Padasalai's
Telegram Groups!

(தலைப்பிற்கு கீழே உள்ள லிங்கை கிளிக் செய்து குழுவில் இணையவும்!)

- Padasalai's NEWS - Group
https://t.me/joinchat/NIfCqVRBNj9hhV4wu6_NqA

- Padasalai's Channel - Group
https://t.me/padasalaichannel

- Lesson Plan - Group
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- 12th Standard - Group
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- PGTRB - Group
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- TNPSC - Group
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1. ELECTROSTATICS

1. Given:- $q = 50\,nC = 50\times10^{-9}\,C$

$n = ?$, $e = 1.6\times10^{-19}\,C$

Solution:-

$$n = \frac{q}{e} = \frac{50\times10^{-9}}{1.6\times10^{-19}}$$

$$n = \frac{\cancel{50}^{25}\times10^{10}}{\cancel{1.6}_{0.8}} = \frac{25\times10^{10}}{8\times10^{-1}}$$

$n = 3.125\times10^{11}$ electrons.

(or)

$n = 31.25\times10^{10}$ electrons //

$$\begin{array}{r|l} & 3.125 \\ 8 & 25 \\ & 24 \\ \hline & 10 \\ & 8 \\ \hline & 20 \\ & 16 \\ \hline & 40 \\ & 40 \\ \hline & 0 \end{array}$$

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

$n' = 1\%$ of $10^{28} = \frac{1}{100}\times10^{28} = 10^{26}$

n also loss 1% e_s ⇒ $n = 10^{26}$

$F_e = ?$, $W = ?$

Solution:- (i) $F_e = \frac{1}{4\pi\varepsilon_0}\frac{q\,q'}{r^2}$

$q = ne = 10^{26}\times1.6\times10^{-19} = 1.6\times10^{7}\,C$

$q' = n'e = 10^{26}\times1.6\times10^{-19} = 1.6\times10^{7}\,C$

$$\therefore F_e = \frac{9\times10^{9}\times1.6\times10^{7}\times1.6\times10^{7}}{1^2}$$

$F_e = 9\times2.56\times10^{23}$

$F_e = 23.04\times10^{23}\,N$

$$\begin{array}{r} 2.56\times9 \\ \hline 23.04 \end{array}$$

$\therefore \boxed{F_e = 23\times10^{23}\,N}$

(ii) weight, $W = mg = 60\times9.8$

$\boxed{W = 588\,N}$

$$\begin{array}{r} 9.8\times6 \\ \hline 58.8 \end{array}$$

$$\therefore \frac{F_e}{W} = \frac{23\times10^{21}}{588}$$

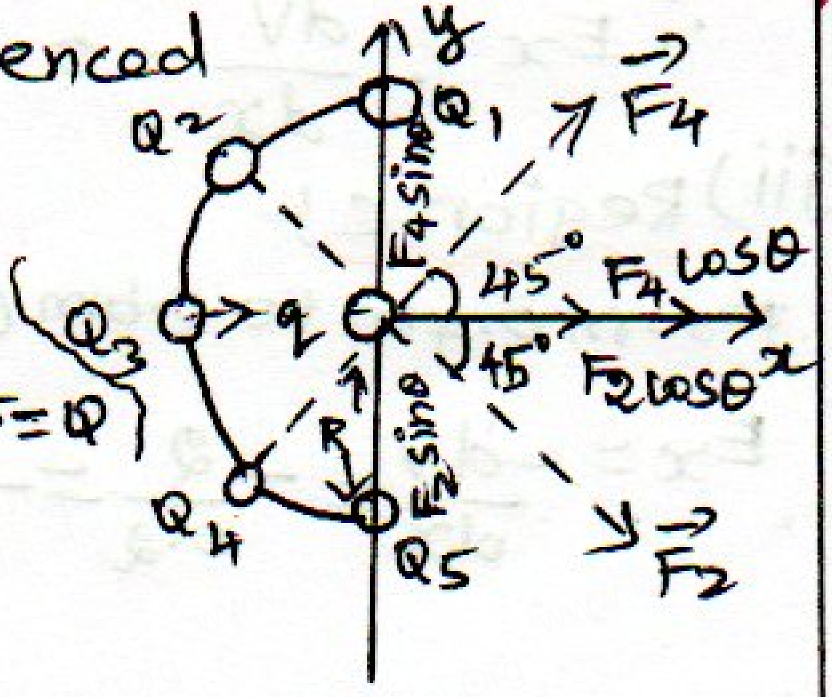
$23 \Rightarrow 1.3617$ (−)
$588 \Rightarrow 2.7694$
$\overline{2}.5923$
Antilog ⇒ 3.902×10^{-2}

$\therefore F_e/W = 3.9\times10^{21}$ //

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 (i.e $\vec{F_4}$) 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 $\vec{F_3}$.

∴ Total force acting on q is

$$\vec{F} = \vec{F_3} + F_2\cos\theta\,\hat{i} + F_4\cos\theta\,\hat{i}$$

$(\because \theta = 45°)$

$$\vec{F} = \frac{KqQ}{R^2}\hat{i} + \frac{Kq\cdot Q}{R^2}\cos45°\,\hat{i} + \frac{KqQ}{R^2}\cos45°\,\hat{i}$$

$$= \frac{KqQ}{R^2}\hat{i}\left[1 + \frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}}\right]$$

$$= \frac{KqQ}{R^2}\hat{i}\left[1 + \frac{2}{\sqrt{2}}\right] = \frac{KqQ}{R^2}\hat{i}\left[1 + \frac{\cancel{\sqrt{2}}\sqrt{2}}{\cancel{\sqrt{2}}}\right]$$

$$\therefore \boxed{\vec{F} = \frac{1}{4\pi\varepsilon_0}\frac{qQ}{R^2}[1+\sqrt{2}]\,\hat{i}\,N} \quad \left(K = \frac{1}{4\pi\varepsilon_0}\right)$$

4. Given:- $m_E = 5.9\times10^{24}\,kg$

(i) $q = ?$ $m_M = 7.9\times10^{22}\,kg$

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

Solution:- (a) $F_e = F_g$

$$\frac{1}{4\pi\varepsilon_0}\frac{q\cdot q}{r^2} = \frac{G M_E M_m}{r^2}$$

$9\times10^{9}\times q^2 = 6.67\times10^{-11}\times5.9\times10^{24}\times7.9\times10^{22}$

$$q^2 = \frac{6.67\times5.9\times7.9\times10^{35}}{9\times10^{9}}$$

$$q = \sqrt{\frac{6.67\times5.9\times7.9\times10^{26}}{9}}$$

$$q = 10^{13}\sqrt{\frac{6.67\times5.9\times7.9}{9}}$$

$6.67 \Rightarrow 0.8241$
$5.9 \Rightarrow 0.7709$
$7.9 \Rightarrow 0.8976$ (+)
$\overline{}2.4926$ (−)
$9 \Rightarrow 0.9542$
$0.7692 \Leftarrow 1.5384$ ÷2
5.878×10^{0}

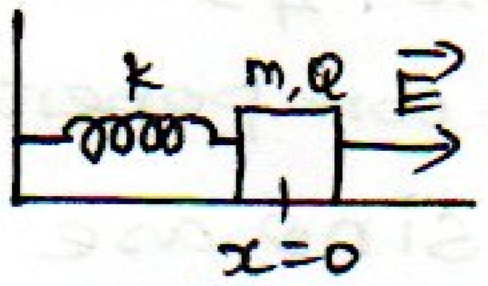
$\therefore q = 5.87 \times 10^{-19} C$,

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

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

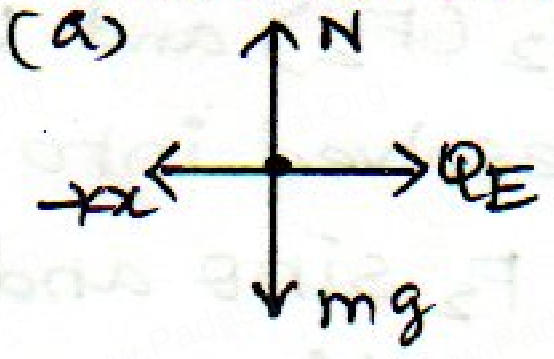
5. Given:-

(a)

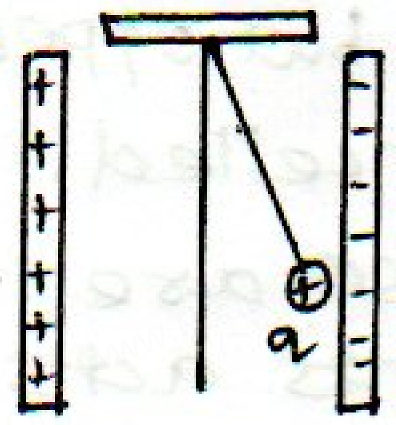


Free body diagram

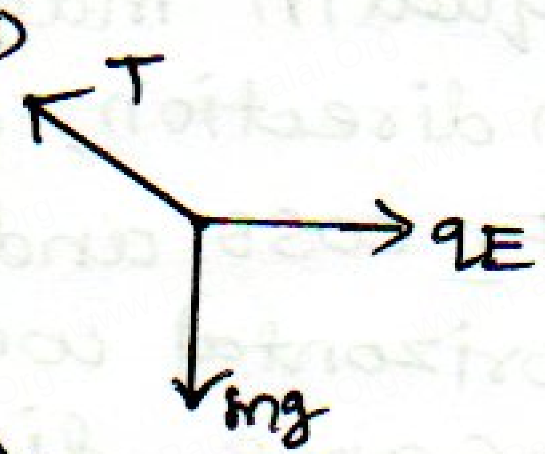
(a)



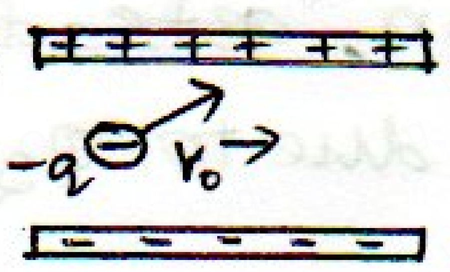
(b)



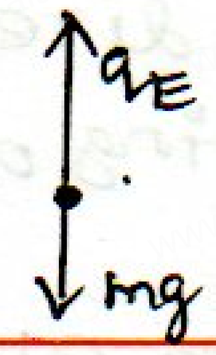
(b)



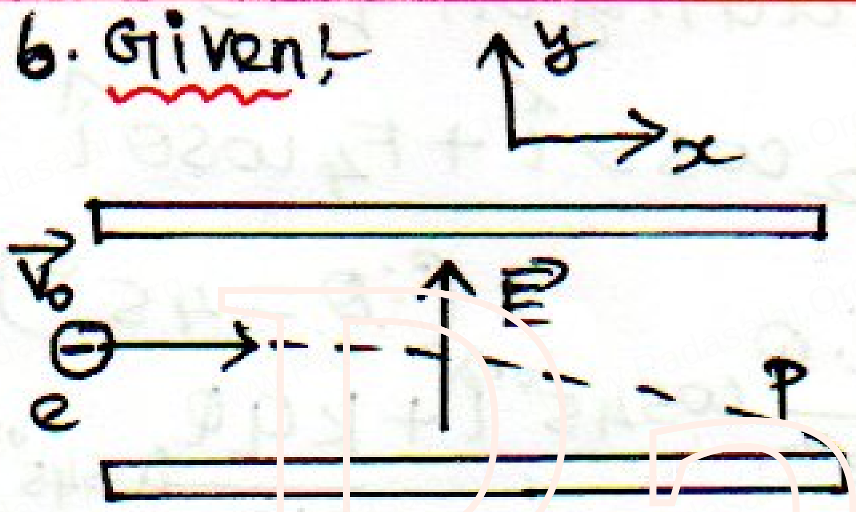
(c)



(c)



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 $(\vec{v})$:-

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

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

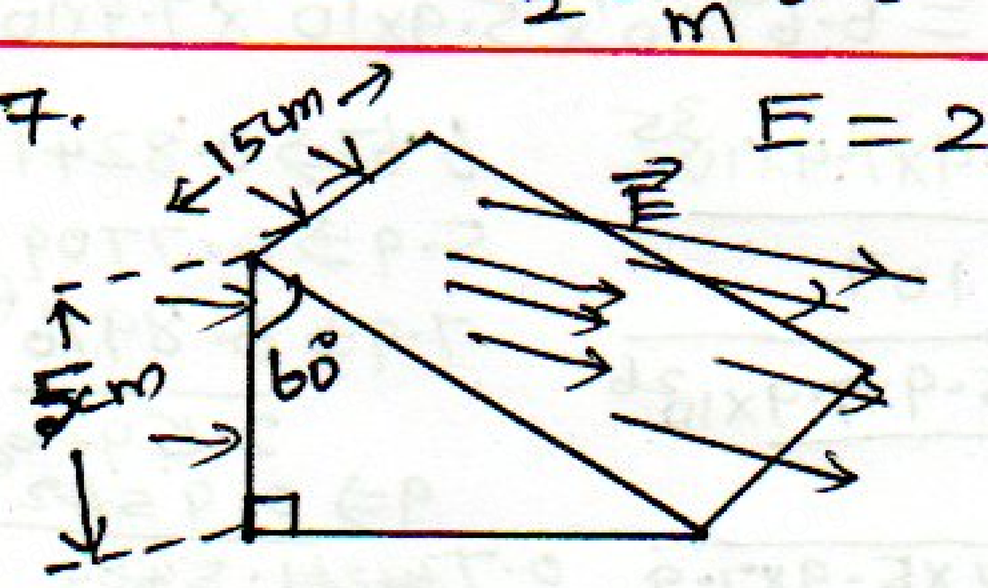
(iii) Position vector $(\vec{r})$:-

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

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

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

7.



$E = 2 \times 10^3 \, NC^{-1}$

$\phi_E = ?$

(a) vertical rectangle surface

$\phi_E = EA\cos\theta$, $A = 15cm \times 5cm$

$A = 75 \times 10^{-4} m^2$

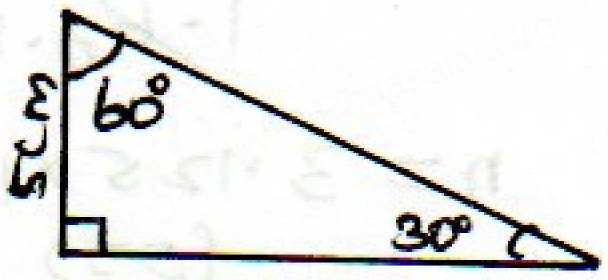
$\phi_E = 2\times10^3 \times 75\times10^{-4} \times \cos 0°$

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

$\phi_E = 15 \, Nm^2C^{-1}$

(b) Slanted surface:-

$\phi_E = EA\cos\theta$



Area of the slanted surface,

$A = 15\times10^{-2} \times 10\times10^{-2} \, m^2$

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

$\sin\theta = \frac{\text{opposite}}{\text{hyp}}$

$\sin 30° = \frac{5\times10^{-2}}{\text{hyp}}$

$\text{hyp} = \frac{5\times10^{-2}}{1/2}$

$\therefore \text{hyp} = 10\times10^{-2} m$

$\therefore \phi_E = 2\times10^3 \times 150\times10^{-4} \times \cos 60°$

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

$\phi_E = 15 \, Nm^2C^{-1}$

(c) Entire surface:-

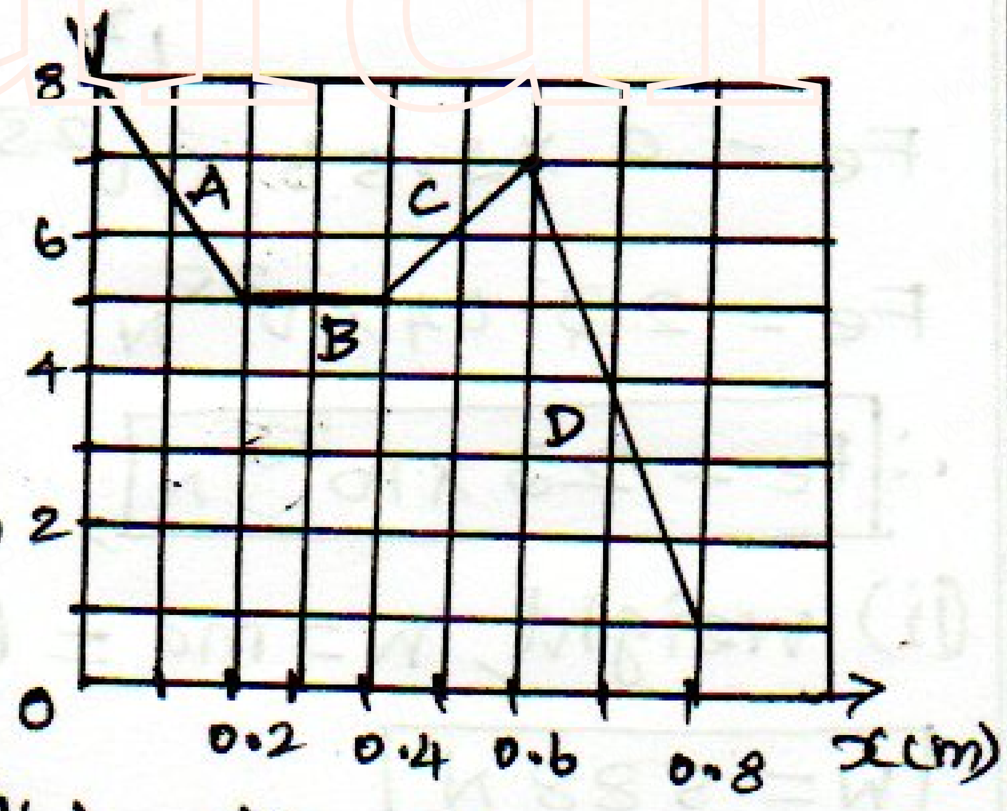
Inward flux = outward flux

$\phi_E = 0$.

$\therefore$ Net flux is zero.

8. Given:-

$E_x = ?$



(i) Region A:-

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

From 0 to 0.2m slope is -ve.

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

(ii) Region B:-

From 0.2m to 0.4m, potential is constant.

$V = 5V$,

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

(iii) Region C:-

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

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

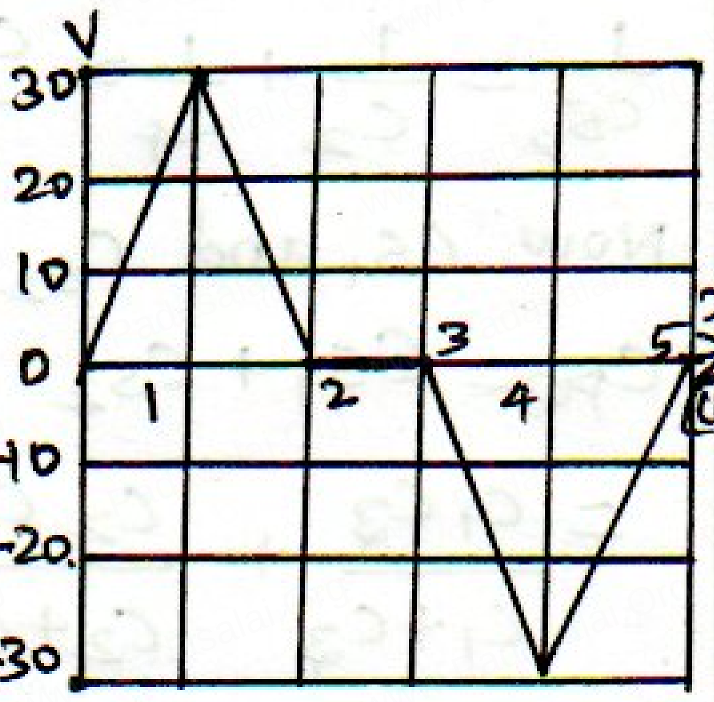
③

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

Slope is negative.

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

II. For Figure (b) :-



(i) From 0 to 1m

Slope is +ve.

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

$\boxed{E_x = -30\,Vm^{-1}}$

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

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

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

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

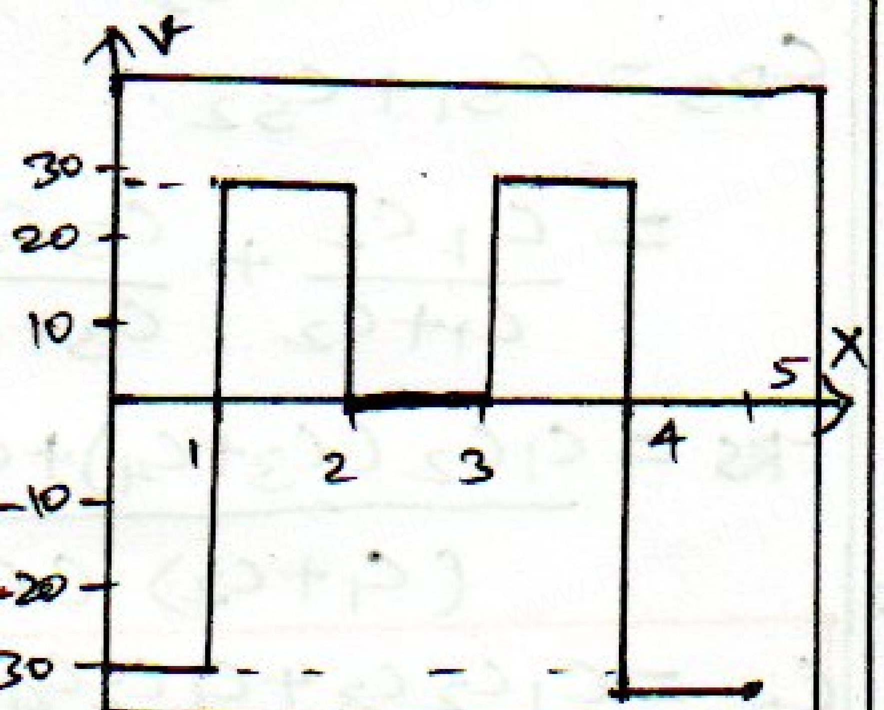
(iv) From 3 to 4m, slope is −ve

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

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

$E_x = -\frac{dV}{dx} = \frac{-30}{1} = -30\,Vm^{-1}$

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



9. Given :- $E = 3\times10^6\,Vm^{-1}$, $d = 0.6mm$

$d = 6\times10^{-4}m$

Solution :- $V = ?$

(a) Potential difference, $V = E\times d$

$V = 3\times10^6 \times 6\times10^{-4} = 18\times10^2$ Volt.

$\therefore V = 1800$ Volt

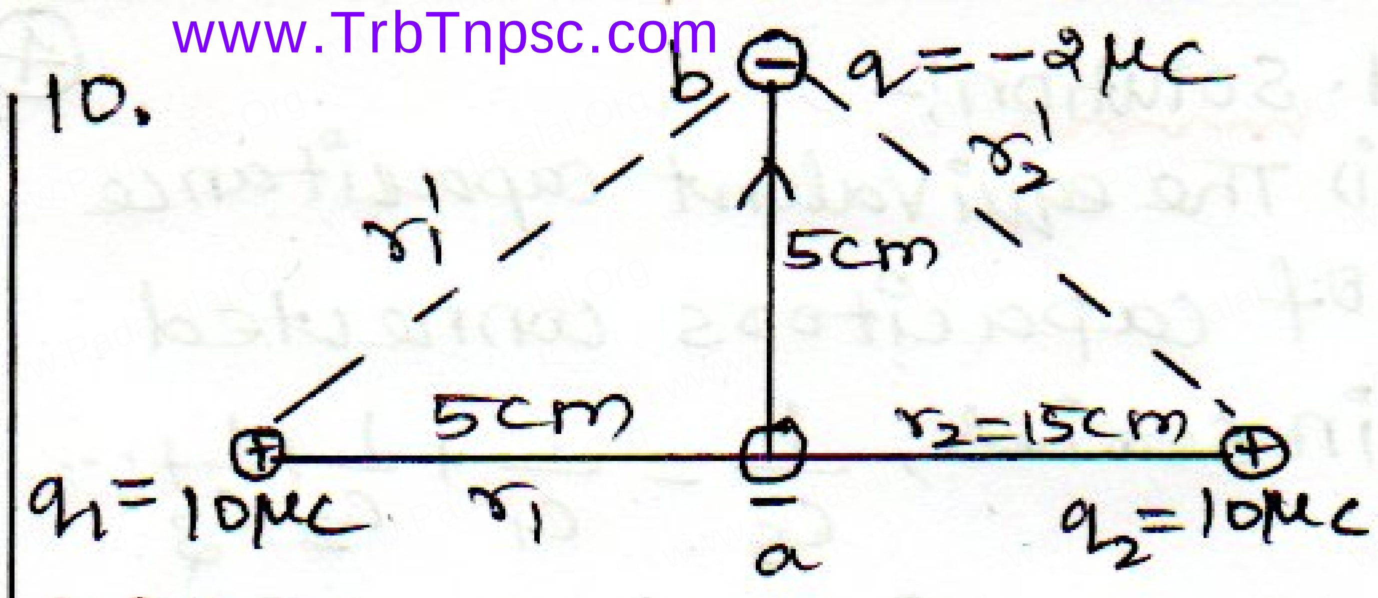
(b) $V \propto d$

If gap increases, then potential also will increase.

(c) If $d = 1mm$, $V = E\times d$

$V = 3\times10^6 \times 1\times10^{-3} = 3\times10^3 V = 3000V$

10.



Given :- $q_1 = q_2 = 10\mu C$, $q = -2\mu C$

$r_1 = 5cm$, $r_2 = 15cm$.

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

$r_2' = \sqrt{15^2+5^2} = \sqrt{250} = \sqrt{25\times10} = 5\sqrt{10}\,cm$

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

Solution :-

(i) Initial potential energy (U_i) when $-2\mu C$ charge at 'a'

$U_i = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q}{r_1} + \frac{1}{4\pi\varepsilon_0}\frac{q_2\cdot q}{r_2}$

$= \frac{q q_1}{4\pi\varepsilon_0}\left[\frac{1}{r_1}+\frac{1}{r_2}\right]$ $[\because q_1 = q_2]$

$U_i = 9\times10^9 \times(-2\times10^{-6})\times10\times10^{-6}\times\left[\frac{1}{5}+\frac{1}{15}\right]\times\frac{1}{10^{-2}}$

$= -18\times10^{-2}\times\frac{4}{15}\times\frac{1}{10^{-2}} = -\frac{24}{5}$

$\boxed{U_i = -4.8J}$

(ii) Final potential energy (U_f) when a point charge ($-2\mu C$) moved to 'b'

$U_f = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q}{r_1'} + \frac{1}{4\pi\varepsilon_0}\frac{q_2\cdot q}{r_2'}$

$= \frac{q q_1}{4\pi\varepsilon_0}\left[\frac{1}{r_1'}+\frac{1}{r_2'}\right]$ $(\because q_1 = q_2)$

$= 9\times10^9\times(-2\times10^{-6})\times10\times10^{-6}\times\left[\frac{1}{5\sqrt{2}}+\frac{1}{5\sqrt{10}}\right]\times\frac{1}{10^{-2}}$

$= \frac{-18\times10^{-2}}{5\times10^{-2}}\times\left[\frac{1}{\sqrt{2}}+\frac{1}{\sqrt{10}}\right]$

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

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

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

$= -3.6\times1.023$

$U_f = -3.683J$

$\begin{array}{r} 1.023\times3.6 \\ \hline 6138 \\ 3069 \\ \hline 3.6828 \end{array}$

$\begin{array}{r} 4.800 \\ 3.683 \\ \hline 1.117 \end{array}$

$\therefore$ Change in potential energy $\Delta U = U_f - U_i$

$= -3.683-(-4.8)$

$= 1.117J$

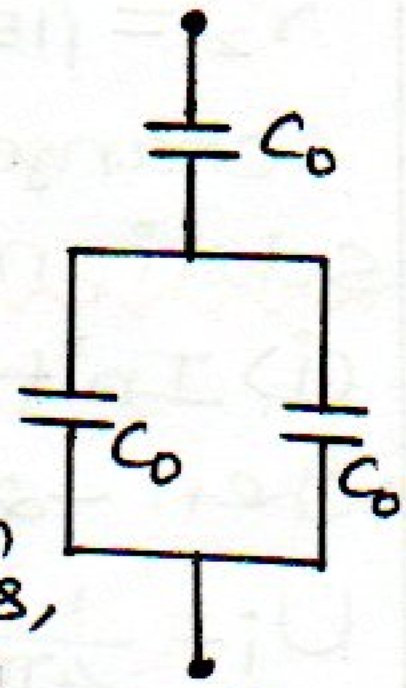
$\boxed{\therefore \Delta U = 1.12J}$

11. Solution:-

(i) The equivalent capacitance of capacitors connected in series, $\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$

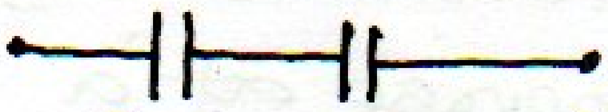
* The equivalent capacitance in capacitors connected in parallel, $C_P = C_1 + C_2 + C_3 + \cdots$

Figure (a):-



* C_0 and C_0 in parallel,

$\therefore C_P = C_0 + C_0 = 2C_0$

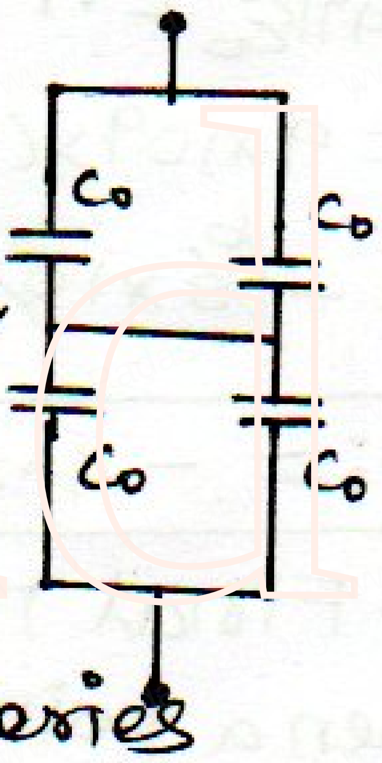


C_0 & $2C_0$ in series,

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

$\therefore \boxed{C_S = 2C_0/3}$

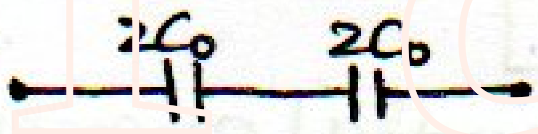
Figure (b):-



* C_0 and C_0 in parallel,

$C_P = C_0 + C_0 = 2C_0$

Now,

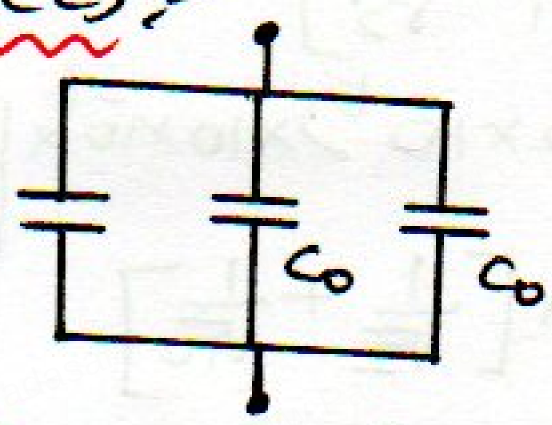


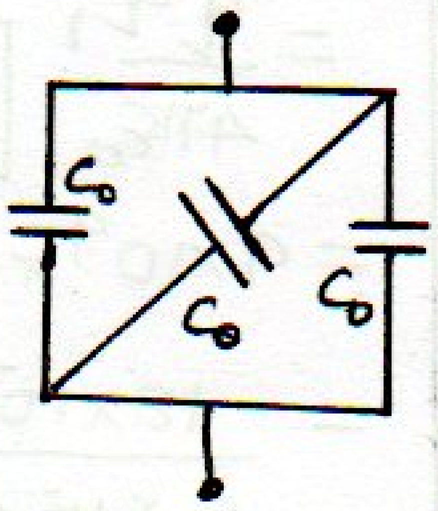
$2C_0$ and $2C_0$ are in series

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

$\therefore \boxed{C_S = C_0}$

Figure (c):-



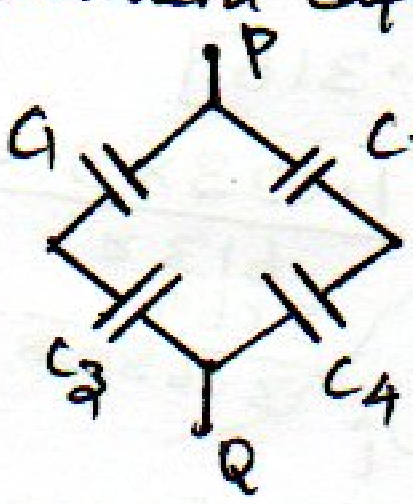


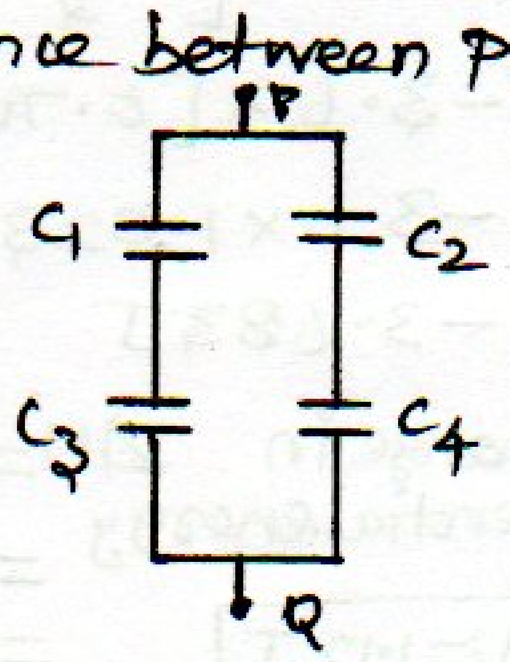
Now C_0, C_0 and C_0 are in parallel,

$C_P = C_0 + C_0 + C_0$ $\quad \therefore \boxed{C_P = 3C_0}$

Figure (d):-

Equivalent capacitance between P and Q:-





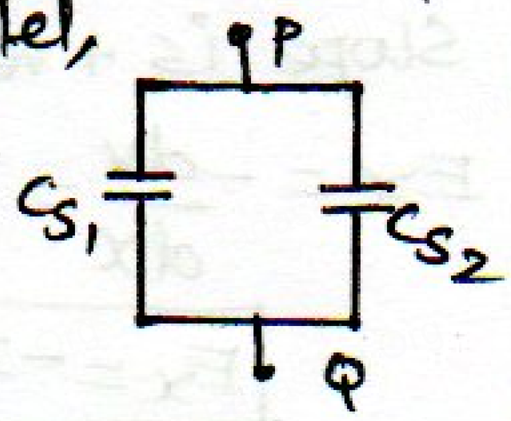
Now C_1 and C_3 in series

$$\frac{1}{C_{S_1}} = \frac{1}{C_1} + \frac{1}{C_3} = \frac{C_3 + C_1}{C_1 C_3}\ ;\ C_{S_1} = \frac{C_1 C_3}{C_1 + C_3}$$

C_2 and C_4 in series,

$$\frac{1}{C_{S_2}} = \frac{1}{C_2} + \frac{1}{C_4} = \frac{C_4 + C_2}{C_2 C_4}\ ;\ C_{S_2} = \frac{C_2 C_4}{C_2 + C_4}$$

Now, C_{S_1} and C_{S_2} in parallel,

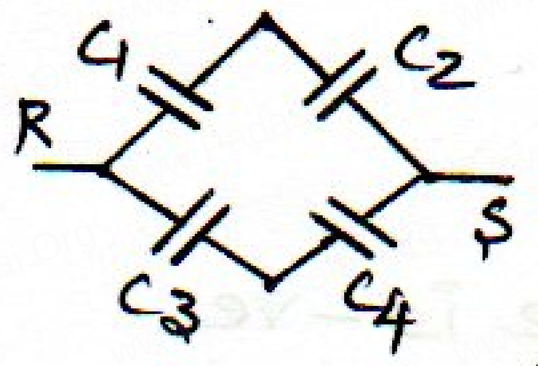


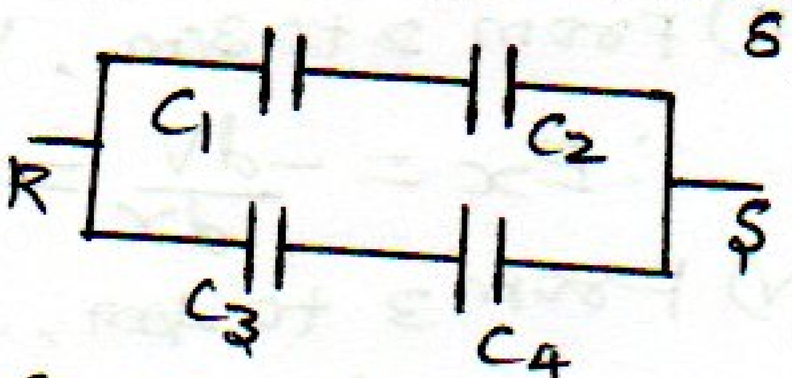
$$C_{PQ} = C_{S_1} + C_{S_2}$$

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

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

* Equivalent capacitance between R and S:-





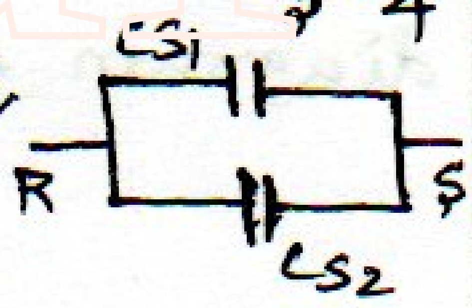
Now C_1, C_2 are in series

$$\frac{1}{C_{S_1}} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{C_2 + C_1}{C_1 C_2}\ ;\ C_{S_1} = \frac{C_1 C_2}{C_1 + C_2}$$

C_3 and C_4 in series,

$$\frac{1}{C_{S_2}} = \frac{1}{C_3} + \frac{1}{C_4} = \frac{C_4 + C_3}{C_3 C_4} \Rightarrow C_{S_2} = \frac{C_3 C_4}{C_3 + C_4}$$

Now, C_{S_1} and C_{S_2} in parallel,



$$C_{RS} = C_{S_1} + C_{S_2}$$

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

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

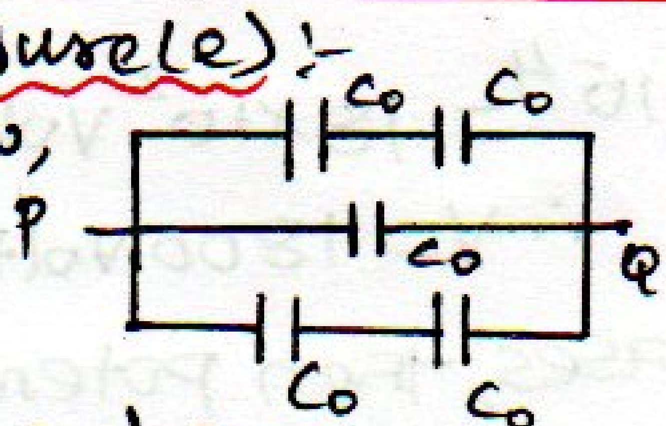
$$\boxed{C_{RS} = \frac{C_1 C_2 C_3 + C_1 C_2 C_4 + C_1 C_3 C_4 + C_2 C_3 C_4}{(C_1 + C_2)(C_3 + C_4)}}$$

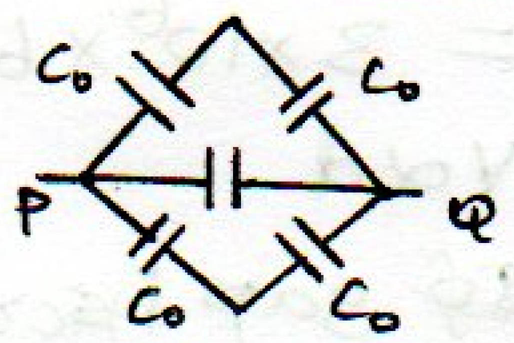
and

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

Figure (e):-

Now,



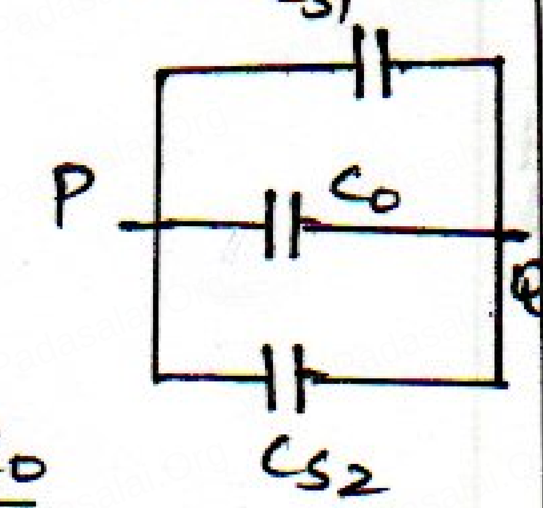


C_0 and C_0 in series,

$$\frac{1}{C_{S_1}} = \frac{1}{C_0} + \frac{1}{C_0} = \frac{2}{C_0}\ ;\ C_{S_1} = C_0/2$$

$$\frac{1}{C_{S_2}} = \frac{1}{C_0} + \frac{1}{C_0} = \frac{2}{C_0}\ ;\ C_{S_2} = C_0/2$$

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



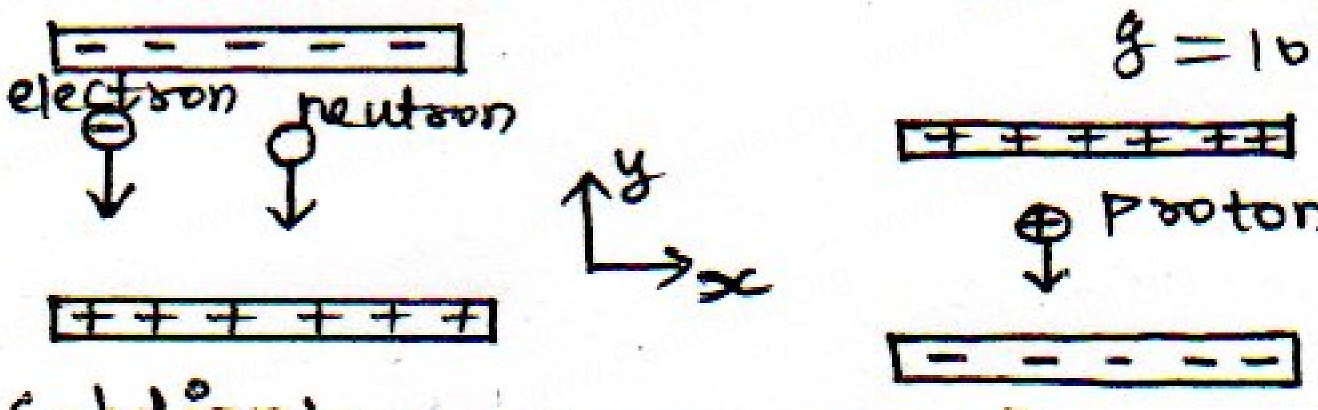
$C_p = C_{s1} + C_0 + C_{s2}$

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

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

∴ $\boxed{C_p = 2C_0}$

12. Given:- $m_p = 1.6\times10^{-27}$ kg, $m_e = 9.1\times10^{-31}$ kg, $g = 10\, ms^{-2}$



Solution:- $h = 1mm = 1\times10^{-3} m$; $V = 5$ volt.

(i) Time of flight (t_e) ∴ $E = \frac{V}{h} = \frac{5}{10^{-3}} = 5\times10^{3}\, NC^{-1}$

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

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

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

$t_e = \sqrt{\frac{2m_e h}{eE}} = \sqrt{\frac{2\times9.1\times10^{-31}\times1\times10^{-3}}{1.6\times10^{-19}\times5\times10^{3}}}$

$t_e = \sqrt{\frac{18.2\times10^{-18}}{8}} = \frac{10^{-9}}{2}\sqrt{9.1}$

$t_e = \frac{3\times10^{-9}}{2} = 1.5\times10^{-9}\, s$. $(\because \sqrt{9.1} \approx 3)$

∴ $\boxed{t_e = 1.5\, ns}$

(ii) Time of flight for proton (t_p):- $s = ut + \frac{1}{2}at^2$; $s = h$, $u = 0$, $t = t_p$

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

∴ $t_p = \sqrt{\frac{2m_p h}{eE}} = \sqrt{\frac{2\times1.6\times10^{-27}\times1\times10^{-3}}{1.6\times10^{-19}\times5\times10^{3}}}$

$t_p = \sqrt{0.4\times10^{-14}} = 10^{-7}\sqrt{0.4}$ $\left(\frac{1}{2}\log 0.4 \Rightarrow \frac{\bar{1}.6021}{2}\right.$ Antilog $\bar{1}.8010$ 6.324×10^{-1}

∴ $t_p = 6.3\times10^{-7}\times10^{-1} = 6.3\times10^{-9}\, s$

∴ $\boxed{t_p = 6.3\, ns}$

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

∴ $t_n = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2\times1\times10^{-3}}{10}}$ $s = ut + \frac{1}{2}at^2$, $u = 0$, $a = g$, $s = h$, $t = t_n$

$t_n = 10^{-2}\sqrt{2} = 1.414\times10^{-2}\, s$. $= 14.14\times10^{-3}\, s$

∴ $\boxed{t_n = 14.14\, ms}$

∴ $t_e < t_p < t_n$

∴ electrons will reach the bottom first.

13. Given:- $E = 3\times10^{6}\, Vm^{-1}$; $d = 1000\, m$, $V = ?$, $U = ?$ $q = 25C$

Solution:-

(i) Electric potential difference, $V = E\times d$

$V = 3\times10^{6}\times1000 = 3\times10^{9}$ Volt

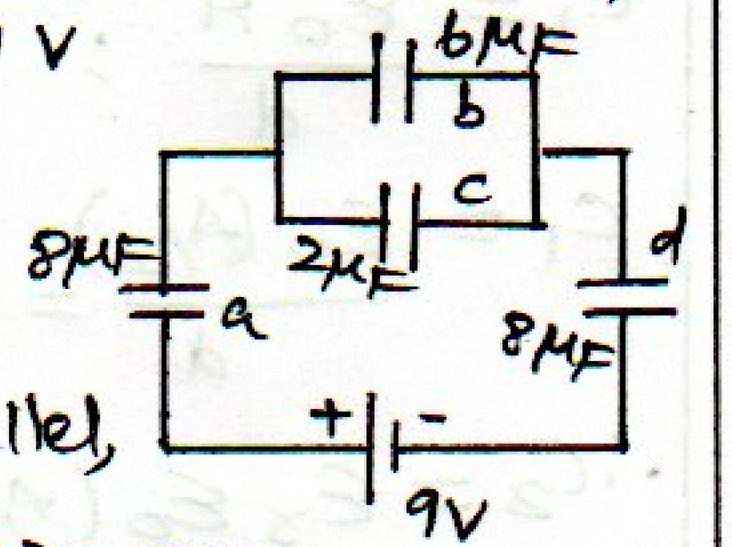
(ii) Electrostatic potential energy (U):-

$U = V\times q = 3\times10^{9}\times25 = 75\times10^{9}\, J$

14. Solution:- $V = 9\, V$

$C_a = 8\mu F$, $C_b = 6\mu F$

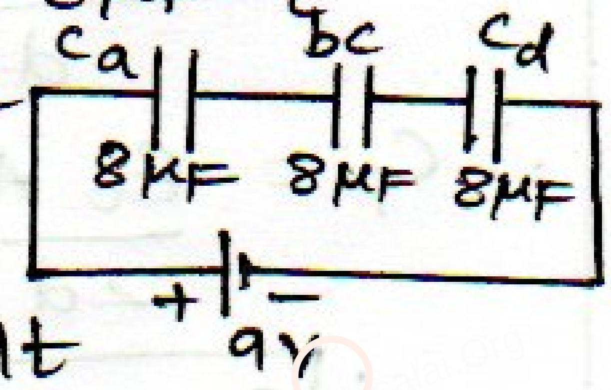
$C_c = 2\mu F$, $C_d = 8\mu F$



* C_b and C_c in parallel,

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

* Potential difference in each capacitor:-



∴ $V_a = \frac{V}{3} = \frac{9}{3} = 3$ Volt

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

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

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

* Charge on each capacitor

$q_a = C_a V_a = 8\times10^{-6}\times3 = 24\times10^{-6}\, C$ ∴ $\boxed{q_a = 24\mu C}$

$q_b = C_b V_b = 6\times10^{-6}\times3$

$q_b = 18\times10^{-6}\, C$, $\boxed{q_b = 18\mu C}$

$q_c = C_c V_c = 2\times10^{-6}\times3 = 6\times10^{-6}\, C$, $\boxed{q_c = 6\mu C}$

$q_d = C_d V_d = 8\times10^{-6}\times3 = 24\times10^{-6}\, C$, $\boxed{q_d = 24\mu C}$

* Energy stored in each capacitor

$U_a = \frac{1}{2}C_a V_a^2 = \frac{1}{2}\times8\times10^{-6}\times(3)^2 = 36\times10^{-6}\, J$ $\boxed{U_a = 36\mu J}$

$U_b = \frac{1}{2}C_b V_b^2$

$= \frac{1}{2}\times6\times10^{-6}\times(3)^2 = 27\times10^{-6}\, J$; $\boxed{U_b = 27\mu J}$

$U_c = \frac{1}{2}C_c V_c^2 = \frac{1}{2}\times2\times10^{-6}\times(3)^2 = 9\times10^{-6}\, J$ $\boxed{U_c = 9\mu J}$

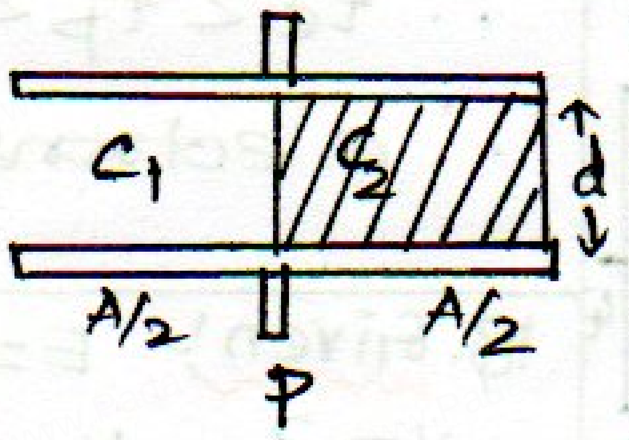
$U_d = \frac{1}{2}C_d V_d^2$

$= \frac{1}{2}\times8\times10^{-6}\times(3)^2 = 36\times10^{-6}\, J$; $\boxed{U_d = 36\mu J}$

15. Capacitor 'P'

(b)

(i) capacitance of a parallel plate capacitor, $C = \frac{\varepsilon_0 A}{d}$



* with dielectric, $C = \frac{\varepsilon_r \varepsilon_0 A}{d}$

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

$C_1 = \frac{\varepsilon_0 A}{d}$; here $A = A/2$

$C_1 = \frac{\varepsilon_0 (A/2)}{d} = \frac{\varepsilon_0 A}{2d}$

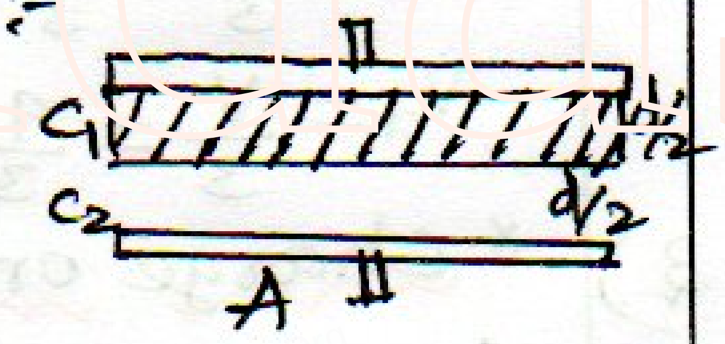
$\therefore C_2 = \frac{\varepsilon_r \varepsilon_0 (A/2)}{d} = \frac{\varepsilon_r \varepsilon_0 A}{2d}$

$\therefore C_P = \frac{\varepsilon_0 A}{2d} + \frac{\varepsilon_r \varepsilon_0 A}{2d}$

$\therefore \boxed{C_P = \frac{\varepsilon_0 A}{2d}(1+\varepsilon_r)}$

In capacitor Q :-

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



C_1, C_2 are in series,

$\frac{1}{C_Q} = \frac{1}{C_1} + \frac{1}{C_2}$; $C_1 = \frac{\varepsilon_r \varepsilon_0 A}{d/2}$

$C_2 = \frac{\varepsilon_0 A}{d/2} = \frac{2\varepsilon_0 A}{d}$, $C_1 = \frac{2\varepsilon_r \varepsilon_0 A}{d}$

$\therefore \frac{1}{C_Q} = \frac{d}{2\varepsilon_r \varepsilon_0 A} + \frac{d}{2\varepsilon_0 A}$

$= \frac{d}{2\varepsilon_0 A}\left[\frac{1}{\varepsilon_r} + 1\right]$

$\frac{1}{C_Q} = \frac{d}{2\varepsilon_0 A}\left[\frac{1+\varepsilon_r}{\varepsilon_r}\right]$

$\therefore \boxed{C_Q = \frac{2\varepsilon_0 A}{d}\left[\frac{\varepsilon_r}{1+\varepsilon_r}\right]}$

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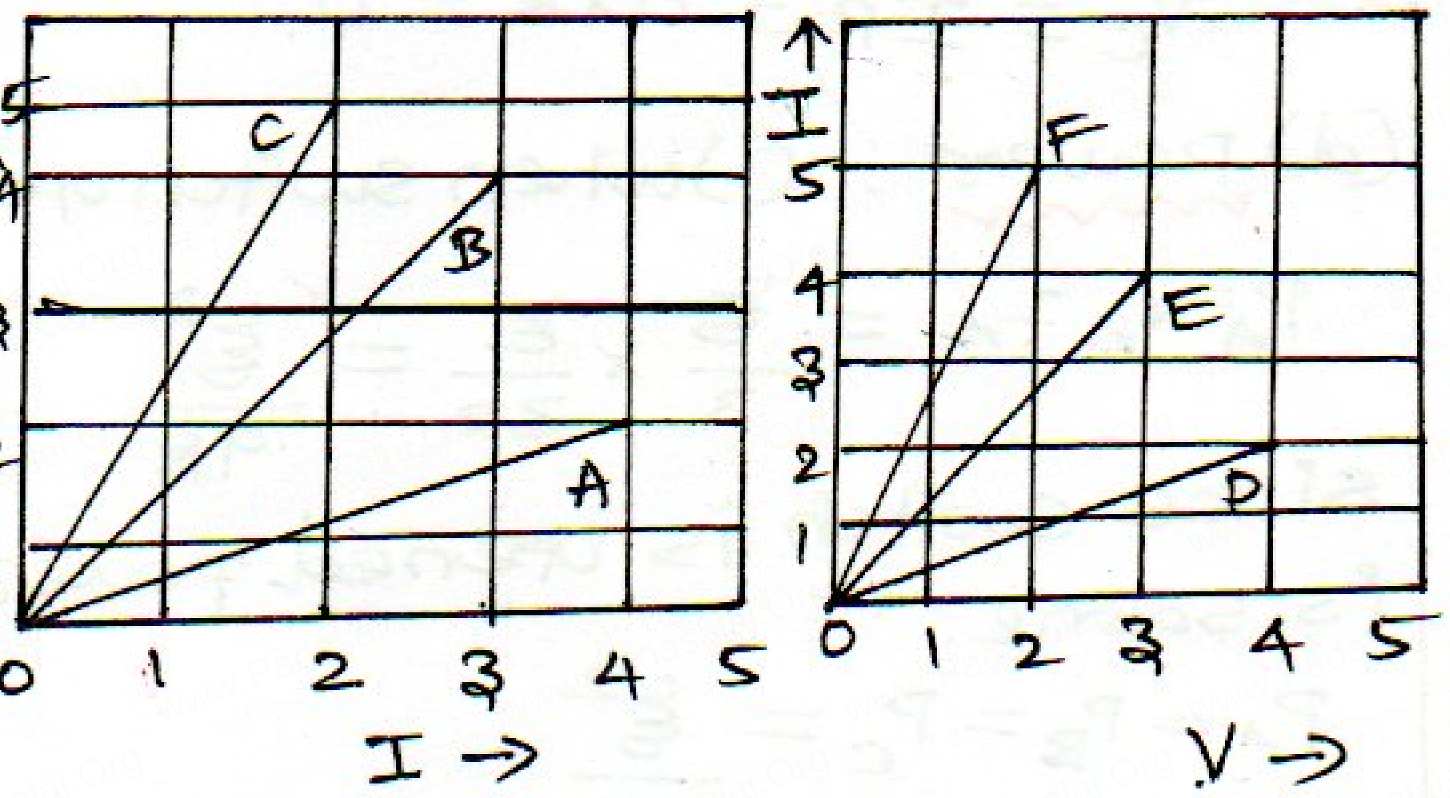
2. CURRENT ELECTRICITY

1. Given:-



$R_{Least} = ?$; $R_{max} = ?$

Solution:- According to ohm's law

$V = IR$, $R = \frac{V}{I}$.

Graph 1:-

For A:- $\text{slope} = R_A = \frac{\Delta V}{\Delta I} = \frac{\cancel{2}^{1}}{\cancel{4}_{2}} = 0.5\,\Omega$

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

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

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

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

Maximum Resistance, $R_C = 2.5\,\Omega$

2. Given:- $W = 10^9\,J$, $V = 5\times10^7$ volt, $t = 0.2\,s = 2\times10^{-1}\,s$, $q = ?$ $I = ?$ $P = ?$

Solution:-

(i) Total amount of charge transferred

$W = Vq$

$$q = \frac{W}{V} = \frac{10^9}{5\times10^7} = 0.2\times10^2 = 20\,C$$

(ii) Current in the lightening bolt.

$$I = \frac{q}{t} = \frac{\cancel{20}^{10}}{\cancel{2}\times10^{-1}} = 100\,A$$

(iii) Power delivered in 0.2 second

$$P = VI = 5\times10^7\times10^2 = 5\times10^9\,W$$

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

3. Given:- $A = 10^{-6}\,m^2$, $I = 5A$, $n = 8\times10^{28}$, $J = ?$, $v_d = ?$

Solution:-

(i) $J = \frac{I}{A} = \frac{2}{10^{-6}} = 2\times10^6\,Am^{-2}$

(ii) $J = nev_d$

$$v_d = \frac{J}{ne} = \frac{\cancel{2}\times10^6}{\cancel{8}_{4}\times10^{28}\times1.6\times10^{-19}}$$

$$v_d = \frac{10^{-3}}{6.4} = 1.56\times10^{-4}\,ms^{-1}$$

$10^{-3} \Rightarrow \bar{3}.0000$
$6.4 \Rightarrow 0.8062$ (−)
$\bar{4}.1938$
1.563×10^{-4}

4. Given:- $R_0 = 10\,\Omega$, $T_0 = 0°C$, $R_{100} = ?$, $T = 100°C$.

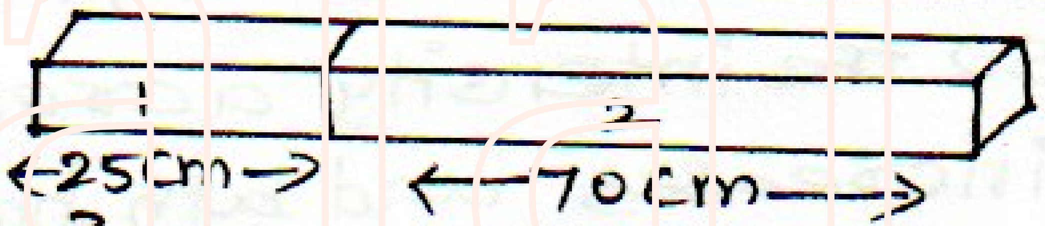
Solution:- $\alpha = 0.004/°C$

$$R_t = R_0(1+\alpha(T-T_0))$$
$$R_{100} = 10[1+0.004\times100]$$
$$= 10[1+0.4] = 10\times1.4$$

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

∴ As temperature increases, the resistance of wire also increases

5.



Given:- $\rho_1 = 4\times10^{-3}\,\Omega m$, $l_1 = 25\,cm$

$\rho_2 = 5\times10^{-3}\,\Omega m$, $l_2 = 70\,cm$, $R_s = ?$

Side length = 3mm, Area = $(3\times10^{-3}\,m)^2$

Solution:- Area, $A = 9\times10^{-6}\,m^2$

∴ $R_s = R_1 + R_2 \rightarrow (1)$

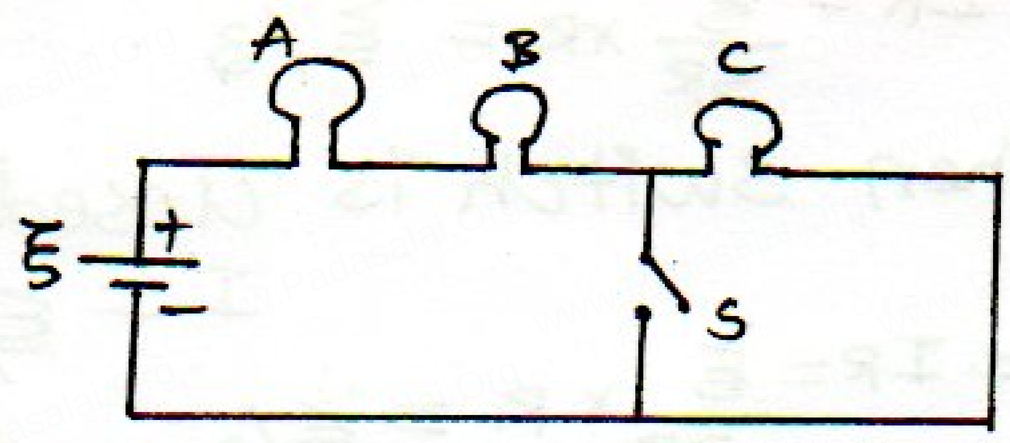
$$R_1 = \frac{\rho_1 l_1}{A} = \frac{4\times10^{-3}\times25\times10^{-2}}{9\times10^{-6}} = \frac{1000}{9}\,\Omega$$

$$R_1 = \frac{\rho_2 l_2}{A} = \frac{5\times10^{-3}\times70\times10^{-2}}{9\times10^{-6}} = \frac{3500}{9}\,\Omega$$

(1) ⇒ $R_s = \frac{1000}{9} + \frac{3500}{9} = \frac{4500}{9} = 500\,\Omega$

∴ 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, $V = IR$

$\xi = V$.

$R_1 = R_2 = R_3 = R$

Three lamps are connected in series

$R_S = R_1 + R_2 + R_3 = R + R + R = 3R$.

when switch is open

$I = \frac{V}{R_S} = \frac{\xi}{3R}$

when switch is closed, then no current flow through lamp 'c'

$I = \xi/2R$

(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' 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. $I = \xi/3R$

$V_A = IR = \frac{\xi}{3\cancel{R}} \times \cancel{R} = \xi/3$

$V_B = IR = \frac{\xi}{3R} \times R = \xi/3$.

$V_B = IR = \frac{\xi}{3R} \times R = \xi/3$.

(ii) when switch is closed.

$I = \xi/2R$

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

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

(8) Bulb 'c' is in parallel

$\therefore I = 0$.

$V_C = IR = 0 \times R = 0$.

(d) Power :- (i) when switch open.

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

since switch is opened power is same.

$P_A = P_B = P_C = \frac{\xi^2}{9R}$.

(ii) when switch is closed :-

$P_A = V_A I_A$ $\qquad I = \frac{\xi}{2R}$

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

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

Bulb 'c' is in parallel

$V_c = 0 \quad I_c = 0$.

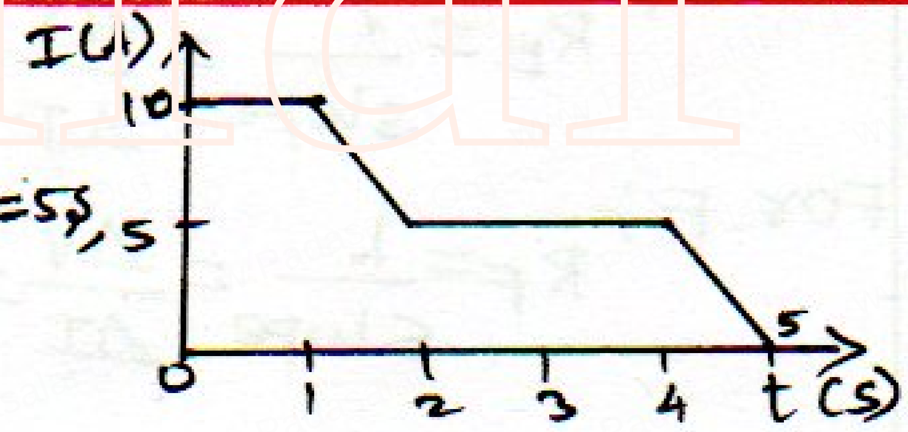
$\therefore P_c = V_c I_c$

$P_c = 0 \times 0 = 0$.

$\therefore$ 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, $t = 2s$,

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

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

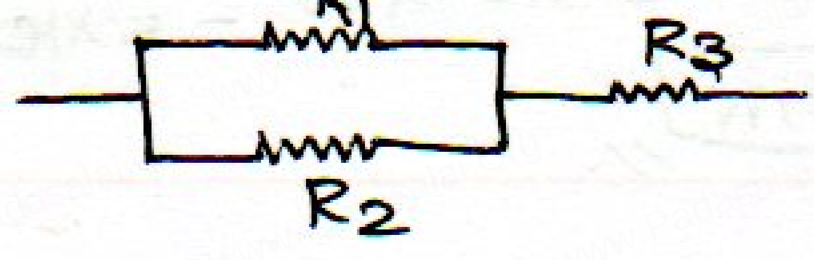
(iii) At, $t = 5s$.

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

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

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

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



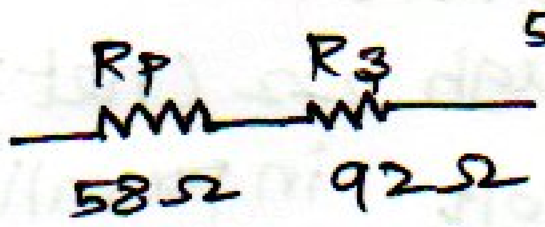
R_1 and R_2 are connected in Parallel, $R_P = \frac{R_1 R_2}{R_1+R_2} = \frac{220 \times 79}{220+79}$

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

$17380 \Rightarrow 4.2400$
$299 \Rightarrow 2.4757$ (−)
Antilog ↙ 1.7643
$58.12 \Leftarrow 5.812 \times 10^1$

$\boxed{R_P = 58\Omega}$

Now,



∴ R_3, R_P are in series,

$R_S = R_P + R_3 = 58 + 92 = 150\Omega$

∴ $R_S = 150\Omega$

∴ Parallel combination of 220Ω and 79Ω in series with 92Ω

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

Solution:-

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

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

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

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

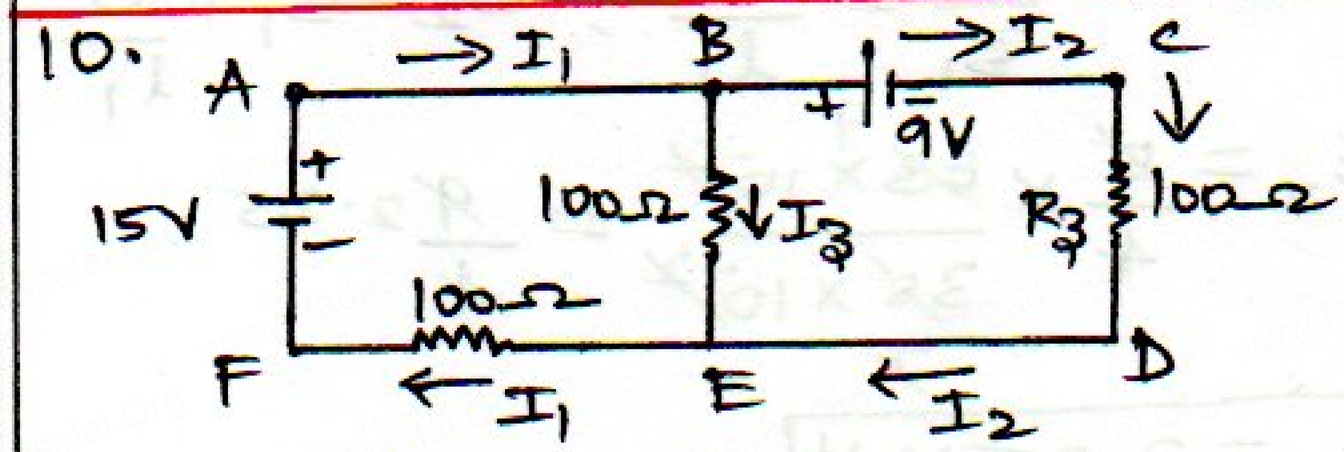
$r[I_1 - I_2] = I_2 R_2 - I_1 R_1$

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

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

∴ $\boxed{r = 0.5\Omega}$

10.



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

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

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

Apply kirchoff's voltage rule for closed path ABEFA,

$100 I_1 + 100 I_3 = 15$

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

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

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

Apply kirchoff's voltage rule for closed path BCDEB,

$100 I_2 - 100 I_3 = -9$

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

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

$200 I_2 - 100 I_1 = -9$

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

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

$(3) \times 2 \Rightarrow \cancel{-200 I_1} + 400 I_2 = -18$ (+)

$\frac{3\cancel{00} I_2}{100} = -\cancel{3}$

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

$(2) \Rightarrow 200 I_1 - 1\cancel{00} \times \frac{1}{1\cancel{00}} = 15$

$200 I_1 + 1 = 15$, $\frac{2\cancel{00} I_1}{100} = 1\cancel{4}7$

$\boxed{I_1 = 0.07A}$, $I_1 = 7/100$

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

∴ $\boxed{I_3 = 0.08A}$

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

Solution:- Effective resistance for two resistors in series combination

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

$R_S = 3000\Omega$.

∴ $I = \xi / R = \frac{4}{3000} A$.

∴ Potential drop across the wire,

$V = Ir = \frac{4}{\cancel{3000}_{150}} \times \cancel{20} = \frac{4}{150}$ volt.

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

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

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

15) 100 (0.66
90
100
90
10

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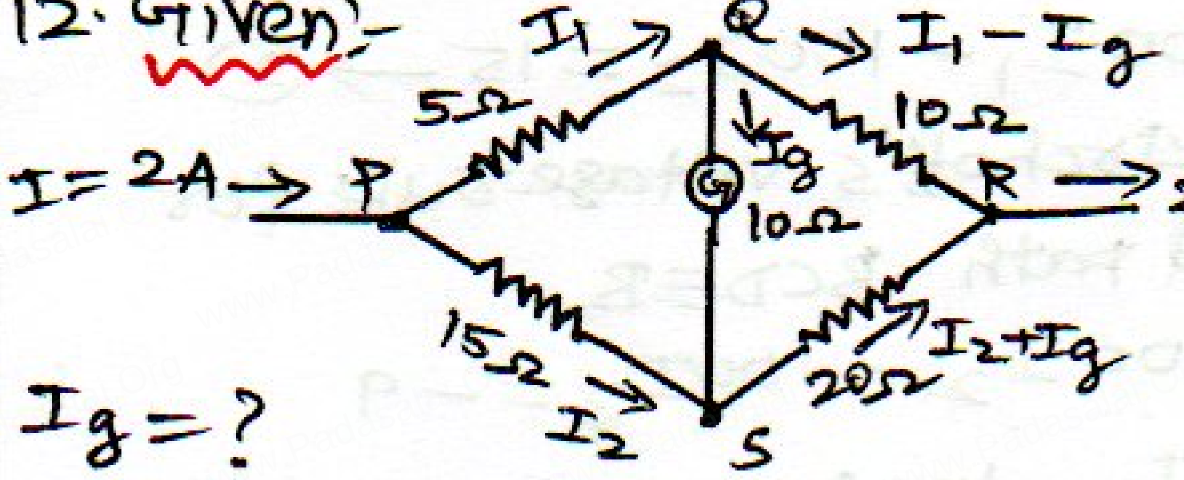
12. Given:-



$I_g = ?$

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

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

Apply Kirchoff'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 Kirchoff'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) $\Rightarrow 10I_1 - 40I_g - 20(I - I_1) = 0$.

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

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

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

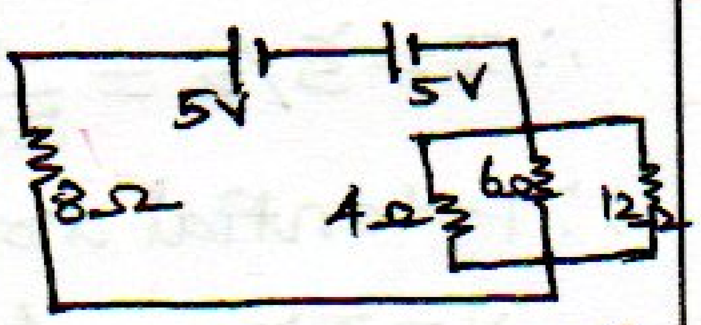
(2) $\times 3 \Rightarrow 60I_1 + 30I_g = 90$

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

$110I_g = 10$

$\boxed{I_g = 1/11 \ A}$

13.



$I = ?$

Solution:-

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

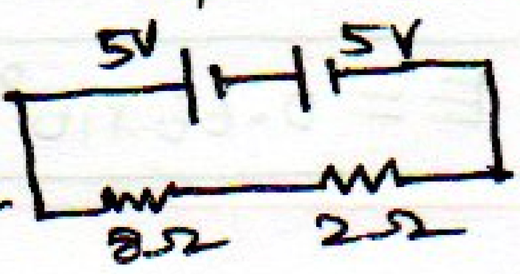
$R_3 = 12\Omega$ are connected in parallel,

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

$\frac{1}{R_P} = \frac{6}{12_2}\Omega$

$\therefore \boxed{R_P = 2\Omega}$

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

$\therefore \mathcal{E} = \mathcal{E}_1 + \mathcal{E}_2 = 5 + 5 = 10$ Volt.

$\therefore$ current drawn from each cell,

$I = \frac{\mathcal{E}}{R_S} = \frac{10}{10} = 1 A$

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

$V = 1 \times 8 = 8$ volt.

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

$V = IR = 1 \times 2 = 2$ volt.

(i) Current through 8Ω resistor,

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

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

$R = 4\Omega$, $I = \frac{V}{R} = \frac{2}{4_2} = 0.5 A$

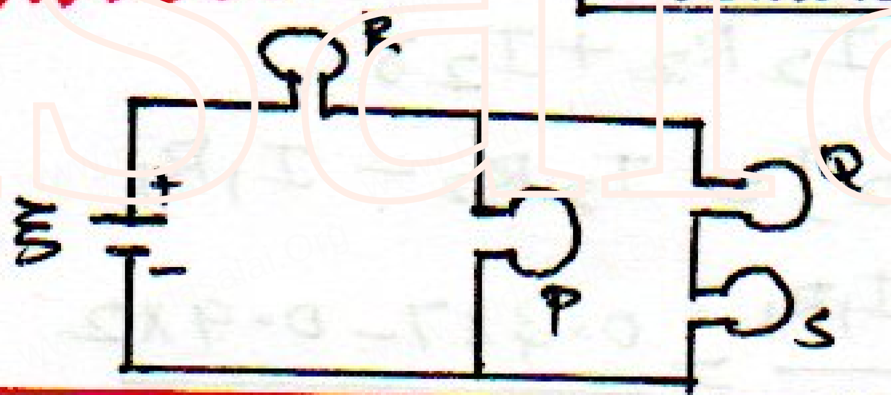
$R = 6\Omega$, $I = \frac{2^1}{6_3} = 0.33 A$

$R = 12\Omega$, $I = 2/12_6 = 0.166 A$

14.

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

Solution:-



15. Given:- $\mathcal{E}_1 = 1.25V$, $\mathcal{E}_2 = ?$ $\mathcal{E} = \frac{5}{4}V$

$l_1 = 35 \times 10^{-2} m$, $l_2 = 63 \times 10^{-2} m$.

Solution:-

$\frac{\mathcal{E}_2}{\mathcal{E}_1} = \frac{l_2}{l_1}$; $\mathcal{E}_2 = \mathcal{E}_1 \times \frac{l_2}{l_1}$

$\mathcal{E}_2 = \frac{5}{4} \times \frac{63^9 \times 10^{-2}}{35_7 \times 10^{-2}} = \frac{9}{4} 2.25$

$\boxed{\mathcal{E}_2 = 2.25 \text{ volt}}$

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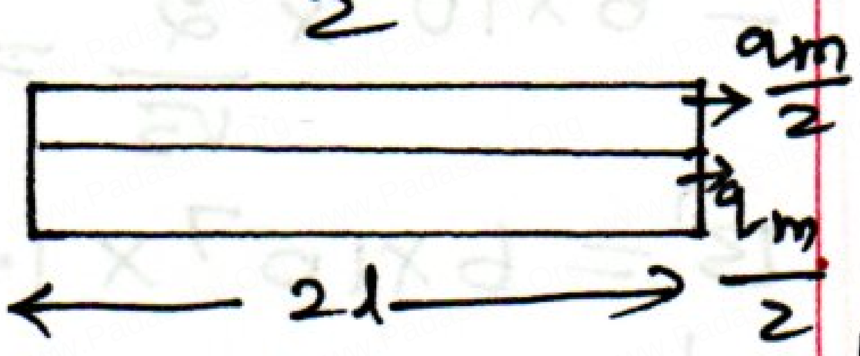
3. Magnetism and magnetic effects of electric current.

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 $\vec{P_m}' = \frac{\vec{P_m}}{2}$

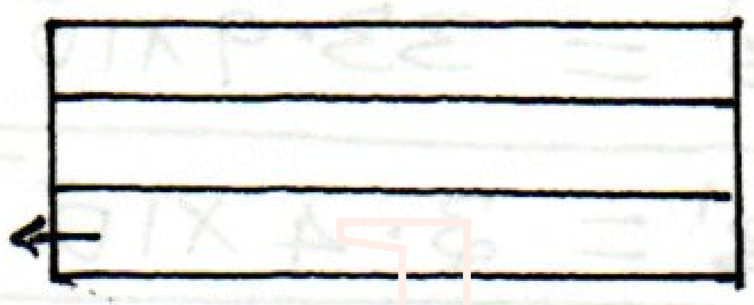
$\vec{P_m}' = q_m' \times 2l$



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

$\vec{P_m}' = \frac{\vec{P_m}}{2}$ $\quad (\because \vec{P_m} = q_m \times 2\vec{l})$

* Each pieces is further cut into pieces.



$q_m'' \Rightarrow \frac{q_m}{4}$

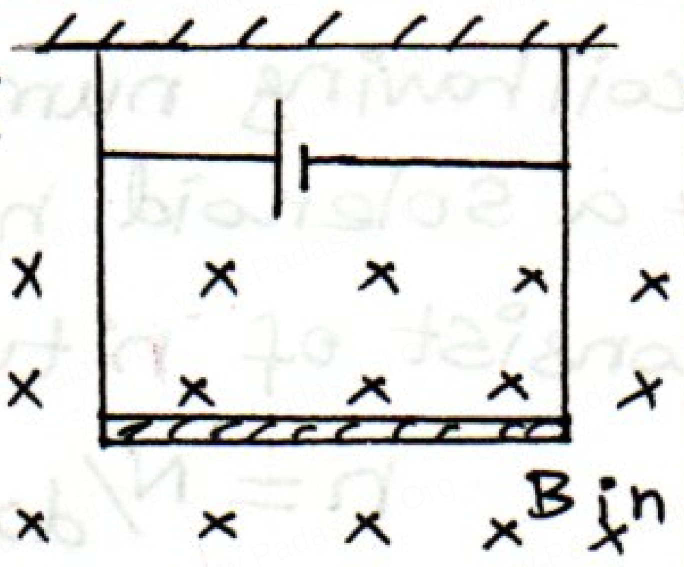
$\therefore \vec{P_m}'' = q_m'' \times 2l = \frac{q_m}{4} \times 2l$

$\boxed{\therefore \vec{P_m}'' = \frac{\vec{P_m}}{4}}$

2. magnetic field, $B = 1T$,

Downward force,

$F = mg$



Linear mass density

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

$m =$ Linear mass density $\times l$

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

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

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

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

This is upward magnetic force acting on the wire.

From (1) and (2)

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

3. cross-sectional area of coil,

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

$A = 0.1 \times 10^{-4} m^2$, $n = 10^{28} m^{-3}$

$B = 0.2T$, $I = 3A$

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

(a) Total torque on the coil,

$\tau = ABI \sin\theta$

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

$\boxed{\tau = 0}$ $\quad (\because \sin 0° = 0)$

(b) Total force on the coil,

$F = BIl \sin\theta$

$F = 0.2 \times 3 \times l \times \sin 0°$

$\boxed{F = 0}$

(c) Average force:

$F = q v_d B$, Drift velocity,

$v_d = \frac{I}{neA}$

$\therefore F = \cancel{e} \times \frac{I}{n\cancel{e}A} \times B$ $\quad (\because q = e)$

$F = \frac{IB}{nA} = \frac{3 \times 0.2}{10^{28} \times 0.1 \times 10^{-4}}$

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

4. $B = 0.8T$, $\theta = 30°$, $\tau = 0.2\,Nm$

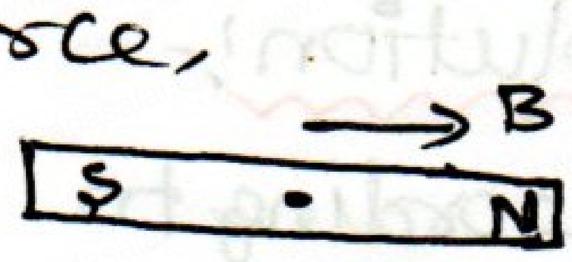
Solution: (i) $\tau = P_m B \sin\theta$

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

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

(ii) In stable configuration workdone by an applied force,

$U_i = -P_m B \cos\theta$

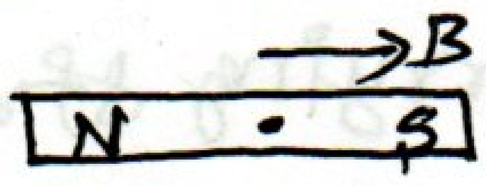


$U_i = -P_m B \cos 0°$ $\quad \theta = 0°$, $\cos 0° = 1$

$U_i = -P_m B$

(ii) In unstable configuration workdone by an applied force,

$U_f = -P_m B \cos\theta$



$U_f = -P_m B \cos 180°$ $\quad \theta = 180°$

$U_f = P_m B$. $\quad \cos 180° = -1$

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

$= P_m B - (-P_m B)$

$W = 2 P_m B$

$W = 2 \times 0.5 \times 0.8$

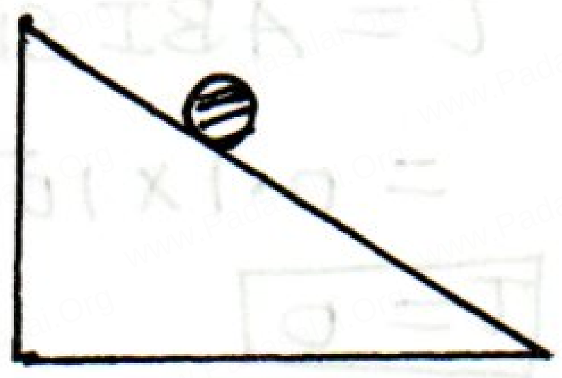
$\boxed{W = 0.8 J}$

5.

Mass of the sphere, (m)

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

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



Number of turns, $n = 5$

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

$I = ?$

Solution:- At equilibrium,

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

$f_s R = P_m B \sin\theta$, $\theta = 90°$

$\left[P_m = IA, \text{ for 'n' turns } P_m = N \times IA \right.$

$mgR = NIAB$

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

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

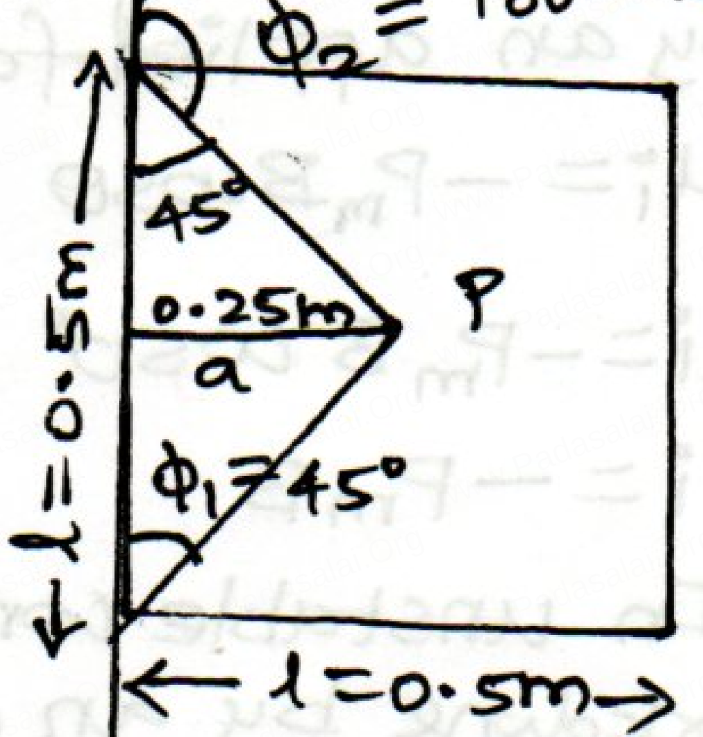
$I = \frac{20 \times 10^{-1}}{\pi}$, $\boxed{I = \frac{2}{\pi} A}$

6. $I = 1.5 A$, length of each loop $l = 50cm = 0.5m$

Magnetic field at the centre of current carrying square loop, $B' = ?$

Solution:-

According to Biot-Savart laws Magnetic field due to a current carrying straight wire.



⑫ $B' = \frac{\mu_0 I}{4\pi a} [\cos\phi_1 - \cos\phi_2]$

$= \frac{\cancel{4\pi} \times 10^{-7} \times 1.\cancel{5}^{6}}{\cancel{4\pi} \times 0.\cancel{25}} [\cos 45° - \cos(180° - 45°)]$

$= 6 \times 10^{-7} [\cos 45° + \cos 45°)$

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

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

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

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

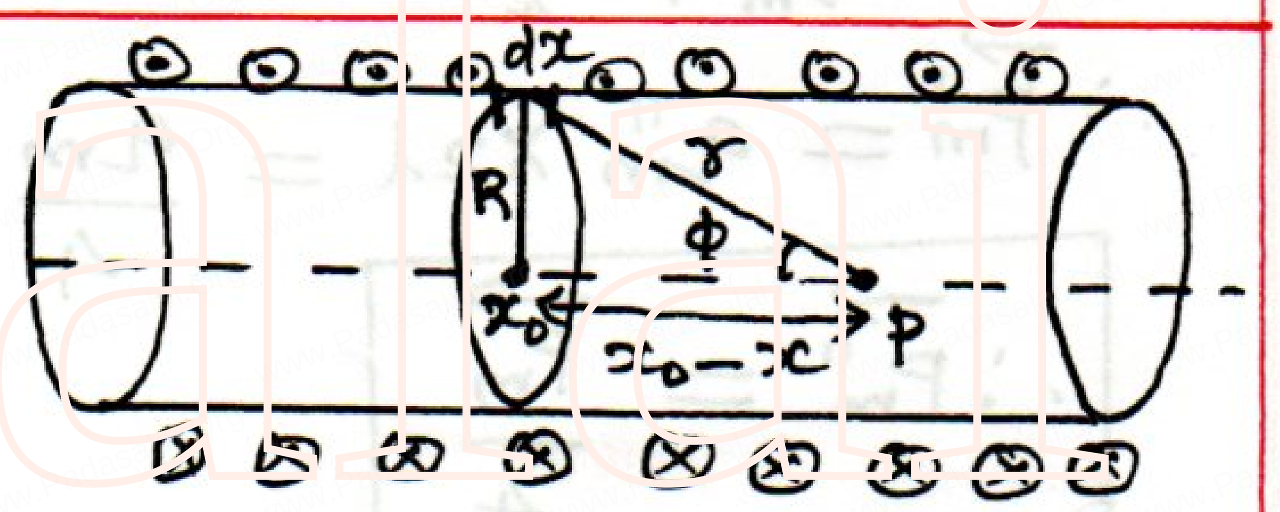
$\therefore$ For four sides,

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

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

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

6.



* A solenoid is a long cylindrical coil having number of circular turns.
* a solenoid having radius 'R' consist of 'n' turns per units length

$n = N/dx$; $N = n dx$.

* Let 'P' be the point at a distance x_0 from the origin of the solinoid.
* '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 $dB = \frac{\mu_0 I R^2 \times N}{2r^3}$

where, $N = n dx$

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

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

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

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

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

$\cancel{-}\frac{dx}{d\phi} = \cancel{-}R\operatorname{cosec}^2\phi$; $\frac{dx}{d\phi} = R\operatorname{cosec}^2\phi$

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

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

$$dB = \frac{\mu_0 n I \cancel{R^2} \times \cancel{R}\cancel{\operatorname{cosec}^2}\phi\, d\phi}{2 \cancel{R^3} \operatorname{cosec}^{\cancel{3}}\phi}$$

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

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

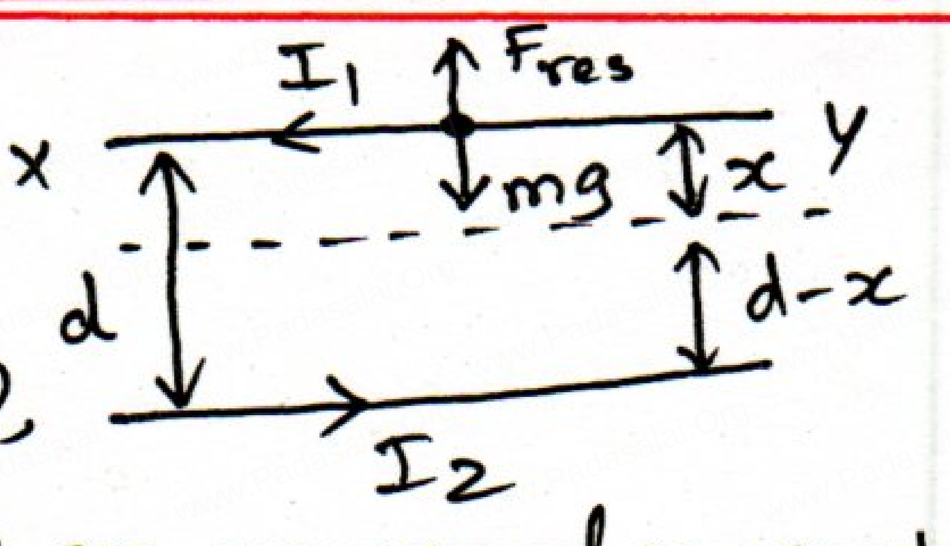
$$\int dB = \int_{\phi_1}^{\phi_2} \frac{\mu_0 n I}{2}\sin\phi\, d\phi$$

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

$$= \frac{\mu_0 n I}{2}\left[-\cos\phi_2 - (-\cos\phi_1)\right]$$

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

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) $\therefore$ 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,

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

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

$\therefore F_{res} = \frac{-mg\,x}{d-x}$ ($d >> x$, hence x can be neglected)

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

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

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

$\omega = \sqrt{g/d}$

since acceleration is proportional to displacement 'x' and oppositely directed, the wire XY on being released, would execute SHM. Its time period is $T = \frac{2\pi}{\omega}$

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

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4. Electromagnetic Induction and Alternating current.

1. Given:- cross-sectional Area

$A = 30\times10^{-2}\times30\times10^{-2}\ m^2$

$A = 900\times10^{-4} = 9\times10^{-2}\ m^2$

$B = 0.4T$, Plane inclined to the field, $\theta = 30°$

$\therefore \theta = 90° - 30° = 60°$

$N = 500$ turns, $\phi_B = ?$

Solution:-

$\phi_B = NBA\cos\theta = 500\times0.4\times9\times10^{-2}\times\cos60°$

$\phi_B = 5\times\cancel{10^2}\times\cancel{4}^{2}\times10^{-1}\times9\times\cancel{10^{-2}}\times\frac{1}{\cancel{2}}$

$\phi_B = 10\times10^{-1}\times9$, $\boxed{\phi_B = 9\ Wb}$

2. Given:- $d\phi = 4\ mWb$

change in magnetic flux, $d\phi = 4\times10^{-3}\ Wb$

" time, $dt = 0.4\ s = 4\times10^{-1}\ s$

$\varepsilon = ?$

Solution:- Magnitude of induced emf, $\varepsilon = \frac{d\phi}{dt} = \frac{\cancel{4}\times10^{-3}}{\cancel{4}\times10^{-1}} = 10\times10^{-3}\ V$

$\boxed{\varepsilon = 10\ mV}$

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

$R = 5\Omega$, $t = 3\ s$

$i = ?$

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

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

$\varepsilon = (6t^2+8t+8)$

$t = 3\ s$, $\varepsilon = 6\times(3)^2+8\times3+8$

$\varepsilon = 6\times9+24+8$

$\varepsilon = 54+32 = 86\ V$

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

$\boxed{i = 17.2\ A}$

$5\,\overline{)86}$ = 17.2
85
10

4. Given:- radius, $r = 0.02\ m$

$r = 2\times10^{-2}\ m$

$B_1 = 8000T$, $B_2 = 2000T$,

$dt = 6\ s$, $\varepsilon = 44$ Volt.

$\theta = 0°$, $N = ?$

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

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

$A = \pi r^2 = 3.14\times(2\times10^{-2})^2$

$\varepsilon = 44$ volt, $\theta = 0°$

$\therefore \cancel{44}^{11} = \frac{N\times3.14\times\cancel{4}\times10^{-4}\times\cos0°\times(8000-2000)}{6}$

$11 = \frac{N\times3.14\times10^{-4}\times1\times\cancel{6000}^{1000}}{\cancel{6}}$

$11 = N\times3.14\times10^{-1}$

$N = \frac{110}{3.14} = \frac{110\cancel{}5}{22/7} = 5\times7 = 35$

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

5. Given:- $A = 6\ cm^2 = 6\times10^{-4}\ m^2$

$N = 3500 = 35\times10^2$ turns, $B = 0.4T$

$B = 4\times10^{-1}T$

$\theta_1 = 0°$, $\theta_2 = 180°$

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

Solution:-

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

(only considering magnitude)

$\varepsilon = \frac{35\times10^2\times4\times10^{-1}\times6\times10^{-4}\times(\cos0° - \cos180°)}{1}$

$\varepsilon = \frac{840\times10^{-3}\times(1+1)}{1} = 1680\times10^{-3}\ V$

$i = \frac{\varepsilon}{R} = \frac{1680\times10^{-3}}{35} = 48\times10^{-3}\ A$

$q = it$, $\therefore$ charge, $q = 48\times10^{-3}\times1$

$q = 48\times10^{-3}\ C$, $\boxed{q = 48\ mC}$

6. Given:- Induced current, $i = 2.5\,mA$

Resistance, $R = 100\,\Omega$, $\frac{d\Phi_B}{dt} = ?$

Solution:-

$$\frac{d\Phi_B}{dt} = \varepsilon, \quad \varepsilon = iR$$

$$\frac{d\Phi_B}{dt} = 2.5\times10^{-3}\times100 = 250\times10^{-3}$$

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

7. Given:- $l = 0.4m$, $B = 4\times10^{-3}\,T$

$\varepsilon = 0.02V = 2\times10^{-2}\,V$, $\omega = ?$

∴ Area, $A = \pi r^2 = 3.14\times(0.4)^2$

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

$[N=1,\ \theta=90^\circ,\ \sin90^\circ=1]$.

$$\omega = \frac{\varepsilon}{NBA\sin\theta} = \frac{\cancel{2}\times10^{-2}}{1\times\cancel{4}_{2}\times10^{-3}\times3.14\times(0.4)^2\times\sin90^\circ}$$

$$\omega = \frac{\cancel{10}\,5}{\cancel{2}\times3.14\times0.16\times1}$$

$\omega = 9.95$ revolutions persecond.

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

$\log 5 \Rightarrow 0.6990$
$3.14 \Rightarrow 0.4969$
$0.16 \Rightarrow \bar{1}.2041$ (+)
$\bar{1}.7010$

0.6990
$\bar{1}.7010$ (−)
0.9980

Antilog $9.954\times10^0 \Leftarrow 0.9980$

8. Given:- $l = 1m$, $B = 4\times10^{-5}\,T$

Area, $A = \pi r^2 = 3.14\times(1)^2 = 3.14\,m^2$

emf, $\varepsilon = 31.4\,mV = 31.4\times10^{-3}\,V$

$\omega = ?$ $\quad \varepsilon = 3.14\times10^{-2}\,V$.

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

$$\omega = \frac{\varepsilon}{NBA\sin\theta}, \quad [N=1,\ \theta=90^\circ] \ \sin90^\circ=1$$

$$\omega = \frac{3.\cancel{14}\times10^{-2}}{1\times4\times10^{-5}\times3.\cancel{14}\times\sin90^\circ}$$

$$\omega = \frac{\cancel{1000}\,250}{\cancel{4}\times1} = 250 \text{ revolutions/s}$$

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

9) $N = 4000$ turns, $l = 2m$,

diameter, $d = 0.04m$, $r = 0.02m$

$L = ?$, $A = \pi r^2$ $\quad r = 2\times10^{-2}\,m$.

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

$$L = \frac{\mu_0 N^2 A}{l} = \frac{\cancel{4}\,2\pi\times10^{-7}\times(4000)^2\times3.14\times(2\times10^{-2})^2}{\cancel{2}}$$

$L = 2\times3.14\times10^{-7}\times16\times10^{6}\times3.14\times4\times10^{-4}$

$L = 3.14\times3.14\times128\times10^{-5}$

$L = 1262.02\times10^{-5}\,H$

$L = 12.62\times10^{-3}\,H$

$\boxed{L = 12.62\,mH}$

$3.14 \Rightarrow 0.4969$
$3.14 \Rightarrow 0.4969$
$128 \Rightarrow 2.1072$ (+)
3.1010

Antilog $\Leftarrow$ 1.262×10^3

10. Given:- $N = 200 = 2\times10^2$ turns,

$I = 4A$, $\Phi_B = 6\times10^{-5}\,wb$, $U_B = ?$

Solution:-

$U_B = \frac{1}{2}LI^2$; $\quad LI = N\Phi_B$.

$L = N\Phi_B/I$.

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

$$\therefore U_B = \frac{1}{\cancel{2}}\times\cancel{2}\times10^2\times6\times10^{-5}\times4$$

$U_B = 24\times10^{-3}\,J$

$\boxed{\therefore U_B = 0.024\,J}$

11. Given:- $l = 50\,cm = 5\times10^{-1}\,m$.

$n = 400$ turns per cm $= \frac{400}{10^{-2}m} = 4\times10^4$ turns.

diameter, $d = 0.04m$, radius, $r = 0.02m$.

∴ Area, $A = \pi r^2 = 3.14\times(2\times10^{-2})^2\,m^2$ $\quad r = 2\times10^{-2}\,m$.

$A = 3.14\times4\times10^{-4}\,m^2 = 12.56\times10^{-4}\,m^2$

$\Phi_B = ?$ $\quad I = 1A$

Solution:-

$\Phi_B = LI$, $\quad L = \mu_0 n^2 A l$

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

$= 4\pi\times10^{-7}\times(4\times10^4)^2\times12.56\times10^{-4}\times5\times10^{-1}\times1$

$= 12.56\times10^{-12}\times16\times10^{8}\times12.56\times5$

$= 12.56\times12.56\times80\times10^{-4}$

$= 1.262\times10^{4}\times10^{-4}\,wb$

$\boxed{\Phi_B = 1.262\,wb}$

$12.56 \Rightarrow 1.0990$
$12.56 \Rightarrow 1.0990$
$80 \Rightarrow 1.9031$ (+)
4.1011

Antilog $\Leftarrow$ 1.262×10^4

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

$N = nl = \frac{400}{10^{-2}} \times 5\times10^{-1} = 2\times10^{4}$ turns

$\cancel{2}\times10^{4}\ \phi_B = 1.\cancel{262}^{0.631}$

$\boxed{\therefore \phi_B = 0.631\times10^{-4}\ wb}$

12. $N = 200$ turns, $I = 0.4A = 4\times10^{-1}$

$\phi_B = 4\,mwb \Rightarrow 4\times10^{-3}\ wb$, $L = ?$

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

$\therefore L = \frac{200\times\cancel{4}\times10^{-3}}{\cancel{4}\times10^{-1}} \Rightarrow \boxed{L = 2H}$

13. $l = 80cm = 8\times10^{-1}$, $A = 5cm^2$

$M = ?$, $N_1 = 1200$ turns, $A = 5\times10^{-4}m^2$

$N_1 = 12\times10^{2}$, $N_2 = 400 = 4\times10^{2}$

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

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

$\therefore M = \frac{4\pi\times10^{-7}\times\cancel{12}^{6}\times10^{2}\times\cancel{4}\times10^{2}\times5\times10^{-4}}{\cancel{2}\cancel{8}\times10^{-1}}$

$= 4\times3.14\times30\times10^{-6}$

$= 12.56\times3\times10^{-5}$

$M = 37.68\times10^{-5}H$

$\therefore M = 0.3768\times10^{-3}H$

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

14. $N_1 = \frac{400}{10^{-2}} = 400\times10^{2} = 4\times10^{4}$

$N_2 = 100 \Rightarrow 10^{2}$, $A = 4cm^2 = 4\times10^{-4}m^2$

$I = 2A$, $t = 0.04\,s \Rightarrow 4\times10^{-2}s$.

$\varepsilon = ?$

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

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

$n_1 = \frac{N_1}{l}$, $n_2 = \frac{N_2}{l}$

$M = \frac{4\pi\times10^{-7}\times4\times10^{4}\times10^{2}\times4\times10^{-4}}{1}$

$= 4\times3.14\times16\times10^{-5} = 12.56\times16\times10^{-5}$

$M = 200.96\times10^{-5}$, $M = 2\times10^{-3}\ H$

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

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

$\varepsilon = \cancel{2}\times10^{-3}\times\frac{\cancel{2}}{\cancel{2}\cancel{4}\times10^{-2}} = 10^{-1}V$

$\boxed{\varepsilon = 0.1V}$

15. $N_2 = 200$, $r = 2\times10^{-2}m$, $A = \pi r^2$

$N_1 = 90$ turns/cm $= \frac{90}{10^{-2}} = 90\times10^{2}$, $M = ?$

Solution:-

$M = \frac{\mu_0 N_1 N_2 A}{l} \Rightarrow \frac{4\pi\times10^{-7}\times9\times10^{3}\times2\times10^{2}\times3.14\times(2\times10^{-2})^2}{1}$

$A = \pi r^2 = 3.14\times(2\times10^{-2})^2$

$M = 4\times3.14\times18\times3.14\times4\times10^{-4}\times10^{2}$

$= 12.56\times18\times12.56\times10^{-6}$

$M = 2.84\times10^{-3}H$

$\boxed{M = 2.84mH}$

12.56 ⇒ 1.0990
12.56 ⇒ 1.0990 (+)
18 ⇒ 1.2553
Antilog $\bar{3}.4533$
2.840×10^{-3}

16. Given:- $\mu_r = 900 = 9\times10^{2}$, $l = 0.04m$

Area, $A = 4cm^2 = 4\times10^{-4}m^2$, $l = 4\times10^{-2}m$

$N_1 = 200 = 2\times10^{2}$ turns, $N_2 = 800 = 8\times10^{2}$

$dI = I_2 - I_1 = 8 - 2 = 6A$, $t = 0.04s$

$I_1 = 2A$, $I_2 = 8A$, $\varepsilon_2 = ?$ $t = 4\times10^{-2}s$.

Solution:-

The induced emf in solenoid 2 is

$\varepsilon_2 = -M\frac{dI}{dt}$; $M = \frac{\mu_0\mu_r N_1 N_2 A}{l}$

$M = \frac{4\pi\times10^{-7}\times2\times10^{2}\times8\times10^{2}\times\cancel{4}\times10^{-4}\times9\times10^{2}}{\cancel{4}\times10^{-2}}$

$= 4\times3.14\times16\times9\times10^{-3}$

$= 12.56\times144\times10^{-3}$

$M = 1.81\times10^{-3}\times10^{3}$

$\boxed{M = 1.81H}$

12.56 ⇒ 1.0990
144 ⇒ 2.1584 (+)
Antilog 3.2574
1.809×10^{3}
1.81×10^{3}

$\therefore \mathcal{E}_2 = -M\frac{dI}{dt} = -1.81 \times \frac{\cancel{6}\ 3\ 1.5}{\cancel{2}\ \cancel{4} \times 10^{-2}}$

$\mathcal{E}_2 = -2.715 \times 10^2 V$

$\mathcal{E}_2 = -271.5\ V$

1.81×1.5 = 905, 181, 2.715

$\therefore$ magnitude of emf

$\boxed{\mathcal{E} = 271.5 V}$

17. Given:- $V_p = 220V$, $V_s = 11V$,

output power $= V_s I_s = 88 W$

Solution:- $k = ?$, $I_p = ?$

(i) transformer Ratio $(k) = \frac{V_s}{V_p} = \frac{\cancel{11}}{\cancel{220}\ 20}$

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

(ii) $V_s I_s = 88$, $\cancel{11} \times I_s = \cancel{88}\ 8$

$I_s = 8A$,

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

$I_p = \frac{\cancel{11}}{\cancel{220}\ \cancel{20}\ 5} \times \cancel{8}\ 2 = 0.4A$.

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

$\frac{I_p}{I_s} = k$; $I_p = k \times I_s = \frac{1}{\cancel{20}\ 5} \times \cancel{8}\ 2$

$\boxed{I_p = 0.4A}$

18. Given:- $V_p = 200V$, $V_s = 120V$,

$\eta = 90\% = \frac{90}{100}$, $R_s = 40\Omega$, $I_p = ?$

Solution:- $V_s = I_s R_s$

$I_s = \frac{V_s}{R_s} = \frac{\cancel{120}\ 3}{\cancel{40}} = 3A$, $\boxed{\therefore I_s = 3A}$

$\therefore \eta = \frac{V_s I_s}{V_p I_p}$; $\frac{\cancel{90}\ 10}{\cancel{100}\ \cancel{10}\ 2} = \frac{\cancel{120} \times \cancel{3}\ 3}{\cancel{200}\ 5 \times I_p}$

$\boxed{I_p = 2A}$

19. Given:- $N_p = 300$, $R_p = 0.82\Omega$,

$N_s = 1200$, $R_s = 6.2\Omega$, $V_p = ?$ $V_s = 1600V$

output power $= V_s I_s = 32 kW = 32 \times 10^3 W$

$I_p^2 R_p = ?$ $\eta = 80\%$

$I_s^2 R_s = ?$ $\eta = \frac{80}{100}$

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

$V_p = \frac{N_p}{N_s} \times V_s = \frac{300}{\cancel{1200}\ 4} \times \cancel{1600}\ 400$; $\boxed{V_p = 400V}$

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

$I_s = \frac{\cancel{32}\ 2 \times 10^{\cancel{3}}}{\cancel{16} \times \cancel{10^2}} = 20A$, $\boxed{I_s = 20A}$

(iii) $\eta = \frac{V_s I_s}{V_p I_p}$; $\frac{\cancel{80}\ 4}{100} = \frac{1600 \times \cancel{20}\ 4}{400 \times I_p}$

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

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

$\therefore I_p^2 R_p = (100)^2 \times 0.82 = 8200W = 8.2 \times 10^3 W$

$\boxed{I_p^2 R_p = 8.2 kW}$

power loss in secondary coil,

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

$= 24.8 \times 10^2$

$= 2.48 \times 10^3 W$

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

20. $\theta = 60°$, $i = ?$, $I_{av} = ?$, $I_{rms} = ?$

Solution:- $I_m = 20A$

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

$\theta = \omega t$, $i = 20 \sin 60° = \cancel{20}\ 10 \times \frac{\sqrt{3}}{\cancel{2}}$

$i = 10 \times 1.732 = 17.32A$,

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

$40 \Rightarrow 1.6021$
$3.14 \Rightarrow 0.4969$ (-)
Antilog 1.1052
1.275×10^1

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

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

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

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

0.707×20 = 000, 1414, 14.140

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5. ELECTROMAGNETIC WAVES

1. Given:- conduction current, $I_c = 5A$

$I_d = ?$

Solution:-

Electric flux, $\phi_E = \frac{q}{\varepsilon_0}$

$\therefore I_d = \varepsilon_0 \cdot \frac{d\phi_E}{dt} = \varepsilon_0 \cdot \frac{d}{dt}\left(\frac{q}{\varepsilon_0}\right)$

$I_d = \frac{dq}{dt} = \frac{d(I_c t)}{dt}$ $\left[I_c = q/t,\ q = I_c t \right.$

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

$\boxed{\therefore I_d = I_c = 5A}$

2. Given:- $L = 1\mu H = 10^{-6} H$, $C = 1\mu F = 10^{-6} F$, $\lambda = ?$

Solution:-

Wavelength of EM wave, $\lambda = \frac{c}{f}$

$f = \frac{1}{2\pi\sqrt{LC}}$, Speed of light, $c = 3\times10^8 ms^{-1}$

$\therefore$ frequency, $f = \frac{1}{2\times3.14\sqrt{10^{-6}\times10^{-6}}}$

$f = \frac{1}{6.28\times10^{-6}} = \frac{10^6}{6.28} Hz$

$\therefore \lambda = \frac{c}{f} = \frac{3\times10^{\cancel{8}\,10^2}\times6.28}{\cancel{10^6}} = 18.84\times10^2$

$\therefore \boxed{\lambda = 18.84\times10^2 m}$

3. Given:- $t = 10^{-6}s$, Power $= 60\times10^{-3}W$

momentum, $P = ?$

Solution:- Final momentum, $p = \frac{U}{c}$

Energy, U = power $\times$ time

$c \Rightarrow$ speed of light $= 3\times10^8 ms^{-1}$

$\therefore$ Momentum, $p = \frac{\cancel{60}^{20}\times10^{-3}\times10^{-6}}{\cancel{3}\times10^8}$

$\boxed{P = 20\times10^{-17} kg\,ms^{-1}}$

4. Given:- $f = 10^{10} Hz$, $B_0 = 10^{-5} T$,

$\lambda = ?$, Expression for $\vec{E} = ?$

$c = 3\times10^8 ms^{-1}$ (speed of light).

Solution:- (i) wavelength, $\lambda = \frac{c}{f}$

$\lambda = \frac{3\times10^8 ms^{-1}}{10^{10} s^{-1}} = 3\times10^{-2} m$; $\boxed{\lambda = 3\times10^{-2} m}$

(ii) Amplitude of oscillating electric field

$E_0 = cB_0 = 3\times10^8\times10^{-5} = 3\times10^3 NC^{-1}$

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

$k = \frac{2\pi}{\lambda} = \frac{2\times3.14}{3\times10^{-2}} = \frac{6.28\times10^2}{3} = 2.09\times10^2$

$\omega = 2\pi f = 2\times3.14\times10^{10} = 6.28\times10^{10}$

$\boxed{\therefore \vec{E} = 3\times10^3 \sin(2.09\times10^2 x - 6.28\times10^{10} t)\hat{i} \quad (\text{unit} \Rightarrow NC^{-1})}$

5. Given:- relative permeability, $\mu_r = 1.0$

relative permittivity of the medium, $\varepsilon_r = 2.25$

$v = ?$

Solution:-

Speed of Electromagnetic wave in vaccum (or) Free space, $c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

$\therefore$ Speed of EM wave in medium, $v = \frac{1}{\sqrt{\mu\varepsilon}}$

$\mu = \mu_0\mu_r$, $\varepsilon = \varepsilon_0\varepsilon_r$

$\therefore v = \frac{1}{\sqrt{\mu_0\mu_r\times\varepsilon_0\varepsilon_r}} = \frac{c}{\sqrt{\mu_r\varepsilon_r}} = \frac{3\times10^8}{\sqrt{1\times2.25}}$

$v = \frac{\cancel{3}^{2}\times10^8}{\cancel{1.5}} = 2\times10^8 ms^{-1}$

$\therefore \boxed{v = 2\times10^8 ms^{-1}}$

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