f_e = 2 \text{ cm}$$

$$(1) \Rightarrow v_o + 2 \text{ cm} = 6.5 \text{ cm}$$

$$v_o = 4.5 \text{ cm}$$

$\therefore$ focal length of the eyepiece is $f_e = 2 \text{ cm}$

UNIT 7 Dual Nature of Radiation and Matter

1. Given:- Power, $P = 50 \text{ mW} = 50 \times 10^{-3} \text{ W}$
 $\lambda = 640 \text{ nm} = 640 \times 10^{-9} \text{ m} = 6.4 \times 10^{-7} \text{ m}$
 $n_{\text{photon}}/t = ?$

Solution:-

The energy of each photon is

$$E_p = h\nu = \frac{hc}{\lambda} \quad (\nu = c/\lambda)$$

$\therefore$ The number of photons emitted per second = $\frac{P}{E_p}$

$$\therefore \frac{n_p}{t} = \frac{P}{E_p} = \frac{P\lambda}{hc}$$

$$\frac{n_p}{t} = \frac{50 \times 10^{-3} \times 6.4 \times 10^{-7}}{6.626 \times 10^{-34} \times 3 \times 10^8}$$

$$= \frac{320 \times 10^{16}}{19.878} \quad \log 320 \Rightarrow 2.5052$$

$$19.878 \Rightarrow 1.2982$$

$$\frac{n_p}{t} = 1.61 \times 10^{17} \text{ s}^{-1}$$

2. Given:- $K.E_{\text{max}} = eV_0 = ?$

$$V_{\text{max}} = ? \quad V_0 = 81 \text{ V}$$

Solution:-

$$(i) K.E_{\text{max}} = eV_0 = 1.6 \times 10^{-19} \times 81$$

$$K.E_{\text{max}} = 129.6 \times 10^{-19} \text{ J}$$

$$= 1.296 \times 10^{-17} \text{ J}$$

$$\therefore K.E_{\text{max}} = 1.3 \times 10^{-17} \text{ J}$$

$$(ii) \frac{1}{2} m v_{\text{max}}^2 = K.E_{\text{max}}$$

$$v_{\text{max}}^2 = \frac{K.E_{\text{max}} \times 2}{m}$$

$$V_{\text{max}} = \sqrt{\frac{2 K.E_{\text{max}}}{m_e}}$$

$$V_{\text{max}} = \sqrt{\frac{2 \times 1.3 \times 10^{-17}}{9.1 \times 10^{-31}}}$$

$$= \sqrt{\frac{2.6 \times 10^{14}}{9.1}} \quad \log 2.6 \Rightarrow 0.4150$$

$$9.1 \Rightarrow 0.9590$$

$$= 10^7 \sqrt{\frac{2.6}{9.1}} \quad \text{Antilog } 1.4560$$

$$T.7280 \Rightarrow 5.346 \times 10^6$$

$$V_{\text{max}} = 5.35 \times 10^6 \text{ m/s}$$

3. Given:- $E = ?$

For (i) Violet $\lambda = 413 \text{ nm} = 413 \times 10^{-9} \text{ m}$

(ii) x-rays $\lambda = 0.1 \text{ nm}$, (iii) Radio waves

Solution:-

$\lambda = 10 \text{ m}$

Energy of the photon, $E = h\nu = \frac{hc}{\lambda}$

(i) For violet

$$E = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{413 \times 10^{-9}} \text{ J}$$

$$= \frac{19.878 \times 10^{-17}}{413 \times 10^{-9}} \text{ eV}$$

$$= \frac{19.878 \times 10^2}{413} \text{ eV}$$

$$= \frac{19.878 \times 10^2}{413} \text{ eV}$$

$$19.878 \Rightarrow 1.2982$$

$$413 \Rightarrow 2.6150$$

$$E = 3 \text{ eV}$$

(ii) For x-rays

$$E = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{0.1 \times 10^{-9}} \text{ J}$$

$$E = \frac{19.878 \times 10^{-17}}{0.1 \times 10^{-9}} \text{ eV}$$

$$E = \frac{19.878 \times 10^2}{0.1} \text{ eV}$$

$$E = 1.9878 \times 10^4 \text{ eV}$$

$$E = 1.242 \times 10^4 \text{ eV}$$

$$E = 12420 \text{ eV}$$

(iii) For Radio waves

$$E = \frac{19.878 \times 10^{-17}}{10 \times 1.6 \times 10^{-19}} \text{ eV} = \frac{19.878 \times 10^{-7}}{16}$$

$$E = 1.242 \times 10^{-7} \text{ eV}$$

B. Arokia Raj, M.Sc., B.Ed., Neyveli Township, Cell: 9487380576, 8667656700

$$\log 19.878 \Rightarrow 1.2982$$

$$16 \Rightarrow 1.2041$$

$$\text{Antilog } 0.0941$$

$$1.242 \times 10^0$$

6

4. Given:- Power, $P = 150 \text{ W}$,
 $\lambda = 5500 \text{ \AA} = 5500 \times 10^{-10} \text{ m}$,
 efficiency $\eta = 12\% = \frac{12}{100}$, $\frac{n_p}{t} = ?$

Solution:- For 12% of efficiency,
 number of photons
 emitted per second, $\frac{n_p}{t} = \frac{P}{E_p} \times \eta$

Energy of photon, $E_p = h\nu = \frac{hc}{\lambda}$

$$\therefore \frac{n_p}{t} = \frac{150 \times 5500 \times 10^{-10} \times 12}{6.626 \times 10^{-34} \times 3 \times 10^8 \times \frac{1}{100}} = \frac{P \times \lambda}{hc} \times \eta$$

$$= \frac{1800 \times 55 \times 10^{16}}{19.878} = \frac{99000}{19.878} \Rightarrow 4.982 \times 10^{19} \text{ photons}$$

$$\frac{n_p}{t} = 4.98 \times 10^{19} \text{ photons}$$

5. Given:- $n_p = ?$, $\nu = 10^{14} \text{ Hz}$,
 $E = 19.86 \text{ eV}$

Solution:- $E = nh\nu$; $n = \frac{E}{h\nu}$

$$\therefore n_p = \frac{19.86}{6.626 \times 10^{-34} \times 10^{14}} = \frac{19.86}{6.626} \times 10^{20}$$

$$n_p = \frac{19.86 \times 10^{20}}{6.626} = \frac{19.86}{6.626} \times 10^{20} \Rightarrow 2.997 \times 10^{20}$$

$$\therefore n_p = 3 \times 10^{20} \text{ Photons}$$

6. Given:- $\nu = ?$, $\lambda = 4000 \text{ \AA}$

Solution:- $\lambda = 4 \times 10^{-7} \text{ m}$, $P = mv$

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

$$\therefore \nu = \frac{h}{m\lambda} = \frac{6.626 \times 10^{-34}}{9.1 \times 10^{-31} \times 4 \times 10^{-7}}$$

$$\nu = \frac{6.626 \times 10^4}{36.4} = 1.821 \times 10^3 \text{ ms}^{-1}$$

$$\nu = 1.821 \times 10^3 \text{ ms}^{-1}$$

$$\nu = 1821 \text{ ms}^{-1}$$

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7. Given:- $\nu = 9 \times 10^{14} \text{ Hz}$,
 $\nu = 8 \times 10^5 \text{ ms}^{-1}$

Solution:- $\nu_0 = ?$
 Einstein's photoelectric equation

$$h\nu = h\nu_0 + \frac{1}{2} m v_{\text{max}}^2$$

$$h\nu_0 = h\nu - \frac{1}{2} m v_{\text{max}}^2$$

$$h\nu_0 = 6.626 \times 10^{-34} \times 9 \times 10^{14} - \frac{1}{2} \times 9.1 \times 10^{-31} \times (8 \times 10^5)^2$$

$$= 59.634 \times 10^{-20} - 9.1 \times 10^{-31} \times 64 \times 10^{10}$$

$$= 59.634 \times 10^{-20} - 29.12 \times 10^{-20}$$

$$h\nu_0 = 30.514 \times 10^{-20} \text{ J}$$

$$\nu_0 = \frac{30.514 \times 10^{-20}}{h}$$

$$\nu_0 = \frac{30.514 \times 10^{-20}}{6.626 \times 10^{-34}}$$

$$\nu_0 = \frac{30.514 \times 10^{14}}{6.626}$$

$$\nu_0 = 4.6 \times 10^{14} \text{ Hz}$$

$$\nu_0 = 4.6 \times 10^{14} \text{ Hz}$$

8. $\lambda = 6000 \text{ \AA} = 6 \times 10^{-7} \text{ m}$, $\nu_0 = 0.8 \text{ V}$

Given:- (i) $\nu = ?$, $E = ?$, $\phi_0 = ?$, $\nu_0 = ?$

Solution:- net $E = ?$

(i) Frequency, $\nu = \frac{c}{\lambda}$

$$\nu = \frac{3 \times 10^8}{6 \times 10^{-7}} = 0.5 \times 10^{15} \text{ Hz}$$

(ii) Energy, $E = h\nu = 6.626 \times 10^{-34} \times 5 \times 10^{14}$

$$E = \frac{33.13 \times 10^{-20}}{1.6 \times 10^{-19}} \text{ eV}$$

$$= \frac{33.13}{1.6} \times 10^{-1} \text{ eV}$$

$$= 2.07 \text{ eV}$$

$$[E = 2.07 \text{ eV}]$$

(iii) work function (ϕ_0):

$$\phi_0 = h\nu - K \cdot E_{\text{max}} \quad (e\nu_0 = K \cdot E_{\text{max}})$$

$$\phi_0 = h\nu - e\nu_0$$

$$\phi_0 = 2.07 \text{ eV} - \frac{1.6 \times 10^{-19} \times 0.8}{1.6 \times 10^{-19}} \text{ eV}$$

$$\phi_0 = 1.27 \text{ eV}$$

$$2.07$$

$$0.8$$

$$1.27$$

(IV) Threshold frequency (γ_0):-

$$\gamma_0 = \frac{\phi_0}{h} = \frac{1.27 \times 10^{-19}}{6.626 \times 10^{-34}} = \frac{1.27 \times 10^{-19}}{6.626 \times 10^{-34}}$$

$$\gamma_0 = \frac{2.032 \times 10^5}{6.626}$$

$$\gamma_0 = 3.07 \times 10^{14} \text{ Hz}$$

$$2.032 \Rightarrow 0.3079$$

$$6.626 \Rightarrow 0.8213$$

$$\text{Antilog } 0.4866$$

$$3.066 \times 10^1$$

$$3.07 \times 10^1$$

$$(\because E = h\nu)$$

(V) Net energy:-

$$K.E_{\text{net}} = E - \phi_0$$

$$K.E_{\text{net}} = 2.07 \text{ eV} - 1.27 \text{ eV}$$

$$K.E_{\text{net}} = 0.8 \text{ eV}$$

9. Given:- $\lambda_1 = 3310 \text{ \AA} = 3.31 \times 10^{-7} \text{ m}$

$$K.E_1 = 3 \times 10^{-19} \text{ J}, \lambda_2 = 5000 \text{ \AA} = 5 \times 10^{-7} \text{ m}$$

$$K.E_2 = 0.972 \times 10^{-19} \text{ J}, h = ?, \lambda_0 = ?$$

Solution:-

$$h\nu = \phi_0 + K.E$$

$$\frac{hc}{\lambda_1} = \phi_0 + K.E_1 \rightarrow (1)$$

$$\frac{hc}{\lambda_2} = \phi_0 + K.E_2 \rightarrow (2)$$

(1) - (2)

$$hc \left[\frac{1}{\lambda_1} - \frac{1}{\lambda_2} \right] = K.E_1 - K.E_2$$

$$hc \left[\frac{\lambda_2 - \lambda_1}{\lambda_1 \lambda_2} \right] = K.E_1 - K.E_2$$

$$h = \frac{K.E_1 - K.E_2}{c} \times \frac{\lambda_1 \lambda_2}{\lambda_2 - \lambda_1}$$

$$h = \frac{(3 - 0.972) \times 10^{-19}}{3 \times 10^8} \times \frac{3.31 \times 10^{-7} \times 5 \times 10^{-7}}{(5 - 3.31) \times 10^{-7}}$$

$$= \frac{2.028 \times 16.55 \times 10^{-34}}{3 \times 1.69}$$

$$= \frac{2.028 \times 16.55 \times 10^{-34}}{5.07}$$

$$h = 6.62 \times 10^{-34} \text{ Js}$$

$$3.000$$

$$0.972$$

$$2.028$$

$$3.31 \times 5$$

$$16.55$$

$$5.00$$

$$3.31$$

$$1.69 \times 3$$

$$5.07$$

$$2.028 = 0.3071$$

$$16.55 = 1.2188$$

$$1.5259$$

$$5.07 = 0.7050$$

$$\text{Antilog } 0.8209$$

$$6.62 \times 10^{-34}$$

Work function (ϕ_0):-

$$\phi_0 = \frac{hc}{\lambda_1} - K.E_1$$

$$\phi_0 = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{3.31 \times 10^{-7}} - 3 \times 10^{-19}$$

$$= \frac{19.86 \times 10^{-19}}{3.31} - 3 \times 10^{-19}$$

$$= 6 \times 10^{-19} - 3 \times 10^{-19}$$

$$\phi_0 = 3 \times 10^{-19} \text{ J}$$

Threshold wavelength, $\lambda_0 = \frac{hc}{\phi_0}$

$$\lambda_0 = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{3 \times 10^{-19}}$$

$$\lambda_0 = 6.62 \times 10^{-7} \text{ m} = 6620 \times 10^{-10} \text{ m}$$

$$\lambda_0 = 6620 \text{ \AA}$$

$$19.86 = 1.2980$$

$$3.31 = 0.5198$$

$$\text{Antilog } 0.7782$$

$$6.00 \times 10^0$$

10. Given:- $E = 4 \text{ cal cm}^{-2} \text{ min}^{-1}$ no. of photons = ? - $\lambda = 5500 \text{ \AA}$ Solution:- $\lambda = 5.5 \times 10^{-7} \text{ m}$ Total energy received, $E = \frac{4 \text{ cal}}{\text{cm}^2 \text{ min}} = \frac{4 \times 4.184}{\text{cm}^2 \text{ min}}$

$$E_{\text{tot}} = 16.74 \text{ cal cm}^{-2} \text{ min}^{-1}$$

$$\text{Energy of one photon, } E = \frac{hc}{\lambda} = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{5.5 \times 10^{-7}}$$

$$E = \frac{19.878 \times 10^{-19}}{5.5}$$

$$E = 3.6 \times 10^{-19} \text{ J}$$

$$n_p = \frac{E_{\text{total}}}{E \text{ for 1 photon}}$$

$$n_p = \frac{16.74}{3.6 \times 10^{-19}}$$

$$n_p = 4.65 \times 10^9 \text{ photons}$$

$$\log 19.878 \Rightarrow 1.2982$$

$$5.5 \Rightarrow 0.7404$$

$$\text{Antilog } 0.5578$$

$$3.613 \times 10^0$$

$$\log 16.74 \Rightarrow 1.2237$$

$$3.6 \Rightarrow 0.5563$$

$$\text{Antilog } 0.6674$$

$$4.649 \times 10^0$$

$$4.65$$

8

11. Given:- $\lambda = 1800 \text{ \AA} = 1800 \times 10^{-10} \text{ m} = 1.8 \times 10^{-7} \text{ m}$
 $\lambda_0 = 4965 \text{ \AA} = 4.965 \times 10^{-7} \text{ m}$

Solution:- $K \cdot E_{\text{max}} = ?$

$$h\nu = \phi_0 + K \cdot E_{\text{max}}, \quad \phi_0 = h\nu_0$$

$$h\nu = h\nu_0 + K \cdot E_{\text{max}}$$

$$K \cdot E_{\text{max}} = h\nu - h\nu_0$$

$$= \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

$$= hc \left[\frac{1}{\lambda} - \frac{1}{\lambda_0} \right]$$

$$= hc \left[\frac{\lambda_0 - \lambda}{\lambda \lambda_0} \right]$$

$$= hc \left[\frac{(4.965 - 1.8) \times 10^{-7}}{1.8 \times 4.965 \times 10^{-7} \times 10^{-7}} \right] \text{ J}$$

$$= \frac{6.626 \times 10^{-34} \times 3 \times 10^8 \times 10^7 \times 3.165}{8.96} \text{ J}$$

$$= 19.878 \times 3.165 \times 10^{-19} \text{ (eV)}$$

$$= \frac{19.878 \times 3.165}{14.34} \text{ (eV)}$$

$$K \cdot E_{\text{max}} = 1.40 \text{ eV}$$

$$19.878 \Rightarrow 1.2982 \text{ (e)}$$

$$3.165 \Rightarrow 0.5004 \text{ (e)}$$

$$14.34 \Rightarrow 1.1565 \text{ (e)}$$

$$\text{Antilog } 0.6421$$

$$4.396 \times 10^0 \Rightarrow 4.40$$

12. Given:- $\lambda_p = ?$ $K = 81.9 \times 10^{-15} \text{ J}$

$$m_p = 1836 m_e, \quad m_p = 1.67 \times 10^{-27} \text{ kg}$$

Solution:- $\lambda_p = \frac{h}{\sqrt{2m_p K}}$

$$\lambda = \frac{6.626 \times 10^{-34}}{\sqrt{2 \times 1.67 \times 10^{-27} \times 81.9 \times 10^{-15}}}$$

$$\lambda = \frac{6.626 \times 10^{-34}}{10^{-21} \sqrt{3.34 \times 81.9}}$$

B.Arokia Raj, M.Sc., B.Ed., Neyveli Township, Cell: 9487380576, 8667656700

$$\lambda_p = \frac{6.626 \times 10^{-34}}{\sqrt{3.34 \times 81.9}} \left\{ \begin{array}{l} 3.34 = 0.5237 \\ 81.9 \Rightarrow 1.9133 \end{array} \right\}$$

$$\therefore \lambda_p = 4 \times 10^{-14} \text{ m}$$

$$\frac{2.4370}{2}$$

$$1.2185$$

$$6.626 = 0.8213$$

$$1.2185 \text{ (e)}$$

$$\text{Antilog } \frac{1.6028}{4.006 \times 10^{-1}}$$

13. Given:- $m_d = 2m_p, m_\alpha = 4m_p$
 deuteron (${}_1\text{H}^2$) $\Rightarrow$ charge = +e

α -particle (${}_2\text{He}^4$) $\Rightarrow$ charge = +2e

$$\lambda_d \& \lambda_\alpha = ? \quad K_d \& K_\alpha = ?$$

Solution:- (i) wave length:-

$$\lambda = \frac{h}{\sqrt{2m_e V}}; \quad \lambda_d = \frac{h}{\sqrt{2 \times 2m_p \times eV}}$$

$$\lambda_\alpha = \frac{h}{\sqrt{2 \times 4m_p \times 2eV}}$$

$$\frac{\lambda_d}{\lambda_\alpha} = \frac{\sqrt{2 \times 4m_p \times 2eV}}{\sqrt{2 \times 2m_p \times eV}} \times \frac{1}{1}$$

$$\frac{\lambda_d}{\lambda_\alpha} = \frac{\sqrt{2 \times 4m_p \times 2eV}}{\sqrt{2 \times 2m_p \times eV}} = 2$$

$$\boxed{\lambda_d = 2\lambda_\alpha}, \therefore \lambda_d > \lambda_\alpha$$

(ii) kinetic energy:- $\lambda = \frac{h}{\sqrt{2mK}}$

$$\lambda_\alpha = \frac{h}{\sqrt{2 \times 4m_p \times K_\alpha}}, \quad \lambda_d = \frac{h}{\sqrt{2 \times 2m_p \times K_d}}$$

$$\frac{\lambda_\alpha}{\lambda_d} = \frac{K_d}{K_\alpha} \times \frac{\sqrt{2 \times 2m_p \times K_d}}{\sqrt{2 \times 4m_p \times K_\alpha}}$$

$$\frac{\lambda_\alpha}{\lambda_d} = \sqrt{\frac{K_d}{2K_\alpha}} \Rightarrow \text{Squaring on both sides}$$

$$\frac{\lambda_\alpha^2}{\lambda_d^2} = \frac{K_d}{2K_\alpha}$$

$$\frac{\lambda_{\alpha}^2}{(2\lambda_{\alpha})^2} = \frac{k_d}{2k_{\alpha}} \quad (\lambda_d = 2\lambda_{\alpha})$$

$$\frac{\lambda_{\alpha}^2}{2\lambda_{\alpha}^2} = \frac{k_d}{2k_{\alpha}} ; \therefore k_d = k_{\alpha}/2$$

$$\therefore k_d < k_{\alpha}$$

$$\therefore x = 64 \text{ Volts}$$

14. Given:- $V = 81 \text{ volt}$.

Solution:- $\lambda = ?$

$$\begin{aligned} \lambda &= \frac{12.27}{\sqrt{V}} \text{ \AA} \\ &= \frac{12.27}{\sqrt{81}} \text{ \AA} \\ &= \frac{12.27}{9} \text{ \AA} \end{aligned}$$

$$\begin{array}{r} 1.36 \\ 9 \overline{) 12.27} \\ \underline{9} \\ 32 \leftarrow \\ \underline{27} \\ 57 \leftarrow \\ \underline{54} \\ 3 \end{array}$$

$$\lambda = 1.36 \text{ \AA}$$

* This wavelength corresponds to X-rays.

15. Given:- $V_p = 512 \text{ volt}$.

$$\frac{\lambda_p}{\lambda_{\alpha}} = 1 ; \lambda_p = \lambda_{\alpha}, x = ?$$

Solution:-

$$\lambda = \frac{h}{\sqrt{2meV}} ; \lambda_p = \frac{h}{\sqrt{2m_p \times e \times 512}}$$

$$\lambda_{\alpha} = \frac{h}{\sqrt{2 \times 4m_p \times 2e \times x}}$$

$$\therefore \frac{h}{\sqrt{2m_p \times e \times 512}} = \frac{h}{\sqrt{2 \times 4m_p \times 2e \times x}}$$

$$\sqrt{2m_p \times e \times 512} = \sqrt{2 \times 4m_p \times 2e \times x}$$

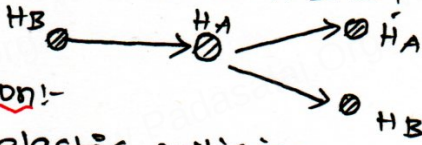
take square on both sides

$$2m_p \times e \times 512 = 2 \times 4m_p \times 2e \times x$$

$$25664 \therefore x = 64 \text{ V}$$

UNIT 8 Atomic and Nuclear physics

1. Given:- minimum K.E = ?



Solution:-

In elastic collision,

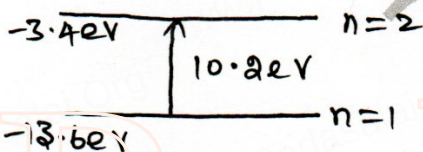
Kinetic energy ?
Before collision } K.E_i = K.E after collision (K.E_f)

$$\frac{1}{2} m v_i^2 = \frac{1}{2} m v_f^2 + \frac{1}{2} m v_f^2$$

$$K.E_i = K.E_f + K.E_f$$

(after collision H_A and H_B moving together).

$$K.E_i = 2 K.E_f$$



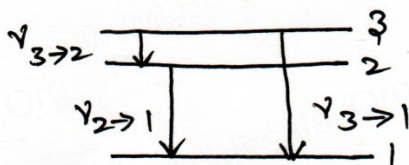
K.E_f = 10.2 eV is the minimum energy required for excitation.

∴ Minimum kinetic energy required = 2 × 10.2 eV

$$\boxed{K.E_{\min} = 20.4 \text{ eV}}$$

2. Given:- $\gamma = RC \left(\frac{1}{n^2} - \frac{1}{m^2} \right)$, $n < m$

$$\gamma_{3 \rightarrow 1} = \gamma_{3 \rightarrow 2} + \gamma_{2 \rightarrow 1}$$



Solution:- For transition

(i) $m=3, n=2$ $\gamma = RC \left[\frac{1}{n^2} - \frac{1}{m^2} \right]$

$$\gamma_{3 \rightarrow 2} = RC \left[\frac{1}{2^2} - \frac{1}{3^2} \right] = RC \left[\frac{1}{4} - \frac{1}{9} \right]$$

$$\gamma_{3 \rightarrow 2} = \frac{5RC}{36}$$

(ii) $m=2, n=1$

$$\gamma_{2 \rightarrow 1} = RC \left[\frac{1}{1^2} - \frac{1}{2^2} \right] = RC \left[1 - \frac{1}{4} \right]$$

$$\gamma_{2 \rightarrow 1} = \frac{3RC}{4}$$

(iii) $m=3, n=1$

$$\gamma_{3 \rightarrow 1} = RC \left[\frac{1}{1^2} - \frac{1}{3^2} \right] = RC \left[1 - \frac{1}{9} \right]$$

$$\gamma_{3 \rightarrow 1} = \frac{8RC}{9}$$

$$\therefore \gamma_{3 \rightarrow 1} = \gamma_{3 \rightarrow 2} + \gamma_{2 \rightarrow 1}$$

$$\frac{8RC}{9} = \frac{5RC}{36} + \frac{3RC}{4}$$

$$\frac{8RC}{9} = \frac{5RC}{36} + \frac{3RC \times 9}{4 \times 9}$$

$$\frac{8RC}{9} = \frac{5RC}{36} + \frac{27RC}{36}$$

$$\frac{8RC}{9} = \frac{32RC}{36}$$

$$\therefore \frac{8RC}{9} = \frac{8RC}{9}$$

$$\therefore \gamma_{3 \rightarrow 1} = \gamma_{3 \rightarrow 2} + \gamma_{2 \rightarrow 1}$$

3. Given:- $\lambda = 97.5 \text{ nm} = 97.5 \times 10^{-9} \text{ m}$

$$\lambda = 975 \times 10^{-10} \text{ m (i) } n = ?$$

(ii) number of possible lines = ?

Solution:-

(i) Energy of the excited state

$$E = h\nu = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{975 \times 10^{-10}} \text{ J}$$

$$E = \frac{19.878 \times 10^{-16}}{975 \times 1.6 \times 10^{-19}} \text{ eV}$$

$$E = \frac{19.878 \times 10^3}{1560} \text{ eV}$$

$$\frac{975 \times 1.6}{5850}$$

$$\frac{975}{1560.0}$$

B. Arokia Raj, M.Sc., B.Ed., Neyveli Township, Cell: 9487380576, 8667656700

$$E = 1.274 \times 10^3 \times 10^{-2} \text{ eV} \quad 19.878 = 1.2982$$

$$E = 12.74 \text{ eV} \quad 1560 = 3.1931$$

$$\therefore \text{Energy of the ground state} = -13.6 \text{ eV}$$

$$\therefore E_n = -13.6 + 12.74 = -0.86 \text{ eV}$$

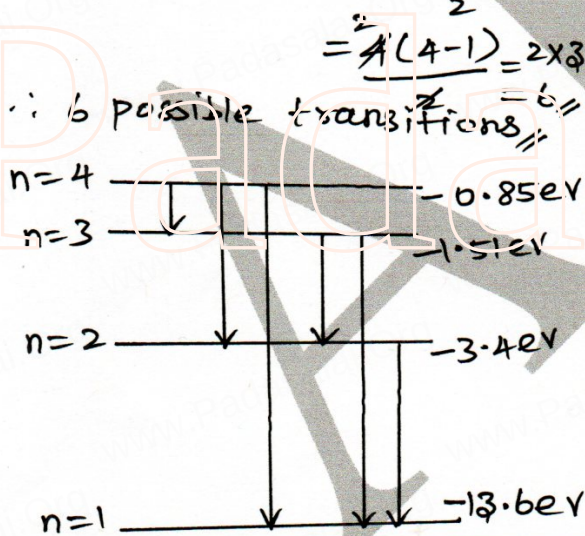
$$\therefore E_n = \frac{-13.6}{n^2} \text{ eV} \quad 13.6 \Rightarrow 1.1335$$

$$n^2 = \frac{-13.6}{E_n} \quad 0.86 \Rightarrow 7.9345$$

$$n^2 = \frac{-13.6}{-0.86} = 16$$

$\therefore n = 4$ The principal Quantum number of excited state is $n = 4$

(ii) Total number of possible lines in emission spectrum = $\frac{n(n-1)}{2}$



4. Given: density of earth (P_E) = density of nucleus (P_n)

$$P_E = P_n = 2.3 \times 10^{17} \text{ kg m}^{-3}$$

mass of Earth, $M_E = 5.97 \times 10^{24} \text{ kg}$

Solution:

$$\text{Density of Earth } (P_E) = \frac{M_E}{\text{Volume}} = \frac{M_E}{\frac{4}{3} \pi R_E^3}$$

$$R_E^3 = \frac{M_E}{\frac{4}{3} \pi P_E} \quad (P_E = P_n)$$

$$R_E^3 = \frac{5.97 \times 10^{24}}{\frac{4}{3} \pi \times 2.3 \times 10^{17}}$$

$$= \frac{5.97 \times 10^{24} \times 3}{4 \times 3.14 \times 2.3 \times 10^{17}}$$

$$= \frac{17.91 \times 10^7}{28.89}$$

$$R_E^3 = 179.1 \times 10^6$$

$$R_E = \left(\frac{179.1 \times 10^6}{28.89} \right)^{1/3}$$

$$= \left(\frac{179.1}{28.89} \right)^{1/3} \times (10^6)^{1/3}$$

$$= 1.84 \times 10^2$$

$$R_E = 184 \text{ m}$$

5. Given: $\Delta m = ?$ $BE/A = ?$

mass of ${}_{47}^{108}\text{Ag} = 107.905949 \text{ u}$

Solution:

mass of 47 protons = $47 \times 1.007825 \text{ u}$

$$\Rightarrow 47.367775 \text{ u}$$

mass of 61 neutrons = $61 \times 1.008665 \text{ u}$

$$= 61.528565 \text{ u}$$

Total mass of nucleons

$$= 47.367775 \text{ u} + 61.528565 \text{ u}$$

$$= 108.89634 \text{ u}$$

Actual mass of the ${}_{47}^{108}\text{Ag}$ nucleus = 107.905949 u

mass defect, $\Delta m = \text{Total mass of nucleons} - \text{actual mass of nucleus}$

$$\Delta m = 108.89634 \text{ u} - 107.905949 \text{ u}$$

$$\Delta m = 0.990391 \text{ u}$$

$\therefore$ mass defect $\Delta m = 0.990391 u$

$$1 u = 931 \text{ MeV}$$

Binding energy of $^{108}_{47}\text{Ag}$ nucleus $= 0.990391 \times 931 \text{ MeV}$

$$B.E = 922.05 \text{ MeV}$$

$\therefore$ Binding energy per nucleon $(\frac{BE}{A}) = \frac{922.05}{108} \text{ MeV}$

$$\therefore \frac{BE}{A} = 8.5 \text{ MeV}$$

$$\begin{aligned} 922.05 &\Rightarrow 2.9647 \\ 108 &\Rightarrow 2.0334 \\ \text{Antilog } 0.9313 & \\ 8.537 & \end{aligned}$$

6. Given:- For element A, $T_{1/2} = 20 \text{ mins}$
For element B, $T_{1/2} = 40 \text{ minutes}$
Both samples have equal numbers of nuclei initially.

Ratio of decayed $(\frac{N_A}{N_B})$ after 80 minutes $= ?$

Solution:- $\therefore$ Total life = 80 mins

$$n = \frac{\text{Total life}}{\text{Half life}}$$

$$\text{For A, } n = \frac{80}{20} = 4; \quad \text{For B, } n = \frac{80}{40} = 2$$

Number of atoms undecayed after 80 mins $\Rightarrow N = (\frac{1}{2})^n \times N_0$

$$\text{For A, } N_A = (\frac{1}{2})^4 \times N_0 = \frac{N_0}{16}$$

$$\text{For B, } N_B = (\frac{1}{2})^2 \times N_0 = \frac{N_0}{4}$$

$\therefore$ Number of atoms decayed after 80 mins $\Rightarrow N_0 - N$

$$\text{For A, } \Rightarrow N_0 - N_A = N_0 - \frac{N_0}{16} = \frac{15N_0}{16}$$

$$\text{For B, } \Rightarrow N_0 - N_B = N_0 - \frac{N_0}{4} = \frac{3N_0}{4}$$

$\therefore$ Ratio of decayed after 80 minutes $\frac{N_0 - N_A}{N_0 - N_B} = \frac{\frac{15N_0}{16}}{\frac{3N_0}{4}} = \frac{5}{4}$

$$\therefore \text{Ratio of } \frac{N_0 - N_A}{N_0 - N_B} = 5 : 4$$

Given:- Half life, $T_{1/2} = 5.0 \text{ days}$

Initial activity, $R_0 = 1 \text{ MCI}$

$R = ?$, $\lambda = ?$, $\tau = ?$, $N_0 = ?$

Solution:- total life, $T = 365 \text{ days}$
number of Half life, $n = \frac{\text{Total life}}{\text{Half life}} = \frac{365}{5.01} \approx 73$
 $\therefore n = 73$

(i) Activity of the sample

after 365 days $R = (\frac{1}{2})^n \times R_0$

$$R = \frac{1}{2^{73}} \times 1 \text{ MCI} \quad (\log m^n = n \log m)$$

$$R = 2^{-73} \times 1 \text{ MCI} \quad \log(2)^{-73} \Rightarrow -73 \log 2$$

$$R = 10^{-22} \text{ MCI} \quad \text{Antilog } \Rightarrow 22.0000$$

(ii) Decay constant (λ)

$$\lambda = \frac{0.6931}{T_{1/2}} = \frac{0.6931}{5.01} \text{ per day}$$

$$\lambda = \frac{0.6931}{5.01 \times 24 \times 60 \times 60} \text{ per second} \quad (1 \text{ day} = 86400 \text{ sec})$$

$$\lambda = \frac{0.6931}{5.01 \times 86400} \text{ s}^{-1}$$

$$\lambda = 1.6 \times 10^{-6} \text{ s}^{-1} \quad \text{Antilog } 5.6363$$

(iii) Mean life (τ)

$$\tau = \frac{T_{1/2}}{0.6931} = \frac{5.01}{0.6931}$$

$$\tau = 7.23 \text{ days} \quad \text{Antilog } 5.6363$$

(iv) Initial number of atoms (N_0)

$$R_0 = \lambda N_0; \quad \text{CICI} = 3.7 \times 10^{10} \text{ decay/sec}$$

$$N_0 = \frac{R_0}{\lambda} = \frac{1 \text{ MCI}}{1.6 \times 10^{-6}} \quad 3.7 \Rightarrow 0.5682$$

$$N_0 = 2.31 \times 10^{10} \text{ atoms} \quad 1.6 \Rightarrow 0.2041$$

8. Given:- $t = ?$ $T_{1/2} = 3.8 \text{ days}$.

amount of sample decayed = 60%.

Solution:- Present = 40%.
Using law of radioactive decay,

$$N = N_0 e^{-\lambda t}$$

$N_0 \rightarrow$ original amount of sample present initially

$$N = 40\% N_0 = \frac{40}{100} N_0$$

$$\frac{N_0 \frac{40}{100}}{2.5} = N_0 e^{-\lambda t}$$

$$\log_{10} 2.5 \Rightarrow 0.3979$$

$$\log 3.8 \Rightarrow 0.5798$$

$$0.3979 \Rightarrow T.5998$$

$$2.302 \Rightarrow 0.3621$$

$$0.5417$$

$$0.6931 \Rightarrow T.8408$$

$$\text{Antilog } 0.7009$$

$$5.023 \times 10^0$$

$$\frac{1}{2.5} = \frac{1}{e^{\lambda t}}$$

$$\therefore e^{\lambda t} = 2.5$$

Take logarithm,

$$\lambda t = \log_e 2.5$$

$$t = \frac{1}{\lambda} \log_e 2.5$$

$$\lambda = \frac{0.6931}{T_{1/2}}$$

$$\therefore t = \frac{T_{1/2}}{0.6931} \log_{10} 2.5 \times 2.302$$

$$t = \frac{3.8}{0.6931} \times 0.3979 \times 2.302$$

$$t = 5.023 \text{ days}$$

9. Given:- Energy per fission = 200 MeV

Required power = 1 watt = 1 J/s

number fissions required per second = ?

Solution:-

Energy released = 200 MeV

Per fission

$$= 2 \times 10^2 \times 10^6 \times 1.6 \times 10^{-19} \text{ J}$$

$$= 3.2 \times 10^{-11} \text{ J}$$

$$N = \frac{\text{Total energy released per second}}{\text{Energy per fission}}$$

$$N = \frac{1}{3.2 \times 10^{-11}} \quad 10^{11} \Rightarrow 11.0000$$

$$N = \frac{10^{11}}{3.2} = 3.125 \quad 3.2 \Rightarrow 0.5052$$

$$\text{Antilog } 0.4948$$

$$\therefore N = 3.125 \text{ fissions per second}$$

10. Given:- $T_{1/2} = 1600 \text{ years}$.

activity, $\frac{dN}{dt} = 1 \text{ Ci} = 3.7 \times 10^{10} \text{ decays/second}$

Amount of ${}^{226}_{88}\text{Ra} = 1 \text{ g}$

Solution:- From law of radioactive decay,

$$\frac{dN}{dt} = -\lambda N \quad (-\text{ve sign implies } N \text{ decrease with time})$$

$$\therefore \frac{dN}{dt} = \lambda N$$

$$N = \frac{1}{\lambda} \times \frac{dN}{dt}$$

$$\lambda = 0.6931$$

$$T_{1/2}$$

$$\lambda = \frac{0.6931}{1600} \text{ per year}$$

$$\lambda = 0.6931 \text{ per second}$$

$$1600 \times 365 \times 24 \times 60 \times 60$$

$$N = \frac{16 \times 10^2 \times 365 \times 24 \times 36 \times 10^2 \times 3.7 \times 10^{10}}{0.6931}$$

$$N = 16 \times 365 \times 24 \times 36 \times 3.7 \times 10^{14}$$

$$0.6931$$

$$N = 2.694 \times 10^{21} \text{ atoms}$$

$$226 \Rightarrow 2.3541$$

$$2.694 \Rightarrow 0.4305$$

$$10^3 \Rightarrow 2.0000$$

$$0.7846$$

$$6.023 \times 10^{23} \text{ atoms} = 226 \text{ g of radium}$$

$$2.694 \times 10^{21} \text{ atoms}$$

$$\text{of radium} = \frac{226 \times 2.694 \times 10^{21}}{6.023 \times 10^{23}}$$

$$\Rightarrow \frac{226 \times 2.694 \times 10^{-2}}{6.023} = 1.01 \text{ g}$$

$$0.7846$$

$$6.023 \Rightarrow 0.7798$$

$$\text{Antilog } 0.0048$$

$$1.011 \times 10^0$$

11. Given: $N = 17.5\% \text{ of } N_0$

$N \rightarrow$ Number of sample present

$N_0 \rightarrow$ original amount of sample present initially

Solution: $t = ?$ $N = \frac{17.5}{100} N_0$

Half-life, C-14 = 5730 years.

From law of radioactive decay

$$N = N_0 e^{-\lambda t}$$

$$\frac{17.5}{100} N_0 = N_0 e^{-\lambda t} \quad 10^2 \Rightarrow 2.0000$$

$$\frac{17.5}{100} = e^{-\lambda t} \quad 17.5 \Rightarrow 1.2430$$

$$\text{Antilog } 0.7570$$

$$\frac{17.5}{100} = \frac{1}{e^{\lambda t}} \quad 5.715 \times 10^0$$

$$e^{\lambda t} = \frac{100}{17.5}$$

$$e^{\lambda t} = 5.715$$

Take logarithm

$$\lambda t = \log_e 5.715$$

$$t = \frac{1}{\lambda} \times \log_e 5.715$$

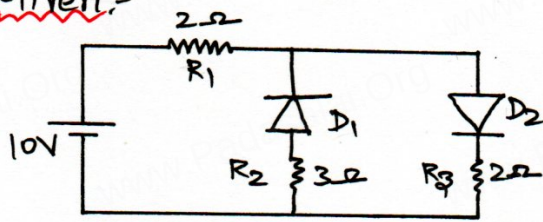
$$\lambda = \frac{0.6931}{T_{1/2}}$$

$$t = \frac{T_{1/2}}{0.6931} \times \log_{10} 5.715 \times 2.302$$

$$t = \frac{5730}{0.6931} \times 0.7570 \times 2.302$$

$$t = 1.44 \times 10^4 \text{ years}$$

UNIT 9 Semiconductor Electronics

1. Given:-current I through $(R_1) = ?$ Solution:-

Diode D_1 is reverse biased, so it will block the current and diode D_2 is forward biased so it will allow the current.

∴ current flowing through the resistor R_1 is, $I = \frac{V}{R} = \frac{10}{2+2}$

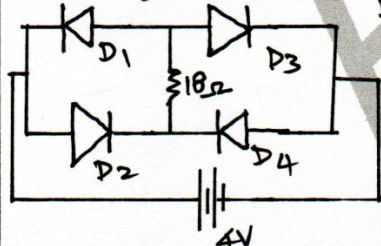
$$I = \frac{10}{4} = 2.5 \text{ A} \quad \boxed{I = 2.5 \text{ A}}$$

2. Given:-

$$R = 18 \Omega$$

Diodes resistance = 1Ω I flows through $18 \Omega = ?$ Solution:-

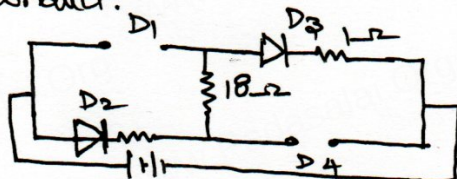
First we can draw the diagram



Note:- If 3V, 10Ω
Net Voltage = $3 - 1.4 = 1.6$
Net $R = 1 + 10 + 1 = 12$
Current through 10Ω is $I = \frac{1.6}{12} = 0.13 \text{ A}$
 $I = 0.13 \text{ A}$

* Diodes D_2 and D_3 are forward biased, acts closed switch.

* Diodes D_1 and D_4 are reverse biased, acts open switch, it will not conduct.



For silicon diode Barrier voltage is 0.7 V .

$$\therefore \text{Net voltage} = 4 - 0.7 - 0.7 = 2.6 \text{ Volt.}$$

$$\therefore \text{Total Resistance} = 1 + 18 + 1 = 20 \Omega$$

$$\therefore \text{Current through } 18 \Omega \text{ resistor, } I = \frac{V}{R} = \frac{2.6}{20}$$

$$\boxed{I = 0.13 \text{ A}}$$

3. Given:-

$$V_{CE} = 0.2 \text{ V}$$

$$V_{CC} = 3 \text{ V}$$

$$\beta = 50$$

$$R_C = 1 \text{ k}\Omega = 10^3 \Omega, I_B = ?$$

Solution:-

$$V_{CC} = I_C R_C + V_{CE}$$

$$I_C R_C = V_{CC} - V_{CE}$$

$$I_C = \frac{V_{CC} - V_{CE}}{R_C} = \frac{3 - 0.2}{10^3} = 2.8 \times 10^{-3} \text{ A}$$

$$\beta = I_C / I_B$$

$$\therefore I_C = 2.8 \times 10^{-3} \text{ A}$$

$$I_B = \frac{I_C}{\beta} = \frac{2.8 \times 10^{-3}}{50} = 5.6 \times 10^{-5} \text{ A}$$

$$I_B = 5.6 \times 10^{-5} \text{ A}; \quad \boxed{I_B = 5.6 \mu\text{A}}$$

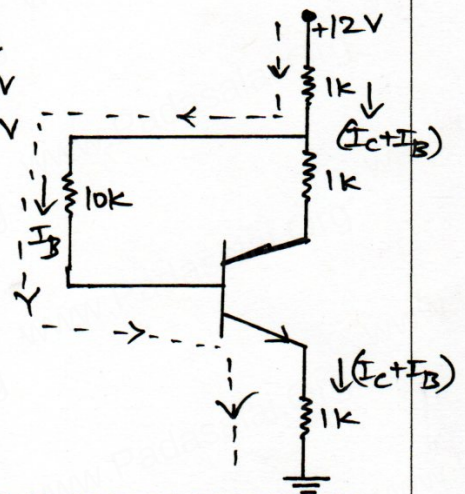
4. Given:-

$$\alpha = 0.99,$$

$$V_{BE} = 0.7 \text{ V}$$

$$V_{CC} = +12 \text{ V}$$

$$I_C = ?$$



16

Solution:- Applying Kirchhoff's voltage law for base circuit,

$$(I_C + I_B)1k + I_B 10k + (I_C + I_B)1k =$$

$$\therefore I_B = I_C / \beta$$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.99}{1-0.99} = \frac{99 \times 10^{-2}}{0.01} = \frac{99 \times 10^{-2}}{1 \times 10^{-2}}$$

$$\therefore I_B = I_C / 99 \quad \therefore \beta = 99$$

$$\Rightarrow (I_C + \frac{I_C}{99})1k + \frac{I_C}{99} \times 10k + (I_C + \frac{I_C}{99})1k$$

$$(\because 1k = 10^3) = 12 - 0.7$$

$$\frac{I_C + \frac{I_C}{99}}{99} + \frac{10I_C}{99} + I_C + \frac{I_C}{99} = \frac{11.3}{10^3}$$

$$2I_C + \frac{12I_C}{99} = 11.3 \times 10^{-3}$$

$$\frac{198I_C + 12I_C}{99} = 11.3 \times 10^{-3}$$

$$210I_C = 99 \times 11.3 \times 10^{-3}$$

$$I_C = \frac{1118.7 \times 10^{-3}}{210}$$

$$I_C = 5.3 \times 10^{-3} A$$

$$I_C = 5.3 \text{ mA}$$

$$\begin{aligned} 1118.7 &\Rightarrow 3.0484 \\ 210 &\Rightarrow 2.7222 \\ \text{Antilog } 0.7262 & \\ 5.323 \times 10^0 & \end{aligned}$$

5. Given:- $\beta = 50$

$$V_{EB} = 600 \text{ mV} \\ = 600 \times 10^{-3} \text{ V}$$

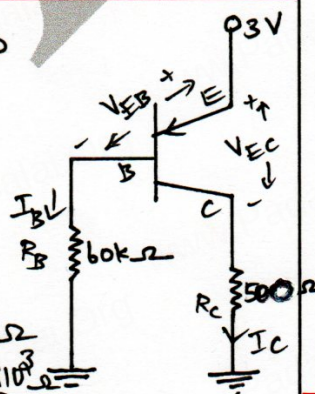
$$V_{EB} = 0.6 \text{ V}$$

$$V_{EC} = ?$$

$$V_E = 3 \text{ V}, R_B = 60k\Omega$$

$$R_B = 60 \times 10^3 \Omega$$

$$R_C = 500\Omega, R_C = 0.5 \times 10^3 \Omega$$



Solution:- $V_{EB} = V_E - V_B$

$$\therefore V_B = V_E - V_{EB}$$

$$V_B = 3 - 0.6 = 2.4 \text{ V}$$

$$I_B = \frac{V_B}{R_B} = \frac{2.4}{60 \times 10^3} = \frac{4}{6} \times 10^{-1}$$

$$I_B = 4 \times 10^{-5} = 40 \times 10^{-6} A = 40 \mu A$$

$$I_C = \beta I_B = 50 \times 40 \mu A$$

$$I_C = 2000 \mu A ; I_C = 2 \text{ mA}$$

$$\therefore V_C = I_C R_C$$

$$= 2 \times 10^{-3} \times 0.5 \times 10^3$$

$$V_C = 1 \text{ V}$$

$$\therefore V_{EC} = V_E - V_C$$

$$= 3 - 1$$

$$V_{EC} = 2 \text{ V}$$

Another method:-

From Kirchhoff's voltage rule for E-B loop.

$$I_B R_B = V_E - V_{EB}$$

$$60k \times I_B = 3 - 0.6$$

$$I_B = \frac{2.4}{60 \times 10^3} = \frac{4}{6} \times 10^{-1} = 4 \times 10^{-5}$$

$$I_B = 4 \times 10^{-6} A, I_B = 40 \mu A$$

$$I_C = \beta I_B = 50 \times 40 \times 10^{-6} A$$

$$I_C = 2000 \times 10^{-6} A$$

$$I_C = 2 \times 10^{-3} A, I_C = 2 \text{ mA}$$

$$\therefore V_C = I_C R_C$$

$$\therefore V_{EC} = V_E - V_C = V_E - I_C R_C$$

$$= 3 - 2 \times 10^{-3} \times 0.5 \times 10^3$$

$$V_{EC} = 3 - 1 = 2 \text{ V}; \quad V_{EC} = 2 \text{ V}$$

B.Arokiaaraj, M.Sc., B.Ed., Neyveli Township, Cell: 487380576, 8667656700