Solutions

of

Electricity & Magnetism

Lesson 20th to 25th

By DC Pandey

20 Current Electricity

Introductory Exercise 20.1

1. $i \quad \frac{q}{t}$, here $q \quad e, t \quad \frac{2 \quad r}{v}$

$$i \quad \frac{ev}{2 \quad r}$$

$$\frac{1.6 \quad 10^{\ 19} \quad 2.2 \quad 10^{6}}{2 \quad 3.14 \quad 5 \quad 10^{\ 11}}$$

$1.12 \quad 10^{\ 3}$ A

1.12 mA

2. No. of atoms in 63.45 g of Cu $\quad 6.023 \quad 10^{23}$

No. of atoms in 1 cm^3 (8.89 g) of Cu

$$\frac{6.023 \quad 10^{23}}{63.54} \quad 8.89$$

$8.43 \quad 10^{22}$

As one conduction electron is present per atoms,

$n \quad 8.43 \quad 10^{22}\ cm^{\ 3}$ or $8.43 \quad 10^{28}\ m^{\ 3}$

As $i \quad neAv_d$

$$v_d \quad \frac{i}{neA}$$

$$\frac{2.0}{8.43 \quad 10^{28} \quad 1.6 \quad 10^{\ 19} \quad 3.14 \quad (0.5 \quad 10^{\ 3})^2}$$

$1.88 \quad 10^{\ 6}\ ms^{\ 1}$

3. Yes.

As current always flows in the direction of electric field.

4. False.

In the absence of potential difference, electrons passes random motion.

5. Current due to both positive and negative ions is from left to right, hence, there is a net current from left to right.

6. $i \quad 10 \quad 4t \quad \frac{dq}{dt} \quad 10 \quad 4t$

$$\int_0^q dq \quad \int_0^{10} (10 \quad 4t)\, dt$$

$$q \quad [10t \quad 2t^2]_0^{10} \quad 300\ \text{C}$$

Introductory Exercise 20.2

1. $R \quad \frac{L}{A}$

$$1.72 \quad 10^{\ 8} \quad \frac{35}{3.14 \quad \left(\frac{2.05}{2} \quad 10^{\ 3}\right)^2}$$

0.57

2. (a) $\quad J \quad \frac{E}{}$

$$i \quad JA \quad \frac{EA}{}$$

$$\frac{0.49 \quad 3.14 \quad (0.42 \quad 10^{\ 3})^2}{2.75 \quad 10^{\ 8}}$$

9.87 A

(b) $V \quad EL \quad 0.49 \quad 12 \quad 5.88$ V

(c) $R \quad \frac{V}{i} \quad \frac{5.88}{9.87} \quad 0.6$

3. Let us consider the conductor to be made up of a number of elementary discs. The conductor is supposed to be extended to form a complete cone and the vertex O of the cone is taken as origin with the conductor placed along x-axis with its two ends at $x \quad r$ and $x \quad l \quad r$. Let be the semi-vertical angle of the cone.

Consider an elementary disc of thickness dx at a distance x from origin.

Resistance of this disc,

$$dR \quad \frac{dx}{A}$$

If y be the radius of this disc, then

$$A \quad y^2$$

But $y \quad x$ tan

$$dR \quad \frac{dx}{x^2 \tan^2}$$

Resistance of conductor

$$R \quad dR \quad \int_r^{l\ r} \frac{dx}{x^2 \tan^2}$$

$$R \quad \frac{}{\tan^2} \quad \left[\frac{1}{x}\right]_r^{l\ r}$$

$$\frac{}{\tan^2} \quad \frac{1}{r} \quad \frac{1}{l \quad r}$$

$$R \quad \frac{l}{r(l \quad r)\tan^2}$$

But, $\quad r \tan \quad a$

$(r \quad l) \tan \quad b$

$$R \quad \frac{l}{ab}$$

4. True.

$$\frac{1}{}$$

$$\frac{1}{} \qquad 1$$

5. $R_{Cu} \quad R_{Fe}$

$4.1(1 \quad {}_{Cu} \ T) \quad 3.9(1 \quad {}_{Fe} \ T)$

$4.1[1 \quad 4.0 \quad 10^{\ 3}(T \quad 20)]$

$3.9[1 \quad 5.0 \quad 10^{\ 3}(T \quad 20)]$

$4.1 \quad 16.4 \quad 10^{\ 3}(T \quad 20)$

$3.9 \quad 19.5 \quad 10^{\ 3}(T \quad 20)$

$3.1 \quad 10^{\ 3}(T \quad 20) \quad 0.2$

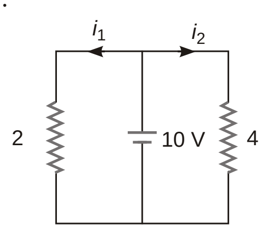
$$T \quad 20 \quad \frac{0.2}{3.1 \quad 10^{\ 3}}$$

64.5 C

$T \quad 84.5$ C

Introductory Exercise 20.3

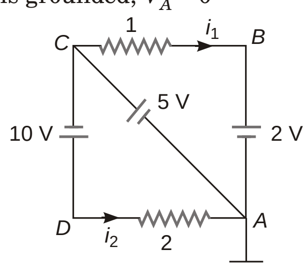
1. Potential difference across both the resistors is 10 V.



Hence, $\quad i_1 \quad \frac{10}{2} \quad 5$ A

and $\quad i_2 \quad \frac{10}{4} \quad 2.5$ A

2. As A is grounded, $V_A \quad 0$



$V_B \quad V_A \quad 2 \quad 2$ V

$V_C \quad V_A \quad 5 \quad 5$ V

$V_D \quad V_C \quad 10 \quad 15$ V

$$i_1 \quad \frac{V_C \quad V_B}{1} \quad 3 \text{ A}$$

and $\quad i_2 \quad \dfrac{V_D \quad V_A}{2} \quad \dfrac{15}{2} \quad 7.5$ A

3. Current in the given loop is

$$i \quad \frac{E \quad 15}{8}$$

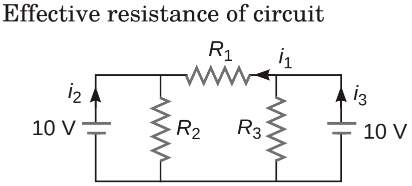
$$V_{AB} \quad E \quad 2i \quad E \quad 2 \quad \frac{E \quad 15}{8} \quad 0$$

$E \quad 5$ V

4. Effective emf,

$E \quad 8 \quad 1 \quad 2 \quad 1 \quad 6$ V

Effective resistance of circuit



$$R \quad R_{\text{external}} \quad 10r \quad 2 \quad 10 \quad 1 \quad 12$$
$$i \quad \frac{E}{R} \quad \frac{6}{12} \quad 0.5\text{ A}$$

5. As $R_2 \quad R_3$ and $V_1 \quad V_2$

Potential difference across R_1 is zero.

Hence, current through $R_1 \quad i_1 \quad 0$

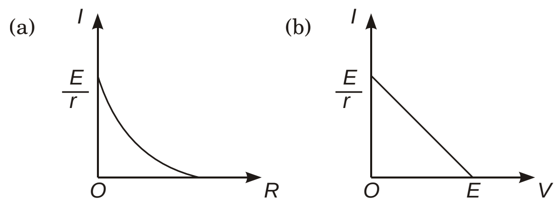
and current through R_2

$$i_2 \quad \frac{V_1}{R_2}$$
$$\frac{10}{10} \quad 1\text{ A}$$

6. $i \quad \dfrac{E}{R \quad r}$

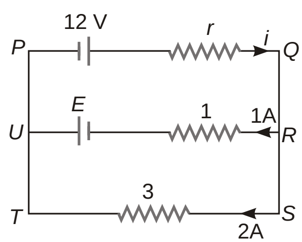
Also, $V \quad E \quad ir$

$$i \quad \frac{E \quad V}{r}$$



Introductory Exercise 20.4

1.



Applying KCL at junction R

$$i \quad 1 \quad 2 \quad 3\text{ A}$$
$$V_{ST} \quad V_{RU} \quad V_{QP}$$

Taking $V_{ST} \quad V_{RU}$

$$6 \quad 1 \quad E$$
$$E \quad 5\text{ V}$$

And from

$$V_{ST} \quad V_{QP}$$
$$6 \quad ir \quad 12$$
$$r \quad \frac{12 \quad 6}{i} \quad \frac{6}{3} \quad 2$$

2. Power delivered by the 12 V power supply,

$$P_1 \quad Vi \quad 12 \quad 3 \quad 36\text{ W}$$

and power dissipated in 3 resister,

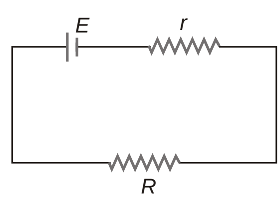
$$P_3 \quad i_3^2 R_3 \quad 2^2 \quad 3 \quad 12\text{ W}$$

Introductory Exercise 20.5

1. $$E \quad \frac{\frac{E_1}{r_1} \quad \frac{E_2}{r_2} \quad \frac{E_3}{r_3}}{\frac{1}{r_1} \quad \frac{1}{r_2} \quad \frac{1}{r_3}} \quad \frac{\frac{10}{1} \quad \frac{4}{2} \quad \frac{6}{2}}{\frac{1}{1} \quad \frac{1}{2} \quad \frac{1}{2}}$$
$$\frac{10 \quad 2 \quad 3}{2}$$
$$7.5\text{ V}$$

and $$\frac{1}{r} \quad \frac{1}{r_1} \quad \frac{1}{r_2} \quad \frac{1}{r_3}$$
$$\frac{1}{1} \quad \frac{1}{2} \quad \frac{1}{2} \quad 2$$
$$r \quad \frac{1}{2}$$
$$0.5$$

2. $i \quad \dfrac{E}{R \quad r}$



Rate of dissipation of energy

$$P \quad i^2 R \quad \frac{E^2 R}{(R \quad r)^2}$$

For maximum or minimum power

$$\frac{dP}{dR} \quad 0$$
$$E^2 \quad \frac{(R \quad r)^2 \quad 2R(R \quad r)}{(R \quad r)^4} \quad 0$$

$$E^2 \frac{(R \quad r)(r \quad R)}{(R \quad r)^4} \quad 0$$

$$\frac{E^2(r \quad R)}{(R \quad r)^3} \quad 0$$

$$R \quad r$$

$$\frac{d^2P}{dR^2} \quad E^2 \frac{(R \quad r)^3(\quad 1) \quad 3(r \quad R)(R \quad r)^2}{(R \quad r)^6}$$

$$\frac{E^2(4r \quad 2R)}{(R \quad r)^4}$$

Clearly $\frac{d^2P}{dR^2}$ is negative at $R \quad r$.

Hence, P is maximum at $R \quad r$

and $P_{\max} \quad \frac{E^2 r}{(r \quad r)^2} \quad \frac{E^2}{4r}$

3. When the batteries are connected in series

$$E_{\text{eff}} \quad 2E \quad 4\text{V}, r_{\text{eff}} \quad 2r \quad 2$$

For maximum power

$$R \quad r_{\text{eff}} \quad 2$$

and $P_{\max} \quad \frac{E_{\text{eff}}^2}{4r_{\text{eff}}} \quad \frac{(4)^2}{4 \quad 2} \quad 2\text{ W}$

4. $I_g \quad 5\text{ mA}, G \quad 1 \quad , V \quad 5\text{ V}$

$$R \quad \frac{V}{I_g} \quad G \quad \frac{5}{5 \quad 10^{\quad 3}} \quad 1$$

$$999$$

A 999 resistance must be connected in series with the galvanometer.

5. $G \quad 100 \quad , i_g \quad 50 \quad \text{A}, i \quad 5\text{ mA}$

$$S \quad \frac{i_g G}{i \quad i_g} \quad \frac{50 \quad 10^{\quad 6} \quad 100}{5 \quad 10^{\quad 3} \quad 50 \quad 10^{\quad 6}}$$

$$\frac{1}{1 \quad 0.01} \quad \frac{1}{0.99}$$

$$\frac{100}{99}$$

By connecting a shunt resistance of $\frac{100}{99}$.

6. $i_g \quad \frac{V}{G}$

and $R \quad \frac{nV}{i_g} \quad G \quad (n \quad 1)G$

7. $V_{AB} \quad \frac{15}{16} E$

Potential gradient

$$k \quad \frac{V_{AB}}{L} \quad \frac{15E}{16 \quad 600}$$

$$\frac{E}{640}\text{ V/cm}$$

(a) $\frac{E}{2} \quad kL \quad L \quad \frac{E}{2k} \quad 320\text{ cm}$

(b) $V \quad kl \quad \frac{E}{640} \quad 560 \quad \frac{7E}{8}$

Also, $V \quad E \quad ir$

$$E \quad ir \quad \frac{7E}{8}$$

$$i \quad \frac{E}{8r}$$

AIEEE Corner

Subjective Questions (Level 1)

1. $i \quad \frac{q}{t} \quad \frac{ne}{t}$

Given,

$$i \quad 0.7 \,, t \quad 1\text{ s}, e \quad 1.6 \quad 10^{\quad 19}\text{ C}$$

$$n \quad \frac{it}{e} \quad \frac{0.7 \quad 1}{1.6 \quad 10^{\quad 19}}$$

$$4.375 \quad 10^8$$

2. $q \quad it \quad 3.6 \quad 3 \quad 3600$

$$38880\text{ C}$$

3. (a) $q \quad it \quad 7.5 \quad 45 \quad 337.5\text{ C}$

(b) $q \quad ne \quad n \quad \frac{q}{e}$

$$\frac{337.5}{1.6 \quad 10^{\quad 19}} \quad 2.11 \quad 10^{21}$$

4. $T \quad \frac{2 \quad r}{v} \quad f \quad \frac{1}{T} \quad \frac{v}{2 \quad r}$

$$\frac{2.2 \quad 10^6}{2 \quad 3.14 \quad 5.3 \quad 10^{\quad 11}}$$

$$6.6 \quad 10^{19}\text{ s}^{\quad 1}$$

$$I \quad \frac{q}{T} \quad ef$$

$$1.6 \quad 10^{\quad 19} \quad 6.6 \quad 10^{19}$$

$$10.56\text{ A}$$

5. (a) $I \quad 55 \quad 0.65\,t^2$

$$I \quad \frac{dq}{dt}$$

$$dq \quad Idt$$

$$q \quad I\,dt$$

$$q \quad {}_0^8\, Idt \quad {}_0^8\,(55 \quad 0.65\,t^2)\,dt$$

$$55[t]_0^8 \quad 0.65 \quad \frac{t^2}{2}\ {}_0^8$$

$$440 \quad 20.8 \quad 419.2\text{ C}$$

(b) If current is constant

$$I \quad \frac{q}{t} \quad \frac{419.2}{8} \quad 52.4\text{ A}$$

6. $i \quad v_d$

$$\frac{v_{d_2}}{v_{d_1}} \quad \frac{i_2}{i_1}$$

$$v_{d_2} \quad \frac{i_2}{i_1} v_{d_1} \quad \frac{6.00}{1.20} \quad 1.20 \quad 10^{\ 4}$$

$$6.00 \quad 10^{\ 4}\text{ ms}^{\ 1}$$

7. $v_d \quad \dfrac{i}{neA}$

$$\frac{1}{8.5 \quad 10^{28} \quad 1.6 \quad 10^{\ 19} \quad 1 \quad 10^{\ 4}}$$

$$0.735 \quad 10^{\ 6}\text{ ms}^{\ 1}$$

$$0.735 \quad \text{m/s}$$

$$t \quad \frac{l}{v_d} \quad \frac{10^3}{0.735 \quad 10^{\ 6}}$$

$$1.36 \quad 10^9\text{ s} \quad 43\text{ yr}$$

8. Distance covered by one electron in 1 s

$$1 \quad 0.05 \quad 0.05\text{ cm}$$

Number of electrons in 1 cm of wire

$$2 \quad 10^{21}$$

Number of electrons crossing a given area per second

Number of electrons in 0.05 cm of wire

$$0.05 \quad 2 \quad 10^{21} \quad 10^{20}$$

$$i \quad \frac{q}{t} \quad \frac{ne}{t}$$

$$\frac{10^{20} \quad 1.6 \quad 10^{\ 19}}{1} \quad 1.6 \quad 10 \quad 16\text{ A}$$

9. $R \quad \dfrac{L}{A}$

Given,

$$0.017 \quad \text{-m}$$

$$1.7 \quad 10^{\ 8} \quad \text{-m}$$

$$l \quad 24.0\text{ m}$$

$$A \quad \frac{d}{2}^{\ 2} \quad 3.14 \quad \frac{2.05}{2} \quad 10^{\ 3\ \ 2}$$

$$3.29 \quad 10^{\ 6}\text{ m}^2$$

$$R \quad 1.7 \quad 10^{\ 8} \quad \frac{24.0}{3.29 \quad 10^{\ 6}}$$

$$0.12$$

10. $R \quad \dfrac{L}{A}$

$$A \quad \frac{L}{R}$$

If D is density, then

$$m \quad DV \quad DA\,L \quad \frac{D \quad L^2}{R}$$

$$\frac{8.9 \quad 10^3 \quad 1.72 \quad 10^{\ 8} \quad (3.5)^2}{0.125}$$

$$1.5 \quad 10^{\ 2}\text{ kg} \quad 15\text{ g}$$

11. At 20 C,

$R_1 \quad 600 \quad , R_2 \quad 300$

At 50 C,

$$R_1 \quad R_1(1 \quad {}_1\ t)$$

$$600(1 \quad 0.001 \quad 30) \quad 600 \quad 1.03$$

$$618$$

$$R_2 \quad R_2(1 \quad {}_2\ t)$$

$$300(1 \quad 0.004 \quad 30) \quad 336$$

$$R \quad R_1 \quad R_2 \quad 618 \quad 336$$

$$954$$

$$\frac{R \quad R}{R \quad t} \quad \frac{954 \quad 900}{900 \quad 30}$$

$$R \quad 600 \quad 300 \quad 900$$

$$0.002 \quad \text{C}^{\ 1}$$

12. As both the wires are connected in parallel,

$$V_{\text{Al}} \quad V_{\text{Cu}}$$

$$i_{\text{Al}} R_{\text{Al}} \quad i_{\text{Cu}} R_{\text{Cu}}$$

$$i_{\text{Al}} \ {}_{\text{Al}} \frac{L_{\text{Al}}}{d_{\text{Al}}^2} \quad i_{\text{Cu}} \ {}_{\text{Cu}} \frac{L_{\text{Cu}}}{d_{\text{Cu}}^2}$$

$$d_{\text{Cu}} \quad d_{\text{Al}} \sqrt{\frac{i_{\text{Cu}} \ {}_{\text{Cu}} L_{\text{Cu}}}{i_{\text{Al}} \ {}_{\text{Al}} L_{\text{Al}}}}$$

$$1 \quad 10^{\ 3} \sqrt{\frac{2 \quad 0.017 \quad 6}{3 \quad 0.028 \quad 7.5}}$$

$$0.569 \quad 10^{\ 3}\text{ m}$$

$$0.569\text{ mm.}$$

13. (a) $E \quad \frac{V}{L} \quad \frac{0.938}{75 \quad 10^{\ 2}} \quad 1.25\ \text{V/m}$

(b) $J \quad \frac{E}{} \quad \frac{1.25}{4.4 \quad 10^{7}}$

$2.84 \quad 10^{\ 8} \quad \text{-m}$

14. (a) $J \quad \frac{E}{} \quad \frac{V}{L}$

Current density is maximum when L is minimum, *ie*, $L \quad d$, potential difference should be applied to faces with dimensions $2d \quad 3d$.

$$J_{\text{min.}} \quad \frac{V}{d}.$$

(b) $i \quad \frac{V}{R} \quad \frac{VA}{L}$

Current is maximum when L is minimum and A is maximum.

Hence, in this case also, V should be applied to faces with dimensions $2d \quad 3d$

and $i_{\text{max}} \quad \frac{V(2d \quad 3d)}{(d)} \quad \frac{6Vd}{}.$

15. (a) $R \quad \frac{L}{A}$

$\frac{RA}{L}$

$[r \quad \frac{d}{2} \quad 1.25\ \text{mm} \quad 1.25 \quad 10^{\ 3}\ \text{m}]$

$$\frac{0.104 \quad 3.14 \quad (1.25 \quad 10^{\ 3})^2}{14.0}$$

$3.64 \quad 10^{\ 7} \quad \text{-m}$

(b) $i \quad \frac{V}{R} \quad \frac{EL}{R} \quad \frac{1.28 \quad 14}{0.104} \quad 172.3\ \text{A}$

(c) $i \quad neAv_d$

$$v_d \quad \frac{i}{neA}$$

$$\frac{172.3}{8.5 \quad 10^{28} \quad 1.6 \quad 10^{\ 19} \quad 3.14 \quad (1.25 \quad 10^{\ 3})^2}$$

$2.58 \quad 10^{\ 3}\ \text{ms}^{\ 1}$

16. For zero thermal coefficient of resistance, $R \quad 0$

$R_C \quad {}_C \quad T \quad R_{Fe} \quad {}_{Fe} \quad T \quad 0$

$$\frac{R_1}{R_2} \quad \frac{{}_{Fe}}{{}_C} \quad \frac{5.0 \quad 10^{\ 3}}{0.5 \quad 10^{\ 3}} \quad 10$$

$R_1 \quad 10R_2$

Also, $R_1 \quad R_2 \quad 20$

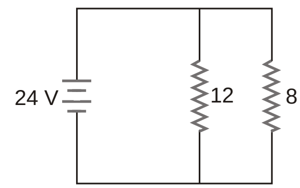
$10R_2 \quad R_2 \quad 20$

$R_2 \quad \frac{20}{11} \quad 1.82$

and $R_1 \quad 20 \quad R_2 \quad 20 \quad 1.82$

18.2

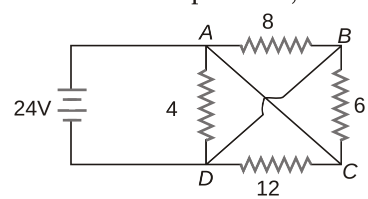
17. The circuit can be redrawn as



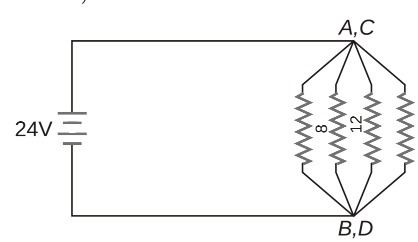
$$R_{\text{eff}} \quad \frac{8 \quad 12}{12 \quad 8} \quad 4.8$$

$$I \quad \frac{V}{R_{\text{eff}}} \quad \frac{24}{4.8} \quad 5\ \text{A}$$

18. Here, A and C are at same potential and B and D are at same potential,



Hence, the circuit can be redrawn as



$$\frac{1}{R} \quad \frac{1}{4} \quad \frac{1}{8} \quad \frac{1}{12} \quad \frac{1}{6}$$

$$\frac{6 \quad 3 \quad 2 \quad 4}{24}$$

$$\frac{15}{24} \quad \frac{5}{8}$$

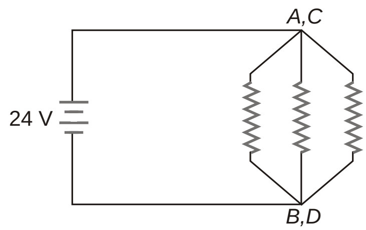
$R \quad \frac{8}{5}$

1.6

$i \quad \frac{V}{R} \quad \frac{24}{1.6}$

$15\ \text{A}$

19. Given circuit is similar to that in previous question but 4 resistor is removed. So the effective circuit is given by



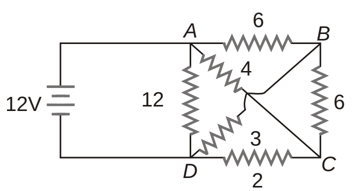
$$\frac{1}{R} \quad \frac{1}{8} \quad \frac{1}{12} \quad \frac{1}{6}$$

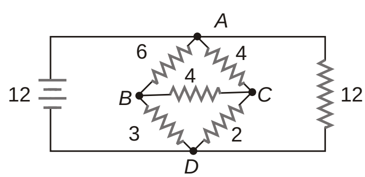
$$\frac{1}{R} \quad \frac{3 \quad 2 \quad 4}{24} \quad \frac{9}{24} \quad \frac{3}{8}$$

$$R \quad \frac{8}{3} \qquad 2.67$$

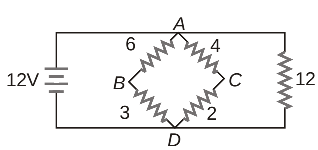
$$i \quad \frac{V}{R} \quad \frac{24}{2.67} \quad 9\text{ A}$$

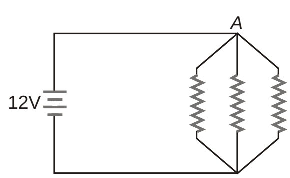
20.

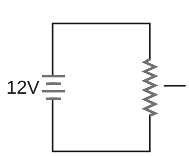




Wheatstone bridge is balanced, hence 4 resistance connected between B and C be removed and the effective circuit becomes



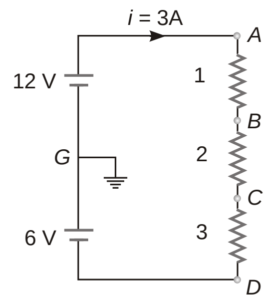




$$i \quad \frac{V}{R} \quad \frac{12}{36/13}$$

$$\frac{13}{3}\text{ A}$$

21. (a) $i \quad \frac{12 \quad 6}{1 \quad 2 \quad 3} \quad 3\text{ A}$



$$V_G \quad 0$$

$$V_A \quad V_G \quad 12 \quad 12\text{ V}$$

$$V_A \quad V_B \quad 3\text{ V}$$

$$V_B \quad 12 \quad 3 \quad 9\text{ V}$$

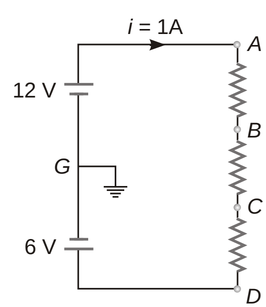
$$V_B \quad V_C \quad 6\text{ V}$$

$$V_C \quad 9 \quad 6 \quad 3\text{ V}$$

$$V_G \quad V_D \quad 6\text{ V}, V_D \qquad 6\text{ V}$$

(b) If 6 V battery is reversed

$$i \quad \frac{12 \quad 6}{1 \quad 2 \quad 3} \quad 1\text{ A}$$



$$V_G \quad 0,$$

$$V_A \quad v_G \quad 12\text{ V}, \; V_A \quad 12\text{ V}$$

$$V_A \quad V_B \quad 1\text{ V}$$

$$V_B \quad 11\text{ V}$$

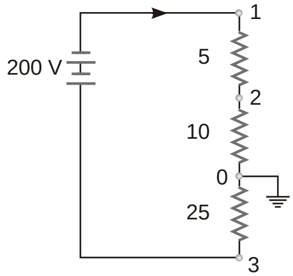
$$V_B \quad V_C \quad 2\text{ V}$$

$$V_C \quad 9\text{ V}$$

$$V_D \quad V_G \quad 6\text{ V}$$

$$V_D \quad 6\text{ V}$$

22. $i \quad \dfrac{200}{5 \quad 10 \quad 25} \quad 5\text{ A}$



(i) $V_3 \quad V_0 \quad 5 \quad 25$

$V_3 \quad 125\text{ V}$

(ii) $V_0 \quad V_2 \quad 5 \quad 10$

$V_2 \quad 50\text{ V}$

(iii) $V_2 \quad V_1 \quad 5 \quad 5$

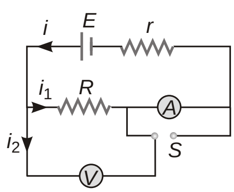
$V_1 \quad 75\text{ V}$

(iv) $V_{3 \quad 2} \quad 5 \quad 35 \quad 175\text{ V}$

(v) $V_{1 \quad 2} \quad 5 \quad 5 \quad 25\text{ V}$

(vi) $V_{1 \quad 3} \quad 200\text{ V}$

23. (a)



$R_{\text{eff}} \quad R \| R_v \quad R_a \quad r$

$\dfrac{50 \quad 200}{50 \quad 200} \quad 2 \quad 1$

43

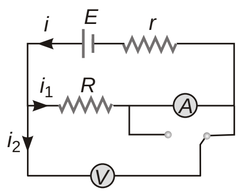
$i \quad \dfrac{E}{R_{\text{eff}}} \quad \dfrac{4.3}{43} \quad 0.1\text{ A}$

Reading of ammeter, $i \quad 0.1\text{ A}$

and reading of voltmeter $\quad i(R \| R_v)$

$0.1 \quad 40 \quad 4\text{ V}$

(b)



$R_{\text{eff}} \quad (R_a \quad R) \| R_v \quad r$

$\dfrac{52 \quad 200}{52 \quad 200} \quad 1$

42.26

$i \quad \dfrac{E}{R_{\text{eff}}} \quad 0.102$

Reading of voltmeter

$V \quad E \quad ir$

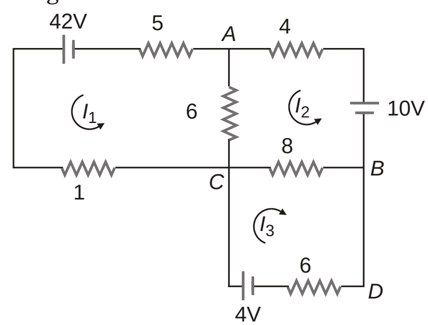
$4.3 \quad 0.102 \quad 1$

4.2

Reading of Ammeter,

$i_1 \quad \dfrac{V}{R \quad R_a} \quad \dfrac{4.2}{42} \quad 0.08\text{ A}$

24. Consider the directions of current as shown in figure.



Applying KVL in loop 1, 2 and 3, we respectively get,

$I_1 \quad 6(I_1 \quad I_2) \quad 5I_1 \quad 42$

$12I_1 \quad 6I_2 \quad 42$

$2I_1 \quad I_2 \quad 7 \qquad$ ...(i)

$4I_2 \quad 6(I_2 \quad I_1) \quad 8(I_2 \quad I_3) \quad 10$

$9I_2 \quad 3I_1 \quad 4I_3 \quad 5 \qquad$ ...(ii)

$8(I_2 \quad I_3) \quad 16I_3 \quad 4$

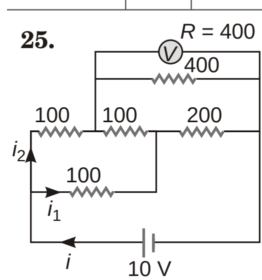
$2I_2 \quad 6I_3 \quad 1 \qquad$ ...(iii)

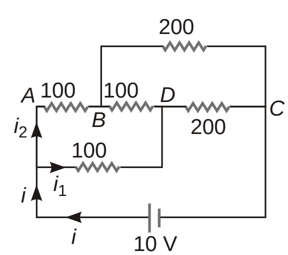
On solving, we get,

$I_1 \quad 4.7\text{ A}, I_2 \quad 2.4\text{ A}, I_3 \quad 0.5\text{ A}$

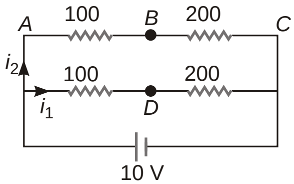
Resistor	5	1	4	6	8	16
Current	4.7 A	4.7 A	2.4 A	2.3 A	2.9 A	0.5 A

25.





As Wheatstone bridge is balanced, 100 resistance between B and D can be removed, *ie*,



$$i_1 \quad i_2 \quad \frac{10}{300} \quad \frac{1}{30}\text{ A}$$

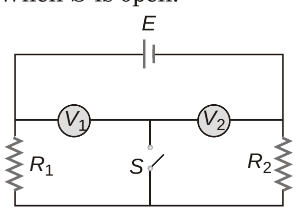
Hence, reading of voltmeter

Potential difference between B and C

$$200 \quad i_2 \quad \frac{20}{3}\text{ V}$$

6.67 V

26. (a) (i) When S is open.



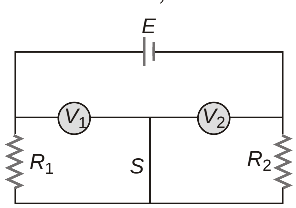
$$V_1 \quad \frac{R_1}{R_{V_1} \quad R_{V_2}} E \quad \frac{3000}{5000} \quad 200$$

120 V

$$V_2 \quad \frac{R_{V_2}}{R_{V_1} \quad R_{V_2}} E \quad \frac{2000}{5000} \quad 200$$

80 V

(ii) When S is closed,

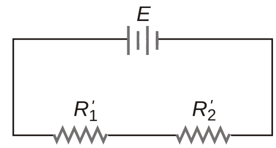


Now, R_1 and V_1 are in parallel and their effective resistance

$$R_1 \quad \frac{R_1 R_{V_1}}{R_1 \quad R_{V_1}} \quad \frac{6000}{5} \quad 1200$$

Similarly,

R_2 and V_2 are in parallel with their effective resistance,



$$R_2 \quad \frac{R_2 R_{V_2}}{R_2 \quad R_{V_2}} \quad \frac{6000}{5} \quad 1200$$

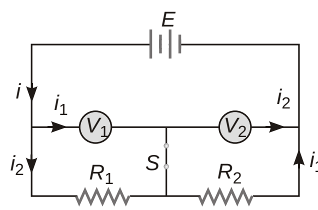
As $\quad R_1 \quad R_2$

Hence,

reading of V_1 reading of V_2

$$\frac{1200}{1200 \quad 1200} \quad 200 \quad 100\text{ V}$$

(b) Current distribution is shown in figure



$$i \quad \frac{E}{R_1 \quad R_2}$$

$$i \quad \frac{200}{2400} \quad \frac{1}{12}\text{ A}$$

$$i_1 \quad \frac{R_{V_1}}{R_1 \quad R_{V_1}} i \quad \frac{3000}{5000} \quad \frac{1}{12}$$

$$\frac{1}{20}\text{ A}$$

$$i_2 \quad \frac{R_1}{R_1 \quad R_{V_1}} i \quad \frac{2000}{5000} \quad \frac{1}{12}$$

$$\frac{1}{30}\text{ A}$$

Current flowing through

$$S \quad i_1 \quad i_2 \quad \frac{1}{20} \quad \frac{1}{30}$$

$$\frac{1}{60}\text{ A}$$

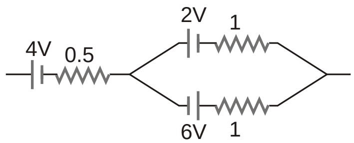
27. Effective emf of 2 V and 6 V batteries connected in parallel

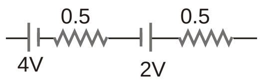
$$E \quad \frac{E_1 r_2 \quad E_2 r_1}{r_1 \quad r_2} \quad \frac{2 \quad 1 \quad 6 \quad 1}{1 \quad 1}$$

2 V

and $\quad r \quad \frac{r_1 r_2}{r_1 \quad r_2} \quad \frac{1}{2}$

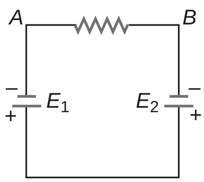
0.5





Net emf, $E \quad 4 \quad 2 \quad 2\,\text{V}$

28. (a)



As $E_1 \quad E_2$

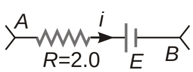
Current will flow from B to A.

(b) E_1 is doing positive work

(c) As current flows from B to A through resistor, B is at higher potential.

29. $i^2R \quad 2\,\text{W} \quad 5\,\text{W}$

Clearly X is doing negative work.

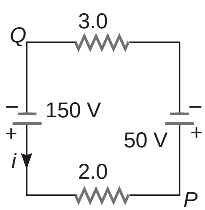


(a) $P \quad Vi \quad V \quad \frac{P}{i} \quad \frac{0.5}{1.0} \quad 5.0\,\text{V}$

(b) $E \quad V \quad iR \quad 5 \quad 2 \quad 3\,\text{V}$

(c) It is clear from figure that positive terminal of X is towards left.

30. $i \quad \frac{150 \quad 50}{3 \quad 2} \quad 20\,\text{A}$



$V_P \quad V_Q \quad 50 \quad 3.0\,i$

$V_Q \quad 100 \quad (50 \quad 60)$

$10\,\text{V}$

31. (a) As voltmeter is ideal, it has infinite resistance, therefore current is zero.

(b) $V \quad E \quad ir \quad E \quad 5.0\,\text{V}$

(c) Reading of voltmeter $\quad V \quad 5.0\,\text{V}$

32. $V_1 \quad E \quad i_1 r \quad E \quad 1.5r \quad 8.4$ ...(i)

$V_2 \quad E \quad i_2 r \quad E \quad 3.5r \quad 9.4$ ...(ii)

On solving, we get

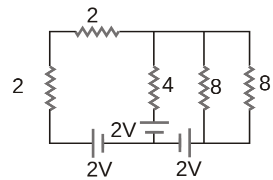
$r \quad 0.2$

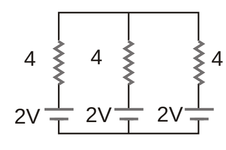
$E \quad 8.7\,\text{V}$

33. In case of charging

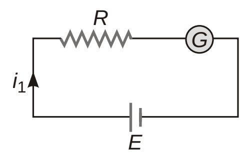
$V \quad E \quad ir \quad 2 \quad 5 \quad 0.1 \quad 2.5\,\text{V}$

34. Clearly current through each branch is zero.

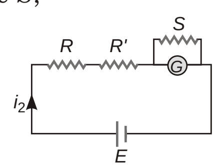




35. $i_1 \quad \frac{E}{R \quad G}$



On shunting the galvanometer with resistance S,



$$i_2 \quad \frac{E}{R \quad R \quad \frac{GS}{S \quad G}}$$

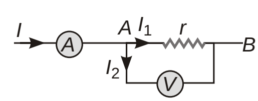
As $i_1 \quad i_2$

$$\frac{E}{R \quad G} \quad \frac{E}{R \quad R \quad \frac{GS}{G \quad S}}$$

$$R \quad R \quad \frac{GS}{G \quad S} \quad R \quad G$$

$$R \quad \frac{G^2}{G \quad S}$$

36.



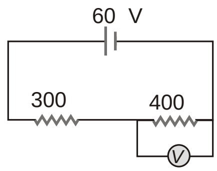
$$I_2 \quad \frac{r}{R \quad r} I \quad \frac{V}{R}$$

$$\frac{r}{R \quad r} \quad \frac{V}{IR}$$

$$\frac{R}{r} \quad \frac{IR \quad V}{V} \quad \frac{5 \quad 2500 \quad 100}{100}$$

$$r \quad \frac{100}{12400} \quad 2500 \quad 20.16$$

37.

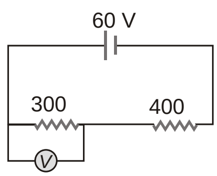


Let R be the resistance of voltmeter

As reading of voltmeter is 30 V,

$$\frac{1}{R} \quad \frac{1}{400} \quad \frac{1}{300} \qquad R \quad 1200$$

If voltmeter is connected across 300 resistor,



Effective resistance of 300 resistor and voltmeter

$$R \quad \frac{300 \quad 1200}{300 \quad 1200} \quad 240$$

$$i \quad \frac{60}{400 \quad 240}$$

$$\frac{60}{640}\text{ A}$$

$$\frac{3}{32}\text{ A}$$

Reading of voltmeter,

$$V \quad iR \quad \frac{3}{32} \quad 240$$

22.5 V

38. $V_2 \quad \frac{R}{R_1 \quad R_2} V,$

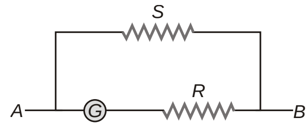
$$R_2 \quad \frac{rR_2}{r \quad R_2} \quad \frac{120}{3}$$

40

$$V_2 \quad \frac{40}{60 \quad 40} 120$$

48 V

39. $S \quad \frac{i_g}{i \quad i_g}(G \quad R)$



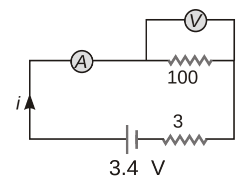
$$R \quad \frac{i \quad i_g}{i_g} S \quad G$$

$$\frac{20 \quad 10^{\;\;3}}{10^{\;\;3}} \quad 0.005 \quad 20$$

79.995

40. $r \quad \frac{L_1 \quad L_2}{L_2} R \quad \frac{0.52 \quad 0.4}{0.4} \quad 5 \quad 1.5$

41. Let R be the resistance of voltmeter



$$R_e \quad 3 \quad 2 \quad \frac{100R}{100 \quad R}$$

$$5 \quad \frac{100R}{100 \quad R}$$

$$i \quad \frac{3.4}{5 \quad \frac{100R}{100 \quad R}} \quad 0.04$$

$$0.2 \quad \frac{4R}{100 \quad R} \quad 3.4$$

$$R \quad 400$$

Reading of voltmeter,

$$V \quad i \quad \frac{100R}{100 \quad R} \quad 0.04 \quad \frac{100 \quad 400}{100 \quad 400}$$

3.2 V

If the voltmeter had been ideal,

Reading of voltmeter

$$\frac{100}{105} \quad 3.4 \quad 3.24\text{ V}$$

42. $\frac{L_1}{L_2} \quad \frac{R_1}{R_2}$

$$\frac{L_1}{40 \quad L_1} \quad \frac{8}{12} \qquad (L_1 \quad L_2 \quad 40\text{ cm})$$

$$L_1 \quad 16\text{ cm} \quad \text{from } A.$$

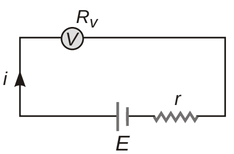
43. $S \quad \frac{i_g}{i \quad i_g}(G \quad R)$

$$R \quad \frac{i \quad i_g}{i_g} S \quad G$$

$$\frac{20 \quad 0.0224}{0.0244} \quad 0.0250 \quad 9.36$$

$$12.94$$

44. (a) $i \quad \frac{E}{R_V \quad r}$



$$V \quad iR_V \quad \frac{E}{R_V \quad r} R_V$$

(b) $\frac{r}{R_V \quad r} \quad 1\% \quad \frac{1}{100}$

$$R_V \quad 99r \quad 99 \quad 0.45$$

$$44.55$$

(c) $\frac{V}{E} \quad \frac{R_V}{R_V \quad r}$

As R_V decreases, V decreases, decreasing accuracy of voltmeter.

45. (a) When ammeter is connected

$$I_A \quad \frac{E}{R_A \quad R \quad r}$$

When ammeter is removed

$$I \quad \frac{E}{R \quad r} \quad \frac{R_A \quad R \quad r}{R \quad r} I_A$$

(b) $\frac{I_A}{I} \quad 99\%$

$$\frac{R \quad r}{R_A \quad R \quad r} \quad \frac{99}{100}$$

$$R_A \quad \frac{1}{99}(R \quad r) \quad \frac{1}{99}(3.8 \quad 0.45)$$

$$R_A \quad 0.043$$

(c) As $\frac{I_A}{I} \quad \frac{R \quad r}{R_A \quad R \quad r}$, as R_A increases, I_A decreases, decreasing the accuracy of ammeter.

46. $I_{max} \quad \sqrt{\frac{max}{R}} \quad \sqrt{\frac{36}{2.4}} \quad \sqrt{15}$ A

For the given circuit

$$R_e \quad \frac{1}{2}R \quad R \quad \frac{3}{2}R$$

Maximum power dissipated by the circuit

$$P_{max} \quad I^2_{max}R_e$$

$$15 \quad \frac{3}{2} \quad 2.4 \quad 54 \text{ W}$$

47. Total power of the circuit, $P \quad P_1 \quad P_2 \quad P_3$

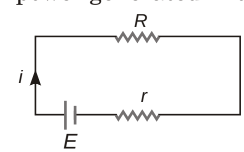
$$40 \quad 60 \quad 75$$

$$175 \text{ W}$$

As $P \quad \frac{V^2}{R} \quad R \quad \frac{V^2}{P}$

$$\frac{(120)^2}{175} \quad 82.3$$

48. Thermal power generated in the battery



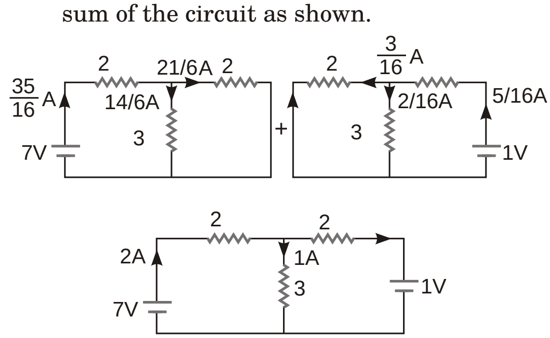
$$P_1 \quad i^2r \quad i(E \quad V)$$

$$0.6 \text{ W}$$

Power development in the battery by electric forces

$$P_2 \quad IE \quad 2.6 \text{ W}$$

49. The given circuit can be considered as the sum of the circuit as shown.



$$P_1 \quad 7 \quad 2 \quad 14 \text{ W},$$

$$P_2 \quad 1 \quad 1 \quad 1 \text{ W}$$

50. (a) $i \quad \frac{E_1 \quad E_2}{R_1 \quad R_2} \quad \frac{12 \quad 6}{4 \quad 8} \quad 0.5$ A

(b) Power dissipated in $R_1 \quad I^2R_1 \quad 1$ W and power dissipated in $R \quad I^2R_2 \quad 2$ W

(c) Power of battery $E_1 \quad E_1I$

$$12 \quad 0.5 \quad 6 \text{ W (supplied)}$$

Power of battery $E_2 \quad E_2I$

$$6 \quad 0.6 \quad 3 \text{ W (absorbed)}$$

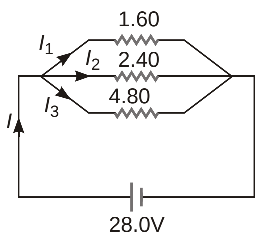
51. $I \quad \dfrac{E}{R \quad r} \quad \dfrac{12}{5 \quad 1} \quad 2$ A

(a) $P \quad EI \quad 12 \quad 2 \quad 24$ W

(b) $P_1 \quad I^2R \quad 2^2 \quad 5 \quad 20$ W

(c) $P_2 \quad I^2r \quad 2^2 \quad 1 \quad 4$ W

52. (a)



$$\frac{1}{R} \quad \frac{1}{R_1} \quad \frac{1}{R_2} \quad \frac{1}{R_3}$$

$$\frac{1}{R} \quad \frac{1}{1.60} \quad \frac{1}{2.40} \quad \frac{1}{4.80}$$

$$R \quad 0.80$$

(b) $I_1 \quad \dfrac{V}{R_1} \quad \dfrac{28.0}{1.60} \quad 17.5$ A

$I_2 \quad \dfrac{V}{R_2} \quad \dfrac{28.0}{2.40} \quad 11.67$ A

$I_3 \quad \dfrac{V}{R_3} \quad \dfrac{28.0}{4.80} \quad 5.83$ A

(c) $I \quad I_1 \quad I_2 \quad I_3 \quad 35.0$ A

(d) As all the resistance connected in parallel, voltage across each resistor is 28.0 V.

(e) $P_1 \quad \dfrac{V^2}{R_1} \quad \dfrac{(28)^2}{1.6} \quad 490$ W

$P_2 \quad \dfrac{V^2}{R_2} \quad \dfrac{(28)^2}{2.4} \quad 326.7$ W

$P_3 \quad \dfrac{V^2}{R_3} \quad \dfrac{(28)^2}{4.8} \quad 163.3$ W

(f) As, $P \quad \dfrac{V^2}{R}$

Resistor with least resistance will dissipate maximum power.

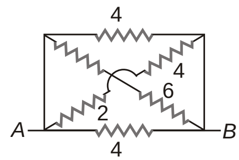
53. (a) $P \quad \dfrac{V^2}{R} \quad V \quad \sqrt{PR}$

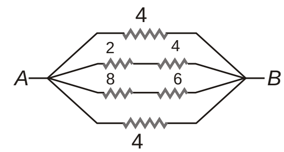
$$\sqrt{5 \quad 15 \quad 10^3} \quad 2.74 \quad 10^2$$

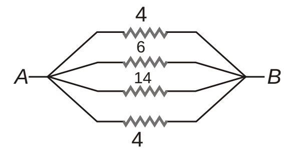
$$274 \text{ V}$$

(b) $P \quad \dfrac{V^2}{R} \quad \dfrac{(120)^2}{9 \quad 10^3} \quad 1.6$ W

54. (a) $\dfrac{1}{R} \quad \dfrac{1}{4} \quad \dfrac{1}{6} \quad \dfrac{1}{14} \quad \dfrac{1}{4}$



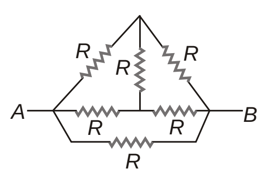


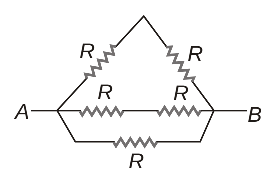


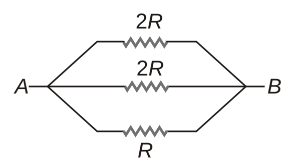
$$\frac{1}{R} \quad \frac{31}{42}$$

$$R \quad \frac{42}{31}$$

(b) $\dfrac{1}{R_e} \quad \dfrac{1}{2R} \quad \dfrac{1}{2R} \quad \dfrac{1}{R}$



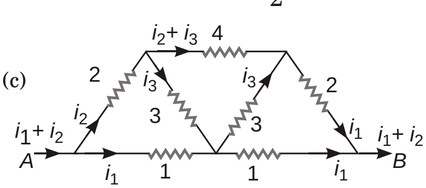


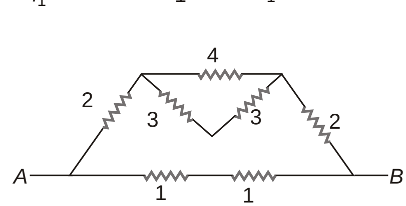


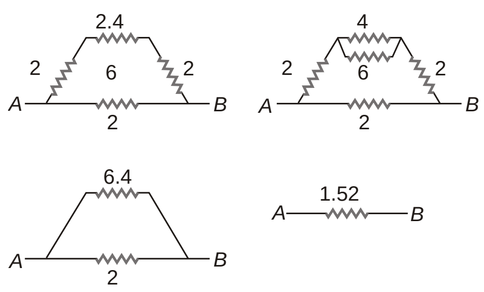
Wheatstone bridge is balanced

$$R_e \quad \frac{R}{2}$$

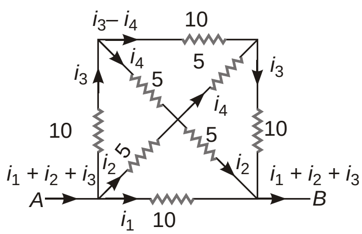
(c)

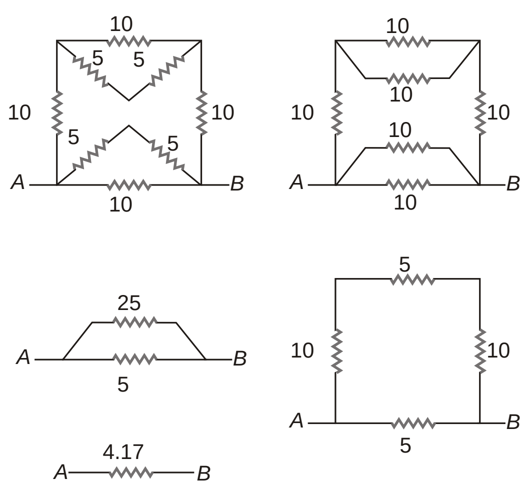




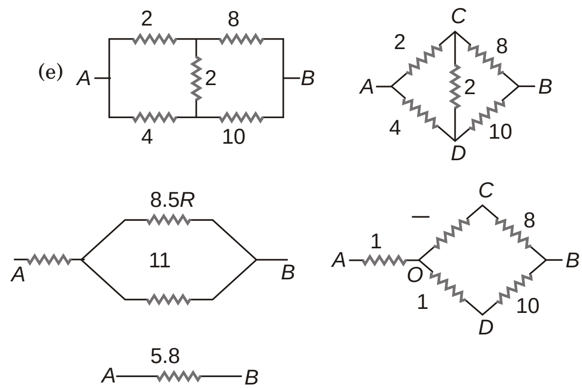


(d)





(e)



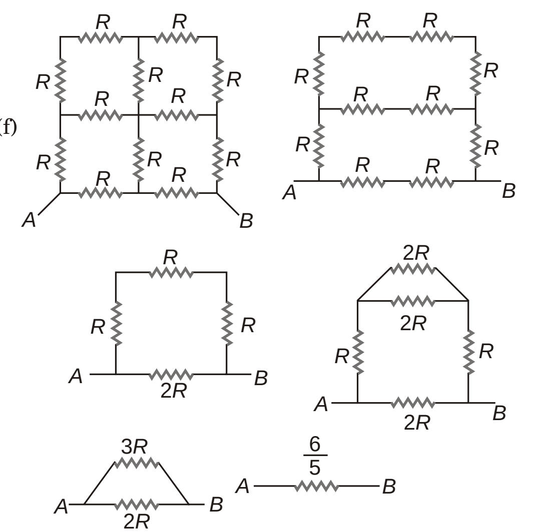
By Star-Delta Method

$$R_A \quad \frac{R_2R_3}{R_1 \quad R_2 \quad R_3}$$

$$R_B \quad \frac{R_1R_3}{R_1 \quad R_2 \quad R_3}$$

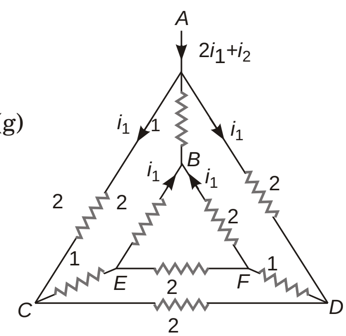
$$R_C \quad \frac{R_2R_3}{R_1 \quad R_2 \quad R_3}$$

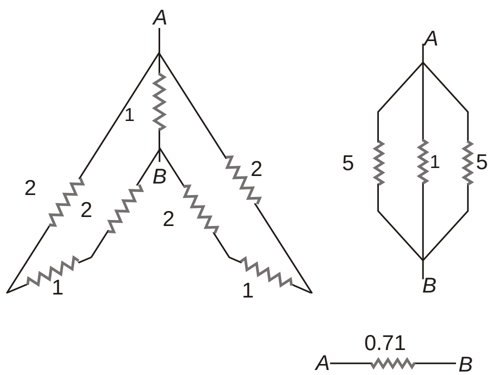
(f)



As circuit is symmetrical about perpendicular bisector of AB, lying on it are at same potential.

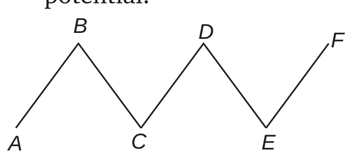
(g)





Clearly C and D, E and F are at same potential.

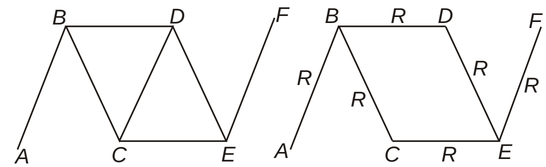
55.



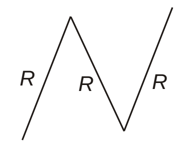
Let R be the resistance of each conductor, and R_1 be the effective resistance between A and F in first case then,

$$R_1 \quad 5R$$

If R_2 be effective resistance between A and F in second case then,



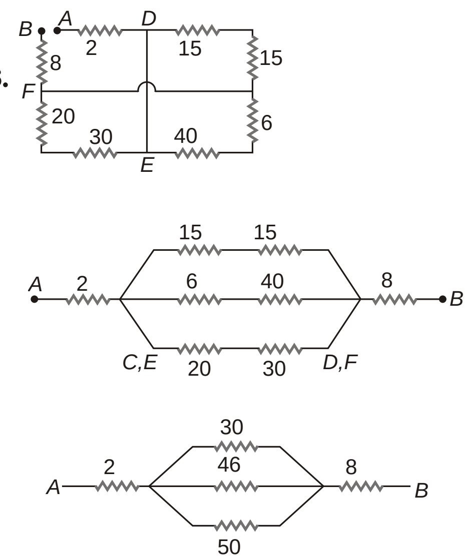
$R_2 = 3R$



$$\frac{R_2}{R_1} \quad \frac{3R}{5R} \quad 0.6$$

$$R_2 \quad 0.6R_1$$

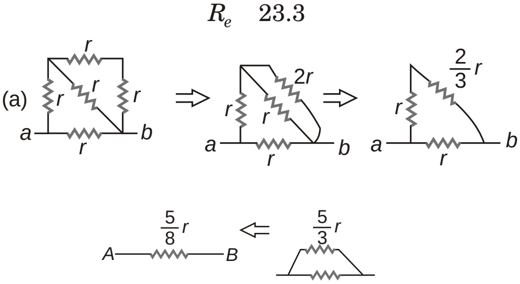
56.

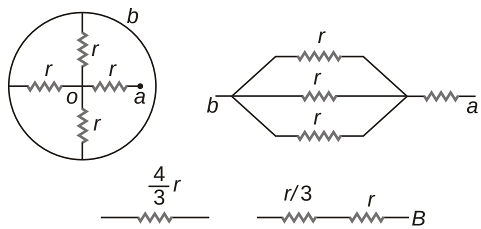


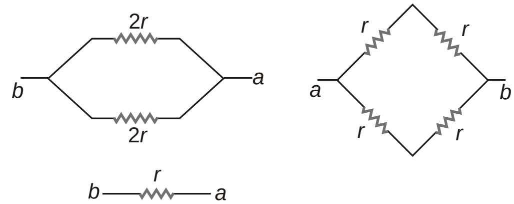
Here, C and E , D and F are at same potential.

$$R_e \quad 23.3$$

57. (a)

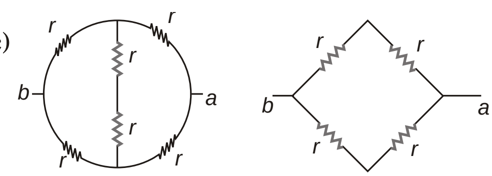


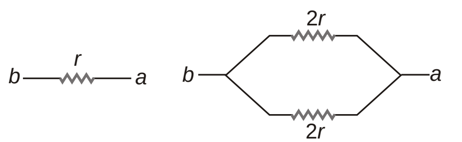
(b) 



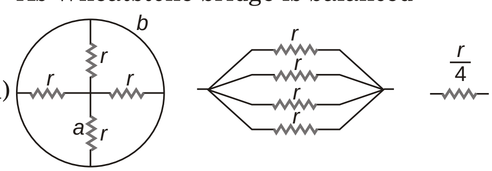
As Wheatstone bridge is balanced.

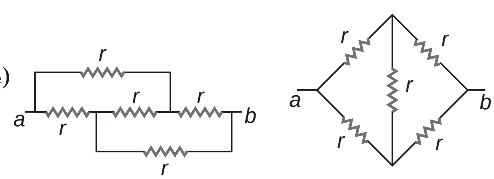
58. $R_e \quad \frac{r}{2}$

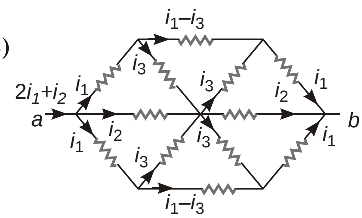
(c) 

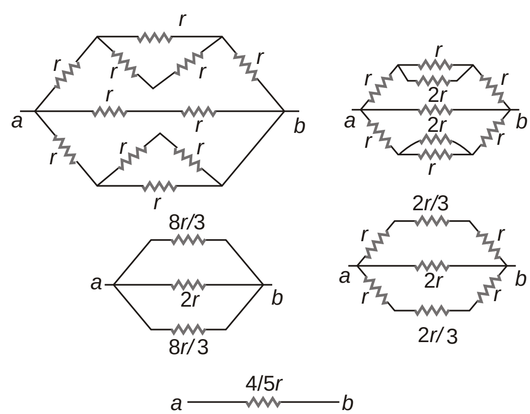


As Wheatstone bridge is balanced

(d) 

(e) 

(b) 



Objective Questions (Level-1)

1. When ammeter is connected in series

$$R_e \quad R \quad R_A$$

Hence, net current decreases. So R_A should be very low.

2. Amount of charge entering per second from one face is equal to the amount of charge leaving per second at the other, hence I is constant.

Again,

$$v_d \quad \frac{I}{neA} \quad \text{not constant.}$$

As $\quad v_d \quad \frac{eF}{m}$

$$E \quad \frac{mv_d}{e} \quad \text{not constant}$$

3. $R \quad \frac{V}{I}$

$$[\text{R}] \quad \frac{[\text{V}]}{[\text{I}]} \quad \frac{[\text{ML}^2\text{T}^{\ 3}\text{I}^{\ 1}]}{[\text{I}]}$$

$$[\text{ML}^2\text{T}^{\ 3}\text{I}^{\ 2}]$$

4. $\frac{1}{\ }$

As unit of resistivity is ohm-m and unit of is ohm ^{1}- m ^{1}.

5. Fact.

6. $E \quad I(R \quad r)$

Case I

$$E \quad 0.5(3.75 \quad r)$$

Case II

$$E \quad 0.4(4.75 \quad r)$$

On solving

$$r \quad 0.25 \quad , E \quad 2\text{ V}$$

7. $\frac{I}{I_g} \quad \frac{50}{20} \quad I \quad \frac{5}{2} I_g$

$$S \quad \frac{I_g}{I \quad I_g} G \quad G \quad \frac{I \quad I_g}{I_g} S$$

$$\frac{3}{2} \quad 12$$

$$18$$

8. $I_g \quad 2\% I \quad \frac{1}{50} I$

$$S \quad \frac{I_g}{I \quad I_g} G \quad \frac{G}{49}$$

9. $P \quad \frac{V^2}{R}$

$$P \quad P \quad \frac{V^2}{R \quad R}$$

As $R \quad l$

$$R \quad 10\% R$$

$$P \quad \frac{V^2}{0.9R} \quad \frac{V^2}{R} \quad \frac{1}{0.9} \quad 1 \; P$$

$$\frac{10}{9} P \quad 11\% P$$

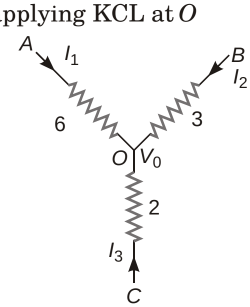
10. Potential difference between any two points is zero.

11. $r \quad \frac{l_1 \quad l_2}{l_2} R$

$$\frac{75 \quad 60}{60} \quad 10$$

$$2.5$$

12. (b) By applying KCL at O



$$I_1 \quad I_2 \quad I_3 \quad 0$$

$$\frac{6 \quad V_0}{6} \quad \frac{3 \quad V_0}{3} \quad \frac{2 \quad V_0}{2} \quad 0$$

$$6 \quad V_0 \quad 2(3 \quad V_0) \quad 3(2 \quad V_0) \quad 0$$

$$V_0 \quad 3\text{ V}$$

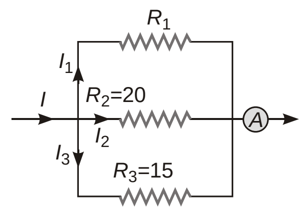
13. $v_d \quad \frac{I}{neA} \quad \frac{I}{ne \quad r^2}$

$$v_d \quad \frac{2I}{ne \quad (2r)^2} \quad \frac{v_d}{2} \quad \frac{v}{2}$$

14. Voltmeter has higher resistance than ammeter.

Again higher the range of voltmeter, higher will be its resistance.

15. $I_2 \quad \frac{\frac{1}{R_2}}{\frac{1}{R_1} \quad \frac{1}{R_2} \quad \frac{1}{R_3}} I$



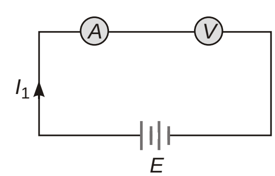
$$\frac{1}{R_1} \quad \frac{I}{I_2 R_2} \quad \frac{1}{R_2} \quad \frac{1}{R_3}$$

$$\frac{0.8}{0.3 \quad 20} \quad \frac{1}{20} \quad \frac{1}{15}$$

$$\frac{1}{60}$$

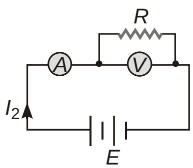
$$R_1 \quad 60$$

16. (d) $I_1 \quad \frac{E}{R_A \quad R_V}, V_1 \quad I_1 R_V$



$$E \quad I_1 R_A$$

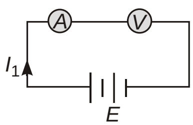
If resistance is connected in parallel with voltmeter,



$$I_2 \quad \frac{E}{R_A \quad \frac{RR_V}{R \quad R_V}} \quad I_1$$

and $\quad V_2 \quad E \quad I_2R_A \quad V_1$

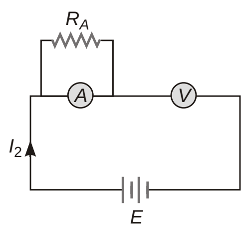
17. Before connectivity resistance is parallel with ammeter



$$I_1 \quad \frac{E}{R_A \quad R_V}, \; V_1 \quad I_1R_V$$

$$E \quad I_1R_A$$

After connecting resistance in parallel to the ammeter.



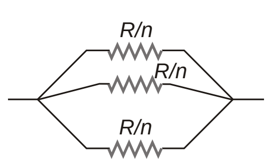
$$I_2 \quad \frac{E}{\frac{R_A}{2} \quad R_V},$$

Reading of ammeter $\quad \frac{1}{2}I_2$

$$\frac{E}{R_A \quad 2R_V} \quad \frac{1}{2}I_1$$

$$V \quad I_2R_V \quad \frac{2E}{R_A \quad 2R_V} \quad 2V_1$$

18. $R_e \quad \frac{R}{n^2}$



$$P \quad \frac{V^2}{R}$$

$$P_e \quad \frac{V^2}{R_e} \quad n^2P$$

19. As bulb A is in series with entire circuit.

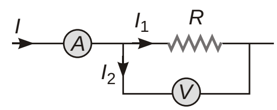
20. $I \quad \frac{E_1 \quad E_2}{R \quad r_1 \quad r_2} \quad \frac{18}{R \quad 3}$

$$V_{ab} \quad E_2 \quad Ir_2 \quad 0$$

$$3 \quad \frac{18}{R \quad 3} \quad 1 \quad 0$$

$$R \quad 3$$

21. $I_2 \quad \frac{R}{R \quad R_V}I$



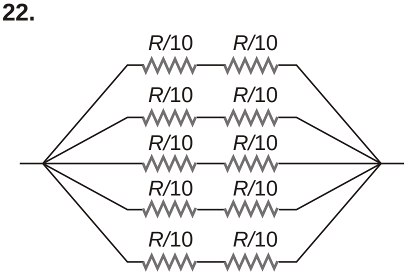
$$\frac{V}{R_V} \quad \frac{R}{R \quad R_V}I$$

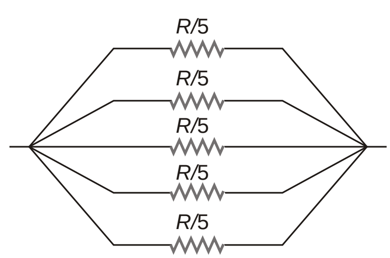
$$\frac{100}{2500} \quad \frac{R}{R \quad 2500}5$$

$$R \quad 2500 \quad 125\,R$$

$$R \quad \frac{2500}{24} \quad 100$$

22.





23. $\frac{R_1}{R_2} \quad \frac{20}{80} \quad \frac{1}{4}$ …(i)

$$\frac{R_1 \quad 15}{R_2} \quad \frac{40}{60} \quad \frac{2}{3}$$

$$\frac{R_1}{R_2} \quad \frac{15}{R_2} \quad \frac{2}{3}$$

$$\frac{15}{R_2} \quad \frac{2}{3} \quad \frac{1}{4} \quad \frac{5}{12}$$

$$R_2 \quad 36 \quad ,$$

$$R_1 \quad \frac{R_2}{4} \quad 9$$

24. (b) As $V_1 \quad \frac{V}{2}$, $R_1 \quad R_2$

$$\frac{R_V \quad 100}{100 \quad R_V} \quad 50$$

$$R_V \quad 100$$

25. (d) $\frac{E}{R_{PB} \quad r} \quad \frac{2}{4 \quad 1} \quad 0.4$

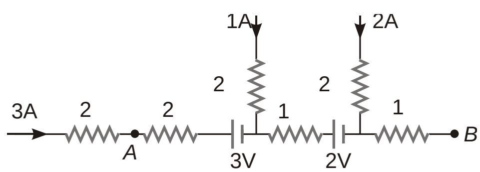
$$V_{AB} \quad IR_{AB} \quad 1.6$$

$$K \quad \frac{V_{PB}}{L} \quad \frac{1.6}{100} \quad 0.016 \text{ V/cm}$$

$$L \quad \frac{E_1}{K} \quad \frac{1.2}{0.016} \quad 75 \text{ cm}$$

26. (d) $V_{AB} \quad 3 \quad 2 \quad 3 \quad 1 \quad 4 \quad 2 \quad 6 \quad 1$

17 V



27. (c) $E_e \quad \frac{E_1 r_2 \quad E_2 r_1}{r_1 \quad r_2} \quad 2 \text{ V}$

$$r_e \quad \frac{r_1 r_2}{r_1 \quad r_2} \quad 0.5$$

For maximum power $R \quad r_e$

and $\quad P_{max} \quad \frac{E_e^2}{4r_e} \quad \frac{(2)^2}{4 \quad 0.5} \quad 2 \text{ W}$

28. (a) $V \quad \frac{R}{R \quad r} E$

$$r \quad \frac{E}{V} \quad 1 \; R \quad \frac{2.2}{1.8} \quad 1 \; 5$$

$$\frac{10}{9}$$

29. (d) $I \quad \frac{E_1 \quad E_2}{R_1 \quad R_2 \quad r_1 \quad r_2}$

$$\frac{10 \quad 5}{25 \quad 15 \quad 2.5 \quad 2.5} \quad \frac{1}{9} \text{A}$$

$$V_{AB} \quad I(25 \quad 15)$$

$$\frac{1}{9} \quad 40 \quad 4 \text{ V}$$

30. (a) $V_{AB} \quad kL \quad 0.2 \quad 100 \quad 20 \text{ mV}$

$$V_{AB} \quad \frac{R_{AB}}{R_{AB} \quad R} E$$

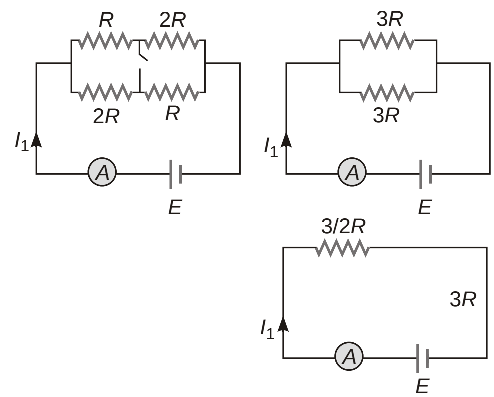
$$0.02 \quad \frac{R_{AB}}{R_{AB} \quad 490} \quad 2$$

$$R_{AB} \quad 490 \quad 100 R_{AB}$$

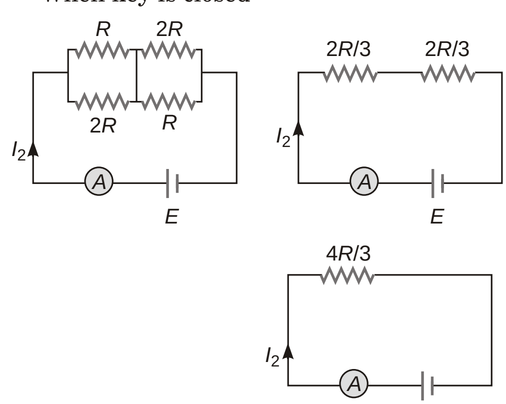
$$R_{AB} \quad \frac{490}{99} \quad 4.9$$

31. (c) When key is open,

$$I_1 \quad \frac{2E}{3R}$$



When key is closed



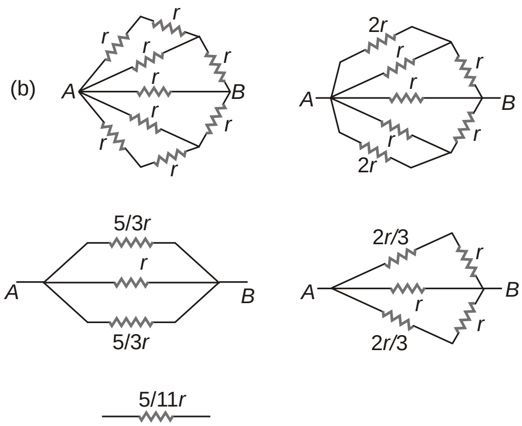
$$I_2 \quad \frac{3E}{4R}$$

$$\frac{I_1}{I_2} \quad \frac{8}{9}$$

32. (b) $S \quad \frac{I_g}{I \quad I_g} G \quad \frac{\frac{1}{34} I}{\frac{33}{34} I} \quad 3663$

111

33. (b)

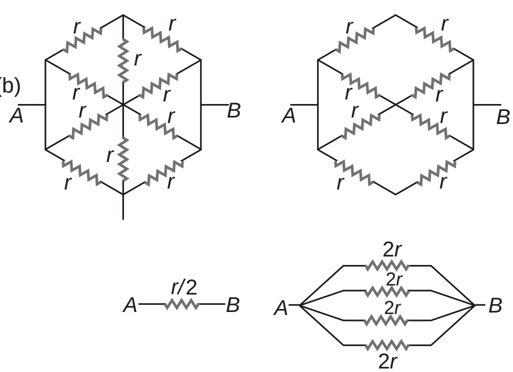


$R_e \quad \frac{5}{11} r$

$r \quad \frac{11}{5} \quad 1.5$

3.3

34. (b)

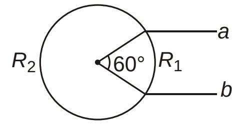


As the circuit is symmetrical about perpendicular bisector of AB, all points lying on it are at same potential.

35. (c) $R_1 \quad \frac{L_1}{L_1 \quad L_2} R$

$R_1 \quad \frac{R}{6} \quad 3$

$R_2 \quad \frac{l_2}{l_1 \quad l_2} \qquad R_2 \quad 15$

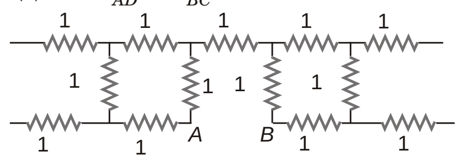


Hence R_1 and R_2 are in parallel

$R_e \quad \frac{R_1 R_2}{R_1 \quad R_2}$

2.5

36. (c) Let $R_{AD} \quad R_{BC} \quad x$



Clearly $x \quad 1$ as 1 resistor is in parallel with some combination.

Now $\qquad R_{AB} \quad x \quad 1 \quad x$

$2x \quad 1$

As $x \quad 1$

$1 \quad R_{AB} \quad 3$

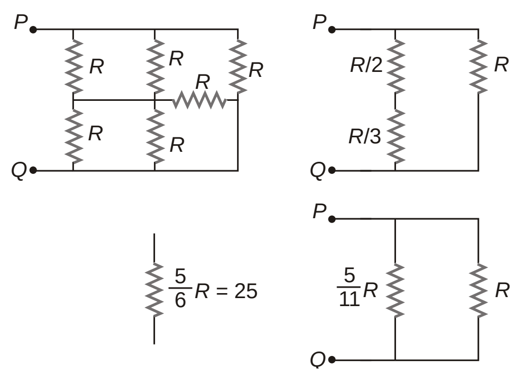
37. (d) $R_{AB} \quad R \quad \frac{R(R \quad R_0)}{2R \quad R_0} \quad R_0$

$2R^2 \quad RR_0 \quad R^2 \quad RR_0 \quad 2RR_0 \quad R_0^2$

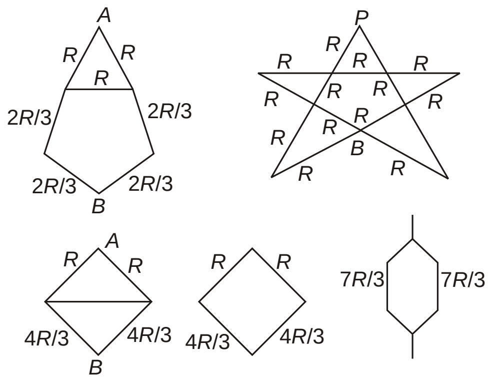
$3R^2 \quad R_0^2$

$R \quad \frac{R_0}{\sqrt{3}}$

38.



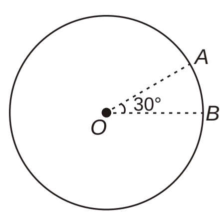
39. Wheatstone bridge is balanced.



$$R_e \quad \frac{7}{6}R$$

40. (d) $R_1 \quad \frac{L_1}{L_1 \quad L_2} R \quad \frac{1}{12} R$

$$3$$



$$R_2 \quad \frac{L_2}{L_1 \quad L_2} \quad \frac{11}{12} R \quad 33$$

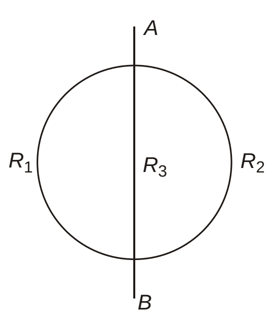
R_1 and R_2 are in parallel,

$$R_e \quad \frac{R_1 R_2}{R_1 \quad R_2} \quad \frac{3 \quad 33}{3 \quad 33}$$

$$2.75$$

41. (a) Resistance per unit length of wire

$$\frac{4}{2 \quad r}$$



$$R_1 \quad \frac{4}{2 \quad r} \quad r \quad 2 \quad R_2$$

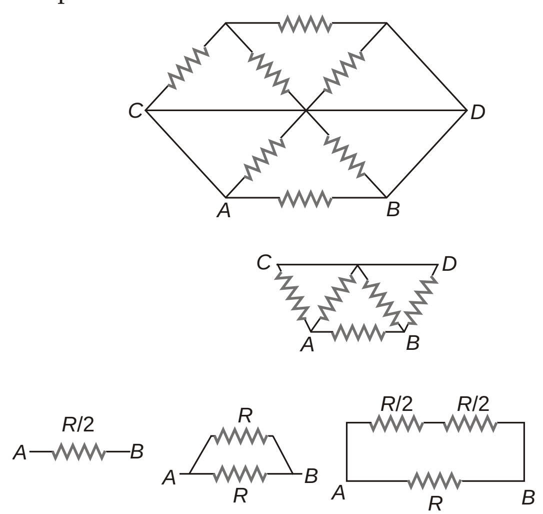
$$R_3 \quad \frac{4}{2 \quad r} \quad 2r \quad \frac{4}{}$$

$$\frac{1}{R_e} \quad \frac{1}{R_1} \quad \frac{1}{R_2} \quad \frac{1}{R_3}$$

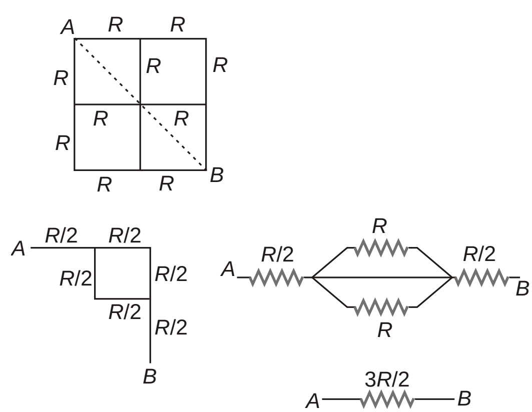
$$\frac{1}{2} \quad \frac{1}{2} \quad \frac{}{4} \quad \frac{4}{4}$$

$$R_e \quad \frac{4}{4}$$

42. (d) Points C and D are shorted hence the portion above line CD can be removed.



43. (b) As AB is line of symmetry, we can fold the network about AB.



JEE Corner

Assertion and Reason

1. (d) $V \quad IR$, If $V \quad 0$ either $I \quad 0$ or $R \quad 0$
2. (b) As all the resistors are in parallel potential difference is same, hence
   $P \quad \frac{V^2}{R}$ is maximum if R is minimum.
3. (b) $dH \quad I^2 dRt \quad \frac{I^2 t}{A} dH$

   I is same everywhere, hence portion having less area is more heated.

   Again $J \quad \frac{I}{A}$

   $J_A \quad J_B$.

   Reason is also correct but does not explain assertion.
4. (b) Both assertion and reason are correct but reason does not explain the cause of decrease in voltmeter reading.
5. (b) As $R_A \quad R_V$, more current passes through ammeter when positions of ammeter and voltmeter are interchanged and potential difference across voltmeter becomes less that emf of cell.
6. (c) During charging current inside the battery flows from positive terminal to negative terminal. Reason is false while assertion is true.
7. (d) $I \quad \frac{E}{R \quad r}$ is maximum when R is zero hence reason is false.

   $P \quad \frac{E^2 R}{(R \quad r)^2}$ is maximum at $R \quad r$.
8. (c) $I \quad \frac{V}{R}$, $P \quad \frac{V^2}{R}$ both I and P are inversly proportional to R hence both decrease with increase in R which increases with temperature.

   According to Ohm's law $V \quad I$ not $V \quad IR$.

   As R can be variable also.
9. (d) Drift velocity is average velocity of all the electrons but velocity of all electrons is not constant.
10. (a) $R \quad \frac{L}{A}$

    $\frac{m}{ne^2}$

    with increase in temperature, electron collide more frequently, *i.e.*, decreases, increasing and hence R.
11. (d) $E \quad \frac{E_1 r_2 \quad E_2 r_1}{r_1 \quad r_2} \qquad E_1 \quad E \quad E_2$

    If $E_1 \quad E_2$

    $r \quad \frac{r_1 r_2}{r_1 \quad r_2}, r \quad r_1, r \quad r_2$
12. (d) $\frac{R_1}{R_2} \quad \frac{L_1}{L_2}$

    Hence there is no effect of one while measuring using meter bridge.

Objective Questions (Level-2)

1. (b) $I \quad \frac{E_2 \quad E_1}{r_1 \quad r_2} \quad \frac{1.5 \quad 1.3}{r_1 \quad r_2}$

   $\frac{0.2}{r_1 \quad r_2}$ ...(i)

   $V \quad E_1 \quad Ir_1$

   $1.45 \quad 1.3 \quad \frac{0.2}{r_1 \quad r_2} r_1$

   $\frac{r_1}{r_1 \quad r_2} \quad \frac{0.15}{0.2} \quad 0.2 r_1 \quad 0.15 r_1 \quad 0.15 r_2$

   $0.05 r_1 \quad 0.15 r_2 \; r_1 \quad 3 r_2$
2. (c) Let R Resistance of voltmeter,

   $V_1 \quad \frac{ER}{R_1 \quad R} \quad 198\text{ V}$ ...(i)

   $V_2 \quad \frac{ER}{R_2 \quad R} \quad \frac{ER}{2R_1 \quad R} \quad 180\text{ V}$ ...(ii)

   $\frac{2R_1 \quad R}{R_1 \quad R} \quad \frac{198}{180} \quad \frac{11}{10}$

   $20R_1 \quad 10R \quad 11R_1 \quad 11R$

   $9R_1 \quad R$

From Eq. (i),

$$\frac{ER}{R_1 \quad R} \quad 198$$

$$E \quad 198 \quad \frac{10R_1}{9R_1} \quad 220\,\text{V}$$

3. (b) $P \quad I^2R$

As R is same for all bulbs and maximum current passes through bulb A, it will glow most brightly.

4. (c) $R \quad R_A \quad \frac{V}{I} \quad 5$

$$R \quad 5 \quad R_A \quad 5$$

5. (a) $r \quad \frac{L_1 \quad L_2}{L_2} R \quad \frac{10}{60} \quad 132.40$

$$22.1$$

6. (b) Current through R when S is open.

$$I_1 \quad \frac{E_1 \quad E_2}{R \quad r_1 \quad r_2}$$

Current through R when S is closed

$$I_2 \quad \frac{E_1}{R \quad r_1}$$

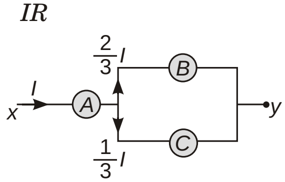
$$I \quad I_2 \quad I_1$$

$$\frac{E_1}{R \quad r_1} \quad \frac{E_1 \quad E_2}{R \quad r_1 \quad r_2}$$

$$\frac{E_1 r_2 \quad E_2(R \quad r_1)}{(R \quad r_1)(R \quad r_1 \quad r_2)}$$

I + ve if $E_1 r_2 \quad E_2(R \quad r_1)$

7. (a) $V_A \quad IR$



$$V_B \quad \frac{2}{3} I \quad 1.5R \quad IR$$

$$V_C \quad \frac{1}{3} I \quad 3R \quad IR$$

$$V_A \quad V_B \quad V_C$$

8. (d) Current through 15 resistor

$$\frac{30}{15} \quad 2\,\text{A}$$

$$V_{BC} \quad (2 \quad 5) \quad 5 \quad 35\,\text{V}$$

Voltage drop across R 100 (30 55)

35 V

Required ratio $\frac{35}{35} \quad 1$

9. (a) $r \quad \frac{L_1 \quad L_2}{L_2} R \quad \frac{x \quad y}{y} R$

10. (d) $\frac{R \quad 20}{40 \quad 20} \quad \frac{t \quad 10}{30 \quad 20}$

$$R \quad t \quad 10$$

$$I \quad \frac{E}{R} \quad \frac{10}{t \quad 10}$$

$$\frac{dq}{dt} \quad \frac{10}{t \quad 10}$$

$$q \quad \int_{10}^{30} \frac{10}{t \quad 10} dt \quad 10 \log_e(t \quad 10) \Big|_{10}^{30}$$

$$10 \log_e 2$$

11. (b) Let l_1 length is kept fixed and l_2 is stretched,

$$R_1 \quad \frac{l_1}{A}, R_2 \quad \frac{l_2}{A}$$

Initial resistance,

$$R \quad R_1 \quad R_2 \qquad \ldots\text{(i)}$$

Now full is stretched $\frac{3}{2}$ times, *ie*,

$$l_2 \quad \frac{3}{2}(l_1 \quad l_2) \quad l_1$$

$$\frac{1}{2}(l_1 \quad 3l_2)$$

$$A_2 \quad \frac{A_2 \; l_2}{l_2} \quad \frac{2Al_2}{l_1 \quad 3l_2}$$

$$R_2 \quad \frac{\frac{1}{2}(l_1 \quad 3l_2)^2}{2Al_2}$$

$$R_2 \quad \frac{(l_1 \quad 3l_2)^2}{4Al_2}$$

Now, $R \quad 4R$

$$R_1 \quad R_2 \quad 4(R_1 \quad R)$$

$$l_1 \quad \frac{(l_1 \quad 3l_2)^2}{4l_2} \quad 4(l_1 \quad l_2)$$

$$\frac{l_2}{l_1} \quad \frac{1}{7}$$

$$\frac{l_2}{l_1 \quad L_2} \quad \frac{1}{8}$$

12. (b) $\frac{X}{R} \quad \frac{l_1}{100 \quad l_1} \quad l_1 \quad 40\,\text{cm}$

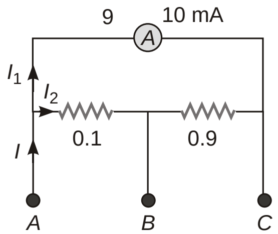
If R 8

$$\frac{X}{R} \quad \frac{l_1}{100 \quad l_1}$$

$$l_1 \quad 60 \text{ cm}$$

$$l_1 \quad l_1 \quad 20 \text{ cm}$$

13. (c) $I_1 \quad \frac{0.1}{0.1 \quad 9.9} I$



But $I_1 \quad 10 \text{ mA}$

$$I \quad \frac{10}{0.1} \quad 10 \text{ mA} \quad 1000 \text{ mA}$$

$$1 \text{ kA}$$

14. (d) Effective emf of two cells

$$E \quad \frac{E_1 r_2 \quad E_2 r_1}{r_1 \quad r_2} \quad \frac{2 \quad 6 \quad 4 \quad 2}{2 \quad 6}$$

$$\frac{20}{8} \quad 2.5 \text{ V}$$

$$R_{AB} \quad 4 \quad 4 \quad 16$$

$$V_{AB} \quad \frac{R_{AB}}{R \quad R_{AB}} E_0 \quad \frac{16}{4 \quad 16} \quad 12$$

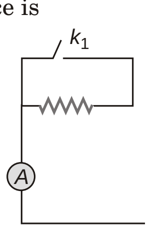
$$9.6 \text{ V}$$

$$k \quad \frac{V_{AB}}{L} \quad 2.4 \text{ V/m}$$

Now, $E \quad kl$

$$L \quad \frac{E}{k} \quad \frac{2.5}{2.4} \quad \frac{25}{24}$$

15. When k_1 and k_2 both are closed, the resistance R_1 is short circuited. Therefore net resistance is



$$R_{net} \quad r \quad \frac{100 \quad 100}{100 \quad 100} \quad r \quad 50$$

$$I_0 \quad \frac{E}{r \quad 50} \qquad \ldots(i)$$

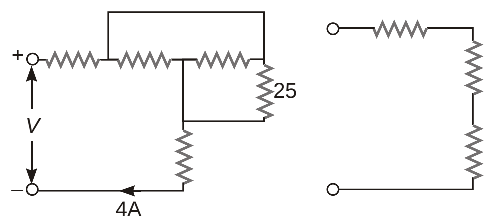
when, k_1 is open and k_2 is closed, net resistance is

$$R_{net} \quad r \quad R_1 \quad \frac{100 \quad 100}{100 \quad 100} \quad (r \quad R_1 \quad 50)$$

$$\frac{I_0}{2} \quad \frac{E}{r \quad R_1 \quad 50} \qquad \ldots(ii)$$

The above two equations are satisfied if $r \quad 0$ and $R_1 \quad 50$.

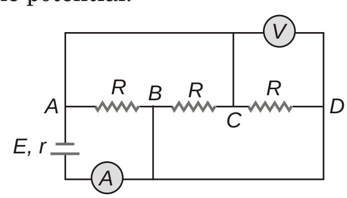
16. (b) 20 , 100 and 25 resistors are in parallel.



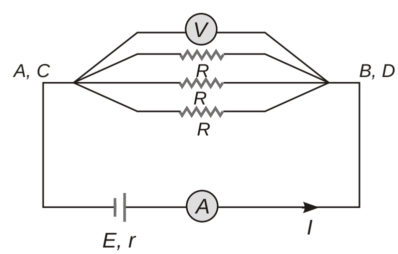
$$R \quad 20$$

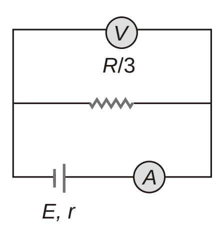
$$V \quad IR \quad 80 \text{ V}$$

17. (a) Hence, points A and C, B and D are at same potential.



The equivalent circuit is given by





$$I \quad \frac{E}{\frac{R}{3} \quad r} \quad 1\,\text{A}$$

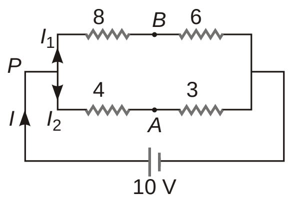
$$V \quad I \quad \frac{R}{3} \quad 3\,\text{V}$$

18. (c) $S \quad \frac{I_g}{I \quad I_g} G, \quad G \quad r, S \quad \frac{r}{4}$

$$I_g \quad \frac{1}{4}(I \quad I_g) \quad I_g \quad \frac{1}{5} I$$

$$0.006\,\text{A}$$

19. (d) $I_1 \quad \frac{10}{14} \quad \frac{5}{7}\,\text{A}$



$$I_2 \quad \frac{10}{7}\,\text{A}$$

$$V_P \quad V_A \quad I_2 \quad 4$$
$$\frac{40}{7}\,\text{A}$$

$$V_P \quad V_B \quad I_1 \quad 8 \quad \frac{40}{7}\,\text{A}$$

$$V_A \quad A_B \quad 0$$

Another method

As, $\frac{R_1}{R_2} \quad \frac{R_3}{R_4}, V_B \quad V_A$

20. (b) For series connection

$$\frac{V_1}{V_2} \quad \frac{R_1}{R_2}$$

$$\frac{R_1}{R_2} \quad \frac{3}{2}$$

Now, $R_1 \quad \frac{L_1}{A_1} \quad \frac{L_1}{r_1^2},$

$$R_2 \quad \frac{L_2}{A_2} \quad \frac{L_2}{r_2^2}$$

$$\frac{R_1}{R_2} \quad \frac{L_1}{L_2} \quad \frac{r_2}{r_1}^2$$

$$\frac{r_1}{r_2} \quad \sqrt{\frac{R_2 L_1}{R_1 L_2}} \quad \sqrt{\frac{2 \quad 6}{3 \quad 1}} \quad 2$$

$$\frac{r_2}{r_1} \quad \frac{1}{2}$$

21. (a) Voltage sensitivity of voltmeter

$$\frac{1}{\text{Resistance of voltmeter}}$$

$$\frac{V_{s_1}}{V_{s_2}} \quad \frac{R_2 \quad G}{R_1 \quad G}$$

$$\frac{30}{20} \quad \frac{R_2 \quad 50}{2950 \quad 50}$$

$$R_2 \quad G \quad \frac{30 \quad 3000}{20} \quad 4500$$

$$R_2 \quad 4450$$

22. (b) For $x \quad 0$

$$V_{AB} \quad E$$

$$k_1 \quad \frac{E}{L}$$

$$E_0 \quad k_1 L_1 \quad \frac{EL_1}{L} \qquad \text{...(i)}$$

For $x \quad x$ (say)

$$V_{AB} \quad \frac{R_{AB}}{R_{AB} \quad x} E$$

$$k_2 \quad \frac{R_{AB} E}{(R_{AB} \quad x) L}$$

$$E_0 \quad k_2 L_2 \quad \frac{R_{AB} E L_2}{(R_{AB} \quad x) L} \qquad \text{...(ii)}$$

From Eqs. (i) and (ii),

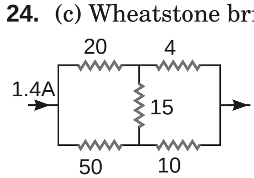
$$L_1 \quad \frac{R_{AB} \quad L_2}{(R_{AB} \quad x)}$$

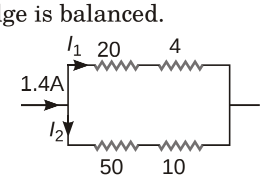
$$20 \quad \frac{10 \quad 30}{10 \quad x}$$

$$x \quad 5$$

23. (d) To obtain null point similar terminal of both the batteries should be connected.

24. (c) Wheatstone bridge is balanced.



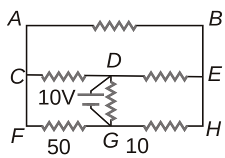


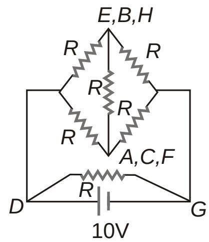
$$I_1 \quad \frac{R_2}{R_1 \quad R_2} \quad I$$

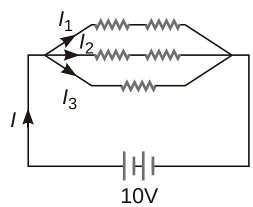
$$\frac{60}{84} \quad 1.4$$

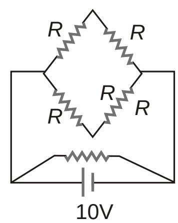
$$1\,\text{A}$$

25. (b)









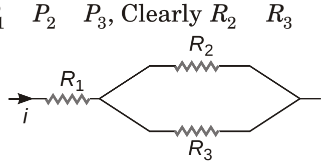
$$I_1 \quad \frac{10}{2 \quad 2} \quad 2.5\,\text{A}$$

26. (b) Effective resistance of voltmeter and 3 k resistor,

$$R_1 \quad \frac{3 \quad 6}{2 \quad 6} \quad 2\,\text{k}$$

$$V_1 \quad \frac{R_1}{R_1 \quad R_2} E \quad \frac{2}{4} \quad 10 \quad 5\,\text{V}$$

27. (d) $P_1 \quad P_2 \quad P_3$, Clearly $R_2 \quad R_3$



$$i_2 \quad i_3 \quad \frac{i}{2}$$

$$P_1 \quad i^2 R_1, P_2 \quad \frac{i}{2}^{2} \quad R_2 \quad \frac{1}{4} i^2 R_2$$

$$P_3 \quad \frac{1}{4} i^2 R_3$$

$$R_2 \quad 4R_1, R_3 \quad 4R_1$$

$$R_1 : R_2 : R_3 \quad 1:4:4$$

28. As $E \quad kL_1 \quad k \quad \frac{E}{L_1} \quad \frac{2}{500} \quad 250$

$$\frac{1}{250}\,\text{V/cm}$$

$$V \quad kL_2 \quad \frac{1}{250} \quad 490\,\text{cm}$$

$$1.96\,\text{V}$$

29. (c) $r \quad \frac{L_1 \quad L_2}{L_2} R$

$$R \quad \frac{L_2 r}{L_1 \quad L_2}$$

$$\frac{490 \quad 10}{10} \quad 490$$

More than One Correct Options

30. $H \quad P_1 t_1 \quad P_2 t_2$

$$t_1 \quad \frac{H}{P_1}, t_2 \quad \frac{H}{P_2}$$

If connected in series

$$\frac{1}{P} \quad \frac{1}{P_1} \quad \frac{1}{P_2}$$

$$t \quad t_1 \quad t_2$$

If connected in parallel

$$P \quad P_1 \quad P_2$$

$$t \quad \frac{t_1 t_2}{t_1 \quad t_2}$$

31. $E \quad \frac{E_1 r_2 \quad E_2 r_1}{r_1 \quad r_2} \quad \frac{6 \quad 3 \quad 5 \quad 2}{2 \quad 3}$

$$5.6\,\text{V}$$

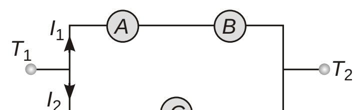
As there is no load.

$$V \quad E \quad 5.6\,\text{V}$$

If $E_1 \quad E_2, I \quad 0$

$$I \quad \frac{E_1 \quad E_2}{r_1 \quad r_2} \quad \frac{6 \quad 5}{2 \quad 3} \quad 0.2\,\text{A}$$

32. Let V Potential difference between T_1 and T_2.



$$I_1 \quad \frac{V}{R_A \quad R_B}$$

$$I_2 \quad \frac{V}{R_C}$$

Now,. $I_A \quad I_B \quad I_1$

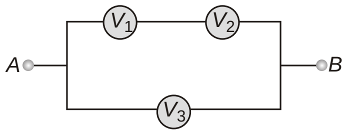
$$I_C \quad I_2$$

Also, $V \quad I_C R_C \quad I_1(R_A \quad R_B)$

$$I_A R_A \quad I_D R_B$$

$$\frac{I_B}{I_C} \quad \frac{I_1}{I_2} \quad \frac{R_C}{R_A \quad R_B}$$

33. As $R_1 \quad R_2$



$$V_1 \quad V_2$$

Also, $\quad V_3 \quad V_1 \quad V_2$

34. As $R_1 \quad R_2$

$$V_1 \quad V_2$$

$$R \quad \frac{L}{A}$$

But

$$L_2 \quad 2L_1$$

and $\quad R_1 \quad R_2$

$$A_2 \quad 2\,A_1$$

Also, $v_d \quad \frac{1}{A}$ (For constant current)

$$v_{d_2} \quad \frac{1}{2} v_{d1} \quad v_{d_1} \quad 2\,v_{d_2}$$

Again, $v_d \quad E$

$$E_1 \quad 2\,E_2$$

35. If $E \quad 18$ V current will flow from B to A and *vice-versa*.

36. $V \quad kl$

If Jockey is shifted towards right, I and hence k will decreases as $k \quad I$.

Hence L will increase.

If E_1 is increased, k will increase, hence L will decrease.

If E_2 is increased L will increase as V will increase.

If   is closed V will decrease hence L will decrease.

37. $I_e \quad \frac{E}{R_e \quad r_e}$, Initially, $I \quad \frac{E}{R \quad r}$

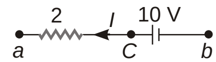
If S_1 is closed

$$I_e \quad \frac{E}{\frac{R}{2} \quad r} \quad I$$

If S_2 is closed

$$I_e \quad \frac{E}{R \quad \frac{r}{2}} \quad I$$

38. $V_b \quad V_a \quad 10 \quad 2I \quad 2$ V

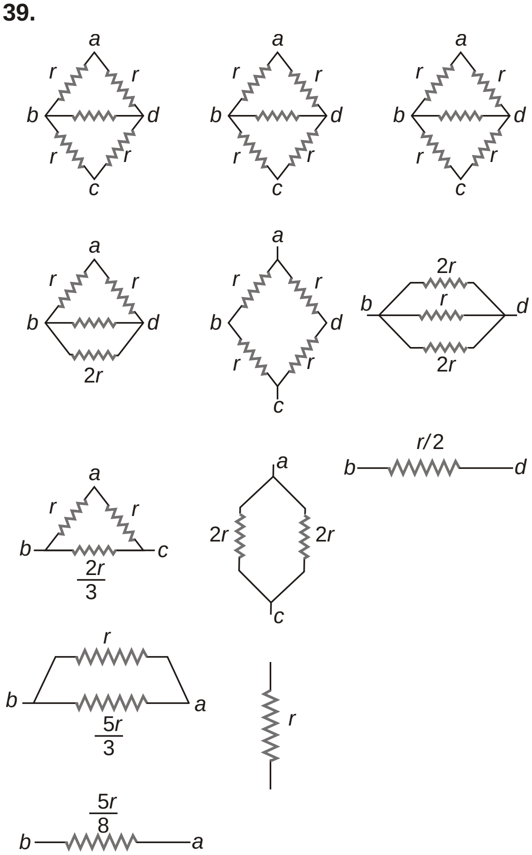


$$I \quad 6\text{ A}$$

From b to a.

$$V_c \quad V_a \quad 2 \quad 6 \quad 12\text{ V}$$

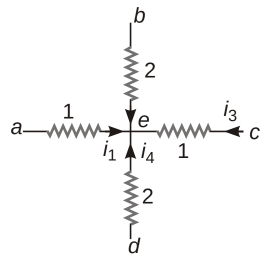
39.



Match the Columns

1. By applying KCL at e

$$i_1 \quad i_2 \quad i_3 \quad i_4 \quad 0$$



$$\frac{2 \quad V_e}{1} \quad \frac{4 \quad V_e}{2} \quad \frac{6 \quad V_e}{1} \quad \frac{4 \quad V_e}{2} \quad 0$$

$$V_e \quad 4\,\text{V}, I_1 \quad 2\,\text{A}, i_2 \quad 0, i_3 \quad 2\,\text{A}, i_4 \quad 0$$

2. Current is same at every point and $A_1 \quad A_2$

$$J \quad \frac{i}{A} \quad J_1 \quad J_2$$

$$v_d \quad \frac{i}{neA} \quad v_{d_1} \quad v_{d_2}$$

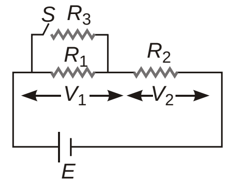
$$r \quad \frac{R}{L} \quad \overline{A} \quad r_1 \quad r_2$$

$$k \quad \frac{V}{L} \quad k_1 \quad k_2$$

3. When switch S is closed

V_1 decreases, V_2 increases,

Current through R_1 decreases and through R_2 increases.



4. $[\text{R}] \quad \frac{[\text{V}]}{[\text{I}]} \quad \frac{[\text{ML}^2\text{T}^{\ 3}\text{A}^{\ 1}]}{[\text{A}]}$

$$[\text{ML}^2\text{T}^{\ 3}\text{A}^{\ 2}]$$

$$[\text{V}] \quad \frac{[W]}{[q]} \quad \frac{[\text{ML}^2\text{T}^{\ 2}]}{[\text{AT}]}$$

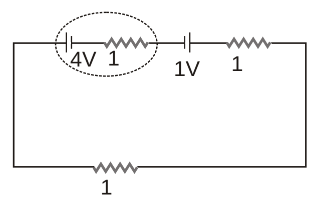
$$[\text{ML}^2\text{T}^{\ 3}\text{A}^{\ 1}]$$

$$[\quad] \quad \frac{[R][A]}{[L]} \quad \frac{[\text{ML}^2\text{T}^{\ 3}\text{A}^{\ 2}][\text{L}^2]}{[\text{L}]}$$

$$[\text{ML}^3\text{T}^{\ 3}\text{A}^{\ 2}]$$

$$[\quad] \quad \frac{1}{[\quad]} \quad [\text{M}^{\ 1}\text{L}^{\ 3}\text{T}^3\text{A}^2]$$

5. $I \quad \frac{E_A \quad E_B}{R \quad r_A \quad r_A} \quad 1\,\text{A}$



$$V_A \quad E_A \quad Ir_A \quad 3\,\text{V}$$

$$V_B \quad E_B \quad Ir_B \quad 2\,\text{V}$$

$$P_A \quad IV_A \quad 3\,\text{W}$$

$$P_B \quad IV_B \quad 2\,\text{W}$$

21 Electrostatics

Introductory Exercise 21.1

1. No, because charged body can attract an uncharged by inducing charge on it.

2. Yes.

3. On clearing, a phonograph record becomes charged by friction.

4. No. of electrons in 3 g mole of hydrogen atom

$$3 \quad 6.022 \quad 10^{23}$$

$$q \quad ne \quad 3 \quad 6.022 \quad 10^{23} \quad 1.6 \quad 10^{\ 19}$$

$$2.9 \quad 10^{5}\ \text{C}$$

Introductory Exercise 21.2

1.

$$F_e \quad \frac{1}{4 \quad _0} \frac{q_1 q_2}{r^2} \quad \frac{1}{4 \quad _0} \frac{e^2}{r^2}$$

$$F_g \quad \frac{G m_1 m_2}{r^2}$$

$$\frac{F_e}{F_g} \quad \frac{e^2}{4 \quad _0 \ G m_1 m_2}$$

$$\frac{9 \quad 10^9 \quad (1.6 \quad 10^{\ 19})^2}{6.67 \quad 10^{\ 11} \quad 9.11 \quad 10^{\ 31} \quad 1.67 \quad 10^{\ 27}}$$

$$2.27 \quad 10^{39}$$

2.

$$F \quad \frac{1}{4 \quad _0} \frac{q_1 q_2}{r^2}$$

$$_0 \quad \frac{q_1 q_2}{4 \ F r^2}$$

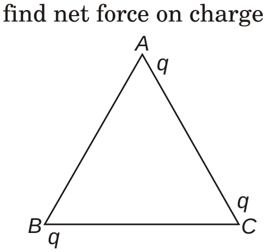
$$[\ _0] \quad \frac{[q_e]^2}{[F][r]^2}$$

$$\frac{[\text{IT}]^2}{[\text{MLT}^{\ 2}][\text{L}]^2}$$

$$[\text{M}^{\ 1}\text{L}^{\ 3}\text{T}^{\ 4}\text{I}^{\ 2}]$$

SI units of $_0$ $\text{C}^{\ 2}\text{N}^{\ 1}\text{m}^{\ 2}$.

3. Let us find net force on charge at *A*.

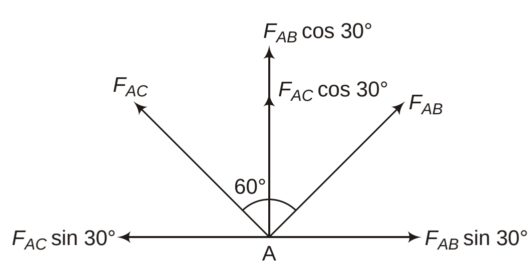


$$F_{AB} \quad \frac{1}{4 \quad _0} \frac{q^2}{a^2} \ F_{AC} \quad \frac{1}{4 \quad _0} \frac{q^2}{a^2}$$

Net force on charge at *A*

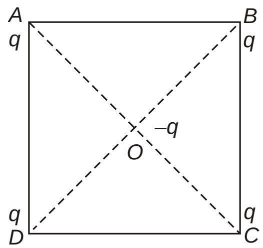
$$F_A \quad F_{AB} \cos 30 \quad F_{AC} \cos 30$$

$$\frac{\sqrt{3} q^2}{4 \quad _0 \ a^2}$$



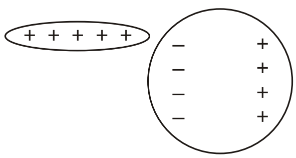
4. $\mathbf{F}_{OA}$ $\mathbf{F}_{OC}$

and $\mathbf{F}_{OB}$ $\mathbf{F}_{OD}$



Hence, net force on charge at centre is zero.

5. No. In case of induction while charge comes closer and like charge moves further from the source.



The cause of attraction is more attractive force due to small distance. But if electrostatic force becomes independent of distance, attractive force will become equal to repulsive force, hence net force becomes zero.

6. When the charged glass rod is brought near the metal sphere, negative induces on the portion of sphere near the charge, hence it get attracted. But when the sphere touches the rod it becomes positively charged due to conduction and gets repelled by the rod.

7. Yes as $q_{\min}$ e

$$F_{\min} \quad \frac{1}{4 \quad _0} \frac{e^2}{r^2}$$

8. No. Electrostatic force is independent of presence or absence of other charges.

9. F_{21} F_{12} $(\ 4\hat{\mathbf{i}} \quad 3\hat{\mathbf{j}})$ N.

Introductory Exercise 21.3

1. False. $E \quad \frac{1}{4 \quad _0} \frac{q}{r^2}$

2. V_A V_B as electric lines of force move from higher potential to lower potential.

3. False. Positively charged particle moves in the direction of electric field while negatively charged particle moves opposite to the direction of electric field.

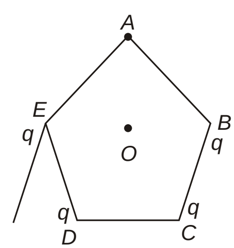
4. False. Direction of motion can be different from direction of force.

5. $E \quad \frac{\quad}{_0} \qquad E \, _0 \quad 3.0 \quad 8.85 \quad 10^{12}$

$$2.655 \quad 10^{11} \text{ C/m}^2$$

6. q_1 and q_3 are positively charged as lines of force are directed away from q_1 and q_3. q_2 is negatively charged because electric field lines are towards q_2.

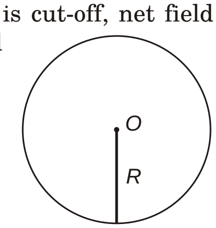
7. If a charge q is placed at A also net field at centre will be zero.



Hence net field at O is same as produced by A done but in opposite direction,02 *i.e.*,

$$E \quad \frac{1}{4} \frac{q}{a^2}$$

8. Net field at the centre (O) of wire is zero. If a small length of the wire is cut-off, net field will be equal to the field due to cut-off portion, *i.e.*,



$$dE \quad \frac{1}{4 \quad _0} \frac{dq}{R^2}$$

$$\frac{1}{4 \quad _0} \frac{\frac{q}{2 \quad R} dl}{R^2}$$

$$\frac{q \, dl}{8 \ ^2 \ _0 R^3}$$

9. $\mathbf{E} \quad \frac{1}{4 \quad _0} \frac{q}{r^3}\mathbf{r}$

$$\frac{9 \quad 10^9 \quad 2 \quad 10^{\ 6}}{(3^2 \quad 4^2)^{3/2}}(3\,\hat{\mathbf{i}} \quad 4\,\hat{\mathbf{j}}) \qquad 144\,(3\,\hat{\mathbf{i}} \quad 4\,\hat{\mathbf{j}})\ \text{N/C}$$

Introductory Exercise 21.4

1. Gain in KE loss of PE

$$\frac{1}{2}mv^2 \quad \frac{1}{4 \quad _0} \ q_1q_2 \ \frac{1}{r_1} \quad \frac{1}{r_2}$$

$$\frac{1}{2} \quad 10^{\ 4}v^2$$

$$1 \quad 10^{\ 6} \quad 2 \quad 10^{\ 6} \quad 9 \quad 10^9 \ \frac{1}{1} \quad \frac{1}{0.5}$$

$$v^2 \quad 360$$

$$v \quad 6\sqrt{10}\ \text{ms}^{\ 1}$$

2. $W \quad q\,(V_A \quad V_B)$

$$2 \quad 10^{\ 6} \ \frac{1}{4 \quad _0} \ \frac{1 \quad 10^{\ 6}}{1} \quad \frac{1}{4 \quad _0} \ \frac{1 \quad 10^{\ 6}}{2}$$

$$9 \quad 10^{\ 3}\ \text{J}$$

$$9\ \text{m J}$$

3. Whenever work is done by electric force, potential energy is decreased.

$$W \qquad U$$

$$U_2 \quad U_1 \quad W \qquad 8.6 \quad 10^{\ 8}\ \text{J}$$

4. No. As $U \ \frac{q_1q_2}{4 \quad _0 r}$

If there are three particles

$$U \quad \frac{1}{4 \quad _0} \ \frac{q_1q_2}{r_{12}} \quad \frac{q_2q_3}{r_{23}} \quad \frac{q_3q_1}{r_{31}}$$

Here U may be zero.

In case of more than two particles PE of systems may same as if they were separated by infinite distance but not in case of two particles.

Introductory Exercise 21.5

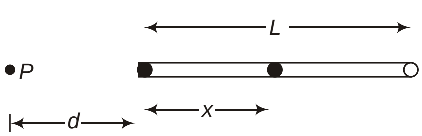
1. $V_{ba} \quad \frac{W_{a \quad b}}{q} \quad 12 \quad 10^2 \quad 1200\ \text{V}$

2. x

(a) SI Units of C/m

$$\overline{x}$$

Hence SI unit of $\frac{\text{C/m}}{\text{m}}$ C/m^2.



(b) Consider an elementary portion of rod at a distance x from origin having length dx. Electric potential at P due to this element.

$$dV \quad \frac{1}{4 \quad _0} \ \frac{dx}{x \quad d}$$

Net electric potential at P

$$V \quad {}_0^L \frac{1}{4 \quad _0} \ \frac{dx}{x \quad d}$$

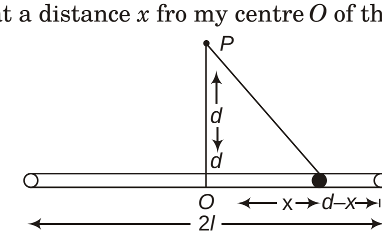
$$\frac{}{4 \quad _0} \ {}_0^L \frac{x\,dx}{x \quad d}$$

$$\frac{}{4 \quad _0} \ {}_0^L dx \quad d \ {}_0^L \frac{dx}{x \quad d}$$

$$\frac{}{4 \quad _0} \ [[x]_0^L \quad d\,[\ln{(x \quad d)}]_0^L]$$

$$\frac{}{4 \quad _0} \quad L \quad d\ln\frac{L \quad d}{d}$$

3. Consider an elementary portion of length dx at a distance x fro my centre O of the rod.



Electric potential at P due to this element,

$$dV \quad \frac{1}{4 \quad _0} \ \frac{dx}{\sqrt{d^2 \quad x^2}}$$

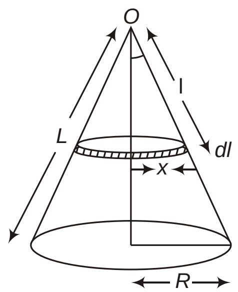
$$V \quad \frac{}{4 \quad _0} \ {}_l^l \frac{dx}{\sqrt{d^2 \quad x^2}}$$

$$\frac{}{4 \ _0} \sin^{1} \frac{x}{d} \Big|_{l}^{l}$$

$$\frac{q}{4 \ _0 \ 2l} \ 2 \sin^{1} \frac{x}{d}$$

$$V \quad \frac{q}{4 \ _0 l} \sin^{1} \frac{x}{d}$$

4. Consider the cone to be made up of large number of elementary rings.



Consider one such ring of radius x and thickness dl. Let be the semi-vertical angle of cone and R be the radius of cone.

Charge on the elementary ring;

$$dQ \quad dA \quad \frac{Q}{RL} \ 2 \ x \, dl$$

or $$dQ \quad \frac{2Ql \sin}{RL} dl$$

Potential at O due to this ring

$$dV \quad \frac{1}{4 \ _0} \frac{dQ}{l}$$

$$\frac{Q \sin}{2 \ _0 RL} dl$$

Total potential at O

$$V \quad \frac{Q \sin}{2 \ _0 RL} \int_0^L dl \quad \frac{QL \sin}{2 \ _0 RL}$$

$$\frac{Q}{2 \ _0 L} [L \sin \quad R]$$

$$U \quad qV$$

$$\frac{Qq}{2 \ _0 L}$$

Introductory Exercise 21.6

1. (a) $V \quad a\,(x^2 \quad y^2)$

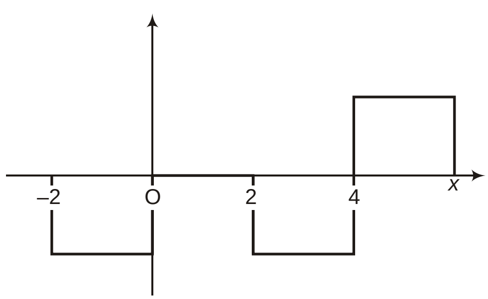
$$E \quad \frac{v}{x}\hat{\mathbf{i}} \quad \frac{v}{y}\hat{\mathbf{j}} \quad 2ax\,\hat{\mathbf{i}} \quad 2y\,\hat{\mathbf{j}}$$

(b) $V \quad axy$

$$E \quad \frac{v}{x}\hat{\mathbf{i}} \quad \frac{v}{y}\hat{\mathbf{j}} \quad a\,(y\,\hat{\mathbf{i}} \quad x\,\hat{\mathbf{j}})$$

2. From $x \quad 2$ to $x \quad 0$ & $x \quad 2$ to $x \quad 4$

V is increasing uniformly.



Hence, E is uniform and negative

From $x \quad 0$ to $x \quad 2$

V is constant hence E is zero.

For $x \quad 4$

V is decreasing at constant rate, hence E is positive.

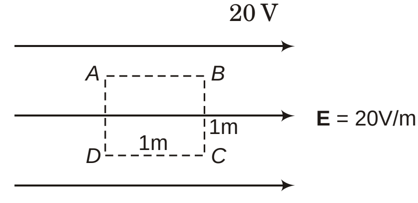
3. $$E \quad \frac{dV}{dr} \quad \frac{(50 \quad 100)}{5 \quad 0} \quad 10 \text{ V/m}$$

True.

4. (a) $V_P \quad V_D \quad \mathbf{E} \ \mathbf{l} \quad 0$

(b) $V_P \quad V_C \quad \mathbf{E} \ \mathbf{l} \quad 20 \quad 1 \quad \cos 0$

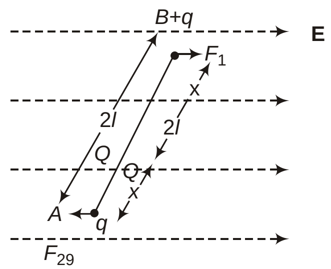
20 V



(c) $V_B \quad V_D \quad 20 \quad 1 \quad 20 \text{ V}$

(d) $V_C \quad V_D \quad 20 \quad 1 \quad 20 \text{ V}$

Introductory Exercise 21.7



1. $F_1 \quad qE$ towards right

$F_2 \quad qE$ towards left

Net torque about ,

$$qE(2l \quad x)\sin \quad qEx \sin$$

$$q(2l)E\sin \quad pE\sin$$

$$\mathbf{p} \quad \mathbf{E}$$

2.

$$E_1 \quad \frac{1}{4 \quad _0} \frac{q}{(\sqrt{y^2 \quad a^2})^2}$$

$$E_2 \quad \frac{1}{4 \quad _0} \frac{q}{(\sqrt{y^2 \quad a^2})^2}$$

$$E_3 \quad \frac{1}{4 \quad _0} \frac{2q}{y^2}$$

Net field at P

$$\mathbf{E} \quad (E_3 \quad E_1 \cos \quad E_2 \cos \quad)\hat{\mathbf{j}}$$

$$\frac{q}{4 \quad _0} \quad \frac{2}{y^2} \quad \frac{\cos}{y^2 \quad a^2} \quad \frac{\cos}{y^2 \quad a^2} \quad \hat{\mathbf{j}}$$

$$\frac{2q}{4 \quad _0} \quad \frac{1}{y^2} \quad \frac{y}{(y^2 \quad a^2)^{3/2}} \quad \hat{\mathbf{j}}$$

$$\frac{2q}{4 \quad _0} \quad \frac{(y^2 \quad a^2)^{3/2} \quad y^3}{y^2(y^2 \quad a^2)^{3/2}} \quad \hat{\mathbf{j}}$$

$$\frac{2q}{4 \quad _0} \quad \frac{y^3 \; 1 \quad \frac{q^2}{y^2}^{\;3/2} \quad y^3}{y^2(y^2 \quad a^2)^{3/2}} \quad \hat{\mathbf{j}}$$

As $y \quad a$

$$E \quad \frac{2q}{4 \quad _0} \quad \frac{y^3 \; 1 \quad \frac{3q^2}{2y^2} \quad y^3}{y^5} \quad \hat{\mathbf{j}}$$

$$E \quad \frac{3qa^2}{4 \quad _0 y^4} \hat{\mathbf{j}}$$

Introductory Exercise 21.8

1. (a) Charge q is completely the hemisphere hence flux through hemisphere is zero.

(b) Charge inside the sphere is q hence flux through hemisphere

$$\frac{q}{_0}$$

(c) As charge q is at the surface, net flux through hemisphere

$$\frac{q}{2 \quad _0}$$

2. When charge is at any of the vertex, net flux through the cube,

$$\frac{q}{8 \quad _0}$$

If charge q is at D,

flux through three faces containing D is zero and the flux is divided equal among other three faces, hence

$$_{\text{EFGH}} \quad \frac{1}{\;} \quad \frac{q}{2 \quad _0}$$

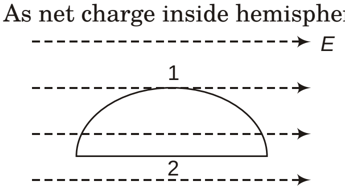
and $\quad _{\text{AEHD}} \quad 0$

3. True. As electric field is uniform, flux entering the cube will be equal to flux leaving it.

$$_{\text{net}} \quad 0 \qquad _{\text{net}} \quad \frac{q}{_0}$$

$$q \quad 0$$

4. (a) As net charge inside hemisphere is zero,



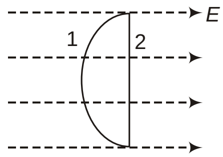
$$_1 \quad _2 \quad 0$$

But E is parallel to surface 2.

$_2 \quad 0$

Hence, $_1 \quad 0$

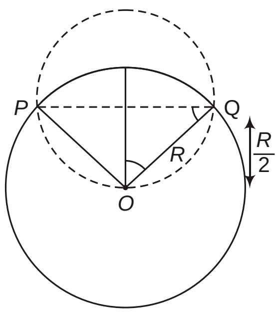
(b) Again, $_1 \quad _2 \quad 0$



$_2 \quad E \quad R^2 \quad R^2E$

$_1 \quad _2 \quad R^2E$

5. $\cos \quad \frac{R/2}{R} \quad \frac{1}{2}, \quad 60$



$POQ \quad 2 \quad 120$

Length of arc $PQ \quad \frac{2}{3} R$

Charge inside sphere,

$$q \quad \frac{q_0}{2\ R} \quad \frac{2}{3} R \quad \frac{q_0}{3}$$

Flux through the sphere

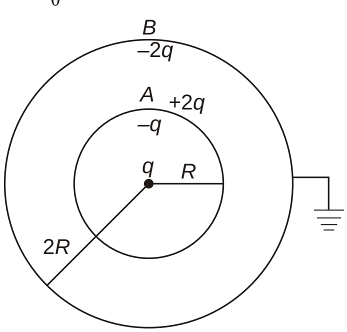
$$\frac{q}{0} \quad \frac{q_0}{3 \quad 0}$$

6. Net charge inside the cube $\quad 0.$

Net flux through the cube $\quad 0.$

Introductory Exercise 21.9

1. $V_B \quad \frac{1}{4 \quad 0} \quad \frac{q \quad q \quad q_B}{2R} \quad 0$



$q_B \quad 2q$

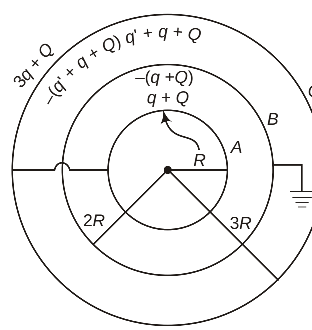
Total charge inside a conducting sphere appears on its outer surface,

Charge on outer surface of $A \quad 2q$

and charge on outer surface of B

$2q \quad 2q \quad 0$

2. Let $q \quad$ charge on sphere B and charge flows from sphere C to A.



$$V_B \quad \frac{1}{4 \quad 0} \quad \frac{q \quad q \quad Q}{2R} \quad \frac{2q \quad Q}{3R} \quad 0$$

$3q \quad q \quad 0$ ...(i)

Again, $V_P \quad V_C$

$$\frac{1}{4 \quad 0} \quad \frac{q \quad Q}{R} \quad \frac{q}{2R} \quad \frac{2q \quad Q}{3R} \quad \frac{1}{4 \quad 0} \quad \frac{3q \quad q}{3R}$$

$$6(q \quad Q) \quad 3q \quad 2(2q \quad Q) \quad 2(3q \quad q\ )$$

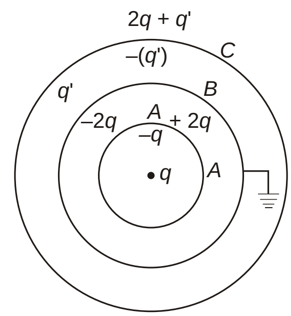
$$4q \quad 4q \quad q \quad 0$$

On solving

$$Q \quad \frac{5}{11}q,\ q \quad \frac{24}{11}q$$

	A	B	C
Charge on inner surface	0	$(q \quad Q)$ $\frac{6}{11}q$	$(q \quad q \quad Q)$ $\frac{18}{11}q$
Charge on outer surface	$q \quad Q \quad \frac{6}{11}q$	$q \quad Q$ $\frac{18}{11}q$	$3q \quad q \quad \frac{9}{11}q$

3.



	A	B	C
Charge on inner surface	q	$2q$	$\frac{4}{3}q$
Charge on outer surface	$2q$	$\frac{4q}{3}$	$\frac{2}{3}q$

AIEEE Corner

Subjective Questions (Level-1)

1. $F \quad \frac{1}{4 \quad _0} \frac{q(Q \quad q)}{r^2}$

For maximum force

$$\frac{dF}{dq} \quad \frac{1}{4 \quad _0} \frac{Q \quad 2q}{r^2} \quad 0$$

$$q \quad \frac{Q}{2}$$

$$\frac{d^2F}{dq^2} \quad \frac{1}{4 \quad _0} \frac{2}{r^2} \quad 0$$

Hence F is maximum at $q \quad \frac{Q}{2}$.

2. Minimum possible charge on a particle e.

$$F_{\min} \quad \frac{1}{4 \quad _0} \frac{e^2}{r^2} \quad \frac{9 \quad 10^9 \quad (1.6 \quad 10^{\ 19})^2}{(1 \quad 10^{\ 2})^2}$$

$$2.3 \quad 10^{\ 24}\ \text{N}$$

3. $F_e \quad \frac{1}{4 \quad _0} \frac{q_1 q_2}{r^2}$ ...(i)

$F_g \quad \frac{G m_1 m_2}{r^2}$ ...(ii)

$$\frac{F_e}{F_g} \quad \frac{q_1 q_2}{4 \quad _0 G m_1 m_2}$$

$$\frac{(3.2 \quad 10^{\ 19})^2 \quad 9 \quad 10^9}{6.67 \quad 10^{\ 11} \quad (6.64 \quad 10^{\ 27})^2}$$

$$3.1 \quad 10^{35}$$

4. $F_1 \quad \frac{1}{4 \quad _0} \frac{q_1 q_2}{r^2}$ ...(i)

$F_2 \quad \frac{1}{4 \quad _0} \frac{q^2}{r^2}$ ...(ii)

[As both the spheres are identical, find charge on both the spheres will be equal]

$$q \quad \frac{q_1 \quad q_2}{2}$$

$$q_1 \quad q_2 \quad 2q$$

From Eq. (ii),

$$q^2 \quad 4 \quad _0 r^2 F_2$$

$$\frac{(50 \quad 10^{\ 2})^2 \quad 0.036}{9 \quad 10^9} \quad 10^{\ 12}$$

$$q \quad 10^{\ 6}\ \text{C} \quad 1 \quad \text{C}$$

From Eq. (i),

$$q_1 q_2 \quad 4 \quad _0 r^2 F_1 \quad \frac{(50 \quad 10^{\ 2})^2 \quad 0.108}{9 \quad 10^9}$$

$$3 \quad 10^{\ 12}$$

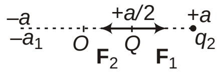
Also, $q_1 \quad q_2 \quad 2q \quad 2 \quad 10^{\ 6}$

On solving

$q_1 \quad 3 \quad \text{C}$

and $q_2 \quad ^{-}1 \quad \text{C}$

5. (a) $F_1 \quad \dfrac{1}{4 \quad _0} \dfrac{q_1 Q}{(3a/2)^2}$



$$F_1 \quad \frac{1}{4 \quad _0} \frac{4q_1 Q}{9a^2} \qquad \text{...(i)}$$

$$F_2 \quad \frac{1}{4 \quad _0} \frac{q_2 Q}{(a/2)^2}$$

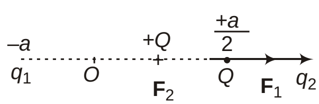
$$\frac{1}{4 \quad _0} \frac{4q_2 Q}{a^2} \qquad \text{...(ii)}$$

For net force on Q to be zero

$$F_1 \quad F_2$$

or $\qquad q_1 \quad 9q_2$

(b) $F_1 \quad \dfrac{1}{4 \quad _0} \dfrac{4q_1 Q}{25a^2}$



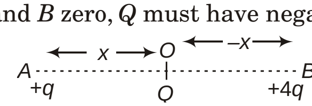
$$F_1 \quad \frac{1}{4 \quad _0} \frac{4q_2 Q}{9a^2}$$

For net force on Q to be zero.

$$F_1 \quad F_2 \quad 0$$

$$\frac{q_1}{q_2} \quad \frac{25}{9}$$

6. (a) In order to make net force on charge at A and B zero, Q must have negative sign.



Let the charge Q is planed at a distance x from A (Q charge)

$$F_{OA} \quad \frac{1}{4 \quad _0} \frac{qQ}{x^2}$$

$$F_{OB} \quad \frac{1}{4 \quad _0} \frac{4qQ}{(x \quad x)^2}$$

For net force on Q to be zero.

$$F_{OA} \quad F_{OB}$$

$$\frac{1}{4 \quad _0} \frac{qQ}{x^2} \quad \frac{1}{4 \quad _0} \frac{4qQ}{(L \quad x)^2}$$

$$(L \quad x)^2 \quad (2x)^2$$

$$x \quad \frac{L}{3}$$

Force on A,

$$F_{AB} \quad \frac{1}{4 \quad _0} \frac{4q^2}{L^2}$$

$$F_{AO} \quad \frac{1}{4 \quad _0} \frac{qQ}{x^2}$$

$$\frac{1}{4 \quad _0} \frac{qqQ}{L^2}$$

For net force on Q to be zero.

$$F_{AB} \quad F_{AO}$$

$$\frac{1}{4 \quad _0} \frac{4q^2}{L^2} \quad \frac{1}{4 \quad _0} \frac{qqQ}{L^2}$$

$$q \quad \frac{9}{4} Q$$

$$Q \quad \frac{4}{9} q$$

As Q is negative $\quad q \quad \dfrac{4}{9} q$

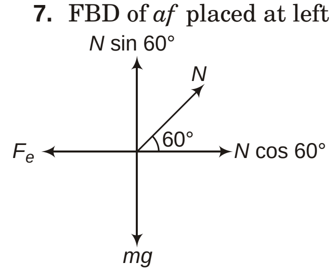
(b) PE of the system

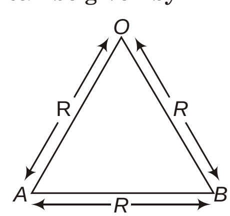
$$U \quad \frac{1}{4 \quad _0} \quad \frac{4q^2}{L} \quad \frac{qQ}{x} \quad \frac{4qQ}{L \quad x}$$

$$\frac{1}{4 \quad _0} \quad \frac{4q^2}{L} \quad \frac{4qQ}{3L} \quad \frac{8qQ}{3L} \qquad 0$$

Hence, equilibrium is unstable.

7. FBD of af placed at left can be given by





ABD is equilateral

As beads are in equilibrium

$$mg \quad N \sin 60$$

$$F_e \quad N \cos 60$$

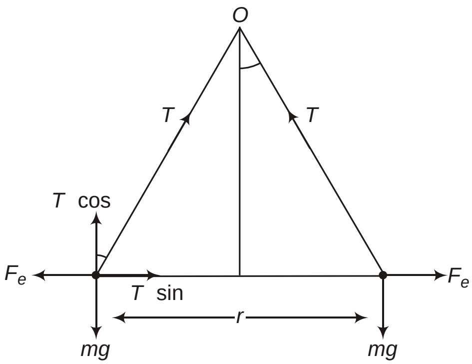
$$\frac{F_e}{mg} \quad \cot 60$$

$$q^2 \quad 4 \quad _0 R^2 \, mg \cot 60$$

$$q \quad \sqrt{\frac{4 \quad _0 R^2 \, mg}{3}}$$

$$2R\sqrt{\frac{6 \quad _0 mg}{\sqrt{3}}}$$

8. As ball are in equilibrium



$$F_e \quad T \sin$$
$$mg \quad T \cos$$
$$F_e \quad mg \tan$$
$$q^2 \quad 4 \quad {}_0 r^2 \tan$$

Here, $\quad r \quad 2\,l \sin$

$$q^2 \quad 16 \quad {}_0\, l^2 \sin^2 \quad \tan$$
$$q \quad 3.3 \quad 10^{\ 8} \text{ C.}$$

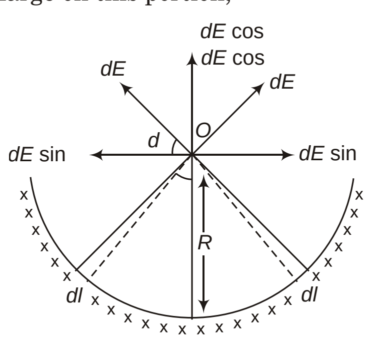
9. Same as Q.7. Introductory Exercise 21.3.

10. See Q.7. Introductory Exercise 21.3.

11.
$$E \quad \frac{1}{4 \quad {}_0} \; 1 \frac{q}{r^3}\, \mathbf{r}$$
$$\frac{9 \quad 10^9 \quad (\quad 8.0 \quad 10^{\ 9})}{((1.2)^2 \quad (1.6)^2)^{3/2}} (1.2\,\hat{\mathbf{i}} \quad 1.6\,\hat{\mathbf{j}})$$
$$18\sqrt{2}\,(1.2\,\hat{\mathbf{i}} \quad 1.6\,\hat{\mathbf{j}}) \text{ N/C.}$$

12. Consider an elementary portion on the ring of length dl subtending angle d at centre 'O' of the ring.

Charge on this portion,



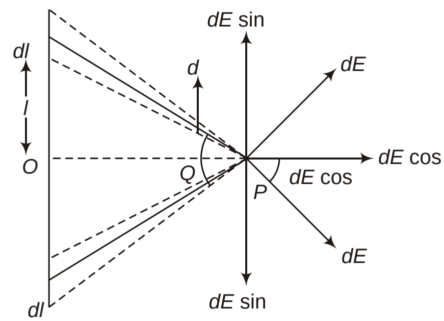
$$dq \qquad dl \qquad Rd$$
$$dE \quad \frac{1}{4 \quad {}_0} \frac{dq}{R^2} \quad \frac{1}{4 \quad {}_0} \frac{d}{R}$$

Here, $dE \sin$ components of field will cancel each other.

Hence, Net field at O

$$E \quad dE \cos \quad \frac{1}{4 \quad {}_0} \frac{}{R} \int_{\ /2}^{/2} \cos \quad d$$
$$\frac{1}{4 \quad {}_0} \frac{2}{R}$$

13. Consider elementary portion of the rod of length dl at a distance l from the centre O of the rod.



Charge on this portion

$$dq \quad dl \quad \frac{Q}{L} dl$$
$$dE \quad \frac{1}{4 \quad {}_0} \frac{dq}{(a \sec \quad)^2}$$
$$\frac{1}{4 \quad {}_0} \frac{Q\,dl}{La^2 \sec^2}$$

Now,

$$l \quad a \tan$$
$$dl \quad a \sec^2 \quad d$$
$$dE \quad \frac{1}{4 \quad {}_0} \frac{Q\,d}{La}$$

Net Electric field at P.

$$E \quad dE \cos$$

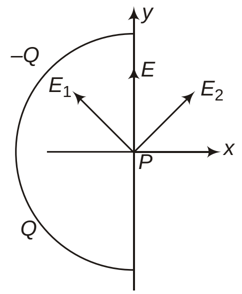
[$dE \sin$ components will cancel each other as rod in symmetrical about P.]

$$\frac{1}{4 \quad {}_0} \frac{Q}{La} \quad \cos \quad d$$
$$\frac{1}{4 \quad {}_0} \frac{2Q \sin}{La}$$

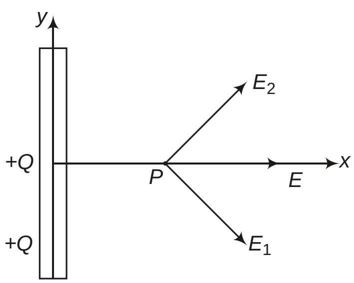
But $\sin \quad \dfrac{L}{2\sqrt{a^2 \quad \left(\dfrac{L}{2}\right)^2}} \quad \dfrac{L}{\sqrt{4a^2 \quad L^2}}$

$$E \quad \frac{1}{4 \quad {}_0} \frac{2Q}{a\sqrt{4a^2 \quad L^2}}$$

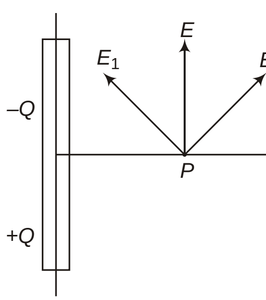
14. (a) As shown in figure, direction of electric field at P will be along + ve y-axis.



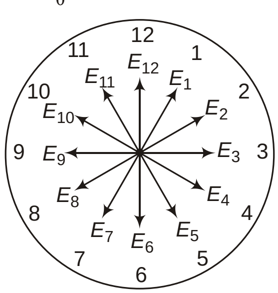
(b) Positive x-axis.



(c) Positive y-axis.

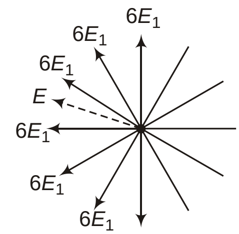


15. Let $E_1 \quad \frac{1}{4 \quad_0} \frac{q}{R^2}$



Resultant fields of two opposite charges can be shown as given in figure.

Clearly resultant field is along angle bisector of field towards 9 and 10.



Hence time shown by clock in the direction of electric field is 9 : 30.

16. (a) $a \quad \frac{F}{m} \quad \frac{eE}{m}$

$$\frac{1.6 \quad 10^{\quad 19} \quad 1 \quad 10^3}{9.1 \quad 10^{\quad 31}}$$

$$1.76 \quad 10^{14} \text{ ms}^{\quad 2}$$

$u \quad 5.00 \quad 10^8$ cm/s $\quad 5 \quad 10^6$ ms $^{\quad 1}$

$v \quad 0$

$v^2 \quad u^2 \quad 2as$

$$s \quad \frac{(5 \quad 10^6)^2}{2 \quad 1.7 \quad 10^{14}} \quad 1.4 \quad 10^{\quad 2} \quad 1.4 \text{ cm}$$

(b) $v \quad u \quad at$

$$t \quad \frac{5 \quad 10^6}{1.76 \quad 10^{14}} \quad 2.8 \quad 10^{\quad 8} \quad 28 \text{ ns.}$$

(c) k work done by electric field.

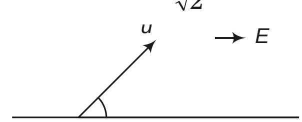
$F \; x \quad eEx$

$1.6 \quad 10^{\quad 19} \quad 1 \quad 10^3 \quad 8 \quad 10^{\quad 3}$

$1.28 \quad 10^{\quad 18}$ J

Loss of KE $\quad 1.28 \quad 10^{\quad 18}$ J

17. Here, $u_x \quad u \cos 45 \quad \frac{25}{\sqrt{2}}$ ms $^{\quad 1}$



$u_y \quad u \sin 45 \quad \frac{25}{\sqrt{2}}$ ms $^{\quad 1}$

$a_x \quad qE \quad 2 \quad 10^{\quad 6} \quad 2 \quad 10^7$

40 ms $^{\quad 1}$

$a_y \quad 10$ ms $^{\quad 1}$

$y \quad u_{yt} \quad \frac{1}{a_y} t^2$

$y \quad \frac{25}{\sqrt{2}} t \quad 5t^2$

at the end of motion,

$$t \quad T \text{ and } y \quad 0$$

$$T \quad \frac{5}{\sqrt{2}} \text{ s}$$

Also at the end of motion,

$$x \quad R$$

$$x \quad u_x t \quad \frac{1}{2} a_x t^2$$

$$R \quad \frac{25}{\sqrt{2}} \quad \frac{5}{\sqrt{2}} \quad 20 \quad \frac{5}{\sqrt{2}} \quad ^2$$

$$312.5 \text{ m}$$

18. (a) $R \quad \frac{^2 \sin 2}{qE}$

$$\sin 2 \quad \frac{qER}{mu^2}$$

$$\frac{1.6 \quad 10^{\ 19} \quad 720 \quad 1.27 \quad 10^{\ 3}}{1.67 \quad 10^{\ 27} \quad (9.55 \quad 10^3)^2}$$

$$0.96$$

$$2 \quad 88 \text{ or } 92$$

$$44 \text{ or } 46$$

$$T \quad \frac{2mh \sin}{2E}$$

$$\frac{2 \quad 9.55 \quad 10^3 \quad \frac{1}{\sqrt{2}} \quad 1.67 \quad 10^{\ 31}}{1.6 \quad 10^{\ 19} \quad 720}$$

$$1.95 \quad 10^{\ 11} \text{ s}$$

19. (a) $\mathbf{a} \quad \frac{e\mathbf{E}}{m} \quad \frac{1.6 \quad 10^{\ 19} \quad 120}{9.1 \quad 10^{\ 31}} \hat{\mathbf{j}}$

$$2.1 \quad 10^{13} \hat{\mathbf{i}} \text{ m/s}$$

(b) $t \quad \frac{x}{u_x} \quad \frac{2 \quad 10^{\ 2}}{1.5 \quad 10^5} \quad \frac{4}{3} \quad 10^{\ 7} \text{ s}$

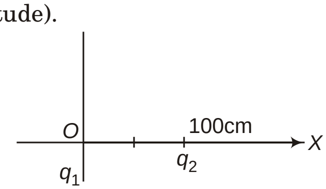
$$v_y \quad u_y \quad a_y t$$

$$3.0 \quad 10^6 \quad 2.1 \quad 10^{13} \quad \frac{4}{3} \quad 10^{\ 7}$$

$$0.2 \quad 10^6 \text{ m/s}$$

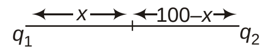
$$\mathbf{v} \quad (1.5 \quad 10^5)\hat{\mathbf{i}} \quad (0.2 \quad 10^6)\hat{\mathbf{j}}$$

20. Absolute potential can be zero at two points on the x-axis. One in between the charges and other on the left of charge a_1 (smaller in magnitude).



Case I.

In between two charges : let potential is zero at a distance x from q_1 towards q_2.



$$V \quad \frac{1}{4 \quad _0} \quad \frac{q_1}{x} \quad \frac{1}{4 \quad _0} \quad \frac{q_2}{100 \quad x} \quad 0$$

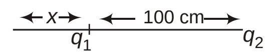
$$\frac{1}{4 \quad _0} \quad \frac{2 \quad 10^{\ 6}}{x} \quad \frac{1}{4 \quad _0} \quad \frac{3 \quad 10^{\ 6}}{100 \quad x} \quad 0$$

$$200 \quad 2x \quad 3x$$

$$x \quad 20 \text{ cm}$$

Case II.

Consider the potential is zero at a distance x from charge q, on its left.



$$V \quad \frac{1}{4 \quad _0} \quad \frac{q_1}{x} \quad \frac{1}{4 \quad _0} \quad \frac{q_2}{100 \quad x} \quad 0$$

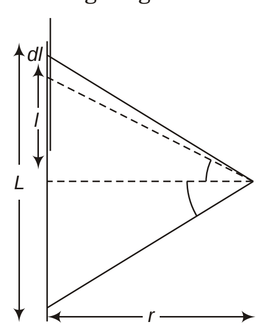
$$\frac{1}{4 \quad _0} \quad \frac{2 \quad 10^{\ 6}}{x} \quad \frac{1}{4 \quad _0} \quad \frac{3 \quad 10^{\ 6}}{100 \quad x} \quad 0$$

$$200 \quad 2x \quad 3x$$

$$x \quad 200 \text{ cm}$$

21. Let us first find the potential at a point on the perpendicular bisector of a line charge.

Consider a line of carrying a line charge density having length L.



Consider an elementary portion of length dl on the rod.

Charge on this portion

$$dq \quad dl$$

$$dV \quad \frac{1}{4 \quad _0} \quad \frac{dl}{r \sec}$$

Now, $$l \quad r \tan$$

$$dl \quad r \sec^2 \quad d$$

$$dV \quad \frac{\sec \quad d}{4 \quad _0}$$

$$V \quad dV \quad \frac{}{4 \quad _0} \quad \sec^2 \quad d$$

$$\frac{}{4 \quad _0}[\ln|\sec \quad \tan \quad |]$$

$$\frac{}{4 \quad _0} \ln \frac{\sec \quad \tan}{\sec \quad \tan}$$

$$\frac{2}{4 \quad _0} \ln|\sec \quad \tan \quad |$$

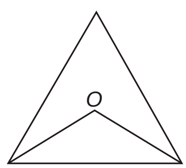
In the given condition

$$60$$

Potential due to one side

$$V_1 \quad V_2 \quad V_3 \quad \frac{2}{4 \quad _0} \ln|\sec 60 \quad \tan 60\ |$$

$$\frac{2}{4 \quad _0} \ln|2 \quad \sqrt{3}\,|$$



Total potential at O

$$V \quad 3V_1 \quad \frac{6}{4 \quad _0} \ln|2 \quad \sqrt{3}\,|$$

$$\frac{Q}{2 \quad _0 a} \ln|2 \quad \sqrt{3}\,|$$

22. (a) $V_2 \quad V_1 \quad \mathbf{E\,d} \quad 250 \quad 20 \quad 10^{\ 2}$

$$50\text{ V}$$

$$W \quad V \quad q(V_2 \quad V_1)$$

$$12 \quad 10^{\ 6} \quad 50 \quad 0.6\text{ mJ}$$

(b) $V_2 \quad V_1 \quad 50\text{ V}$

23. By work energy theorem

$$W \quad K$$

$$q(V_1 \quad V_2) \quad \frac{1}{2}mv_2^2 \quad \frac{1}{2}mv_1^2$$

$$5 \quad 10^{\ 6}(20 \quad 800)$$

$$\frac{1}{2} \quad 2 \quad 10^{\ 4}(V_2^2 \quad (5)^2)$$

$$v_2^2 \quad 55$$

$$v_2 \quad \sqrt{55} \quad 7.42\text{ ms}^{\ 1}$$

When a particle is released in electric field it moves in such a way that, it decreases its PE and increases KE

Hence, particle at B is faster than that at A.

24. Centre of circle is equidistant from every point on its periphery,

Hence, $\quad V_0 \quad \frac{1}{4 \quad _0} \frac{q}{R},$

where $q \quad Q_1 \quad Q_2 \quad SQ$

$$V_0 \quad \frac{1}{4 \quad _0} \frac{5Q}{R}$$

Similarly, $\quad V_p \quad \frac{1}{4 \quad _0} \frac{q}{\sqrt{R^2 \quad Z^2}}$

$$\frac{1}{4 \quad _0} \frac{SQ}{\sqrt{R^2 \quad Z^2}}$$

25. Initial PE

$$U_i \quad \frac{1}{4 \quad _0} \frac{q_1 q_2}{r_1}$$

$$U_f \quad \frac{1}{4 \quad _0} \frac{q_1 q_2}{r_2}$$

Work done by electric force

$$W \quad U \quad (U_f \quad U_i)$$

$$\frac{1}{4 \quad _0} q_1 q_2 \quad \frac{1}{r_2} \quad \frac{1}{r_1}$$

$$W \quad 9 \quad 10^9 \quad 2.4 \quad 10^{\ 6} \quad (\ 4.3 \quad 10^{\ 6}) \quad \frac{1}{0.25\sqrt{2}} \quad \frac{1}{0.15}$$

$$W \quad 0.356\text{ mJ}$$

26. (a) $U \quad \frac{1}{4 \quad _0} \quad \frac{q_1 q_2}{r_{12}} \quad \frac{q_2 q_3}{r_{23}} \quad \frac{q_3 q_1}{r_{31}}$

$$9 \quad 10^9 \quad \frac{4 \quad 10^{\ 9} \quad (\ 3 \quad 10^{\ 9})}{0.2}$$

$$\frac{(\ 3 \quad 10^{\ 9}) \quad (2 \quad 10^{\ 9})}{0.1}$$

$$\frac{4 \quad 10^{\ 9} \quad 2 \quad 10^{\ 9}}{0.1}$$

$$U \quad 9 \quad 10^{\ 8}[\ 6 \quad 6 \quad 8] \quad 360\text{ nJ}$$

(b) Let the distance of q_3 from q_1 is x cm. Then

$$U \quad \frac{1}{4 \quad _0} \quad \frac{q_1 q_2}{0.2} \quad \frac{q_2 q_3}{0.2 \quad x} \quad \frac{q_3 q_1}{x} \quad 0$$

$$9 \quad 10^9 \quad \frac{4 \quad 10^{\ 9} \quad (\ 3 \quad 10^{\ 9})}{20 \quad 10^{0\ 2}}$$

$$\frac{(\ 3 \quad 10^{\ 9}) \quad 2 \quad 10^{\ 9}}{(20 \quad x) \quad 10^{\ 2}}$$

$$\frac{2 \quad 10^{9} \quad 4 \quad 10^{9}}{x \quad 10^{2}} \qquad 0$$

$$\frac{6}{10} \quad \frac{6}{20 \quad x} \quad \frac{8}{x} \quad 0$$

$$x \quad 6.43 \text{ cm}$$

27. Let Q be the third charge

$$U \quad \frac{1}{4 \quad _0} \quad \frac{q^2}{d} \quad \frac{qQ}{d} \quad \frac{qQ}{d} \qquad 0$$

$$Q \quad \frac{q}{2}$$

28. $V \quad \mathbf{E}\ \mathbf{r}$

(a) $\mathbf{r} \quad 5\hat{\mathbf{k}}$

$$V \quad (5\hat{\mathbf{i}} \quad 3\hat{\mathbf{j}}) \quad (5\hat{\mathbf{k}}) \quad 0$$

(b) $\mathbf{r} \quad 4\hat{\mathbf{i}} \quad 3\hat{\mathbf{k}}$

$$V \quad (5\hat{\mathbf{i}} \quad 3\hat{\mathbf{j}}) \quad (4\hat{\mathbf{i}} \quad 3\hat{\mathbf{j}})$$

$$20 \text{ kV}$$

29. $\mathbf{E} \quad 400\hat{\mathbf{j}}$ V/m

(a) $\mathbf{r} \quad 20\hat{\mathbf{j}}$ cm $\quad (0.2\hat{\mathbf{j}})$ m

$$V \quad \mathbf{E}\ \mathbf{r} \quad 80 \text{ V}$$

(b) $\mathbf{r} \quad (\quad 0.3\hat{\mathbf{j}})$ m

$$V \quad \mathbf{E}\ \mathbf{r} \quad 120 \text{ V}$$

(c) $\mathbf{r} \quad (0.15\hat{\mathbf{k}})$

$$V \quad 0$$

30. $\mathbf{E} \quad 20\hat{\mathbf{i}}$ N/C

(a) $\mathbf{r} \quad (4\hat{\mathbf{i}} \quad 2\hat{\mathbf{j}})$ m

$$V \quad \mathbf{E}\ \mathbf{r} \quad 80 \text{ V}$$

(b) $\mathbf{r} \quad (2\hat{\mathbf{i}} \quad 3\hat{\mathbf{j}})$ m

$$V \quad \mathbf{E}\ \mathbf{r} \quad 40 \text{ V}$$

31. (a) $[A] \quad \frac{[V]}{[xy \quad yz \quad zx]} \quad \frac{[\mathrm{ML^2T^{3}I^{1}}]}{[\mathrm{L^2}]}$

$$[\mathrm{ML^0T^{3}I^{1}}]$$

(b) $E \quad V \quad \frac{v}{x}\hat{\mathbf{i}} \quad \frac{v}{y}\hat{\mathbf{j}} \quad \frac{v}{z}\hat{\mathbf{k}}$

$$A[(y \quad z)\hat{\mathbf{i}} \quad (z \quad x)\hat{\mathbf{j}} \quad (x \quad y)\hat{\mathbf{k}}]$$

(c) at (1m, 1m, 1m)

$$E \quad 10(2\hat{\mathbf{i}} \quad 2\hat{\mathbf{j}} \quad 2\hat{\mathbf{k}})$$

$$20(\hat{\mathbf{i}} \quad \hat{\mathbf{j}} \quad \hat{\mathbf{k}})$$

32. $V_B \quad V_0 \quad \mathbf{E}\ \mathbf{r}$

$$V \quad 0 \quad (40 \quad 60)$$

$$V \quad 100$$

33. (a) $E_x \quad \frac{v}{x} \quad (Ay \quad 2Bx)$

$$E_y \quad \frac{V}{y} \quad (Ax \quad C)$$

$$E_z \quad \frac{V}{Z} \quad 0$$

(b) For $E \quad 0$

$$E_x \quad 0 \text{ and } E_y \quad 0$$

Hence, $\quad E_y \quad 0$

$$Ax \quad C \quad 0$$

$$x \quad \frac{C}{A}$$

$E_x \quad 0$

$$Ay \quad 2B \quad \frac{C}{A} \quad 0$$

$$y \quad \frac{2BC}{A^2}$$

Hence, E is zero at $\quad \frac{C}{A}, \quad \frac{2BC}{A^2}$.

34. $\quad \frac{q}{_0}$

$$q \quad _0 \quad 8.8 \quad 10^{12} \quad 360$$

$$3.18 \quad 10^{9} \text{ C}$$

$$3.186 \text{ nC}$$

36. (a) $\quad \frac{q}{_0} \quad \frac{3.60 \quad 10^{6}}{8.85 \quad 10^{12}}$

$$4.07 \quad 10^5 \text{ V-m.}$$

(b) $\quad \frac{q}{_0} \quad q \quad _0$

$$8.85 \quad 10^{12} \quad 780 \quad 6.903 \quad 10^{9}$$

$$q \quad 6.903 \text{ nC}$$

(c) No.
Net flux through a closed surface does not depend on position of charge.

36. $\mathbf{E} \quad \frac{3}{5}E_0\hat{\mathbf{i}} \quad \frac{4}{5}E_0\hat{\mathbf{j}}$

$$\mathbf{S} \quad 0.2\hat{\mathbf{j}}\,\mathrm{m}^2 \quad \frac{1}{5}\hat{\mathbf{j}}\,\mathrm{m}^2$$

$$\mathbf{E}\ \mathbf{S} \quad \frac{4}{25}\,\mathrm{Nm^2/C}$$

$\frac{4}{25}$ 2.0 10^3 N-m^2/C

320 N-m^2/C

37. $\mathbf{E}$ $\frac{E_0 x}{l}\hat{\mathbf{i}}\, x_1$ 0

$\mathbf{E}_1$ 0

x_2 a

$\mathbf{E}_2$ $\frac{E_0 a}{l}\hat{\mathbf{i}}$

Flux entering the surface

$_1$ 0

Flux leaving the surface

$_2$ $E_2 a^2$ $\frac{E_0 a^3}{l}$

$\frac{5 \quad 10^3 \quad (1 \quad 10^{\ 2})^3}{2 \quad 10^{\ 2}}$

0.25 N-m^2/C

Net flux, $\frac{q}{_0}$

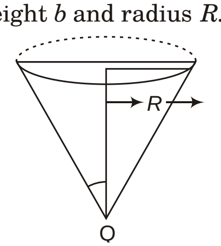
$_2$ $_1$ $\frac{q}{_0}$

q $_0(_2$ $_1)$

8.85 $10^{\ 12}$ 0.25

2.21 $10^{\ 12}$ C 2.21 pC

38. Consider the charge is placed at vertex of the cone of height b and radius R.



Let be the semi-vertical angle of the cone, then solid angle subtended by the cone.

2 (1 cos)

Flux passing through cone

$\frac{\quad}{4}$ $_{total}$

But $\frac{1}{4}$ $_{total}$ (Given)

2 (1 cos)

1 cos $\frac{1}{2}$

cos $\frac{1}{2}$ $\overline{\ \ }$ 3

R b tan $\sqrt{3}b$

Hence proved

39. $\mathbf{E}$ $B\hat{\mathbf{i}}$ $C\hat{\mathbf{j}}$ $D\hat{\mathbf{k}}$, $\mathbf{S}_1$ $L^2\hat{\mathbf{i}}$, $\mathbf{S}_2$ $L^2\hat{\mathbf{j}}$,

$\mathbf{S}_3$ $L^2\hat{\mathbf{i}}$, $\mathbf{S}_4$ $L^2\hat{\mathbf{j}}$, $\mathbf{S}_4$ $L^2\hat{\mathbf{k}}$,

$\mathbf{S}_6$ $L^2\hat{\mathbf{k}}$

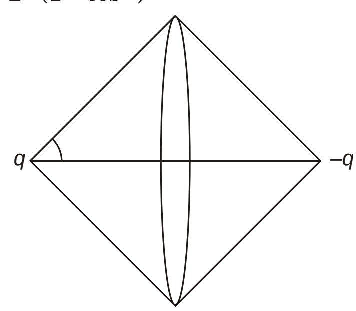
$_1$ $\mathbf{E}\ \mathbf{S}_1$ BL^2, $_2$ $\mathbf{E}\ \mathbf{S}_2$ CL^2,

$_3$ $\mathbf{E}\ \mathbf{S}_3$ BL^2, $_4$ $\mathbf{E}\ \mathbf{S}_4$ CL^2,

$_5$ $\mathbf{E}\ \mathbf{S}_5$ DL^2, $_6$ $\mathbf{E}\ \mathbf{S}_6$ DL^2

(b) $_1$ $_2$ $_3$ $_4$ $_5$ $_6$ 0

40. 2 (1 cos)



$_1$ $_2$ $\frac{\quad}{4}$cot $_{total}$ $\frac{2 \quad (1 \quad \cos \quad)}{4}$ $\frac{q}{_0}$

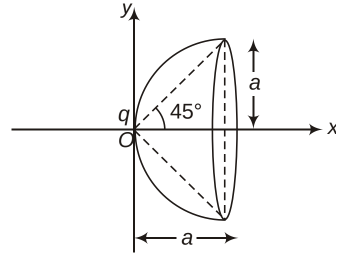
$\frac{1}{2\ _0}$(1 cos)

Total flux through the ring

$_1$ $_2$

$\frac{q}{_0}$(1 cos) $\frac{q}{_0}$ 1 $\frac{l}{\sqrt{R^2 \quad l^2}}$

41. From the given equation,



radius of hemisphere a

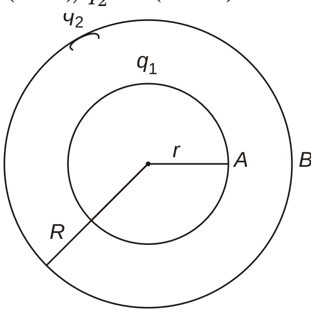
and its centre is at $(a, 0, 0)$

$$2 \quad (1 \quad \cos \quad) \quad 2 \quad 1 \quad \frac{1}{\sqrt{2}}$$

$$\frac{}{4} \quad {}_{\text{total}} \quad \frac{2 \quad 1 \quad \frac{1}{\sqrt{2}}}{4} \quad \frac{q}{{}_0}$$

$$\frac{q}{2 \quad {}_0} \quad 1 \quad \frac{1}{\sqrt{2}}$$

42. $q_1 \quad (4 \ r^2), q_2 \quad (4 \ R^2)$



But, $q_1 \quad q_2 \quad Q \qquad \frac{Q}{4 \ (r^2 \quad R^2)}$

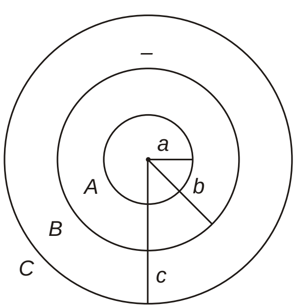
$$V_A \quad \frac{1}{4 \quad {}_0} \quad \frac{q_1}{r} \quad \frac{q_2}{R}$$

$$\frac{1}{4 \quad {}_0} \quad \frac{(4 \ r^2)}{r} \quad \frac{(4 \ R^2)}{R}$$

$$\frac{1}{4 \quad {}_0} \quad \frac{Q\,(r \quad R)}{r^2 \quad R^2}$$

$$V_B \quad \frac{1}{4 \quad {}_0} \quad \frac{q_1 \quad q_2}{R} \quad \frac{1}{4 \quad {}_0} \quad \frac{Q}{R}$$

43. $q_A \quad (4 \ a^2), q_B \quad (4 \ b^2)$



$$q_C \quad (4 \ c^2)$$

$$V_A \quad \frac{1}{4 \quad {}_0} \quad \frac{q_A}{a} \quad \frac{q_B}{b} \quad \frac{q_C}{c}$$

$$\frac{}{{}_0}(a \quad b \quad c)$$

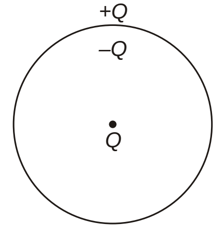
$$V_B \quad \frac{1}{4 \quad {}_0} \quad \frac{q_A \quad q_B}{b} \quad \frac{q_C}{c}$$

$$\frac{}{{}_0} \quad \frac{a^2}{b} \quad b \quad c$$

$$V_C \quad \frac{1}{4 \quad {}_0} \quad \frac{q_A \quad q_B \quad q_C}{c}$$

$$\frac{}{} \quad \frac{a^2 \quad b^2 \quad c^2}{c}$$

44. (a) As charge Q is placed at the centre of the sphere, charge Q will appear on the inner surface and Q on its outer surface.



Hence, $\quad {}_{\text{in}} \quad \frac{Q}{4 \ a^2}$

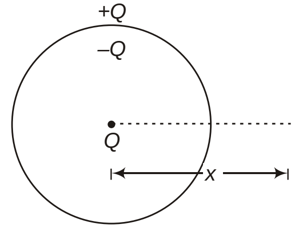
and $\quad {}_{\text{out}} \quad \frac{Q}{4 \ a^2}$

(b) Entire charge inside the sphere appears on its outer surface, hence

$${}_{\text{in}} \quad \frac{Q}{4 \ a^2} \text{ and } {}_{\text{out}} \quad \frac{Q \quad q}{4 \ a^2}$$

(c) In case (a)

$$E \quad \frac{1}{4 \quad {}_0} \quad \frac{Q}{x^2}$$



In case (b)

$E \quad E_1 \quad E_2$

$E_1 \quad$ Field due to charge Q.

$E_2 \quad$ Field due to charge on shell.

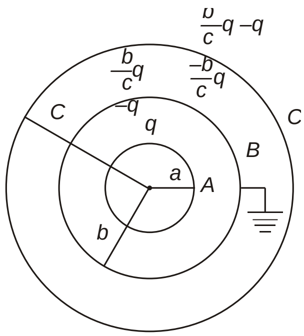
$$E \quad \frac{1}{4 \quad {}_0} \quad \frac{Q}{x^2}$$

for $x \quad a$

As field due to shell is zero for $x \quad a$.

and $E \quad \frac{1}{4 \quad _0} \quad \frac{Q \quad q}{x^2}$, for $x \quad a$

45. Let Q be the charge on the shell B,

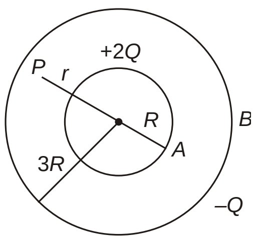


$$V_B \quad \frac{1}{4 \quad _0} \quad \frac{q \quad Q}{b} \quad \frac{q}{c} \quad 0$$

$$Q \quad q \ \frac{b \quad c}{c}$$

Charge distribution on different surfaces is shown in figure.

46. (a) Let E_1 and E_2 be the electric field at P due to inner shell and outer shell respectively.



Now, $E_1 \quad \frac{1}{4 \quad _0} \ \frac{2Q}{r}$ and $E_2 \quad 0$

$$E \quad E_1 \quad E_2 \quad E_1 \quad \frac{1}{4 \quad _0} \ \frac{2Q}{r}$$

(b) $V_A \quad \frac{1}{4 \quad _0} \quad \frac{2Q}{R} \quad \frac{Q}{3R}$

$$V_B \quad \frac{1}{4 \quad _0} \quad \frac{2Q \quad Q}{3R}$$

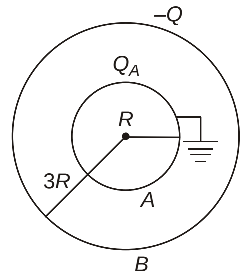
$$V_A \quad V_B \quad \frac{1}{4 \quad _0} \quad \frac{2Q}{R} \quad \frac{2Q}{3R}$$

$$\frac{1}{4 \quad _0} \ \frac{4Q}{3R}$$

(c) Whenever two concentric conducting spheres are joined by a conducting wire entire charge flows to the outer sphere.

$$Q_A \quad 0, Q_B \quad 0$$

(d) Let Q_A be the charge on inner sphere.



$$V_A \quad \frac{1}{4 \quad _0} \quad \frac{Q_A}{R} \quad \frac{Q}{3R} \quad 0$$

$$Q_A \quad \frac{Q}{3}$$

47. (a) At $r \quad R$

$$V \quad \frac{1}{4 \quad _0} \quad \frac{Q}{R} \quad \frac{2Q}{2R} \quad \frac{3Q}{3R}$$

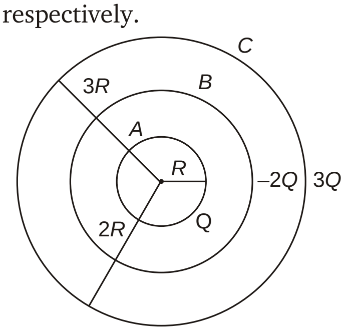
$$\frac{1}{4 \quad _0} \ \frac{Q}{R}$$

At $r \quad 3R$

$$V \quad \frac{1}{4 \quad _0} \quad \frac{Q \quad 2Q \quad 3Q}{3R}$$

$$\frac{1}{4 \quad 9} \ \frac{2Q}{3R}$$

(b) Let E_1, E_2 and E_3 be the electric fields at $r \quad \frac{5}{2}R$ due to shells A, B and C respectively.



$$E_1 \quad \frac{1}{4 \quad _0} \quad \frac{Q}{\frac{5}{2}R^{\ 2}}$$

$$\frac{1}{4 \quad _0} \ \frac{4Q}{25R} \qquad \text{(outwards)}$$

$$E_2 \quad \frac{1}{4 \quad _0} \quad \frac{2Q}{\frac{5}{2}R^{\ 2}}$$

$$\frac{1}{4 \quad _0} \frac{8Q}{25R} \qquad \text{(inward)}$$

$$E_3 \quad 0$$

Net field at $r \quad \frac{5}{2}R$

$$E \quad E_2 \quad E_1 \quad \frac{1}{4 \quad _0} \frac{4Q}{25R} \qquad \text{(inward)}$$

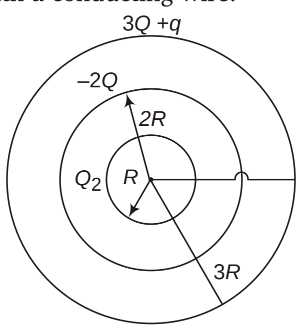
(c) Total electrostatic energy of system is the sum of self-energy of three shell and the energy of all possible pairs *i.e.*,

$$U \quad \frac{1}{4 \quad _0} \quad \frac{Q^2}{2R} \quad \frac{(\quad 2Q)^2}{2 \quad 2R} \quad \frac{(3Q)^2}{2 \quad 3R}$$

$$\frac{Q(\quad 2Q)}{2R} \quad \frac{(\quad 2Q) \quad 3Q}{3R} \quad \frac{Q \quad 3Q}{3R}$$

$$U \quad \frac{1}{4 \quad _0} \frac{Q}{R}$$

(d) Let q charge flows from innermost shell to outermost shell on connecting them with a conducting wire.



$$V_A \quad \frac{1}{4 \quad _0} \quad \frac{Q \quad q}{R} \quad \frac{2Q}{2R} \quad \frac{3Q \quad q}{3R}$$

$$\frac{1}{4 \quad _0} \frac{3Q \quad 2q}{3R}$$

$$V_B \quad \frac{1}{4 \quad _0} \quad \frac{Q \quad q \quad 2Q \quad 3Q \quad q}{3R}$$

$$\frac{1}{4 \quad _0} \frac{2Q}{3R}$$

But $V_A \quad V_B$

$$\frac{1}{4 \quad _0} \frac{3Q \quad 2q}{3R} \quad \frac{1}{4 \quad _0} \frac{2Q}{3R}$$

$$q \quad \frac{Q}{2}$$

Charge on innermost shell $Q \quad q \quad \frac{Q}{2}$

and charge on outermost shell $3Q \quad q \quad \frac{7Q}{2}$

and $\quad V_A \quad \frac{1}{4 \quad _0} \frac{3Q \quad 2q}{3R}$

$$\frac{1}{4 \quad _0} \frac{2Q}{3R}$$

(c) In this case

$$E_1 \quad \frac{1}{4 \quad _0} \frac{Q}{2R \quad \frac{5}{2}R^{\,2}}$$

$$\frac{1}{4 \quad _0} \frac{2Q}{25R} \qquad \text{(outward)}$$

$$E_2 \quad \frac{1}{4 \quad _0} \frac{2Q}{\frac{5}{2}R^{\,2}}$$

$$\frac{1}{4 \quad _0} \frac{8Q}{25R} \qquad \text{(inward)}$$

Net electric field at $r \quad \frac{5}{2}R$

$$E \quad E_2 \quad E_1 \quad \frac{1}{4 \quad _0} \frac{6Q}{25R} \qquad \text{(inward)}$$

Objective Questions (Level-1)

1. $\quad E \;\; A$

Units of $\quad$ N/C $\quad \mathrm{m}^2 \quad \mathrm{N\text{-}m^2/C}$

or V/m $\quad \mathrm{m}^2 \quad$ V - m

2. Net force

$$F \quad mg \quad qE$$

$$g \quad g \quad \frac{qE}{m}$$

$$T \quad 2 \sqrt{\frac{l}{g_1}} \quad T$$

3. Electric lines of force terminate at negative charge.

4. $F \quad \frac{1}{4 \quad _0} \frac{q^2}{l^2}$

Initial PE

$$U_i \quad \frac{1}{4 \quad _0} \quad \frac{q^2}{l} \quad \frac{q^2}{l} \quad \frac{q^2}{l} \quad 3Fl$$

Find PE

$$U_f \quad \frac{1}{4 \quad _0} \quad \frac{q^2}{2l} \quad \frac{q^2}{2l} \quad \frac{q^2}{2l} \quad \frac{3}{2}Fl$$

$$W \quad U_f \quad U_i \quad \frac{3}{2}Fl$$

5. KE qV

$$\frac{1}{2}mv^2 \quad qV$$

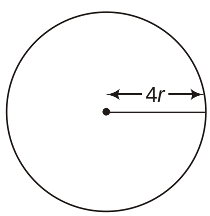
$$v \quad \sqrt{\frac{2qV}{m}}$$

$$V_1 : V_2 : V_3 \quad \sqrt{\frac{q_1V_1}{m_1}} : \sqrt{\frac{q_2V_2}{m_2}} : \sqrt{\frac{q_3V_3}{m_3}}$$

$$V_1 : V_2 : V_3 \quad \sqrt{\frac{e \quad 1}{m}} : \sqrt{\frac{e \quad 2}{2m}} : \sqrt{\frac{2e \quad 4}{4m}}$$

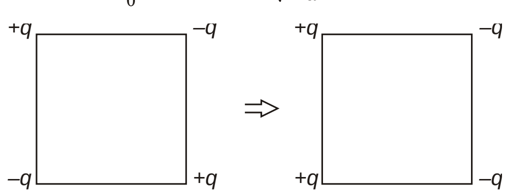
$$V_1 : V : V_3 \quad 1 : 1 : \sqrt{2}$$

6. $V \quad \frac{1}{4 \quad _0} \frac{q}{r}$



$$V \quad \frac{1}{4 \quad _0} \frac{2q}{4r} \quad \frac{V}{2}$$

7. $U_i \quad \frac{1}{4 \quad _0} \quad \frac{q^2}{a} \quad 4 \quad \frac{q^2}{\sqrt{2}\,a} \quad 2$



$$\frac{q^2}{4 \quad _0 a}[4 \quad \sqrt{2}]$$

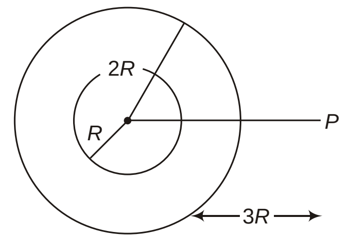
$$U_f \quad \frac{1}{4 \quad _0} \quad \frac{q^2}{a} \quad 2 \quad \frac{q^2}{a} \quad 2 \quad \frac{q^2}{\sqrt{2}} \quad 2$$

$$\frac{\sqrt{2}\,q^2}{4 \quad _0 a}$$

$$W \quad U_f \quad U_i \quad \frac{\sqrt{2}\,q^2}{4 \quad _0 a} \quad \frac{q^2}{4 \quad _0 a}[4 \quad \sqrt{2}]$$

$$\frac{q^2}{4 \quad _0 a}[4 \quad 2\sqrt{2}]\,\text{J}$$

8. Potential at point P



$$V \quad \frac{1}{4 \quad _0} \frac{q_1 \quad q_2}{3R}$$

$$\frac{9 \quad 10^9 \quad 3 \quad 10^{\;6}}{3R} \quad 9000$$

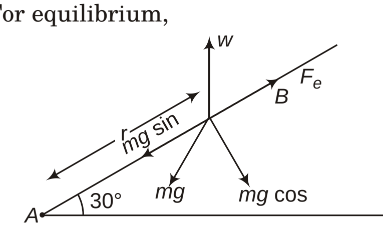
$$R \quad 1\,\text{m}$$

9. As distance of every point of ring from axis is same.

$$V \quad \frac{kq}{\sqrt{R^2 \quad x^2}}, \text{ But } x \quad 2\sqrt{R}$$

$$\frac{kq}{3R}$$

10. For equilibrium,



$$mg \sin 30 \quad F_e$$

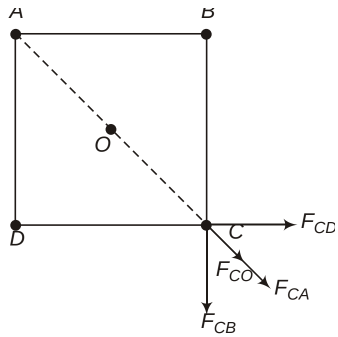
$$mg \sin 30 \quad \frac{1}{4 \quad _0} \frac{q^2}{r^2}$$

$$r \quad q\sqrt{\frac{1}{4 \quad _0\, mg \sin 30}}$$

$$2.0 \quad 10^{\;6} \sqrt{\frac{91 \quad 10^9}{0.1 \quad 10 \quad \frac{1}{2}}}$$

20 cm

11. Net force on $C \quad 0$



$$F_{CB} \quad \frac{1}{4 \quad _0} \frac{(2\sqrt{2} \quad 1)^2 Q^2}{a^2}$$

$$F_{CD} \quad \frac{1}{4 \quad _0} \frac{(2\sqrt{2} \quad 1)^2 Q^2}{a^2}$$

$$F_{CA} \quad \frac{1}{4 \quad _0} \frac{(2\sqrt{2} \quad 1)^2 Q^2}{2a^2}$$

$$F_{CO} \quad \frac{1}{4 \quad _0} \frac{2(2\sqrt{2} \quad 1)Q^2}{a^2}$$

Net force on C

$$F \quad F_{CA} \quad F_{CO} \quad F_{CB} \cos 45 \quad F_{CO} \cos 45$$

$$\frac{(2\sqrt{2} \quad 1)Q}{a^2} \frac{(2\sqrt{2} \quad 1)Q}{2} \quad \frac{(2\sqrt{2} \quad 1)Q}{\sqrt{2}}$$

$$\frac{(2\sqrt{2} \quad 1)Q}{\sqrt{2}} \quad \frac{2q}{1} \quad 0$$

$$q \quad \frac{7Q}{4}$$

12. $E \quad \frac{}{_0}$

$$F \quad eF \quad \frac{e}{_0}$$

Acceleration of proton

$$a \quad \frac{F}{m} \quad \frac{e}{m \quad _0}$$

$$s \quad ut \quad \frac{1}{a} t^2$$

$$u \quad 0$$

$$t \quad \sqrt{\frac{25}{a}} \quad \sqrt{\frac{25 \; m \quad _0}{e}}$$

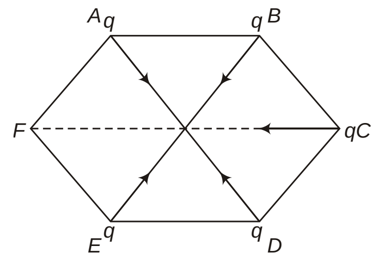
$$\sqrt{\frac{2 \quad 0.1 \quad 1.67 \quad 10^{\;27} \quad 8.8 \quad 10^{\;12}}{2.21 \quad 10^{\;9} \quad 1.6 \quad 10^{\;19}}}$$

$$2\sqrt{2} \quad \text{s}$$

13. Data is not sufficient.

14. If the charges have opposite sign, electric field is zero on the left of smaller charge.

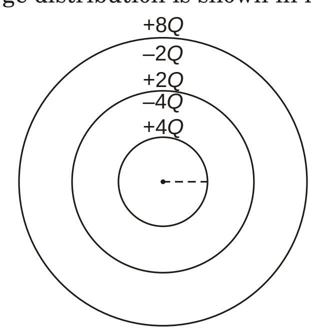
15. Net field is only due to charge on C.



$$E \quad \frac{1}{4 \quad _0} \quad \frac{q}{(2a)^2} \quad \frac{q}{16 \quad _0 a^2}$$

16. On touching two spheres, equal charge will appear on both the spheres and for a given total charge, force between two spheres is maximum if charges on them are equal.

17. Charge distribution is shown in figure.



18. $V \quad \frac{1}{4 \quad _0} \frac{q}{r}$

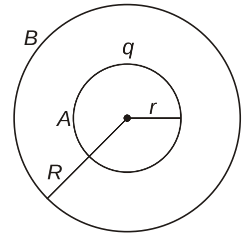
If drops coalesce, total volume remains conserved,

$$\frac{4}{3} \quad R^3 \quad 1000 \quad \frac{4}{3} \quad r^3$$

$$R \quad 10r$$

$$V \quad \frac{1}{4 \quad _0} \frac{1000q}{10q} \quad 10\text{V}$$

19. $V_A \quad \frac{1}{4 \quad _0} \quad \frac{q}{r} \quad \frac{Q}{R}$



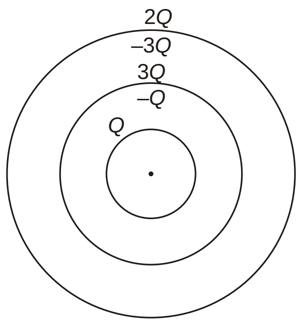
$$V_B \quad \frac{1}{4 \quad _0} \quad \frac{q \quad Q}{R}$$

$$V_A \quad V_B \quad \frac{q}{4 \quad _0} \quad \frac{1}{r} \quad \frac{1}{R}$$

$$V_A \quad V_B \quad q$$

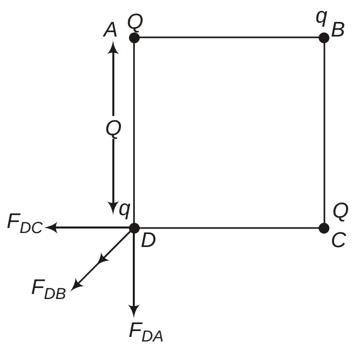
If q is doubled, $V_A \quad V_B$ will become double.

20. Charge distribution is shown in figure.



21. $\quad \mathbf{E} \quad \mathbf{S} \quad (5\hat{\mathbf{i}} \quad 2\hat{\mathbf{j}}) \, (\hat{\mathbf{i}}) \quad 5$ V-m.

22. $F_{DA} \quad F_{DC} \quad \frac{1}{4 \quad _0} \frac{Qq}{a^2}$



$$F_{DB} \quad \frac{1}{4 \quad _0} \frac{q^2}{2a^2}$$

Net force on charge at D

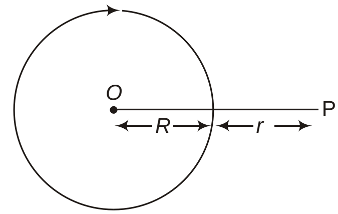
$$\mathbf{F}_0 \quad F_{DB} \quad F_{DA} \cos 45 \quad F_{DB} \cos 45 \quad 0$$

$$\frac{1}{4} 4 \quad _0 \quad \frac{q}{a^2} \quad \frac{q}{2} \quad \frac{Q}{\sqrt{2}} \quad \frac{Q}{\sqrt{2}} \quad 0$$

$$q \quad 2\sqrt{2}Q$$

23. As $V_B \quad 0$, Total charge inside B must be zero and hence charge on its outer surface is zero and on its inner surface is $\quad q$.

24. $V_p \quad \frac{1}{V_0}$



$$\frac{1}{4 \quad _0} \quad \frac{q}{R \quad r} \quad \frac{1}{2} \quad \frac{1}{4 \quad _0} \quad \frac{3q}{2R}$$

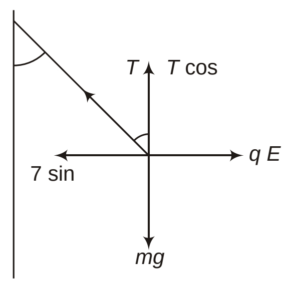
$$\frac{1}{R \quad r} \quad \frac{3}{4R}$$

$$4R \quad 3R \quad 3r$$

$$r \quad \frac{R}{3}$$

25. Net charge on any dipole is zero.

26. For net force to be zero.



$$T \cos \quad mg \quad T \quad \frac{mg}{\cos}$$

$$\text{or } T \sin \quad qE \quad T \quad \frac{qE}{\sin}$$

27.

$$E_1 \quad \frac{1}{4 \quad _0} \quad \frac{q}{a} \quad \frac{V_1}{a}$$

$$E_2 \quad \frac{1}{4 \quad _0} \quad \frac{q}{b^2} \quad \frac{V_2}{b}$$

But $\quad E_1 \quad E_2$

$$\frac{V_1}{a} \quad \frac{V_2}{b}$$

$$\frac{V_1}{V_2} \quad \frac{a}{b}$$

28. Electric field on equatorial lines of dipole is opposite to dipole moment.

29. Potential difference between two concentric spheres is independent of charge on outer sphere.

30. $E \quad \frac{1}{4 \quad _0} \frac{q}{r^2}$

$$V \quad \frac{1}{4\ \ _0}\ \frac{q}{r} \quad Er$$

$$r \quad \frac{V}{E} \quad \frac{3000}{500} \quad 6\ \text{m}$$

$$q \quad 4\ \ _0 rV \quad \frac{6\ \ (\ \ 3000)}{9\ \ 10^9} \qquad 2\ \ \text{C}$$

31. $F_1 \quad F_2$

$$\frac{1}{4\ \ _0}\ \frac{q_1 q_2}{r_1^2} \quad \frac{1}{4\ \ K\ _0}\ \frac{q_1 q_2}{r_2^2}$$

$$r_2 \quad \frac{r_1}{\sqrt{K}} \quad \frac{50}{\sqrt{5}} \quad 10\sqrt{5}\ \text{m}$$

$$22.3\ \text{m}$$

32. Electric field at a distance r from infinite line charge

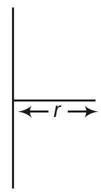
$$E \quad \frac{}{2\ \ _0 r}$$

$$dV \quad E\,dr$$

$$\int_{V_1}^{V_2} dV \quad \int_a^b E\,dr$$

$$V_2 \quad V_1 \quad \frac{}{2\ \ _0}\ \ln\frac{1}{2}$$

$$W \quad q(V_2 \quad V_1) \quad \frac{q}{2\ \ _0}\ \ln\frac{1}{2}$$



33. As negative charge is at less distance from the line charge, it is attracted towards the line charge.

34. $r \quad \sqrt{(4\ \ 1)^2\ \ (2\ \ 2)^2\ \ (0\ \ 4)^2} \quad 5\ \text{m}$

$$V \quad \frac{1}{4\ \ _0}\ \frac{q}{r} \quad \frac{9\ \ 10^9\ \ 2\ \ 10^{\ 8}}{5} \quad 36\ \text{V}$$

(b) and (c) are wrong.

35. $V \quad \frac{1}{4\ \ _0}\ \frac{q}{R}$

At a distance r from the centre,

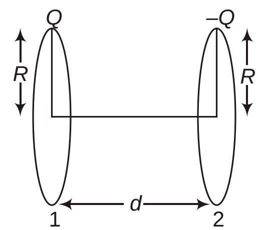
$$E \quad \frac{1}{4\ \ _0}\ \frac{q}{r^2} \quad \frac{VR}{r^2}$$

36. When outer sphere is earthed field between the region of two spheres in non-zero and is zero in all other regions.

37. $W \quad \mathbf{F} \ \ \mathbf{s} \quad qEs\cos$

$$E \quad \frac{W}{qs\cos} \quad \frac{4}{0.2\ \ 2\ \ \cos 60} \quad 20\ \text{N/C}$$

38. $V_1 \quad \frac{1}{4\ \ _0}\ \frac{Q}{R} \quad \frac{Q}{\sqrt{d^2\ \ \ R^2}}$



$$V_2 \quad \frac{1}{4\ \cdot\ _0}\ \frac{Q}{R} \quad \frac{Q}{\sqrt{d^2\ \ \ R^2}}$$

$$V_1 \quad V_2 \quad \frac{1}{4\ \cdot\ _0}\ \frac{2Q}{R} \quad \frac{2Q}{\sqrt{d^2\ \ \ R^2}}$$

$$V_1 \quad V_2 \quad \frac{Q}{4\ \cdot\ _0}\ \frac{1}{R} \quad \frac{1}{\sqrt{d^2\ \ \ R^2}}$$

39. Electric field inside a hollow sphere is always zero.

40. $W \quad \mathbf{F} \ \ \mathbf{r} \quad q\,\mathbf{E} \ \ \mathbf{r}$

$$q(E_1\,\hat{\mathbf{i}} \quad E_2\,\hat{\mathbf{j}}) \quad (a\,\hat{\mathbf{i}} \quad b\,\hat{\mathbf{j}})$$

$$q(aE_1 \quad bE_2)$$

JEE Corner

Assertion and Reason

1. Negative charge always moved towards increasing potential.

On moving from A to B potential energy of negative charge decreases hence its KE increases.

2. $U \quad \frac{1}{4\ \ _0}\ \frac{q_1 q_2}{r}$

If q_1 and q_2 have opposite sign, U decreases with decrease in r.

$F \quad \frac{dU}{dr}$ work done by conservative force always decreases PE.

3. $E \quad \frac{dV}{dr} \quad (10) \quad 10\ \text{V/m}$ along x-axis.

4. $V \quad \frac{1}{4\ \ _0}\ \frac{q}{R}$

Inside the solid sphere.

$$E \quad \frac{1}{4 \quad _0} \frac{qr}{R^3}$$

at $r \quad \frac{R}{2}$

$$E \quad \frac{1}{4 \quad _0} \frac{q}{2R^2} \quad \frac{V}{2R}$$

Assertion is correct.

Reason is false as electric field inside the sphere is directly proportional to distance from centre but not outside it.

5. Gauss theorem is valid only for closed surface but electric flux can be obtained for any surface.

6. Let V_0 Potential at origin,

$$V_A \quad (4\hat{\mathbf{i}} \quad 4\hat{\mathbf{j}})\ (4\hat{\mathbf{i}}) \quad 16\text{ V}$$

$$V_B \quad (4\hat{\mathbf{i}} \quad 4\hat{\mathbf{j}})\ (4\hat{\mathbf{i}}) \quad 16\text{ V}$$

$$V_A \quad V_B$$

Hence, Assertion is false.

7. In the line going A and B, the energy of third charge is minimum at centre.

8. Dipole has both negative and positive charges hence work done is not positive.

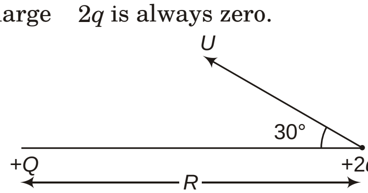
9. Charge outside a closed surface can produce electric field but cannot produce flux.

10. $E \quad \frac{1}{4 \quad _0} \frac{qx}{(x^2 \quad a^2)^{3/2}}$ is maximum at $x \quad \frac{a}{\sqrt{2}}$

But $V \quad \frac{1}{4 \quad _0} \frac{q}{\sqrt{a^2 \quad x^2}}$ is maximum at $x \quad 0$.

Objective Questions (Level-2)

1. Electrostatic force always acts along the line joining the two charges, hence net torque on charge $2q$ is always zero.

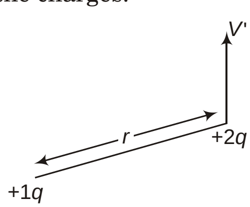


As net torque is zero angular momentum of charge remains conserved.

Initial angular momentum

$$L_i \quad m(V\sin 30 \quad)R$$

When the separation between the charges become minimum, direction of motion of charge $2q$ become perpendicular to the line joining the charges.



find angular momentum

$$L_f \quad mv\ r \quad \frac{mvr}{\sqrt{2}}$$

By conservation of angular momentum

$$L_i \quad L_f \qquad r \quad \frac{\sqrt{3}}{2} R$$

2. $\mathbf{v}_1 \quad v\,\hat{\mathbf{j}},\ \mathbf{v}_2 \quad 2v\cos 30 \ \hat{\mathbf{i}} \quad 2v\sin 30 \ \hat{\mathbf{j}}$

$$\sqrt{3}\,\hat{\mathbf{i}} \quad v\,\hat{\mathbf{j}}$$

As velocity along y-axis is unchanged, electric field along x-axis is zero.

For motion along x-axis,

$$v_x^2 \quad u_x^2 \quad 2a_x(x \quad x_0)$$

$$a_x \quad \frac{(\sqrt{3}v)^2 \quad 0}{2a} \quad \frac{3v^2}{2a}$$

$$F_x \quad ma_x \quad \frac{3mv^2}{2a}$$

$$\mathbf{F} \quad \frac{3mv^2}{2a}\hat{\mathbf{i}}$$

Also, $\qquad \mathbf{F} \quad e\,\mathbf{E}$

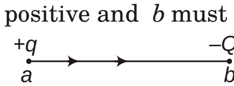
$$\mathbf{E} \quad \frac{3mv^2}{2ea}\hat{\mathbf{i}}$$

Rate of work done by electric field at B

$$P \quad \mathbf{F} \quad \mathbf{v} \quad \frac{3mv}{2a}\hat{\mathbf{i}} \quad (\sqrt{3}v\,\hat{\mathbf{i}} \quad v\,\hat{\mathbf{j}})$$

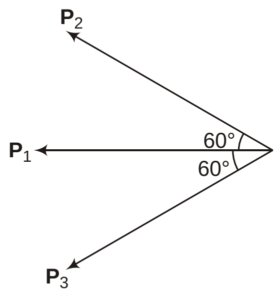
$$\frac{3\sqrt{3}\ mv^3}{2a}$$

3. Electric field is always possible, hence a must be positive and b must be negative.



4. The system can be assumed as a combination of three identical dipoles as shown in figure.

Here, $P_1 \quad P_2 \quad P_3 \quad Q(2a)$



Net dipole moment of the system

$$P \quad P_1 \quad P_2\cos 60 \quad P_3 \cos 60$$
$$2p \quad 4Qa$$

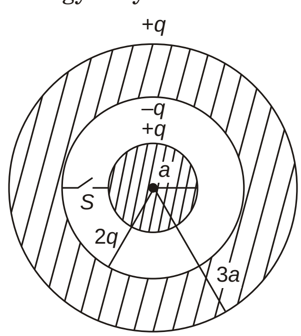
Electric field on equatorial lines of short dipole is given by

$$E \quad \frac{1}{4 \quad _0} \frac{P}{x^3}$$
$$\frac{1}{4 \quad _0} \frac{4Qa}{x^3} \quad \frac{Q\,a}{_0 x^3}$$

5. Potential at centre will be same as potential at the surface of inner shell *i.e.*, 10 V.

6. Initial charge distribution is shown in figure,

Initial energy of system



$$U_i \quad \frac{1}{4 \quad _0} \quad \frac{q^2}{2a} \quad \frac{(\quad q)^2}{2 \quad 2a} \quad \frac{q^2}{2 \quad 3a}$$
$$\frac{q(\quad q)}{2a} \quad \frac{q(q)}{3a} \quad \frac{q(\quad q)}{3a}$$
$$\frac{5a^2}{48 \quad _0 a}$$

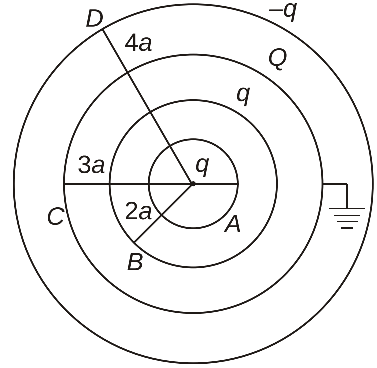
When switch S is closed, entire charge flows to the outer surface of outer shell,

$$U_f \quad \frac{1}{4 \quad _0} \frac{q^2}{2 \quad 3a} \quad \frac{q^2}{24 \quad _0 a}$$

Heat produced $U_i \quad U_f \quad \frac{q^2}{8 \quad _0 a}$

$$\frac{kq^2}{2a}$$

7. Let Q charge flows to C



$$V_C \quad \frac{1}{4 \quad _0} \quad \frac{q \quad Q}{3a} \quad \frac{(\quad q)}{4a} \quad 0$$
$$Q \quad \frac{q}{4}$$
$$V_A \quad \frac{1}{4 \quad _0} \quad \frac{q}{2a} \quad \frac{Q}{3a} \quad \frac{q}{4a}$$
$$\frac{1}{4 \quad _0} \frac{q}{a}$$
$$V_A \quad V_C \quad \frac{1}{4 \quad _0} \frac{q}{a}$$
$$\frac{kq}{a}$$

8. $V_S \quad \frac{1}{4 \quad _0} \frac{q}{R}$

and $V_C \quad \frac{1}{4 \quad _0} \frac{3q}{2R}$

$$V_C \quad V_S \quad \frac{1}{4 \quad _0} \frac{q}{2R}$$
$$\frac{1}{4p \quad _0} \quad \frac{\frac{4}{3} \quad R^3}{2R} \quad \frac{R^2}{E_0}$$

9. As particle comes to rest, force must be repulsive, hence it is positively charged.

Again on moving down its KE first increases than decreases, PE will first decrease than increase.

10. (1) is correct as the points having zero potential are close to Q_2, $|Q_2| \quad |Q_1|$.

Again as potential near Q_1 is positive, Q_1 is positive, hence (2) is correct.

At point A and B potential is zero not field, hence they may or may not be equilibrium point.

Hence (3) is wrong.

At point C potential is minimum, Q positive charge placed at this point will have unstable equilibrium but a negative charge will be in stable equilibrium at this position.

Hence, (4) is wrong.

11. V_1 is always negative and V_2 is always positive.

12. Electric field between the two points is positive near q_1 and negative near q_2, hence q_1 is positive and q_2 is negative.

Again neutral point is closer to q_1, hence $q_1 \quad q_2$.

13. Electric field due to a conductor does not depend on position of charge inside it.

14. $\mathbf{E} \quad 400\cos 45 \ \hat{\mathbf{i}} \quad 4000\sin 45 \ \hat{\mathbf{j}}$

$$200\sqrt{2}(\hat{\mathbf{i}} \quad \hat{\mathbf{j}})$$

$$\mathbf{V}_A \quad \mathbf{V}_B \qquad \mathbf{E}\ \mathbf{r}_{AB}$$

$$200\sqrt{2}(\hat{\mathbf{i}} \quad \hat{\mathbf{j}})\ (2\hat{\mathbf{j}} \quad 3\hat{\mathbf{i}}) \quad 10^{\ \ 2}$$

$$2\sqrt{2}\text{ V} \quad 2.8\text{ V}$$

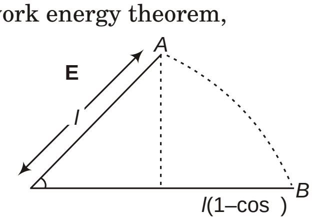
15. Potential difference between two concentric spherical shells does not depend on charge of outer sphere. Hence,

$$V_A \quad V_B \quad V_A \quad V_B$$

But $V_B \quad 0$

$$V_A \quad V_A \quad V_B.$$

16. By work energy theorem,



Work done by electric field

charge is KE

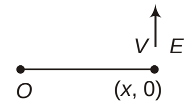
$$qE\,l(1 \quad \cos\ ) \ \frac{1}{2}mv^2 \quad 0$$

$$v \quad \sqrt{\frac{qE\,l}{m}}$$

At point B

$$T \quad qE \quad \frac{mv^2}{r} \quad 2\,qE$$

17. Velocity of particle at any instant



$$V \quad at \quad \frac{qE}{m}t$$

$$L \quad mvr \quad qE\,x_0 t$$

Hence, angular momentum of the particle increases with time.

18. By work energy theorem

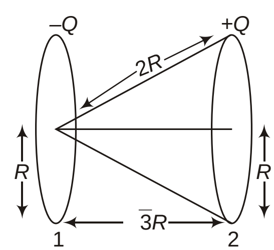
$$W \quad K$$

$$q(V_S \quad V_C) \ \ 0 \ \ \frac{1}{2}mv^2$$

$$q \ \frac{1}{4 \ \ _0} \ \frac{Q}{R} \quad \frac{1}{4 \ \ _0} \ \frac{3Q}{2R} \qquad \frac{1}{2}mv^2$$

$$u \quad \sqrt{\frac{Q\,q}{4 \ \ _0 mR}}$$

19. Potential at the centre of negatively charged ring



$$V_1 \quad \frac{1}{4 \ \ _0} \quad \frac{Q}{R} \quad \frac{Q}{2R}$$

$$\frac{Q}{8 \ \ _0 R}$$

Potential at the centre of positively charged ring

$$V_2 \quad \frac{1}{4 \ \ _0} \quad \frac{Q}{R} \quad \frac{Q}{2R}$$

$$\frac{Q}{8 \ \ _0 R}$$

Kinetic energy required Work done required

$$q(V_2 \quad V_1) \quad \frac{Q}{4 \ \ _0 R}$$

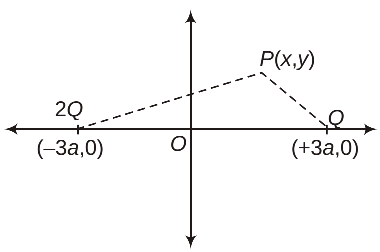
20. $E_x \quad \frac{V_{x_2} \quad V_{x_1}}{x_2 \quad x_1} \quad \frac{16 \quad 4}{2 \quad 2} \quad 3\ \text{V/m}$

$E_y \quad \frac{V_{y_3} \quad V_{y_1}}{y_3 \quad y_1} \quad \frac{12 \quad 4}{4 \quad 2} \quad 4\ \text{V/m}$

$E \quad E_x\,\hat{\mathbf{i}} \quad E_y\,\hat{\mathbf{j}} \quad (3\,\hat{\mathbf{i}} \quad 4\,\hat{\mathbf{j}})\ \text{V/m}.$

21. Consider a point $P(x, y)$ where potential is zero.

Now, V_P



$$V_P \quad \frac{1}{4 \quad _0} \quad \frac{Q}{\sqrt{(3a \quad x)^2 \quad y^2}} \quad \frac{2Q}{\sqrt{(x \quad 3a)^2 \quad y^2}}$$

0

$(x \quad 3a)^2 \quad y^2 \quad 4[(3a \quad x)^2 \quad y^2]$

$3x^2 \quad 3y^2 \quad 30ax \quad 27a^2 \quad 0$

$x^2 \quad y^2 \quad 10ax \quad 9a^2 \quad 0$

The equation represents a circle with radius

$$\sqrt{\frac{10a}{2}^{\ 2} \quad 9a^2} \quad 4a$$

and centre at $\frac{10}{2}a, 0 \quad (5a, 0)$

Clearly points $x \quad a$ and $x \quad 9a$ lie on this circle.

22. Work done qEy Charge in KE

Hence, $K_f \quad \frac{1}{2}mv^2 \quad qEy$

All other statements are correct.

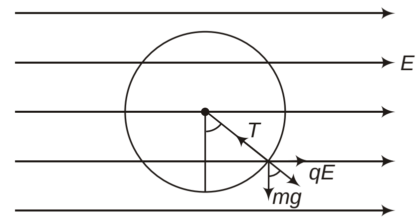
23. Electrostatic force of attraction provides necessary centripetal force.

ie, $\frac{mv^2}{r} \quad \frac{q}{2 \quad _0 r}$

$V \quad \sqrt{\frac{q}{2 \quad _0 m}}$

$T \quad \frac{2 \quad r}{V} \quad 2 \quad r\sqrt{\frac{2 \quad _0 m}{q}} \quad 2 \quad r\sqrt{\frac{m}{2K \quad q}}$

24. $T \quad mg\cos \quad qE\sin \quad \frac{mv^2}{l}$



Tension will be minimum when velocity is minimum.

Minimum possible in the string is zero.

ie, $\frac{mv^2}{l} \quad (mg\cos \quad qE\sin \quad)$

Diff. both sides w.r.t.

$\frac{2mv}{l}\frac{dv}{d} \quad mg\sin \quad qE\sin$ ...(i)

For minima or maxima

$\frac{dv}{d} \quad 0 \quad \tan^{\ 1}\frac{qE}{mg}$

or $\tan^{\ 1}\frac{qE}{mg}$

Differentiating Eq. (i) again,

$\frac{2mv}{l}\frac{d^2v}{d^{\ 2}} \quad \frac{2m}{l} \quad \frac{dv}{d}^{\ 2} \quad mg\sin \quad qE\sin$

$\frac{d^2v}{d^{\ 2}}$ + ve for $\tan^{\ 1}\frac{qE}{mg}$

and –ve for $\tan^{\ 1}\frac{qE}{mg}$

25. $q_A \quad (4 \quad a^2), q_B \quad (4 \quad b^2)$ and $q_C \quad (4 \quad c^2)$

$V_B \quad \frac{1}{4 \quad _0} \quad \frac{q_A \quad q_B}{b} \quad \frac{q_C}{c}$

$\frac{}{_0} \quad \frac{a^2}{b^2} \quad b \quad c$

26. $U_i \quad \frac{1}{4 \quad _0} \quad \frac{q^2}{a} \quad \frac{q^2}{a} \quad \frac{q^2}{a} \quad \frac{q^2}{a} \quad \frac{q^2}{\sqrt{2}a} \quad 2$

$\frac{\sqrt{2}\,q^2}{4 \quad _0 a}$

$U_f \quad \frac{1}{4 \quad _0} \quad \frac{q^2}{a}$

$W \quad U_f \quad U_i \quad \frac{1}{4 \quad _0} \quad \frac{q^2}{a}(\sqrt{2} \quad 1)$

27. $q_A \quad (4\ a^2), q_B \quad (4\ b^2), q_C \quad (4\ c^2)$

Given, $V_A \quad V_C$

$$\frac{1}{4\ _0}\ \frac{q_A}{a}\ \frac{q_B}{b}\ \frac{q_C}{c}\ \ \frac{1}{4\ _0}\ \frac{q_A\ \ q_B\ \ q_C}{c}$$

$$a\ \ b\ \ c\ \ \frac{a^2\ \ b^2}{c}\ \ c$$

$$a\ \ b\ \ c$$

28. Potential at minimum at mid-point in the region between two charges, and is always positive.

29. $U_i \quad \frac{1}{4}\ \frac{q^2}{r} \quad U$

$$U_f \quad \frac{1}{4}\ \frac{q^2}{r}\ \ 3\ \ 3U$$

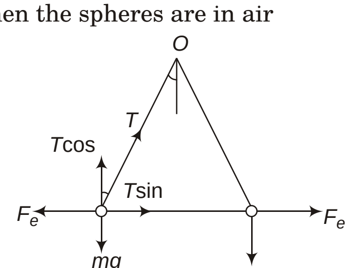
$$W \quad U_f \quad U_i \quad 2U$$

30. Loss of KE Gain in PE

$$\frac{1}{2}mv^2 \quad \frac{1}{4\ _0}\ \frac{qQ}{r}$$

$$r \quad \frac{1}{v^2}$$

31. When the spheres are in air

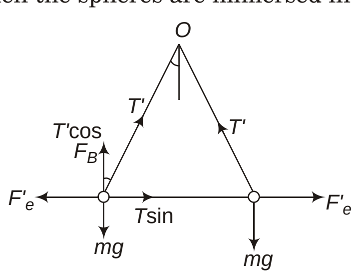


$$T\cos \quad mg$$

$$T\sin \quad F_e$$

$$F_e \quad mg\tan \qquad \text{...(i)}$$

When the spheres are immersed in liquid



$$F_1 \quad T\ \sin$$

$$g \quad F_B \quad T\ \cos$$

$$F_e \quad (mg \quad F_B)\tan \qquad \text{...(ii)}$$

On dividing Eq. (ii) by Eq. (i),

$$\frac{F_e}{F_e} \quad \frac{mg\ \ F_B}{mg}$$

$$\frac{1}{K}\ \ 1\ \ \frac{F_B}{mg}\ \ 1\ \ \frac{0.8}{1.6}\ \ \frac{1}{2}$$

$$K \quad 2$$

32. $V_P \quad \frac{1}{4\ _0}\ \frac{q}{a}\ \ 2\ \ \frac{q}{\sqrt{a^2\ \ b^2}}\ \ 2$

$$\frac{2q}{4\ _0}\ \frac{\sqrt{a^2\ \ b^2}\ \ a}{a\sqrt{a^2\ \ b^2}}$$

$$\frac{2q}{4\ _0}\ \frac{a\ 1\ \ \frac{b^2}{a^2}^{1/2}\ \ a}{a\sqrt{a^2\ \ b^2}} \quad \frac{2q}{4\ _0}\ \frac{b^2}{a^3}$$

[As $b \quad a$]

33. In any case electric field at origin is $\frac{1}{4\ _0}\ \frac{5q}{r^2}$ along x-axis and $\frac{1}{4\ _0}\ \frac{5q}{r^2}$ along y-axis.

34. $u \quad \frac{1}{2}\ _0E^2\ \ \frac{1}{2}\ _0\ \frac{1}{4\ _0}\ \frac{q}{R^2}^2$

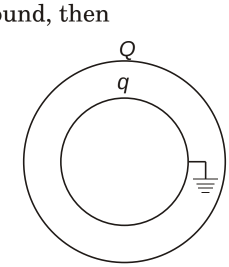
$$\frac{1}{2}\ _0\ \frac{9\ \ 10^9\ \ \frac{1}{9}\ \ 10^{\ 9}}{12}$$

$$\frac{_0}{2}\ \text{J/m}^3$$

35. If Q is initial charge on B

then, $V_A \quad V_B \quad \frac{1}{4\ _0}\ \frac{Q}{b} \quad V$

Now, if A is earthed, let charge q moves on A from ground, then



$$V_A \quad \frac{1}{4\ _0}\ \frac{q}{a}\ \ \frac{Q}{b} \quad 0$$

$$q \quad \frac{a}{b}Q$$

$$V_B \quad \frac{1}{4 \quad _0} \frac{q \quad Q}{b}$$

$$\frac{1}{4 \quad _0} \frac{Q}{b} \quad 1 \quad \frac{a}{b} \qquad V \; 1 \quad \frac{a}{b}$$

36. $$\mathbf{E} \quad \frac{v}{x}\hat{\mathbf{i}} \quad \frac{v}{y}\hat{\mathbf{j}} \quad \frac{v}{z}\hat{\mathbf{k}}$$

$$\frac{2}{1}\hat{\mathbf{i}} \quad \frac{2}{1}\hat{\mathbf{j}} \quad \frac{2}{1}\hat{\mathbf{k}}$$

$$2(\hat{\mathbf{i}} \quad \hat{\mathbf{j}} \quad \hat{\mathbf{k}})\,\text{N/C}$$

If V_P is potential at P, then

$$V_P \quad V_0 \qquad \mathbf{E} \;\; \mathbf{r}$$

$$V_P \quad 10 \qquad 2(\hat{\mathbf{i}} \quad \hat{\mathbf{j}} \quad \hat{\mathbf{k}}) \; (\hat{\mathbf{i}} \quad \hat{\mathbf{j}} \quad \hat{\mathbf{k}}) \qquad 6$$

$$V_P \quad 4\,\text{V}$$

37. On touching two spheres, charge is equally divided among them, then due to induction a charge $\frac{q}{2}$ appears on the earthed sphere.

38. Negative charge will induce on the conductor near P.

39.
$$0 \qquad \text{for} \quad r \quad r_A$$
$$\frac{kQ_P}{r} \qquad \text{for} \quad r_P \quad r \quad r_B$$
$$\frac{k(Q_A \quad Q_B)}{r} \qquad \text{for} \quad r \quad r_B$$

As $|Q_B| \quad |Q_A|$

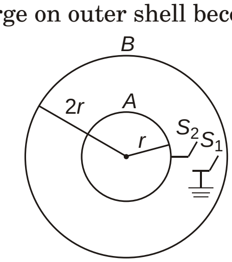
E is –ve for $r \quad r_B$.

40. $$\mathbf{E} \quad \frac{v}{x}\hat{\mathbf{i}} \quad \frac{v}{y}\hat{\mathbf{j}}$$

$$k(y\hat{\mathbf{i}} \quad x\hat{\mathbf{j}})$$

$$|\mathbf{E}| \quad k\sqrt{y^2 \quad x^2} \quad kr$$

41. Let charge on outer shell becomes q.



$$V_B \quad \frac{1}{4 \quad _0} \frac{Q \quad q}{2r} \qquad 0$$

$$q \qquad Q$$

42. Let charge q flows through the switch to the ground, then

$$\frac{1}{4 \quad _0} \frac{Q \quad q}{r} \quad \frac{Q}{2r} \qquad 0$$

$$q \quad \frac{1}{2}Q$$

43. After n steps

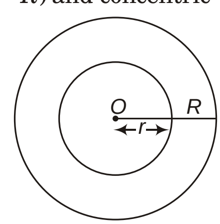
$$q \quad \frac{1}{2^n}Q \text{ and } q \quad \frac{1}{2^{n \quad 1}}Q$$

$$V_A \quad \frac{1}{4 \quad _0} \quad \frac{q}{r} \quad \frac{q}{2r} \qquad 0$$

$$V_B \quad \frac{1}{4 \quad _0} \frac{q \quad q}{2r}$$

$$\frac{1}{2^{n \quad 1}} \frac{Q}{4 \quad _0 r}$$

44. Consider a spherical Gaussian surface of radius $r\,(\quad R)$ and concentric with the sphere,



Charge on a small sphere of radius r

$$dq \qquad dV \quad 4 \; r^2 \; dr$$

$$r \quad _0 \; r^2 \quad \frac{r^3}{R} \quad dr$$

Total charge inside the Gaussian surface,

$$q \quad 4 \quad _0 \int_0^r r^2 \quad \frac{r^3}{R} \quad dr$$

$$4 \quad _0 \quad \frac{r^3}{3} \quad \frac{r^4}{4R}$$

$$E \quad \frac{1}{4 \quad _0} \frac{q}{r^2} \qquad \frac{_0}{_0} \quad \frac{r}{3} \quad \frac{r^2}{4R}$$

45. Total charge inside the surface.

$$Q \quad 4 \quad _0 \frac{R^3}{3} \quad \frac{R^3}{r} \qquad \frac{1}{3} \quad _0 R^3$$

$$E \quad \frac{1}{4 \quad _0} \frac{Q}{r^2} \qquad \frac{_0 R^3}{12 \quad _0 r^2}$$

46. $$E \quad \frac{_0}{_0} \quad \frac{r}{3} \quad \frac{r^2}{4R}$$

For maximum intensity of electric field

$$\frac{dE}{dr} \quad \frac{\ _0}{_0} \frac{1}{3} \quad \frac{r}{2R} \quad 0$$

$$r \quad \frac{2}{3}R$$

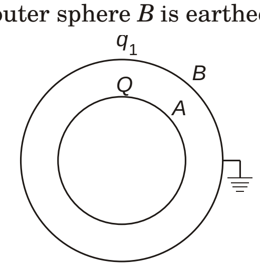
$$\frac{d^2E}{dr^2} \quad \frac{\ _0}{2R\ _0} \quad \text{ve,}$$

hence E is maximum at $r \quad \frac{2}{3}R.$

47. $$E_{\max} \quad \frac{\ _0}{_0} \frac{\frac{2}{3}}{3} \frac{\left(\frac{2R}{3}\right)^2}{4R} \quad \frac{_0 R}{q\ _0}$$

48. Potential difference between two concentric spheres do not depend on the charge on outer sphere.

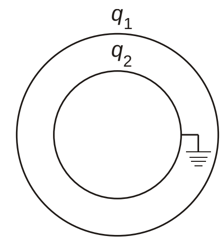
49. When outer sphere B is earthed



$$V_B \quad \frac{1}{4\ _0} \quad \frac{Q \quad q_1}{b} \quad 0$$

$$q_1 \quad Q$$

Now, if A is earthed



$$q_A \quad \frac{1}{4\ _0} \quad \frac{q_2}{a} \quad \frac{q_1}{b} \quad 0$$

$$q_2 \quad \frac{a}{b}q_1 \quad \frac{a}{b}Q$$

50. When connected by conducting wires, entire charge from inner sphere flows to the outer sphere, *ie*,

$$q_3 \quad q_1 \quad q_2 \quad \frac{a}{b} \quad 1\ Q$$

$$\frac{a \quad b}{b}Q$$

More than One Correct Options

1. Before earthing the surface B,

$$V_A \quad \frac{1}{4\ _0} \quad \frac{q_A}{R} \quad \frac{q_B}{2R} \quad 2\,\text{V}$$

$$V_B \quad \frac{1}{4\ _0} \quad \frac{q_A \quad q_B}{2R} \quad \frac{3}{2}\text{V}$$

$$\frac{q_A}{q_B} \quad \frac{1}{2}$$

On earthing the sphere B,

$$q_A \quad q_A$$

$$V_B \quad \frac{1}{4\ _0} \quad \frac{q_A \quad q_B}{2R} \quad 0$$

$$q_B \quad q_A$$

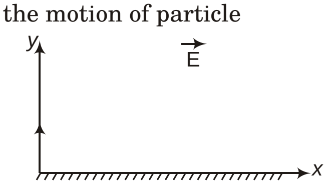
$$\frac{q_A}{q_B} \quad 1$$

As potential difference does not depend on charge on outer sphere,

$$V_A \quad V_B \quad V_A \quad V_B \quad \frac{V}{2}$$

$$V_A \quad \frac{1}{2}V$$

2. For the motion of particle



$$u_x \quad 0, v_x \quad v, a_x \quad \frac{qE}{m}, a_y \quad g,$$

$$x_0 \quad 0, y_0 \quad 0$$

$$x \quad x_0 \quad u_x t \quad \frac{1}{2}a_x t^2$$

$$x \quad \frac{qE}{2m}t^2 \qquad \text{...(i)}$$

$$y \quad y_0 \quad u_y t \quad \frac{1}{2}a_y t^2$$

$$ut \quad \frac{1}{2}gt^2 \qquad \text{...(ii)}$$

At the end of motion

$$t \quad T, y \quad 0, x \quad R$$

From Eq. (ii),

$$0 \quad u \quad \frac{1}{2}gT \quad T$$

$$T \quad \frac{2u}{g} \quad \frac{2 \quad 10}{10} \quad 2\,\text{s}$$

From Eq. (i),

$$R \quad \frac{qE}{2m}T^2$$

$$\frac{1 \quad 10^{\ 3} \quad 10^4}{2 \quad g} \quad 4 \quad 10\,\text{m}$$

Now, $\quad v_y^2 \quad u_y^2 \quad 2a_y(y \quad y_0)$

At highest point (*i.e.*, $y \quad H$), $v_y \quad 0$

$$0 \quad (10)^2 \quad 2 \quad 10(H \quad 0)$$

$$H \quad 5\,\text{m}$$

3. Let R be the radius of the sphere

$$V_1 \quad \frac{1}{4 \quad _0} \quad \frac{q}{R \quad r_1}$$

$$\frac{q \quad 10^9 \quad q}{(R \quad S) \quad 10^{\ 2}} \quad 100 \qquad \ldots\text{(i)}$$

$$V_2 \quad \frac{1}{4 \quad _0} \quad \frac{q}{R \quad r_2}$$

$$\frac{9 \quad 10^9 \quad q}{(R \quad 10) \quad 10^{\ 2}} \quad 75 \qquad \ldots\text{(ii)}$$

On solving,

$R \quad 10$ cm,

$$q \quad \frac{5}{3} \quad 10^{\ 9}\,\text{C} \quad \frac{50}{3} \quad 10^{\ 10}\,\text{C}$$

Electric field on surface,

$$E \quad \frac{1}{4 \quad _0} \quad \frac{q}{R^2} \quad \frac{9 \quad 10^9 \quad \frac{5}{3} \quad 10^{\ 9}}{(10 \quad 10^{\ 2})}$$

$$1500\,\text{V/m}$$

Potential at surface,

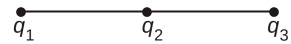
$$V \quad \frac{1}{4 \quad _0} \quad \frac{q}{R} \quad \frac{9 \quad 10^9 \quad \frac{5}{3} \quad 10^{\ 9}}{10 \quad 10^{\ 2}}$$

$$150\,\text{V}$$

Potential at Centre

$$V_C \quad \frac{3}{2}V_S \quad 225\,\text{V}$$

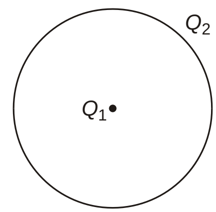
4. For all charges to be in equilibrium, force experienced by either charge must be zero *ie*., force due to other two charges must be equal and opposite.



Hence all the charges must be collinear, charges q_1, and q_3 must have same sign and q_2 must have opposite sign, q_2 must have maximum magnitude.

Such on equilibrium is always unstable.

5. Flux through any closed surface depends only on charge inside the surface but electric field at any point on the surface depends on charges inside as well as outside the surface.



6. As net charge on an electric dipole is zero, net flux through the sphere is zero.

But electric field at any point due to a dipole cannot be zero.

7. Gauss's law gives total electric field and flux due to all charges.

8. If two concentric spheres carry equal and opposite charges, Electric field is **non-zero** only in the region between two sphere and potential is is *zero* only outside both the spheres.

9. As force on the rod due to electric field is towards right, force on the rod due to hinge must be left.

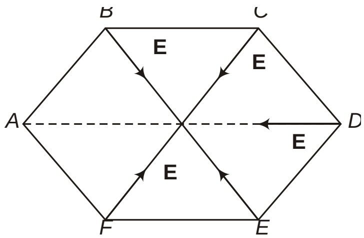
The equilibrium is clearly neutral.

10. If moved along perpendicular bisector, for all identical charges, electrostatic potential energy is maximum at mid point and if moved along the line joining the particles, electrostatic potential energy is minimum at the mid-point.

Match the Columns

1. (a s), (b q), (c r), (d p).

If charge at B is removed



$$E_{\text{net}} \quad E_D \cos 30 \quad E_E \cos 30$$
$$\sqrt{3}E$$

If charge at C is removed

$$E_{\text{net}} \quad E_D \cos 60 \quad E_f \cos 60$$
$$E$$

If charge at D is removed

$$\mathbf{E}_{\text{net}} \quad 0 \text{ and } \mathbf{E}_B \quad \mathbf{E}_E$$

and $\mathbf{E}_E \quad \mathbf{E}_E$

If charge at B and C both are removed,

$$E_{\text{net}} \quad E_E \quad E_D \cos 60 \quad E_F \cos 60$$
$$2E$$

2. (a q), (b p), (c s), (d r).

$$V \quad \mathbf{E} \ \mathbf{r}$$

If $\mathbf{r} \quad 4\hat{\mathbf{i}}, V \quad 8\text{ V}$,

If $\mathbf{r} \quad 4\hat{\mathbf{i}}, V \quad 8\text{ V}$

If $\mathbf{r} \quad 4\hat{\mathbf{j}}, V \quad 16\text{ V}$,

If $\mathbf{r} \quad 4\hat{\mathbf{j}}, V \quad 16\text{ V}$

3. For a solid sphere

$$V_{\text{in}} \quad \frac{1}{4 \quad _0} \frac{q}{2R^3}(3R^2 \quad r^2)$$

at $r \quad \dfrac{R}{2}$

$$V_1 \quad \frac{1}{4 \quad _0} \frac{q}{2R^3} \quad 3R^2 \quad \frac{R^2}{4}$$

$$\frac{11}{8}V$$

$$V_{\text{out}} \quad \frac{1}{4 \quad _0} \frac{q}{r}$$

at $r \quad 2R$

$$V_2 \quad \frac{1}{4 \quad _0} \frac{q}{2R} \quad \frac{V}{2}$$

$$\text{E}_{\text{in}} \quad \frac{1}{4 \quad _0} \frac{qr}{R^3}$$

at $r \quad \dfrac{R}{2}$

$$E_1 \quad \frac{1}{4 \quad _0} \frac{q}{2R^2} \quad \frac{V}{2R} \quad \frac{V}{2} \qquad (\because R \quad 1\text{ m})$$

$$\text{E}_{\text{out}} \quad \frac{1}{4 \quad _0} \frac{q}{r^2}$$

at $r \quad 2R$

$$E_2 \quad \frac{1}{4 \quad _0} \frac{q}{(2R)^2} \quad \frac{V}{4R} \quad \frac{V}{4}$$

(a s), (b q), (c q), (d p).

4. (a r), (b q), (c q), (d s)

5. (a p), (b q), (c r), (d s)

For a spherical shell,

$$E \quad \begin{matrix} 0 & \text{for } r \quad R \\ \dfrac{Kq}{r^2} & \text{for } r \quad R \end{matrix}$$

$$V \quad \begin{matrix} \dfrac{Kq}{R} & \text{for } r \quad R \\ \dfrac{Kq}{r} & \text{for } r \quad R \end{matrix}$$

For a solid sphere,

$$E \quad \begin{matrix} \dfrac{Kqr}{R^3} & \text{for } r \quad R \\ \dfrac{Kq}{r^2} & \text{for } r \quad R \end{matrix}$$

$$V \quad \begin{matrix} \dfrac{Kq}{2R^2}(2R^2 \quad r^2) & \text{for } r \quad R \\ \dfrac{Kq}{r^2} & \text{for } r \quad R \end{matrix}$$

22 Capacitors

Introductory Exercise 22.1

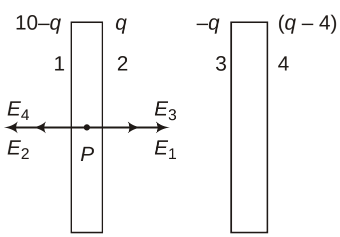
1. $C \quad \frac{q}{V} \quad [C] \quad \frac{[\text{AT}]}{[\text{ML}^2\text{T}^{\ 3}\text{A}^{\ 1}]}$

$$[\text{M}^{\ 1}\text{L}^{\ 2}\text{T}^4\text{A}^2]$$

2. False.

Charge will flow if there is potential difference between the conductors. It does not depend on amount of charge present.

3. Consider the charge distribution shown in figure.



Electric field at point P

$$E_P \quad E_1 \quad E_3 \quad E_2 \quad E_4$$

$$\frac{10 \quad q}{2 \ _0A} \quad \frac{q}{2 \ _0A} \quad \frac{q}{2 \ _0A} \quad \frac{q \quad 4}{2 \ _0A}$$

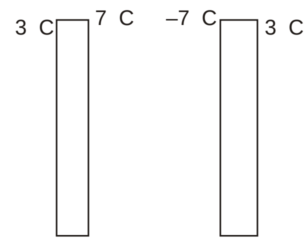
But P lies inside conductor

$$E_P \quad 0$$

$$10 \quad q \quad q \quad q \quad q \quad 4 \quad 0$$

$$q \quad 7 \ \text{C}$$

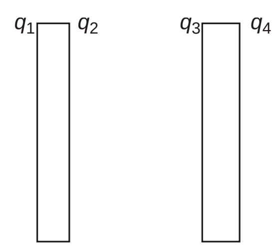
Hence, the charge distribution is shown in figure.



Sort-cut Method

Entire charge resides on outer surface of conductor and will be divided equally on two outer surfaces.

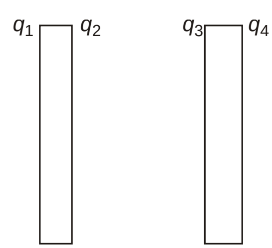
Hence, if q_1 and q_2 be charge on two plates then.



$$q_1 \quad q_4 \quad \frac{q_1 \quad q_2}{2} \quad 3 \ \ \text{C}$$

$$q_2 \quad \frac{q_1 \quad q_2}{2} \quad 7 \ \ \text{C}$$

$$q_3 \quad \frac{q_2 \quad q_1}{2} \quad 7 \ \ \text{C}$$



4. Charge distribution is shown in figure.

$$q_1 \quad q_4 \quad \frac{q_1 \quad q_2}{2} \quad \frac{q}{2}$$

$$q_2 \quad \frac{q_1 \quad q_2}{2} \quad \frac{5q}{2}$$

$$q_3 \quad \frac{q_2 \quad q_1}{2} \quad \frac{5q}{2}$$

Charge on capacitor   Charge on inner side of positive plate.

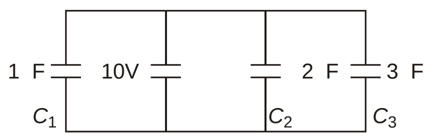
$$q \quad \frac{5q}{2}$$

and $$C \quad \frac{{}_0 A}{d}$$

$$V \quad \frac{q}{C} \quad \frac{5q\,d}{2\ {}_0 A}$$

Introductory Exercise 22.2

1. All the capacitors are in parallel



$$q_1 \quad C_1 V \quad 1 \quad 10 \quad 10 \quad \text{C}$$

$$q_2 \quad C_2 V \quad 2 \quad 10 \quad 20 \quad \text{C}$$

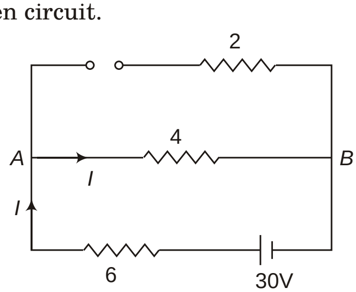
$$q_3 \quad C_3 V \quad 3 \quad 10 \quad 30 \quad \text{C}$$

2. Potential difference across the plates of capacitor

$$V \quad 10\ \text{V}$$

$$q \quad CV \quad 4 \quad 10 \quad 40 \quad \text{C}$$

3. In the steady state capacitor behaves as open circuit.



$$I \quad \frac{30}{6 \quad 4} \quad 3\ \text{A}$$

Potential difference across the capacitor,

$$V_{AB} \quad 4 \quad I \quad 4 \quad 3 \quad 12\ \text{V}$$

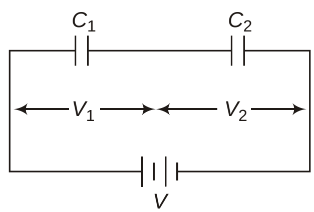
Charge on capacitor

$$q \quad CV_{AB} \quad 2 \quad 12 \quad 24 \quad \text{C}$$

4. (a) $$\frac{1}{C_e} \quad \frac{1}{C_1} \quad \frac{1}{C_2} \quad \frac{1}{1} \quad \frac{1}{2}$$

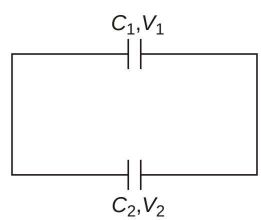
$$C_e \quad \frac{2}{3} \quad \text{C}$$

$$q \quad C_e V \quad \frac{2}{3} \quad 1200 \quad 800 \quad \text{C}$$



(b) $$V_1 \quad \frac{q}{C_1} \quad \frac{800}{1} \quad 800\ \text{V}$$

$$V_2 \quad \frac{q}{C_2} \quad \frac{800}{2} \quad 400\ \text{V}$$



Now, if they are connected in parallel,

Common potential, $$V \quad \frac{C_1 V_1 \quad C_2 V_2}{C_1 \quad C_2}$$

$$\frac{1 \quad 800 \quad 2 \quad 400}{1 \quad 2} \quad \frac{1600}{3}\ \text{V}$$

$$q_1 \quad C_1 V \quad \frac{1600}{3} \quad \text{C},\ q_2 \quad C_2 V \quad \frac{3200}{3} \quad \text{C}$$

5. Common potential

$$V \quad \frac{C_1 V_2 \quad C_2 V_2}{C_1 \quad C_2}$$

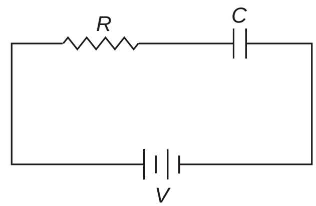
But $V \quad 20,\ V_2 \quad 0,\ V_1 \quad 100\ \text{V},\ C_1 \quad 100 \quad \text{C}$

$$\frac{100 \quad 100 \quad C_2 \quad 0}{400 \quad C_2} \quad 20$$

$$C_2 \quad 400 \quad \text{C}$$

Introductory Exercise 22.3

1. Let q be the final charge on the capacitor, work done by battery



$$W \quad qV$$

Energy stored in the capacitor

$$U \quad \frac{1}{2} qV$$

Energy dissipated as heat

$$H \quad U \quad W \quad \frac{1}{2} qV \quad U$$

2. We have

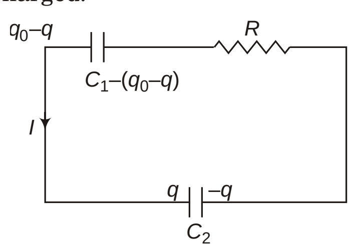
$$I \quad I_0 e^{\;t/}$$

$$\frac{I_0}{2} \quad I_0 e^{\;t/} \qquad e^{\;t/} \quad \frac{1}{2}$$

$$t \qquad \ln 2 \quad 0.693$$

$t \quad 0.693$ time constant.

3. Let capacitor C_1 is initially charged and C_2 is uncharged.



At any instant, let charge on C_2 be q, charge on C_1 at that instant $\quad q_0 \quad q$

By Kirchhoff's voltage law,

$$\frac{(q_0 \quad q)}{C} \quad IR \quad \frac{q}{C} \quad 0$$

$$\frac{dq}{dt} \quad \frac{q_0 \quad 2q}{RC}$$

$$\int_0^q \frac{dq}{q_0 \quad 2q} \quad \int_0^t \frac{dt}{RC}$$

$$\frac{[\ln (q_0 \quad 2q)]_0^q}{2} \quad \frac{1}{RC}[t]_0^t$$

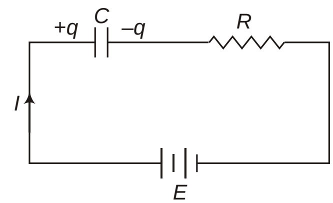
$$q \quad \frac{q_0}{2}(1 \quad e^{\;t/} \;)$$

At time t,

Charge on $C_1 \quad q \quad \frac{q_0}{2}(1 \quad e^{\;t/} \;)$

Charge on $C_2 \quad q_0 \quad q \quad \frac{q_0}{2}(1 \quad e^{\;t/} \;)$

4. Let q be the charge on capacitor at any instant t



By Kirchhoff's voltage law

$$\frac{q}{C} \quad IR \quad E$$

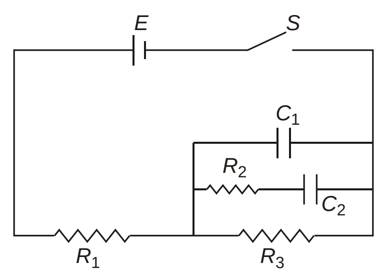
$$\frac{dq}{dt} \quad \frac{CE \quad q}{RC}$$

$$\int_{q_0}^q \frac{dq}{CE \quad q} \quad \int_0^t \frac{dt}{RC}$$

$$q_0 \quad CE(1 \quad e^{\;t/} \;) \quad q_0 e^{\;t/}$$

where, $\quad RC$

5. (a) When the switch is just closed, Capacitors behave like short circuit.



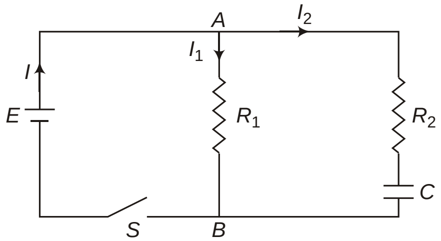
Initial current

$$I_i \quad \frac{E}{R_1}$$

(b) After a long time, *i.e.*, in steady state, both the capacitors behaves open circuit,

$$I_f \quad \frac{E}{R_1 \quad R_3}$$

6. (a) Immediately after closing the switch, capacitor behaves as short circuit,



$$I_1 \quad \frac{E}{R_1} \text{ and } I_2 \quad \frac{E}{R_2}$$

(b) In the steady state, capacitor behaves as open circuit,

$$I_1 \quad \frac{E}{R_1}, I_2 \quad 0$$

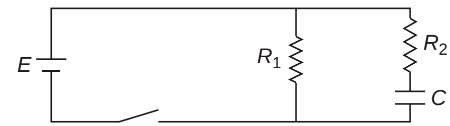
(c) Potential difference across the capacitors in the steady state,

$$V \quad E$$

Energy stored in the capacitor

$$U \quad \frac{1}{2}CE^2$$

(d) After the switch is open



$$R_e \quad R_1 \quad R_2$$
$$R_3C \quad (R_1 \quad R_2)C$$

AIEEE Corner

Subjective Questions (Level-1)

1. $C \quad \frac{{}_0A}{d} \quad A \quad \frac{Cd}{{}_0} \quad \frac{1 \quad 1 \quad 10^{\ 3}}{8.85 \quad 10^{\ 12}}$

$\quad 1.13 \quad 10^8 \text{ m}^2$

2. $C_1 \quad \frac{{}_0A_1}{d}$ and $C_2 \quad \frac{{}_0A_2}{d}$

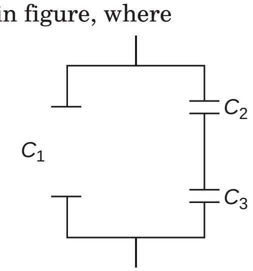
If connected in parallel

$$C \quad C_1 \quad C_2 \quad \frac{{}_0A_1}{d} \quad \frac{{}_2A_2}{d}$$
$$\frac{{}_0(A_1 \quad A_2)}{d} \quad \frac{{}_0A}{d}$$

where, $A \quad A_1 \quad A_2$ effective area.

Hence proved.

3. The arrangement can be considered as the combination of three different capacitors as shown in figure, where



$$C_1 \quad \frac{k_1 \ {}_0 \frac{A}{2}}{2d} \quad \frac{k_1 \ {}_0A}{4d}$$

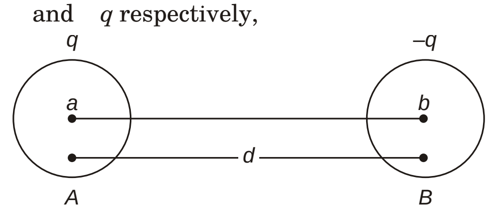
$$C_2 \quad \frac{k_2 \ {}_0 \frac{A}{2}}{2d/2} \quad \frac{k_2 \ {}_0A}{2d}$$

$$C_3 \quad \frac{k_3 \ {}_0 \frac{A}{2}}{2d/2} \quad \frac{k_3 \ {}_0A}{2d}$$

Therefore, the effective capacitance,

$$C \quad C_1 \quad \frac{C_2C_3}{C_2 \quad C_3}$$
$$\frac{{}_0A}{2d} \quad \frac{k_1}{2} \quad \frac{k_1k_3}{k_2 \quad k_3}$$

4. (a) Let the spheres A and B carry charges q and $\quad q$ respectively,



$$V_A \quad \frac{1}{4 \quad {}_0} \quad \frac{q}{a} \quad \frac{q}{d}$$
$$V_B \quad \frac{1}{4 \quad {}_0} \quad \frac{q}{b} \quad \frac{q}{d}$$

Potential difference between the spheres,

$$V \quad V_A \quad V_B \quad \frac{q}{4 \quad {}_0} \quad \frac{1}{a} \quad \frac{1}{b} \quad \frac{2}{d}$$

$$C \quad \frac{q}{V} \quad \frac{4 \quad {}_0}{\frac{1}{a} \quad \frac{1}{b} \quad \frac{2}{d}}$$

Hence proved.

(b) If d

$$C \quad \frac{4 \quad _0}{\frac{1}{a} \quad \frac{1}{b}} \quad \frac{4 \quad _0 \, ab}{a \quad b}$$

If two isolated spheres of radii a and b are connected in series,

then,

$$C \quad \frac{C_1 C_2}{C_1 \quad C_2}$$

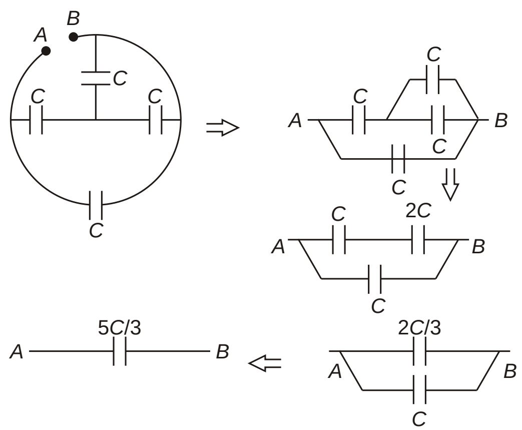
where, $C_1 \quad 4 \quad _0 a, C_2 \quad 4 \quad _0 b$

$$C \quad \frac{4 \quad _0 \, ab}{a \quad b}$$

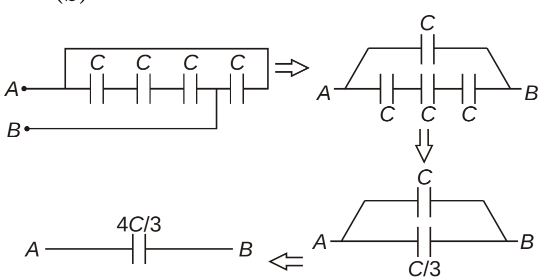
$$C \quad C$$

Hence proved.

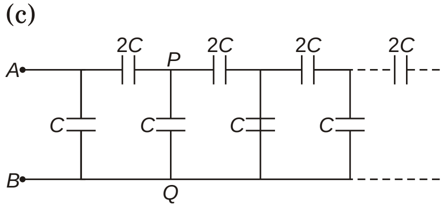
5. (a)



(b)



(c)



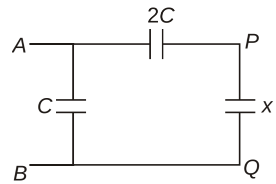
Let effective capacitance between A and B

$$C_{AB} \quad x$$

As the network is infinite,

$$C_{PQ} \quad C_{AB} \quad x$$

Equivalent circuit is shown in figure,



$$R_{AB} \quad C \quad \frac{2Cx}{2C \quad x} \quad x$$

$$2C^2 \quad Cx \quad 2Cx \quad 2Cx \quad x^2$$

$$x^2 \quad Cx \quad 2C^2 \quad 0$$

On solving, $x \quad 2C$ or C

But x cannot be negative,

Hence, $x \quad 2C$

6. $q \quad CV \quad 7.28 \quad 25 \quad 182 \quad$ C

7. (a) $V \quad \frac{q}{C} \quad \frac{0.148 \quad 10^{\ 6}}{245 \quad 10^{\ 12}} \quad 604$ V

(b) $C \quad \frac{_0 A}{d} \quad A \quad \frac{Cd}{_0}$

$$\frac{245 \quad 10^{\ 12} \quad 0.328 \quad 10^{\ 3}}{8.85 \quad 10^{\ 12}}$$

$$9.08 \quad 10^{\ 3} \text{ m}^2$$

$$90.8 \text{ cm}^2$$

(c) $\frac{q}{A} \quad \frac{0.148 \quad 10^{\ 6}}{9.08 \quad 10^{\ 3}} \quad 16.3 \quad \text{C/m}^2$

8. (a) $E_0 \quad 3.20 \quad 10^5$ V/m

$E \quad 2.50 \quad 10^5$ V/m

$$k \quad \frac{E_0}{E} \quad \frac{3.20 \quad 10^5}{2.50 \quad 10^5} \quad 1.28$$

(b) Electric field between the plates of capacitor is given by

$$E \quad \frac{}{_0}$$

$$_0 E \quad 8.8 \quad 10^{\ 12} \quad 3.20 \quad 10^5$$

$$2.832 \quad 10^{\ 6} \text{ C/m}^2$$

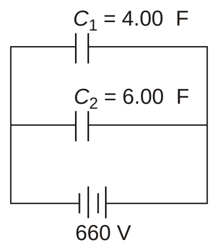
$$2.832 \quad \text{C/m}^2$$

9. (a) $q_1 \quad C_1 V \quad 4 \quad 660 \quad 2640 \quad$ C

$q_2 \quad C_2 V \quad 6 \quad 660 \quad 3960 \quad$ C

As C_1 and C_2 are connected in parallel,

$$V_1 \quad V_2 \quad V \quad 660\text{ V}$$



(b) When unlike plates of capacitors are connected to each other,

Common potential

$$V \quad \frac{C_2V_2 \quad C_1V_1}{C_1 \quad C_2} \quad \frac{6 \quad 660 \quad 4 \quad 660}{6}$$

$$220\text{ V}$$

$$q_1 \quad C_1V \quad 4 \quad 220 \quad 880 \quad \text{C}$$

$$q_2 \quad C_2V \quad 6 \quad 220 \quad 1320 \quad \text{C}$$

10. $E \quad \frac{V}{d} \quad \frac{400}{5 \quad 10^{\quad 3}} \quad 8 \quad 10^4\text{ V/m}$

Energy density,

$$u \quad \frac{1}{2} \quad {}_0E^2 \quad \frac{1}{2} \quad 8.85 \quad 10^{\quad 12} \quad (8 \quad 10^{\quad 4})^2$$

$$2.03 \quad 10^{\quad 2}\text{ J/m}^3$$

$$20.3\text{ mJ/m}^3$$

11. Dielectric strength maximum possible electric field

$$E \quad \frac{V}{d} \quad d \quad \frac{V}{E}$$

$$\frac{5500}{1.6 \quad 10^7} \quad 3.4 \quad 10^{\quad 4}\text{ m}$$

$$C \quad \frac{k \,{}_0A}{d} \quad A \quad \frac{Cd}{k \,{}_0}$$

$$\frac{1.25 \quad 10^{\quad 9} \quad 3.4 \quad 10^{\quad 4}}{3.6 \quad 8.85 \quad 10^{\quad 12}}$$

$$1.3 \quad 10^{\quad 2}\text{ m}^2$$

$$0.013\text{ m}^2$$

12. Let C_P and C_S be the effective capacitance of parallel and series combination respectively.

For parallel combination,

$$U_P \quad 0.19\text{ J}$$

$$U_P \quad \frac{1}{2}C_PV^2$$

$$C_P \quad \frac{2U_P}{V^2} \quad \frac{2 \quad 0.1}{(2)^2} \quad 0.05\text{ F}$$

$$50\text{ mF}$$

For series combination,

$$U_S \quad 1.6 \quad 10^{\quad 2}\text{ J} \quad 0.016\text{ J}$$

$$U_S \quad \frac{1}{2}C_SV^2$$

$$C_S \quad \frac{2U_S}{V^2} \quad \frac{2 \quad 0.016}{(2)^2} \quad 0.008\text{ F}$$

$$8\text{ mF}$$

Now, $C_P \quad C_1 \quad C_2 \quad 5\text{ mF}$

or $C_2 \quad (5 \quad C_1)\text{ mF}$

and $\frac{1}{C_S} \quad \frac{1}{C_1} \quad \frac{1}{C_2} \quad \frac{1}{8}$

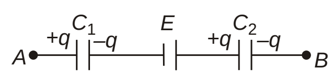
$$\frac{1}{C_1} \quad \frac{1}{S \quad C_1} \quad \frac{1}{8}$$

On solving,

$C_1 \quad 40\text{ mF}, C_2 \quad 10\text{ mF}$ or *vice-versa*.

13. In the given circuit,

$$V_A \quad V_B \quad \frac{q}{C_1} \quad E \quad \frac{q}{C_2} \quad 5$$



$$\frac{q}{10^{\quad 6}} \quad 10 \quad \frac{q}{2 \quad 10^{\quad 6}} \quad 5$$

$$q \quad 10 \quad 10^{\quad 6}\text{ C} \quad 10 \quad \text{C}$$

$$V_1 \quad \frac{q}{C_1} \quad 10\text{ V}, V_2 \quad \frac{q}{C_2} \quad 5\text{ V}$$

14. (a) In order to increase voltage range n times, n-capacitors must be connected in series.

Hence, to increase voltage range to 500V, 5 capacitors must be connected in series.

Now, effective capacitance of series combination,

$$C_S \quad C_n \quad \frac{10}{5} \quad 2\text{ pF}$$

Hence, no parallel grouping of such units is required.

Hence, a series grouping of 5 such capacitors will have effective capacitance 2 pF and can withstand 500 V.

(b) If n capacitors are connected in series and m such units are connected in parallel,

$$V_e \quad nV$$

$$C_e \quad \frac{mC}{n}$$

Here, $V \quad 100\text{ V}$

$$V_e \quad 300\text{ V}$$

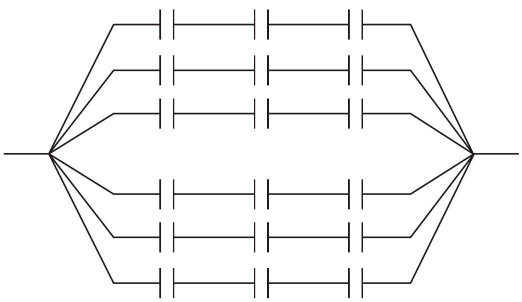
$$n \quad \frac{V_e}{V} \quad 3$$

$C \quad 10 \text{ pF}$

$C_e \quad 20 \text{ pF}$

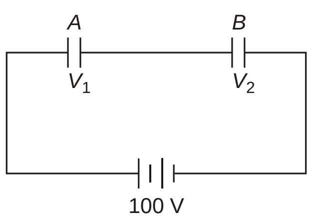
$$m \quad \frac{nC_e}{C} \quad \frac{3 \quad 20}{10} \quad 6$$

Hence, the required arrangement is shown in figure.



15. Case I.

$$V_1 \quad \frac{C_2}{C_1 \quad C_2} V \quad 60 \text{ V}$$



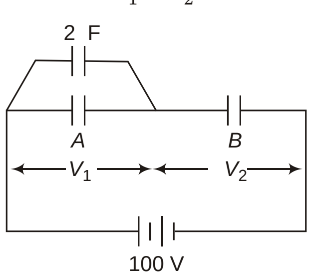
$$V_2 \quad \frac{C_1}{C_1 \quad C_2} V \quad 40 \text{ V}$$

$$\frac{C_1}{C_2} \quad \frac{2}{3}$$

$$C_2 \quad \frac{3}{2} C_1$$

Case II.

$$V_1 \quad \frac{C_2}{C_1 \quad C_2 \quad 2} \quad 10 \text{ V}$$



$$V_2 \quad \frac{C_1 \quad 2}{C_1 \quad C_2 \quad C} \quad 90 \text{ V}$$

$$\frac{C_1 \quad 2}{C_2} \quad \frac{90}{10} \quad 9$$

$$C_1 \quad 2 \quad 9C_2$$

$$C_1 \quad 2 \quad 9 \quad \frac{3}{2} C_1$$

$$\frac{25}{2} C_1 \quad 2 \quad C_1 \quad \frac{4}{25} \quad \text{F}$$

$$0.16 \quad \text{F}$$

$$C_2 \quad \frac{3}{2} C_1 \quad 0.24 \quad \text{F}$$

16. (a) $q \quad CV \quad 10 \quad 12 \quad 120 \quad \text{C}$

(b) $C \quad \frac{{}_0 A}{d}$

If separation is doubled, capacitance will become half. *i.e.,*

$$C \quad \frac{C}{2}$$

$$q \quad E \; V \quad \frac{C}{2} V \quad 60 \quad \text{C}$$

(c) $C \quad \frac{{}_0 A}{d} \quad \frac{{}_0 r^2}{d}$

If r is doubled, C will become four times, *i.e.*,

$$C \quad 4C$$

$$q \quad C \; V \quad 480 \quad \text{C}$$

17. Heat produced Energy stored in the capacitor

$$H \quad \frac{1}{2} CV^2 \quad \frac{1}{2} \quad 450 \quad 10^{\;6} \quad (295)^2$$

$$19.58 \text{ J}$$

18. (a) $C \quad \frac{{}_0 A}{d} \quad \frac{8.85 \quad 10^{\;12} \quad 2}{5 \quad 10^{\;3}}$

$$3.54 \quad 10^{\;6} \text{ F}$$

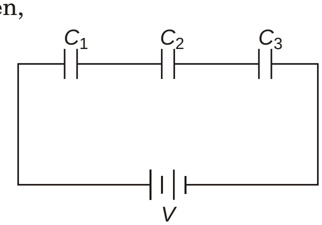
$$3.54 \quad \text{F}$$

(b) $q \quad CV \quad 3.54 \quad 10^{\;9} \quad 10000$

$$35.4 \quad 10^{\;6} \quad 35.4 \quad \text{C}$$

(c) $E \quad \frac{V}{d} \quad \frac{10000}{5 \quad 10^{\;3}} \quad 2 \quad 10^6 \text{ V/m}$

19. Given,



$$C_1 \quad 8.4 \quad \text{F}, C_2 \quad 8.2 \quad \text{F}$$

$$C_3 \quad 4.2 \quad \text{F}, V \quad 36 \text{ V}$$

(a) Effective capacitance,

$$\frac{1}{C_e} \quad \frac{1}{C_1} \quad \frac{1}{C_2} \quad \frac{1}{C_3}$$

$$\frac{1}{8.4} \quad \frac{1}{8.2} \quad \frac{1}{4.2} \qquad C_e \quad 2.09 \quad \text{F}$$

$$q \quad C_e V \quad 2.09 \quad 36 \quad 75.2 \quad \text{C}$$

As combination is series, charge on each capacitor is same, *i.e.*, 75.2 C.

(b) $U \quad \frac{1}{2} qV \quad \frac{1}{2} \quad 75.2 \quad 36 \quad 10^{\ 6}$

$$1.35 \quad 10^{\ 3} \text{ J} \quad 1.35 \text{ mJ}$$

(c) Common potential,

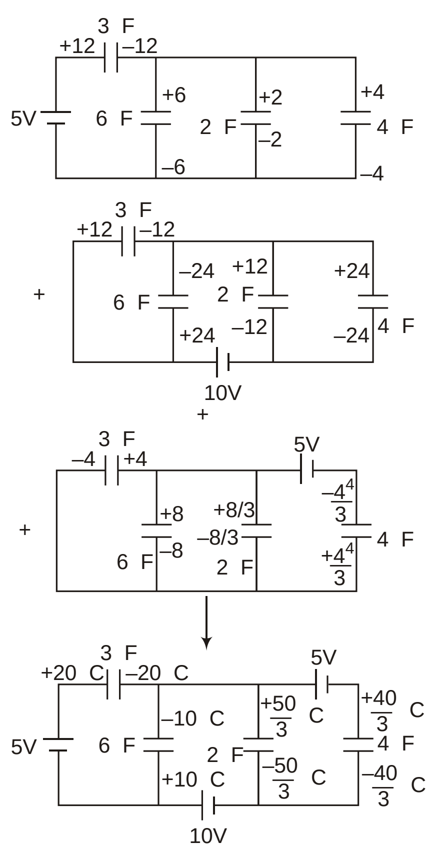
$$V \quad \frac{C_1V_1 \quad C_2V_2 \quad C_3V_3}{C_1 \quad C_2 \quad C_3} \quad 10.85 \text{ V}$$

(d) $U \quad \frac{1}{2}(C_1 \quad C_2 \quad C_3)V^2$

$$\frac{1}{2} \quad (8.4 \quad 8.2 \quad 4.2) \quad (10.85)^2 \quad 10^{\ 6}$$

$$1.22 \quad 10^{\ 3} \text{ J} \quad 1.22 \text{ mJ}$$

20. The Given circuit can be considered as the sum of three circuits as shown

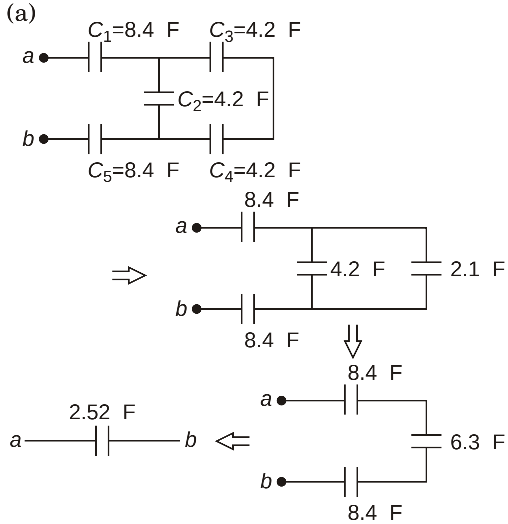


(Charge is shown in C).

Hence, charge on 6 F capacitor 10 C

and Charge on 4 F capacitor $\frac{40}{3}$ C

21. (a)



(b) Charge supplied by the source of emf

$$q \quad CV \quad 2.52 \quad 10^{\ 6} \quad 220$$

$$554.4 \quad \text{C}$$

$$q_1 \quad q_5 \quad q \quad 554.4 \quad \text{C}$$

$$q_2 \quad \frac{4.2}{4.2+2.1} q$$

$$\frac{4.2}{6.3} \quad 554.4 \quad \text{C} \quad 369.6 \quad \text{C}$$

and $q_3 \quad q_4 \quad \frac{2.1}{4.2+2.1} q \quad \frac{2.1}{6.3} \quad 554.4 \quad \text{C}$

$$184.8 \quad \text{C}$$

$$V_1 \quad \frac{q_1}{C_1} \quad \frac{554.4}{8.4} \quad 66 \text{ V} \quad V_5$$

$$V_2 \quad \frac{q_2}{C_2} \quad \frac{369.6}{4.2} \quad 88 \text{ V}$$

$$V_3 \quad V_4 \quad \frac{q_3}{C_3} \quad \frac{184.8}{4.2} \quad 44 \text{ V}$$

22. Let C_1 and C_2 be the capacitances of A and B respectively.

$$C_1 \quad \frac{k_1 \ _0 A_1}{d_1}, C_2 \quad \frac{k_1 \ _0 A_2}{d_2}$$

Now, $\quad V_1 \quad \frac{C_2}{C_1 \quad C_2} V$

$$\frac{C_2}{C_1 \quad C_2} \quad \frac{130}{230} \quad \frac{13}{23} \qquad \text{...(i)}$$

$$V_2 \quad \frac{C_1}{C_1 \quad C_2} V$$

$$\frac{C_1}{C_1 \quad C_2} \quad \frac{10}{23} \qquad \ldots\text{(ii)}$$

From Eqs. (i) and (ii),

$$\frac{C_1}{C_2} \quad \frac{10}{13}$$

If dielectric slab of C_1 is replaced by one for which k 5 then,

$$C_1 \quad \frac{5 \;{}_0 A_1}{d_1} \quad \frac{5}{2} C_1$$

$$\frac{V_2}{V_1} \quad \frac{C_1}{C_2} \quad \frac{5C_1}{2C_2} \quad \frac{50}{26}$$

$$V_2 \quad \frac{50}{26} V_1 \quad 230$$

Also,

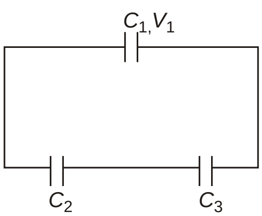
$$V_1 \quad V_2 \quad 230$$

$$V_1 \quad \frac{50}{26} V_1$$

$$V_1 \quad 78.68 \text{ V}$$

and $\quad V_2 \quad 151.32$ V

23. In this case



Common potential,

$$V \quad \frac{C_1 V_1}{C_1 \quad \dfrac{C_2 C_3}{C_2 \quad C_3}}$$

$$V \quad \frac{1 \quad 110}{1 \quad 1.2}$$

$$\frac{110}{2.2}$$

50 V

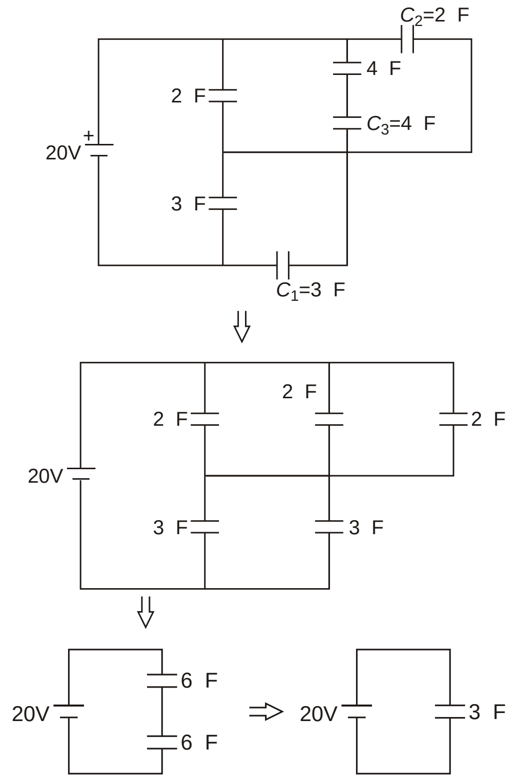
Charge flown through connecting wires,

$$\frac{C_2 C_3}{C_2 \quad C_3} V$$

1.2 50

60 C

24. (a) Hence, effective capacitance across the battery is 3 F.



(b) $q \quad CV$ 3 20 60 C

(c) Potential difference across C_1

$$V_1 \quad \frac{6}{6 \quad 6} \quad 20 \quad 10 \text{ V}$$

$$q_1 \quad C_1 V_1 \quad 3 \quad 10 \quad 30 \text{ C}$$

(d) Potential difference across C_2

$$V_2 \quad \frac{6}{6 \quad 6} \quad 20 \quad 10 \text{ V}$$

$$q_2 \quad C_2 V_2 \quad 2 \quad 10 \quad 20 \text{ C}$$

(e) Potential difference across C_3

$$V_3 \quad \frac{4}{4 \quad 4} \quad V_2 \quad 5 \text{ V}$$

$$q_3 \quad C_3 V_3 \quad 4 \quad 2 \quad 20 \text{ C}$$

25. (a) When switch S_2 is open, C_1 and C_3 are in series, C_2 and C_4 are in series their effective capacitances are in parallel with each other.

Hence,

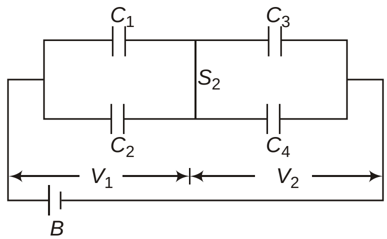
$$q_1 \quad q_3 \quad \frac{C_1 C_3}{C_1 \quad C_3} V$$

$$\frac{1 \quad 3}{1 \quad 3} \quad 12 \quad 9 \quad \text{C}$$

$$q_2 \quad q_4 \quad \frac{C_2 C_4}{C_2 \quad C_4}$$

$$\frac{2 \quad 4}{2 \quad 4} \quad 12 \quad 16 \quad \text{C}$$

(b) When S_2 is closed, C_1 is in parallel with C_2 and C_3 is in parallel with C_4.



Therefore,

$$V_1 \quad V_2 \quad \frac{C_3 \quad C_4}{C_1 \quad C_2 \quad C_3 \quad C_4} \text{V}$$

$$\frac{7}{10} \quad 12 \quad 8.4 \text{ V}$$

$$V_3 \quad V_4 \quad \frac{C_1 \quad C_2}{C_1 \quad C_2 \quad C_3 \quad C_4} \text{V}$$

$$\frac{3}{10} \quad 12 \quad 3.6 \text{ V}$$

$$q_1 \quad C_1 V_1 \quad 1 \quad 8.4 \quad 8.4 \quad \text{C}$$

$$q_2 \quad C_2 q_2 \quad 2 \quad 8.4 \quad 16.8 \quad \text{C}$$

$$q_3 \quad C_3 V_3 \quad 3 \quad 3.6 \quad 10.8 \quad \text{C}$$

$$q_4 \quad C_4 V_4 \quad 4 \quad 3.6 \quad 14.4 \quad \text{C}$$

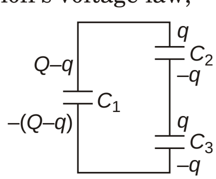
26. Initial charge on C_1

$$Q \quad C_1 V_0$$

Now, if switch S is thrown to right.

Let charge q flows from C_1 to C_2 and C_3.

By Kirchhoff's voltage law,



$$\frac{q}{C_2} \quad \frac{q}{C_3} \quad \frac{Q \quad q}{C_1} \quad 0$$

$$q \quad \frac{1}{C_1} \quad \frac{1}{C_2} \quad \frac{1}{C_3} \quad \frac{Q}{C_1}$$

$$q \quad \frac{C_2 C_3 Q}{C_1 C_2 \quad C_2 C_3 \quad C_3 C_1}$$

$$\frac{C_1 C_2 C_3 V}{C_1 C_2 \quad C_2 C_3 \quad C_3 C_1}$$

$$q_1 \quad Q \quad q \quad \frac{C_1^2 (C_2 \quad C_3) V}{C_1 C_2 \quad C_2 C_3 \quad C_3 C_1}$$

$$q_2 \quad q_3 \quad q \quad \frac{C_1 C_2 C_3 V}{C_1 C_2 \quad C_2 C_3 \quad C_3 C_1}$$

27. $C \quad \frac{{}_0 A}{d}, q \quad CV \quad \frac{{}_0 AV}{d}$

(a) $C \quad \frac{{}_0 A}{2d}, q \quad q$

(As battery is disconnected)

$$V \quad \frac{q}{C} \quad 2 \text{ V}$$

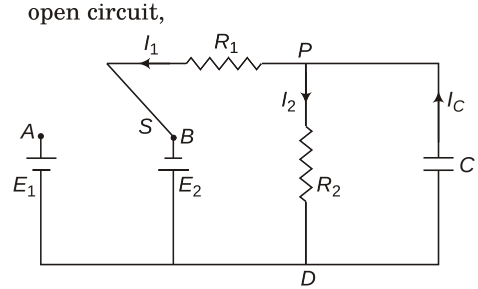
(b) $V_i \quad \frac{1}{2C} V^2 \quad \frac{{}_0 AV^2}{2d}$

$$U_f \quad \frac{1}{2} C \quad V^{\ 2} \quad \frac{1}{2} \frac{{}_0 A}{2d} (2V)^2$$

$$\frac{{}_0 AV^2}{d}$$

(c) $W \quad U_f \quad U_i \quad \frac{{}_0 AV^2}{2d}$

28. In the steady state, capacitor behaves as open circuit,



$$I_1 \quad I_2 \quad \frac{E_1}{R_1 \quad R_2} \quad 1 \text{ mA and } I_C \quad 0$$

$$V_{PD} \quad I_2 R_2 \quad \frac{E_1 R_2}{R_1 \quad R_2}$$

When switch is shifted to B,

At this instant,

$$V_{PD} \quad \frac{E_1 R_2}{R_1 \quad R_2}$$

$$I_2 \quad \frac{V_{PD}}{R_2} \quad \frac{E_1}{R_1 \quad R_2} \quad 1 \text{ mA}$$

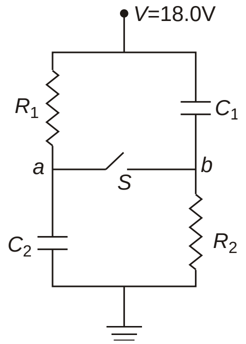
$$I_1 \quad \frac{E_2 \quad V_{PD}}{R_1} \quad \frac{E_2 \quad \dfrac{E_1 R_2}{R_1 \quad R_2}}{R_1}$$

$$\frac{(R_1 \quad R_2) E_2 \quad E_1 R_2}{R_1}$$

2 mA

$$I_C \quad I_1 \quad I_2 \quad 1 \quad 2 \quad 3 \text{ mA}$$

29. (a) When switch S is open, no current pass through the circuit,



Hence,

$$V_b \quad 0 \quad 0$$

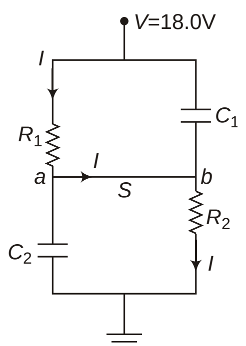
$$V_b \quad 0$$

$$18 \quad V_a \quad 0 \qquad V_a \quad 18 \text{ V}$$

$$V_a \quad V_b \quad 18 \text{ V}$$

(b) a is at higher potential.

(c) When switch S is closed,



$$I \quad \frac{V}{R_1 \quad R_2} \quad 2 \text{ A}$$

$$V_b \quad 0 \quad IR_2 \quad 2 \quad 3$$

$$V_b \quad 6 \text{ V}$$

(d) $q_1 \quad C_1 V \quad 6 \quad 18 \quad 108 \quad$ C

$$q_2 \quad C_2 V \quad 3 \quad 18 \quad 54 \quad \text{C}$$

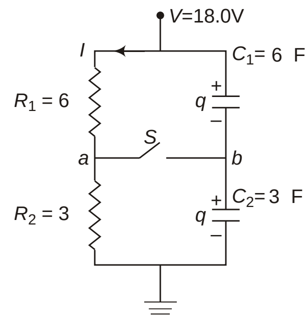
After closing the switch,

$$q_1 \quad C_1 V_1 \quad 6 \quad 12 \quad 72 \quad \text{C}$$

$$q_2 \quad C_2 V_2 \quad 3 \quad 6 \quad 18 \quad \text{C}$$

$$q_1 \quad 18 \quad \text{C}, \quad q_2 \quad 36 \quad \text{C}$$

30. (a) $I \quad \dfrac{V}{R_1 \quad R_2} \quad \dfrac{18}{9} \quad 2 \text{ A}$



$$q \quad \frac{C_1 C_2}{C_1 \quad C_2} V \quad 2 \quad 18 \quad 36 \quad \text{C}$$

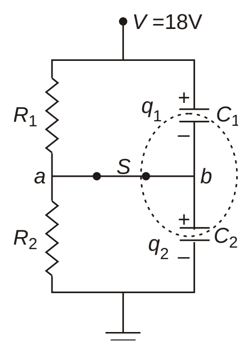
Now, $\quad V_a \quad 0 \quad IR_2 \qquad V_a \quad 6 \text{ V}$

and $\quad V_b \quad 0 \quad \dfrac{q}{C_2} \quad \dfrac{36}{3} \quad 12 \text{ V}$

$$V_a \quad V_b \qquad 6 \text{ V}$$

(b) b is at higher potential.

(c) When switch S is closed, in steady state,



$$V_a \quad v_b \quad 6 \text{ V}$$

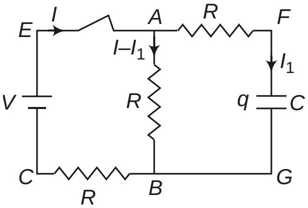
$$q_1 \quad C_1 V_1 \quad 6 \quad 12 \quad 72 \quad \text{C}$$

$$q_2 \quad C_2 V_2 \quad 3 \quad 6 \quad 18 \quad \text{C}$$

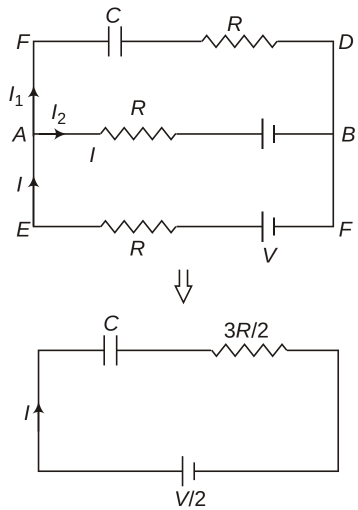
Charge flown through S

$$q_1 \quad q_2 \quad 72 \quad 18 \quad 54 \quad \text{C}$$

31.



(a) Consider the circuit as combination of two cells of emf E and OV.



$$E_e \quad \frac{E_1R_2 \quad E_2R_1}{R_1 \quad R_2} \quad \frac{V}{2}$$

$$R_e \quad R \quad \frac{R}{2} \quad \frac{3R}{2}$$

$$q \quad q_0(1 \quad e^{\ t/\ })$$

$$q_0 \quad \frac{CE}{2}$$

$$\frac{3RC}{2}$$

$$q \quad \frac{CE}{2}(1 \quad e^{\ 2t/3RC})$$

(b) $I_1 \quad \frac{dq}{dt} \quad \frac{E}{3R}e^{\ 2t/3RC}$

In loop $EDBA$ $\frac{q}{C} \quad I_1R \quad I_2R \quad 0$

$$I_2 \quad \frac{q}{RC} \quad I_1$$

$$\frac{E}{2R}(1 \quad e^{\ 2t/3RC}) \quad \frac{E}{3R}e^{\ 2t/3RC}$$

$$\frac{E}{6R}(3 \quad e^{\ 2t/3RC})$$

Objective Questions (Level 1)

1. $F \quad \frac{Q^2}{2 \ _0A}$ is independent of d.

2. $C \quad \frac{q}{V}$

On connecting the plates V becomes zero.

3. The system can assumed to a parallel combination of two spherical conductors.

$$C \quad C_1 \quad C_2 \quad 4 \ _0a \quad 4 \ _0b$$
$$4 \ _0(a \quad b)$$

4. $V \quad \frac{q}{C}$

On connecting in series

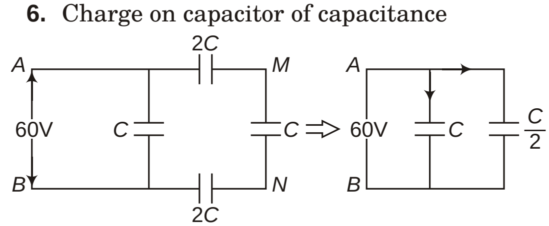
$q \quad q$ Charge on any capacitor

$$C \quad \frac{C}{n}$$

$$V \quad \frac{nq}{C} \quad nV$$

5. Incorrect diagram.

6. Charge on capacitor of capacitance

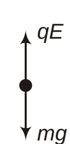


$$\frac{C}{2} \quad \frac{C}{2}V \quad 30\text{ C}$$

$$V_{MN} \quad \frac{q}{C} \quad 30\text{ V}$$

7. For equilibrium,

$$qE \quad mg$$
$$q\frac{V}{d} \quad \frac{4}{3} \quad r^3 \ g$$
$$V \quad \frac{r^3}{q}$$

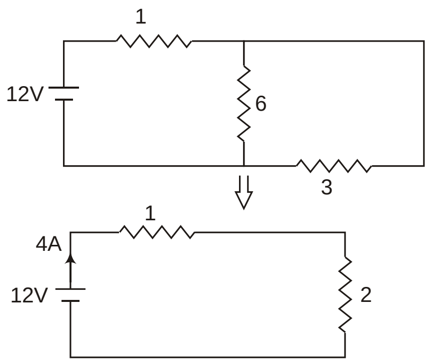


$$\frac{V_2}{V_1} \quad \frac{r_2}{r_1}^{3} \quad \frac{q_1}{q_2}$$

$$V_2 \quad 4\text{ V}$$

8. Electric field between the plates is uniform but in all other regions it is zero.

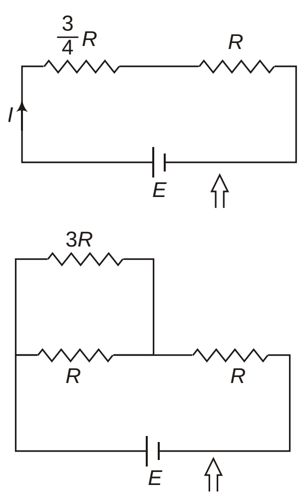
9. Initially the capacitor offers zero resistance.

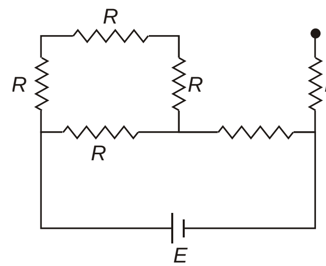


$$i \quad \frac{12}{1 \quad 2} \quad 4\text{ A}$$

10. $q \quad CV \quad CE$

11. In the steady state, capacitor behaves as open circuit. the equivalent diagram is given by





$$I \quad \frac{E}{R \quad \frac{3}{4}R} \quad \frac{4E}{7R}$$

But potential difference across capacitor,

$$V \quad IR$$

$$10 \quad \frac{4E}{7R}R$$

$$E \quad 17.5\text{ V}$$

12. As all the capacitors are connected in series potential difference across each capacitor is

$$V \quad \frac{E}{4} \quad \frac{10}{4} \quad 2.5\text{ V}$$

$$V_A \quad V_N \quad 3\text{V} \quad 7.5\text{ V}$$

$$V_A \quad 7.5\text{ V}$$

$$V_N \quad V_B \quad 2.5\text{ V}$$

$$V_B \quad 2.5\text{ V}$$

13. Heat produced Loss of energy

$$\frac{C_1C_2}{2(C_1 \quad C_2)}(V_1 \quad V_2)^2$$

$$\frac{2 \quad 10^{6} \quad 2 \quad 10^{6}}{2(2 \quad 2) \quad 10^{6}}(100 \quad 0)$$

$$5 \quad 10^{3}\text{ J} \quad 5\text{ mJ}$$

14.

$$q \quad q_0 e^{t/}$$

$$I \quad I_0 e^{t/}$$

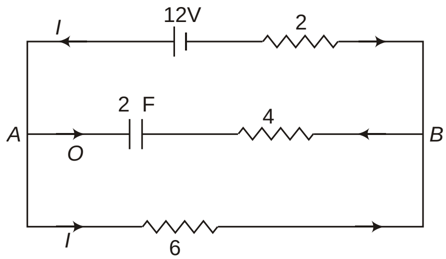
$$P \quad I^2R \quad I_0^2 e^{2t/} \quad R \quad P_0 e^{2t/}$$

$$\overline{2}$$

15. Common potential $\frac{C_1V_1 \quad C_2V_2}{C_1 \quad C_2} \quad \frac{E}{2}$

16. $V_A \quad V_B \quad 6 \quad 3 \quad 2 \quad \frac{9}{1} \quad 3 \quad 3 \quad 12\text{ V}$

17. In the steady state, current through battery



$$I \quad \frac{12}{6 \quad 2} \quad \frac{3}{2} \text{A}$$

Potential difference across the capacitor,

$$V_{AB} \quad 6 \quad \frac{3}{2} \quad 9 \text{ N}$$

$$q \quad CV_{AB} \quad 2 \quad 9 \quad 18 \quad \text{C}$$

18. C_2 and C_3 are in parallel

Hence, $V_2 \quad V_3$

Again Kirchhoff's junction rule

$$q_1 \quad q_2 \quad q_3 \quad 0$$

$$q_1 \quad q_2 \quad q_3$$

19. For the motion of electron

$$R \quad \frac{mu^2 \sin 2}{eE} \quad l \qquad \text{...(i)}$$

and $$H \quad \frac{mu^2 \sin^2}{2eE} \quad d \qquad \text{...(ii)}$$

Dividing Eq. (ii) by Eq. (i),

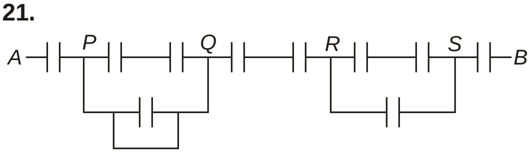
$$\tan \quad \frac{4d}{l}$$

20. $V \quad Ed \quad d \quad \frac{V}{E} \quad \frac{2V\ _0}{6}$

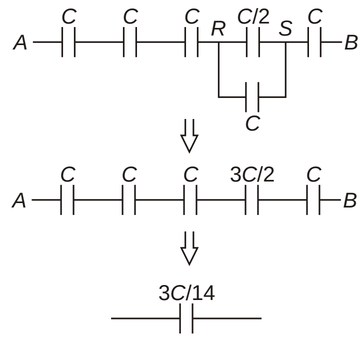
$$\frac{2 \quad 5 \quad 8.85 \quad 10^{\ 12}}{10^{\ 7}}$$

$$8.85 \quad 10^{\ 4} \quad 0.88 \text{ mm}$$

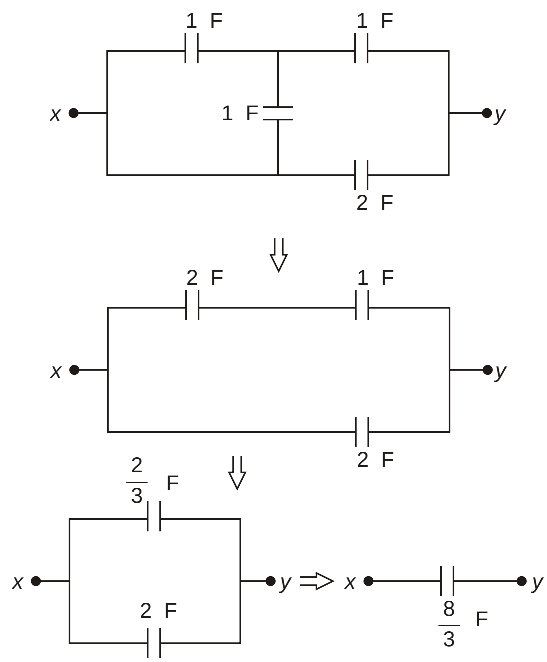
21.



P and Q are at same potential, hence capacitor connected between them have no effect on equivalent capacitance.



22.



23. $C_1 \quad \frac{k_1\ _0A}{2d} \quad \frac{k_2\ _0A}{2d}$

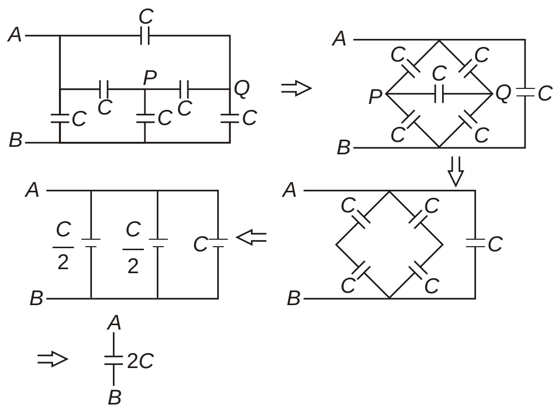
$$\frac{(k_1 \quad k_2)\ _0A}{2d} \qquad \text{(Parallel grouping)}$$

$$\frac{1}{C_2} \quad \frac{d}{2k_1\ _0A} \quad \frac{d}{2k_2\ _0A} \text{(Series grouping)}$$

$$C_2 \quad \frac{2k_1k_2}{k_1 \quad k_2} \frac{_0A}{d}$$

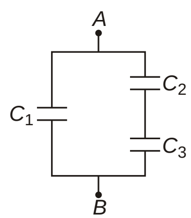
$$\frac{C_1}{C_2} \quad \frac{(k_1 \quad k_2)^2}{4k_1k_2} \quad \frac{(2 \quad 3)^2}{4 \quad 2 \quad 3} \quad \frac{25}{24}$$

24.



25. Cases (a), (b) and (c) are balanced Wheatstone bridge.

26. The given arrangement can be considered as the combination of three capacitors as shown in figure.



Hence, $\qquad C_1 \quad \frac{k_1 \; {}_0A}{2d}$

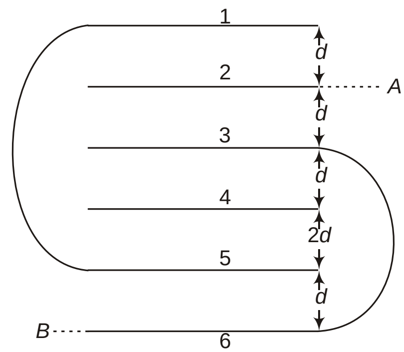
$$C_2 \quad \frac{k_2 \; {}_0 \frac{A}{2}}{d/2} \quad \frac{k_2 \; {}_0A}{d}$$

$$C_3 \quad \frac{k_3 \; {}_0 \frac{A}{2}}{d/2} \quad \frac{k_3 \; {}_0A}{d}$$

Effective capacitance,

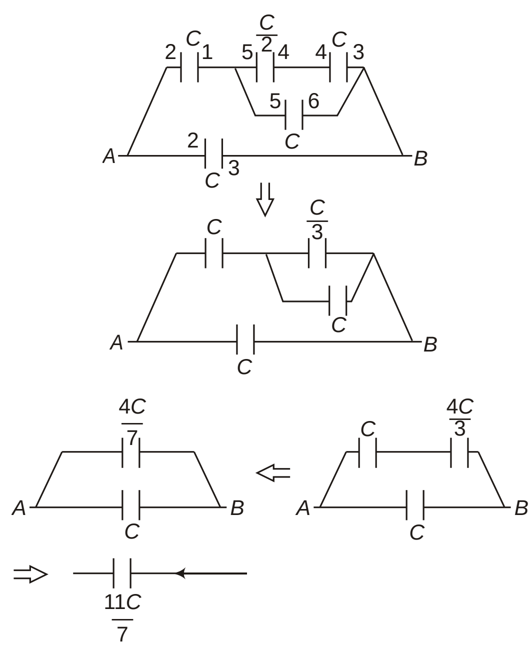
$$C \quad C_1 \quad \frac{C_2C_3}{C_1 \quad C_2} \quad \frac{{}_0A}{d} \quad \frac{k_1}{2} \quad \frac{k_2k_3}{k_2 \quad k_3}$$

27. Here, plate 1 is connected to plate 5 and plate 3 is connected to plate 6.



Capacitance of all other capacitance is same, i.e., $C \quad \frac{{}_0A}{d}$ but that of formed by plates 4 and 5 is $\frac{C}{2}$ as distance between these two plates is $2d$.

The equivalent circuit is shown in figure.



$$C_{eq} \quad \frac{11}{7}C \quad \frac{11 \; {}_0A}{7d} \quad \frac{11}{7} \quad 7 \;\; \text{F} \quad 11 \;\; \text{F}$$

JEE Corner

Assertion and Reason

1. Capacitance $\frac{q}{V}$ is constant for a given capacitor.
2. Reason correctly explains the assertion.
3. $U \quad \frac{1}{2} qV, W \quad qV$
4. For discharging of capacitor

$$q \quad q_0 e^{\quad t/}$$
$$\frac{dq}{dt} \quad \frac{q_0}{\quad} e^{\quad t/}$$
$$\frac{q_0}{RC} e^{\quad t/}$$

Hence, more is the resistance, less will be the slope.

5. Charge on two capacitors will be same only if both the capacitors are initially uncharged.
6. As potential difference across both the capacitors is same, charge will not flow through the switch.
7. C and R_2 are shorted.
8. Time constant for the circuit,

$$RC$$

9. In series, charge remains same

and $\quad U \quad \frac{q^2}{2C} \quad U \quad \frac{1}{C}$

10. In series charge remains same

$$V_1 \quad \frac{q}{C_1}, V_2 \quad \frac{q}{C_2}$$

On inserting dielectric slab between the plates of the capacitor, C_2 increases and hence, V_2 decreases. So more charge flows to C_2.

Objective Questions (Level 2)

1. $$E \quad \begin{cases} \frac{4Q}{\ _0 A} \hat{\mathbf{i}} & \text{for } x \quad d \\ \frac{2Q}{\ _0 A} \hat{\mathbf{i}} & \text{for } d \quad x \quad 2d \\ \frac{4Q}{\ _0 A} \hat{\mathbf{i}} & \text{for } 2d \quad x \quad 3d \end{cases}$$

2. Let E_0 external electric field

and E electric field due to sheet

$$E_1 \quad E_0 \quad E \quad 8$$
$$E_2 \quad E_0 \quad E \quad 12$$
$$E \quad 2\,\text{V/m} \quad \frac{\quad}{2 \ _0} \quad 2$$
$$4 \ _0$$

3. When the switch is just closed, capacitors behave like short circuit, no current pass through either 6 or 5 resistor.
4. For charging of capacitor

$$I \quad I_0 e^{\quad t/}$$
$$\ln I \quad \log I_0 \quad \frac{t}{\quad}$$
$$\ln I \quad \ln \frac{V}{R} \quad \frac{t}{RC}$$

But, $I_{01} \quad I_{02}$

$$\frac{V_1}{R_1} \quad \frac{V_2}{R_2}$$

Also, $\frac{1}{R_1 C_1} \quad \frac{1}{R_2 C_2}$

$$R_2 C_2 \quad R_1 C_1$$

As only two parameters can be different,

$$C_1 \quad C_2$$
$$R_2 \quad R_1$$

and $\quad V_2 \quad V_1$

5. Charge on capacitor at the given instant.

$$q \quad \frac{q_0}{2} \quad \frac{CE}{2}$$

Heat produced Energy stored in capacitor

$$\frac{q^2}{2C} \quad \frac{CE^2}{8}$$

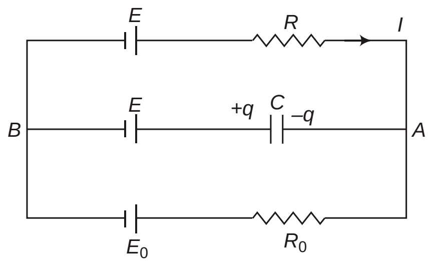
Heat liberated inside the battery,

$$\frac{r}{r \quad 2r} \quad \text{Total heat produced}$$
$$\frac{CE^2}{24}$$

6. Capacitor is not inside any loop.

7. $I \quad \dfrac{E \quad E_0}{R \quad R_0}$

$$V_{BA} \quad \frac{q}{C} \quad E$$



$$E \quad IR \quad \frac{q}{C} \quad E$$

$$q \quad IRC \quad \frac{(E \quad E_0)\,RC}{R \quad R_0}$$

8. $C \quad \dfrac{C_1 C_2}{C_1 \quad C_2}$

$$C_1 \quad C_2 \quad \frac{{}_0A}{d}$$

$$C \quad \frac{{}_0A}{2d}$$

$$C_1 \quad \frac{2\ {}_0A}{d}, C_2 \quad \frac{{}_0A}{2d}$$

$$C \quad \frac{C_1\, C_2}{C_1 \quad C_2} \quad \frac{2\ {}_0A}{5d} \quad C$$

9. $$R_e \quad \frac{R}{3}$$

$$R_e C \quad \frac{RC}{3}$$

$$q \quad q_0(1 \quad e^{\ t/\ })$$

$$CV(1 \quad e^{\ 3t/RC})$$

10. Energy loss $\dfrac{C_1 C_2}{2(C_1 \quad C_2)}(V_1 \quad V_2)^2$

$$\frac{2 \quad 4}{2 \quad (2 \quad 14)}(100 \quad 50)^2 \quad 10^{\ 6}$$

$$1.7 \quad 10^{\ 3}\ \text{J}$$

11. $q \quad q_0 e^{\ t/RC}$

$$I \quad \frac{dq}{dt} \quad \frac{q_0}{RC} e^{\ t/RC}$$

at $t \quad 0$

$$I \quad \frac{q_0}{RC} \quad 10$$

$$V_0 \quad \frac{q_0}{C} \quad 10 \quad R \quad 10 \quad 10 \quad 100\,\text{V}$$

12. $V_A \quad V_B$

ie, $V_A \quad V_P \quad V_P \quad V_B \qquad [V_P \quad 0]$

$$\frac{q}{C_{123}} \quad \frac{q}{C_n}$$

$$C_n \quad C_{123}$$

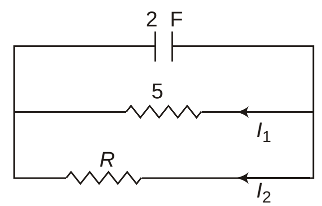
$$\frac{1}{C_n} \quad \frac{1}{C_1} \quad \frac{1}{C_2} \quad \frac{1}{C_3}$$

13. When connected with reverse polarity

$$H \quad \frac{C_1 C_2}{2(C_1 \quad C_2)}(V_1 \quad V_2)^2$$

$$\frac{C \quad 2C}{2(C \quad 2C)} \quad (V \quad 4V)^2 \quad \frac{25}{3}CV^2$$

14. $\dfrac{H_1}{H_2} \quad \dfrac{R_2}{R_1} \quad \dfrac{R}{S}$



Also, $H_1 \quad H_2 \quad \dfrac{1}{2}CV^2 \quad \dfrac{1}{2} \quad 2 \quad 10^{\ 6} \quad (5)^2$

$$H_1 \quad H_2 \quad 25 \quad \text{J}$$

$$H_2 \quad 25 \quad 10 \quad 15 \quad \text{J}$$

$$\frac{10}{15} \quad \frac{R}{5} \quad R \quad \frac{10}{3}$$

15. When current in the resistor is 1 A.

$$IR \quad \frac{q}{C} \quad E$$

$$1 \quad 5 \quad \frac{q}{2} \quad 10$$

$$q \quad 10 \quad \text{C}$$

When the switch is shifted to position 2. In steady state, charge on capacitor

$$q \quad 5 \quad 2 \quad 10 \quad \text{C}$$

but with opposite polarity.

Total charge flown through 5 V battery,

$$q \quad q \quad 20 \quad \text{C}$$

Work done by the battery $\quad 20 \quad 5$

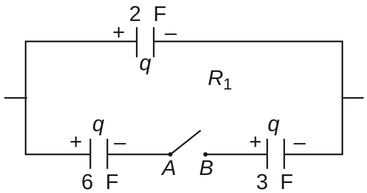
$$100 \quad \text{J}$$

Heat produced $\quad W \quad U$

But, $\quad U \quad 0$

$$H \quad W \quad 100 \quad \text{J}$$

16. $V_A \quad V_B \quad \frac{q}{6} \quad \frac{q}{2} \quad \frac{q}{3} \quad 0$



Hence, no charge will flow from A to B.

17. As potential difference across both the capacitors is same, they are in parallel.

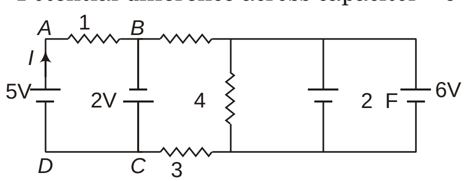
Hence, effective capacitance,

$$C \quad \frac{2 \;_0A}{d}$$

$$U \quad \frac{1}{2}CV^2 \quad \frac{_0A}{d}V^2$$

18. Rate of charging decreases as it just charged.

19. Potential difference across capacitor 6 V



$$q \quad CV \quad 2 \quad 6 \quad 12 \quad C$$

In loop $ABCD$,

$$I \quad 1 \quad 2 \quad 5 \quad 0 \qquad I \quad 7\text{ A}$$

20. While charging

$$R_e \quad R \qquad RC$$

While discharging

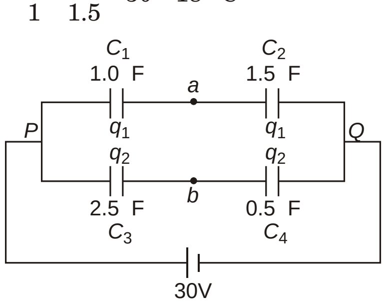
$$R_e \quad 2R \qquad 2RC$$

21. Common potential,

$$V \quad \frac{C_2V_2 \quad C_1V_1}{C_1 \quad C_2} \quad \frac{3 \quad 100 \quad 1 \quad 100}{1 \quad 3}$$

$$25\text{ V}$$

22. $q_1 \quad \frac{1 \quad 1.5}{1 \quad 1.5} \quad 30 \quad 18 \quad C$



$$q_2 \quad \frac{2.5 \quad 0.5}{2.5 \quad 0.5} \quad 30$$

$$12.5 \quad C$$

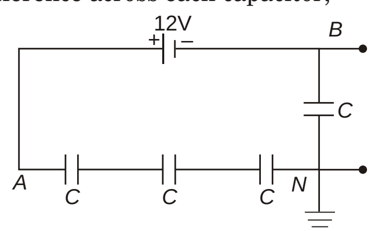
$$V_p \quad V_a \quad \frac{q_1}{C_1} \quad 18\text{ V}$$

$$V_p \quad V_b \quad \frac{q_2}{C_3}$$

$$\frac{12.5}{2.5} \quad 5\text{ V}$$

$$V_b \quad V_a \quad 13\text{ V}$$

23. As all the capacitors are identical, potential difference across each capacitor,



$$V \quad \frac{E}{4} \quad 3\text{ V}$$

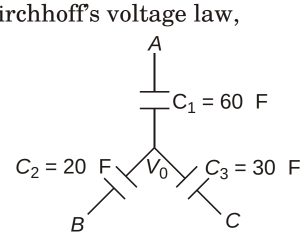
$$V_N \quad V_B \quad 3\text{ V}$$

$$V_B \quad 3\text{ V}$$

$$V_A \quad V_B \quad 12\text{ V}$$

$$V_A \quad 9\text{ V}$$

24. By Kirchhoff's voltage law,



$$q_1 \quad q_2 \quad q_3 \quad 0$$

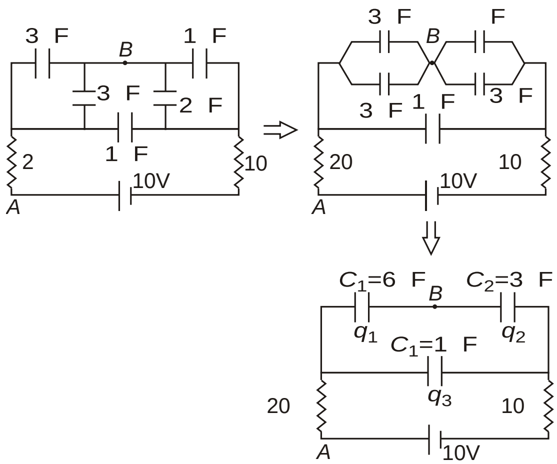
$$C_1(C_A \quad V_0) \quad C_2(V_B \quad V_0) \quad C_3(V_C \quad V_0) \quad 0$$

$$V_0 \quad \frac{C_1V_A \quad C_2V_B \quad C_3V_C}{C_1 \quad C_2 \quad C_3}$$

$$V_0 \quad \frac{60 \quad 6 \quad 2 \quad 20 \quad 3 \quad 30}{60 \quad 20 \quad 30}$$

$$\frac{49}{11}\text{ V}$$

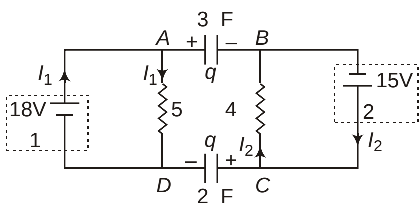
25. In the steady state, there will be no current in the circuit.



$$V_1 \quad \frac{C_2}{C_1 \quad C_2} V \quad \frac{3}{3 \quad 6} 10 \quad \frac{10}{3} \text{ V}$$

26. $I_1 \quad \frac{E_1}{R_1 \quad r_1} \quad \frac{18}{5 \quad 1} \quad 3 \text{ A}$

$$I_2 \quad \frac{E_2}{R_2 \quad r_2} \quad \frac{15}{4 \quad 2} \quad 2.5 \text{ A}$$



In loop $ABCD$,

$$\frac{q}{3} \quad I_2R_2 \quad \frac{q}{2} \quad I_1R_1 \quad 0$$

$$\frac{5q}{6} \quad 3 \quad 5 \quad 2.5 \quad 4 \quad q \quad 30 \text{ C}$$

27. During discharging

$$q \quad q_0 \, e^{\ t/}$$

$$q_0 \quad CE \quad 10 \text{ C}$$

at t 12 s,

$$q \quad 10e^{\ 12/6} \quad 10e^{\ 2}$$

$$(0.37)^2 10 \text{ C}$$

28. $q \quad \frac{C_1C_2}{C_1 \quad C_2}(E_1 \quad E_2)$

$$V_{ap} \quad \frac{q}{C_2} \quad \frac{C_1}{C_1 \quad C_2}(E_1 \quad E_2)$$

$$\frac{E_1 \quad E_2}{C_1 \quad C_2} C_1$$

29. $H \quad \frac{C_1C_2}{2(C_1 \quad C_2)}(V_1 \quad V_2)^2$ is independent of resistance.

30. Immediately after switch is closed, capacitor behaves like short circuit.

31. $i_1 \quad \frac{V}{2R} e^{\ t/RC}, i_2 \quad \frac{V}{R} e^{\ t/RC}$

$$\frac{i_1}{i_2} \quad \frac{1}{2} e^{\frac{5t}{6RC}}$$

Increases with time.

32. $R \quad \frac{d}{A} \quad \frac{d}{A}$

$$C \quad \frac{k \ _0 A}{d}$$

$$RC \quad \frac{d}{A} \quad \frac{k \ _0 A}{d}$$

$$\frac{0}{6} \quad \frac{8.85 \quad 10^{\ 12}}{7.4 \quad 10^{\ 12}} \quad 6 \text{ s}$$

33. $i \quad i_0 e^{\ t/}$

$$\frac{i_0}{2} \quad i_0 e^{\frac{\ln 4}{RC}}$$

$$\frac{\ln 4}{RC} \quad \ln 2$$

$$\ln 4 \quad \ln 2^{RC}$$

$$RC \quad 2$$

$$R \quad \frac{2}{C} \quad \frac{2}{0.5} \quad 4$$

34. Potential difference across each capacitor is equal, hence they are in parallel,

charge on each capacitor

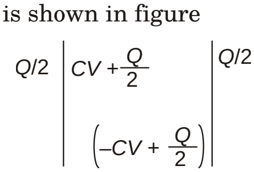
$$q \quad C_e V \quad 2 \quad 10 \quad 20 \text{ C}$$

As plate C contributed to two capacitors,

charge on plate,

$$C \quad 2q \qquad 40 \text{ C}$$

35. Charge distribution on the plates of the capacitor is shown in figure

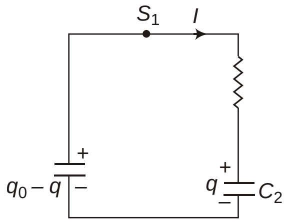


$$V \quad \frac{Q}{C} \quad \frac{CV \quad \frac{Q}{2}}{C}$$

$$V \quad \frac{Q}{2C}$$

36. Let q be the charge on C_2 (or charge flown through the switches at any instant of time)

By Kirchhoff's law



$$IR \quad \frac{q}{C_2} \quad \frac{q_0 \quad q}{C_1} \quad 0$$

$$\frac{dq}{dt} \quad \frac{C_2 q_0 \quad (C_1 \quad C_2) q}{C_1 C_2 R}$$

$$\frac{dq}{C_2 q_0 \quad (C_1 \quad C_2) q}\Big|_0^q \quad \frac{dt}{C_1 C_2 R}\Big|_0^t$$

$$\frac{1}{C_1 \quad C_2} \ln |C_2 q_0 \quad (C_1 \quad C_2) q|_0^q$$

$$\frac{1}{C_1 C_2 R} t$$

$$q \quad \frac{C_2 q_0}{C_1 \quad C_2} \quad 1 \quad e^{\frac{t}{}}$$

$$\frac{C_1 \quad C_2}{C_1 C_2 R}$$

or $$q \quad \frac{C}{C_1} q_0 \quad 1 \quad e^{\frac{t}{RC}}$$

where, $$C \quad \frac{C_1 C_2}{C_1 \quad C_2}$$

37. $$H \quad \frac{C_1 C_2}{2(C_1 \quad C_2)} (V_1 \quad V_2)^2$$

$$\frac{C_1 C_2}{2(C_1 \quad C_2)} \quad \frac{q_0}{C_1}^{\;2}$$

$$\frac{C_2 q_0^2}{2C_1 (C_1 \quad C_2)} \quad \frac{C\, q_0^2}{2C_1^2}$$

38. Electric field in the gap will remain same.

39. Electric field inside the dielectric slab

$$E \quad \frac{E}{k} \quad \frac{V}{kd}.$$

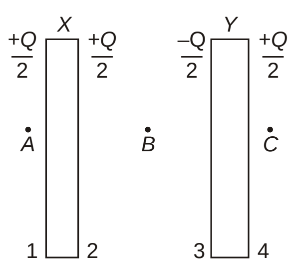
More Than One Correct Options

1. Charge distribution is shown in figure

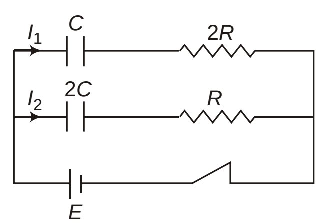
$$E_B \quad E_1 \quad E_2 \quad E_3 \quad E_4$$

$$\frac{Q}{4 \;_0 A} \quad \frac{Q}{4 \;_0 A} \quad \frac{Q}{4 \;_0 A} \quad \frac{Q}{4 \;_0 A}$$

$$\frac{Q}{2 \;_0 A}$$



$|E_A| \quad |E_C| \quad |E_1 \quad E_2 \quad E_3 \quad E_4|$ but E_A and E_C have opposite direction.



$$q_2 \quad 2CE \quad 1 \quad e^{\frac{t}{RC}}$$

$$\frac{dq_1}{dt} \quad \frac{E}{R} e^{\frac{t}{RC}}$$

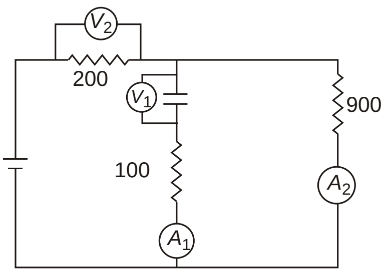
$$\frac{dq_2}{dt} \quad \frac{2E}{R} e^{\frac{t}{2RC}}$$

$$\frac{q_1}{q_2} \quad \frac{1}{2} \quad \frac{q_{0_1}}{q_{0_2}} \quad \frac{1}{2}$$

$$_1 \quad _2 \quad RC$$

2. $$q_1 \quad CE \quad 1 \quad e^{\frac{t}{RC}}$$

3. $$V_1 \quad \frac{q}{C} \quad \frac{4 \quad 10^{\;3}}{100 \quad 10^{\;6}} \quad 40\text{V}$$



$$I_1 \quad 0$$

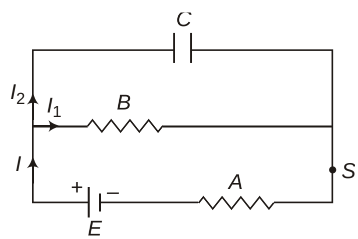
$$I_2 \quad \frac{V_1}{900} \quad \frac{40}{900} \quad \frac{2}{45}\text{ A}$$

$$V_2 \quad I_2 \quad 200 \quad \frac{2}{45} \quad 200 \quad \frac{80}{9}\text{ V}$$

$$E \quad V_1 \quad V_2 \quad 40 \quad \frac{80}{9}$$

$$\frac{440}{9}\text{ V}$$

4. Initially $I_1 \quad 0, I_2 \quad I \quad \frac{E}{R}$



As the capacitor starts charging,

I_2 decreases and I_1 increases,

In the steady state

$$I_1 \quad I \quad \frac{E}{R}, I_2 \quad 0$$

At any instant

$$P_1 \quad I_1^2R, P_2 \quad I_2^2R$$

Steady state potential difference across the capacitor,

$$V \quad \frac{E}{2}$$

$$U \quad \frac{1}{2}CV^2 \quad \frac{CE^2}{8}$$

5. $F \quad \frac{Q^2}{2 \ _0A}$ independent of d.

$E \quad \frac{Q}{_0A}$ independent of d.

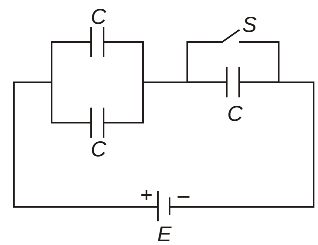
$$U \quad \frac{Q^2}{2C} \quad \frac{Q^2d}{2 \ _0A}$$

$$U \quad d$$

$$V \quad \frac{Q}{C} \quad \frac{Qd}{_0A}$$

$$V \quad d$$

6. When switch S is open



$$C_e \quad \frac{C \quad 2C}{C \quad 2C} \quad \frac{2}{3}C$$

$$q_1 \quad \frac{2}{3}CE$$

When switch S is closed

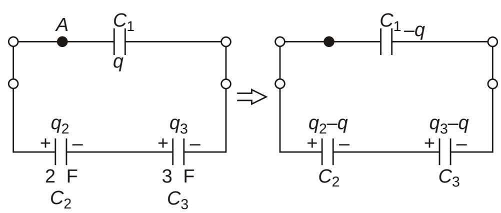
$$C_e \quad 2C$$

$$q_2 \quad 2CE$$

Charge flown through the battery

$$q \quad q_2 \quad q_1 \quad \frac{4}{3}CE \quad \text{positive}$$

7. Let charge q flows to C_1 at it falls to the free end of the wire.



By Kirchhoff's voltage law,

$$\frac{q_2 \quad q}{C_2} \quad \frac{q_3 \quad q}{C_3} \quad \frac{q}{C_1} \quad 0$$

$$q \quad \frac{\frac{q_2}{C_2} \quad \frac{q_3}{C_3}}{\frac{1}{C_1} \quad \frac{1}{C_2} \quad \frac{q}{C_3}}$$

$$\frac{V_2 \quad V_3}{\frac{1}{C_1} \quad \frac{1}{C_2} \quad \frac{1}{C_3}}$$

$$q \quad \frac{150 \quad 120}{\frac{1}{2} \quad \frac{1}{3} \quad \frac{1}{1.5}} \quad 180 \quad \text{C}$$

$$q_2 \quad q_2 \quad q \quad 150 \quad 2 \quad 180$$

$$120 \quad \text{C}$$

8. $C \quad \frac{_0A}{d}$

$$U \quad \frac{Q^2}{2C} \quad \frac{Q^2 d}{2\ _0A} \quad U \quad d$$

$$V \quad \frac{Q}{C} \quad \frac{Qd}{_0A} \quad V \quad d$$

$$C \quad \frac{_0A}{d} \quad C \quad \frac{1}{d}$$

$E \quad \frac{Q}{_0A}$ $\quad E$ is independent of d.

9. $R \quad 1 \quad 2 \quad 3 \quad , C \quad 2\,\text{F}$

$$q_0 \quad CV_0 \quad 2 \quad 6 \quad 12\text{C}$$

At any instant

$$q \quad q_0 \quad e^{\frac{t}{RC}}$$

$$I \quad \frac{dq}{dt} \quad \frac{q_0}{RC} e^{\frac{t}{RC}}$$

at $t \quad 0$

$$I \quad \frac{q_0}{RC} \quad \frac{12}{3 \quad 2} \quad 2\text{ A}$$

at $t \quad 6 \ln 2$

$$I \quad \frac{q_0}{RC} e^{\frac{6 \ln 2}{6}} \quad \frac{12}{6} \quad \frac{1}{2}$$

$$2 \quad \frac{1}{2} \quad 1\text{ A}$$

Potential difference across 1 resistor

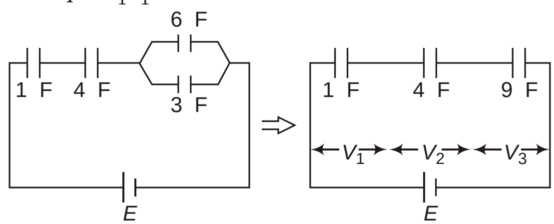
$$1 \quad 1 \quad 1\text{ V}$$

Potential difference across 2 resistor

$$1 \quad 2 \quad 2\text{ V}$$

By Kirchhoff's voltage law, potential difference across capacitors $1 \quad 2 \quad 3$ V.

10. $q \quad C_1V_1 \quad 1 \quad 10 \quad 10 \quad \text{F}$



$$V_2 \quad \frac{q}{C_2} \quad \frac{10}{4} \quad 2.5\text{ V}$$

$$V_3 \quad \frac{q}{C_3} \quad \frac{10}{9}\text{ V}$$

Match the Columns

1. $C_1 \quad kC_1 \quad 8 \quad \text{F},$

$$C_2 \quad \frac{C_2}{k} \quad 2 \quad \text{F}$$

$$q \quad \frac{C_1\ C_2}{C_1 \quad C_2} V \quad (1.6V) \quad \text{C}$$

$$q \quad (2V) \quad \text{C}$$

$q \quad q$

$$U_2 \quad \frac{q^{\ 2}}{C_2} \quad \frac{(1.6\,V)^2}{2 \quad 2} \quad 0.64V^2,$$

$$U_2 \quad \frac{q^2}{2C_2} \quad \frac{(2)^2}{2 \quad 2} \quad (1\,V) \quad \text{C}$$

$U_2 \quad U_2$

$$V_2 \quad \frac{q}{C_2} \quad \frac{1.6V}{8} \quad 0.2V,$$

$$V_2 \quad \frac{q}{C_2} \quad \frac{(2V)}{4} \quad 0.5V$$

$V_2 \quad V$

$$E_2 \quad \frac{q}{_0A} \quad \frac{1.6V}{_0A},$$

$$E_2 \quad \frac{q}{k\ _0A} \quad \frac{2V}{2 \quad _0A} \quad \frac{V}{_0A}$$

$E_2 \quad E_2$

(a q), (b q), (c q), (s p).

2. Before switch S is closed, charge distribution is shown in figure (1).

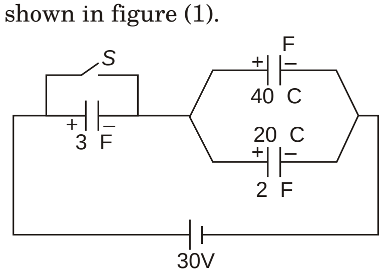


Fig. 1

After switch S is closed, charge distribution is shown in figure (2).

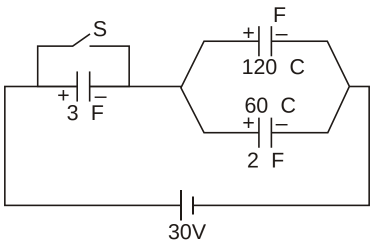
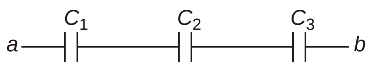


Fig. 2

(a   s), (b   p), (c   q), (d   s).

3. (a   q), (b   p, r), (c   q), (d   p,   )

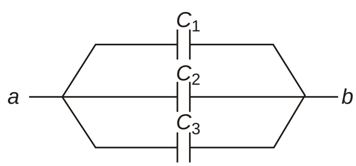
(p)



$$V_1 \quad V_2 \quad V_3 \quad \frac{V}{3}$$

$$q_1 \quad q_2 \quad q_3 \quad \frac{CV}{3}$$

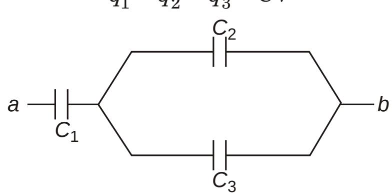
(q)



$$V_1 \quad V_2 \quad V_3 \quad V$$

$$q_1 \quad q_2 \quad q_3 \quad CV$$

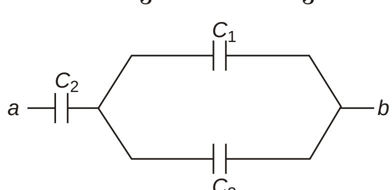
(r)



$$V_1 \quad \frac{2V}{3}, V_2 \quad V_3 \quad \frac{V}{3}$$

$$q_1 \quad \frac{2CV}{3}, q_2 \quad q_3 \quad \frac{CV}{3}$$

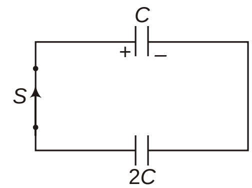
(s)



$$V_2 \quad \frac{2V}{3}, V_1 \quad V_2 \quad \frac{V}{3}$$

$$q_2 \quad \frac{2CV}{3}, q_1 \quad q_3 \quad \frac{CV}{3}$$

4. Common potential



$$V \quad \frac{C_1V_1 \quad C_2V_2}{C_1 \quad C_2} \quad \frac{V}{3}$$

$$U_1 \quad \frac{1}{2}C_1V^{\,2} \quad \frac{1}{18}CV^2$$

$$U_2 \quad \frac{1}{2}C_2V^{\,2} \quad \frac{1}{9}CV^2$$

$$U \quad \frac{C_1C_2}{2(C_1 \quad C_2)}(V_1 \quad V_2)^2$$

$$\frac{C \quad C}{2(C_1 \quad C_2)}(V \quad 0)^2$$

$$\frac{1}{6}CV^2$$

(a   r), (b   p), (c   q).

5. $C_1 \quad \frac{k\ _0A}{2d} \quad \frac{_0A}{2d}$

$$(k \quad 1)\frac{_0A}{2d} \quad \frac{3\ _0A}{2d}$$

$$\frac{1}{C_2} \quad \frac{d}{2k\ _0A} \quad \frac{d}{2\ _0A}$$

$$\frac{d}{2\ _0A} \quad \frac{1 \quad k}{k}$$

$$C_2 \quad \frac{2k\ _0A}{d(1 \quad k)} \quad \frac{4\ _0A}{3d}$$

$$\frac{C_1}{C_2} \quad \frac{9}{8}$$

As combination is series, $q_1 \quad q_2$

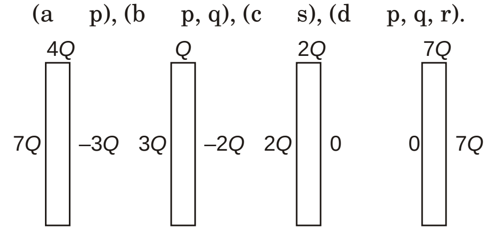
$$\frac{q_1}{q_2} \quad 1$$

$$\frac{U_1}{U_2} \quad \frac{C_2}{C_1} \quad \frac{8}{9}$$

(a   s), (b   s), (c   s).

6. Charge distribution is shown in figure.

(a   p), (b   p, q), (c   s), (d   p, q, r).



23 Magnetics

Introductory Exercise 23.1

1. $[F_e] \quad [F_m]$

$$[qE] \quad [qvB]$$

$$\frac{E}{B} \quad [v] \quad [\mathrm{LT}^{\ \ 1}]$$

2. $\mathbf{F} \quad q(\mathbf{v} \quad \mathbf{B})$

$$\mathbf{F} \quad \mathbf{v} \text{ and } \mathbf{F} \quad \mathbf{B}$$

Because cross product of any two vectors is always perpendicular to both the vectors.

3. No. As $\mathrm{F}_m \quad q(\mathbf{v} \quad \mathbf{B})$

$$|\mathbf{F}_m| \quad qvB\sin$$

If F_m 0, either B 0 or sin 0,

i.e., 0

4. $\mathbf{F} \quad q(\mathbf{v} \quad \mathbf{B})$

$$4 \quad 10^{\ 6} \quad 10^{\ 6} \quad 10^{\ 2}[(2\hat{\mathbf{i}} \quad 3\hat{\mathbf{j}} \quad \hat{\mathbf{k}}) \quad (2\hat{\mathbf{i}} \quad 5\hat{\mathbf{j}} \quad 3\hat{\mathbf{k}})]$$

$$4 \quad 10^{\ 2}(4\hat{\mathbf{i}} \quad 8\hat{\mathbf{j}} \quad 16\hat{\mathbf{k}})$$

$$16(\hat{\mathbf{i}} \quad 2\hat{\mathbf{j}} \quad 4\hat{\mathbf{k}}) \quad 10^{\ 2}\ \mathrm{N}$$

Introductory Exercise 23.2

1. As magnetic field can exert force on charged particle, it can be accelerated in magnetic field but its speed cannot increases as magnetic force is always perpendicular to the direction of motion of charged particle.

2. $\mathbf{F}_m \quad e(\mathbf{v} \quad \mathbf{B})$

By Fleming's left hand rule, **B** must be along positive z-axis.

3. As magnetic force provides necessary centripetal force to the particle to describe a circle.

$$qvB \quad \frac{mv^2}{r}$$

$$r \quad \frac{mv}{qB}$$

(a) $$r \quad \frac{mv}{qB}$$

$$r \quad m$$

Hence, electron will describe smaller circle.

(b) $$T \quad \frac{2 \quad r}{v} \quad \frac{2 \quad m}{qB}$$

$$f \quad \frac{1}{T} \quad \frac{qB}{2 \quad m}$$

$$f \quad \frac{1}{m}$$

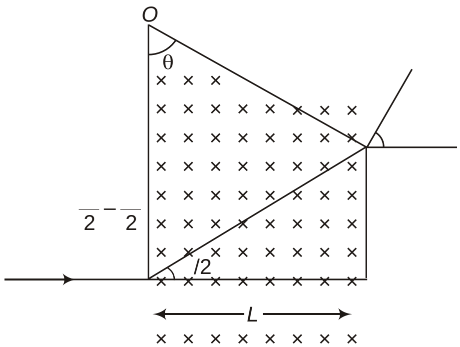
electron have greater frequency.

4. Electrons are refocused on x-axis at a distance equal to pitch, *i.e.,*

$$n \quad p \quad v_{\|}T$$

$$\frac{2 \quad mv\cos}{eB}$$

5. (a) If $L \quad r \quad \frac{mv}{qB}$,



(b) The particle will describe a semi-circle.

Hence,

(c) $\frac{L}{l} \quad \cos\frac{}{2}$

$\frac{L}{2R\sin\frac{}{2}} \quad \cos\frac{}{2}$

$\frac{L}{R} \quad \sin \qquad \sin \qquad \frac{1}{2}$

$\frac{}{6}$

6. $r \quad \frac{mv}{eB} \quad \sqrt{\frac{2mk}{eB}}$

$\frac{\sqrt{2m\,eV}}{eB} \quad \frac{1}{B}\sqrt{\frac{2mV}{e}}$

For electron,

$r \quad \frac{1}{0.2}\sqrt{\frac{2 \quad 9.1 \quad 10^{\;31} \quad 100}{1.6 \quad 10^{\;19}}}$

$1.67 \quad 10^{\;4}\,\text{m} \quad 0.0167\,\text{cm}$

For proton

$r \quad \frac{1}{0.2}\sqrt{\frac{2 \quad 1.67 \quad 10^{\;27} \quad 100}{1.6 \quad 10^{\;19}}}$

$7 \quad 10^{\;3}\,\text{m} \quad 0.7\,\text{cm}$

7. $r \quad \frac{mv}{qB} \quad \frac{\sqrt{2m\,k}}{qB}$

$r \quad \frac{\sqrt{m}}{q}$

$r_p : r_d : r \quad \frac{\sqrt{1}}{1} : \frac{\sqrt{2}}{1} : \frac{\sqrt{4}}{2}$

$1 : \sqrt{2} : 1$

Introductory Exercise 23.3

1. Let at any instant

$\mathbf{V} \quad V_x\,\hat{\mathbf{i}} \quad V_y\,\hat{\mathbf{j}} \quad V_z\,\hat{\mathbf{k}}$

Now, $V_x^2 \quad V_y^2 \quad V_0^2 \quad \text{constant}$

and $V_2 \quad V_0 \quad \frac{qE}{m} f$

$\mathbf{V}$ is minimum when $V_2 \quad 0$

at $f \quad \frac{mv_0}{qE}$

and $V_{\min} \quad V_0$

2. After one revolution, $y \quad 0$,

$x \quad p$ pitch of heating

$\frac{2 \quad mv\sin}{qB}$

Hence, coordination of the particle,

$(x, b) \quad 0, \frac{2 \quad mv\sin}{qB}$

3. $\mathbf{F} \quad i(\mathbf{l} \quad \mathbf{B}) \quad ilB[\hat{\mathbf{i}} \quad (\hat{\mathbf{j}} \quad \hat{\mathbf{k}})]$

$(\mathbf{F}) \quad \sqrt{2}\,ilB$

4. No. as $\hat{\mathbf{i}} \quad (\hat{\mathbf{i}} \quad \hat{\mathbf{j}} \quad \hat{\mathbf{k}}) \quad \hat{\mathbf{i}} \quad \hat{\mathbf{j}} \quad \hat{\mathbf{i}} \quad (\hat{\mathbf{j}} \quad \hat{\mathbf{k}})$

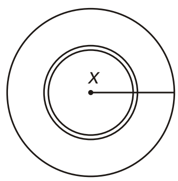
But $\hat{\mathbf{i}} \quad \hat{\mathbf{j}} \quad 0$

$\hat{\mathbf{i}} \quad (\hat{\mathbf{i}} \quad \hat{\mathbf{j}} \quad \hat{\mathbf{k}}) \quad \hat{\mathbf{i}} \quad (\hat{\mathbf{j}} \quad \hat{\mathbf{k}})$

Introductory Exercise 23.4

1. Consider the disc to be made up of large number of elementary concentric rings. Consider one such ring of radius x and thickness dx.

Charge on this ring



$$dq \quad \frac{q}{R^2} dA \quad \frac{q}{R^2} \quad 2 \; x\, dx$$

$$dq \quad \frac{2qx\,dx}{R^2}$$

Current in this ring,

$$di \quad \frac{dq}{T} \quad \frac{dq}{2} \quad \frac{qx\,dx}{R^2}$$

Magnetic moment of this ring,

$$dM \quad di \quad A \quad \frac{qx\,dx}{R^2} \quad x^2$$

$$\frac{q}{R^2} x^3 dx$$

Magnetic moment of entire disc,

$$M \quad dM \quad \frac{q}{R^2} {}_0^R x^3 dx$$

$$\frac{q}{R^2} \; \frac{R^4}{4} \quad \frac{1}{4} \quad qR^2$$

2. $\mathbf{M} \quad i \quad [(\mathbf{OA} \quad \mathbf{AB})]$

$\mathbf{OA} \quad OA \cos \; \hat{\mathbf{j}} \quad OA \sin \; \hat{\mathbf{k}}$

$\mathbf{AB} \quad AB\,\hat{\mathbf{i}}$

$$\mathbf{M} \quad i \quad OA \quad AB\,[(\cos \; \hat{\mathbf{j}} \quad \sin \; \hat{\mathbf{k}}) \quad \hat{\mathbf{i}}]$$

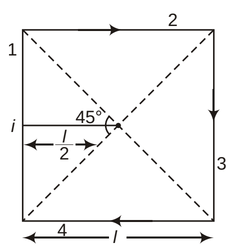
$$4 \quad 0.2 \quad 0.1 \quad \frac{\sqrt{3}}{2}\hat{\mathbf{j}} \quad \frac{1}{2}\hat{\mathbf{k}} \quad \hat{\mathbf{i}}$$

$$(0.04\,\hat{\mathbf{j}} \quad 0.07\,\hat{\mathbf{k}})\ \text{A-m}^2$$

Introductory Exercise 23.5

1. (a) $B_1 \quad B_2 \quad B_3 \quad B_4$

$$\frac{0}{4} \; \frac{i}{l/2} [\sin 45 \quad \sin 45 \;]$$



$$\frac{0}{4} \; \frac{2\sqrt{2}i}{l}$$

Net magnetic field at the centre of the square,

$$B \quad B_1 \quad B_2 \quad B_3 \quad B_4 \quad \frac{0}{4} \; \frac{8\sqrt{2}i}{l}$$

$$\frac{2\sqrt{2} \quad {}_0 i}{l} \quad 28.3 \quad \text{T (inward)}$$

(b) If the conductor is converted into a circular loop, then

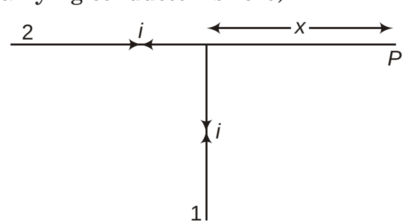
$$2 \; r \quad 4l \quad r \quad \frac{2l}{}$$

$$B \quad \frac{{}_0 i}{2 r} \quad \frac{{}_0 i}{4l} \quad 24.7 \quad \text{T (inward)}$$

2. $B \quad \frac{0}{4} \; \frac{i}{x}$

(As P is lying near one end of conductor 1)

$B_2 \quad 0$ (Magnetic field on the axis of a current carrying conductor is zero)

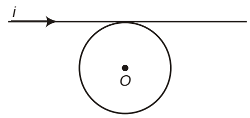


$$B \quad B_1$$

$$\frac{0}{4} \; \frac{i}{x}$$

By right hand thumb rule, direction of magnetic field at P is inward.

3. Magnetic field due to straight conductor at O



$$B_1 \quad \frac{\ _0}{4} \frac{2\,i}{R}$$

Magnetic field at O due to circular loop

$$B_2 \quad \frac{\ _0 i}{2R}$$

By right hand thumb rule, both the filds are acting inward.

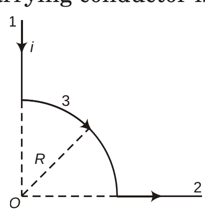
Hence,

$$B \quad B_1 \quad B_2 \quad \frac{\ _0 i}{2\ R}(1 \qquad)$$

$$\frac{4 \quad 10^{\ 7} \quad 7}{2 \quad 10 \quad 10^{\ 2}} \ 1 \quad \frac{22}{7}$$

$$58 \quad 10^{\ 6}\,\mathrm{T} \quad 58 \quad \mathrm{T}\ \text{(inward).}$$

4. $B_1 \quad B_2 \quad 0$ (Magnetic field on the axis of current carrying conductor is zero)



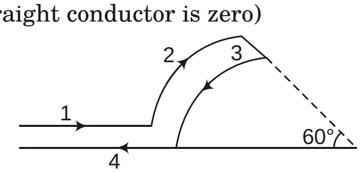
$$B_3 \quad \frac{1}{4} \frac{\ _0 i}{2R} \quad \frac{\ _0 i}{8R}$$

$$\frac{4 \quad 10^{\ 7} \quad 5}{8 \quad 3 \quad 10^{\ 2}}$$

$$2.62 \quad 10^{\ 5}\,\mathrm{T}$$

$$26.2 \quad \mathrm{T}\ \text{(inward).}$$

5. $B_1 \quad B_2 \quad 0$ (Magnetic field on the axis of straight conductor is zero)



$$B_2 \quad \frac{60}{360} \quad \frac{\ _0 i}{2b} \quad \frac{\ _0 i}{12b}\ \text{(inward)}$$

$$B_3 \quad \frac{60}{360} \quad \frac{\ _0 i}{2a} \quad \frac{\ _0}{12a}\ \text{(outward)}$$

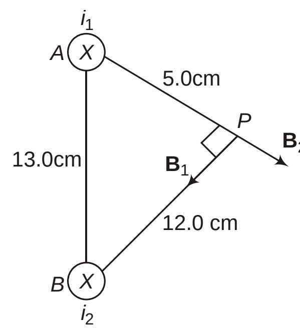
As $B_3 \quad B_2$,

Net magnetic field at P,

$$B \quad B_3 \quad B_2$$

$$\frac{\ _0 i}{12} \ \frac{1}{a} \quad \frac{1}{b}$$

6. AB, AP and BP from Pythagorus triplet, hence $\quad APB \quad 90$



$$\mathbf{B}_1 \quad \frac{\ _0}{4} \frac{2\,i_1}{r_1} \hat{\mathbf{PB}}$$

$$\mathbf{B}_2 \quad \frac{\ _0}{4} \frac{2\,i_2}{r_2} \hat{\mathbf{AP}}$$

$$B \quad \sqrt{B_1^2 \quad B_2^2}$$

$$\frac{\ _0}{2} \sqrt{\frac{i_1}{r_1}^{\ 2} \qquad \frac{i_2}{r_2}^{\ 2}}$$

$$\frac{4 \quad 10^{\ 7}}{2} \sqrt{\frac{3}{0.05}^{\ 2} \qquad \frac{3}{0.12}^{\ 2}}$$

$$1.3 \quad 10^{\ 5}\,\mathrm{T}$$

$$13 \quad \mathrm{T}$$

7. $\quad NIAB \cos$

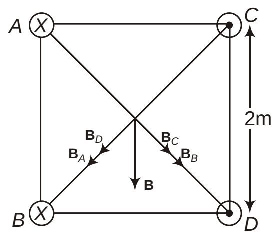
$$100 \quad 1.2 \quad 0.4 \quad 0.3 \quad 0.8 \quad \cos 30$$

$$9.98\ \mathrm{N\text{-}m}$$

Rotation will be clockwise as seen from above.

Introductory Exercise 23.6

1. By right hand thumb rule, direction of magnetic field due to conductor A, B, C and D are as shown in figure.



$$B_A \quad B_B \quad B_C \quad B_D \quad \frac{_0}{4} \frac{2I}{r}$$

Here, $I \quad 5$ A

$$r \quad \frac{a}{\sqrt{2}} \quad \frac{0.2}{\sqrt{2}} \quad 0.14$$

Net magnetic field at P

$$B \quad \sqrt{(B_A \quad B_D)^2 \quad (B_B \quad B_C)^2}$$

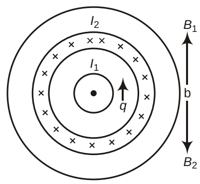
$$\frac{_0}{4} \frac{4\sqrt{2}\, I}{r}$$

$$\frac{10^{\ 7} \quad 4\sqrt{2} \quad 5}{0.2/\sqrt{2}} \quad 20 \quad 10^{\ 6}\ \text{T}$$

$$20 \quad \text{T}$$

Clearly resultant magnetic field is downward.

2. At point A



$$B_1 \quad \frac{_0}{4} \frac{I_1}{r_1}$$

$B_2 \quad 0$ (Magnetic field inside a current carrying hollow cylinder is zero)

$$B_a \quad B_1 \quad B_2 \quad \frac{_0}{4} \frac{I_1}{r_1}$$

$$\frac{10^{\ 7} \quad 1}{1 \quad 10^{\ 3}} \quad 10^{\ 4}\ \text{T}$$

$$100 \quad \text{T (upward)}$$

At point B

$$B_1 \quad \frac{_0}{4 \quad _0} \frac{I_1}{r_2}, B_2 \quad \frac{_0}{4} \frac{I_2}{r_2}$$

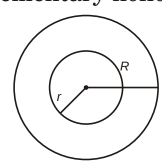
Net field at B

$$B \quad B_2 \quad B_1 \quad \frac{_0}{4} \frac{1}{r_2}(I_2 \quad I_1)$$

$$\frac{10^{\ 7}}{3 \quad 10\ 3} \quad (3 \quad 2) \quad 0.67 \quad 10^{\ 4}\ \text{T}$$

$$67 \quad \text{T}$$

3. Consider the cylinder to be made up of large number of elementary hollow cylinders.



Consider one such cylinder of radius r and thickness dr.

Current passing through this hollow cylinder,

$$di \quad jdA \quad j(2 \quad r\,dr)2 \quad br^2dr$$

(a) Total current inside the portion of radius r_1,

$$I_1 \quad di \quad 2 \quad b \ _0^{r_1} r^2dr$$

$$2 \quad b \ \frac{r_1^3}{3} \Big|_0^{r_1}$$

$$\frac{2}{3} \quad br_1^3$$

By ampere's circuital law,

$$\oint B \quad dl \quad _0 i_1$$

$$2 \ r_1$$

$$B_1 \quad 2 \quad r_1 \quad _0 \ \frac{2}{3} \quad br_1^3$$

$$B_1 \quad \frac{_0\, br_1^2}{3}$$

(b) Total current inside the cylinder

$$i \quad 2 \quad b \ _0^R r^2dr$$

$$\frac{2}{3} \quad bR^3$$

$$B_2 \quad \frac{_0}{4} \frac{2\,i}{r_2} \quad \frac{_0\, bR^3}{3r_2}$$

AIEEE Corner

Subjective Questions (Level-1)

1. Positive. By Flemings left hand rule.

2. $F_m \quad evB\sin$

$$v \quad \frac{F_e}{eB\sin}$$

$$\frac{4.6 \quad 10^{\ 15}}{1.6 \quad 10^{\ 19} \quad 3.5 \quad 10^{\ 3} \quad \sin 60}$$

$$9.46 \quad 10^6 \text{ m/s}$$

3. $F_m \quad qvB\sin$

$$(2 \quad 1.6 \quad 10^{\ 19}) \quad 10^5 \quad 0.8 \quad 1$$

$$2.56 \quad 10^{\ 14} \text{ N}$$

4. (a) $\mathbf{F}_m \quad e(\mathbf{v} \quad \mathbf{B})$

$$1.6 \quad 10^{\ 19}[(2.0 \quad 10^6)\hat{\mathbf{i}} \quad (3.0 \quad 10^6)\hat{\mathbf{j}}]$$

$$(0.03\,\hat{\mathbf{i}} \quad 0.15\,\hat{\mathbf{j}})$$

$$(6.24 \quad 10^{\ 4}\text{ N})\hat{\mathbf{k}}$$

(b) $\mathbf{F}_m\, e(\mathbf{v} \quad \mathbf{B}) \quad (6.24 \quad 10^{\ 4}\text{N})\hat{\mathbf{k}}$

5. $\mathbf{F}_m \quad e(\mathbf{v} \quad \mathbf{B})$

$$(6.4 \quad 10^{\ 19})\hat{\mathbf{k}} \quad 1.6 \quad 10^{\ 19}[(2\hat{\mathbf{i}} \quad 4\hat{\mathbf{j}})$$

$$(B_x\,\hat{\mathbf{i}} \quad 3B_x\,\hat{\mathbf{j}})]$$

$$6.4 \quad 10^{\ 19}\,\hat{\mathbf{k}} \quad 1.6 \quad 10^{\ 19}[2B_x\,\hat{\mathbf{k}}]$$

$$B_x \quad \frac{6.4 \quad 10^{\ 19}}{3.2 \quad 10^{\ 19}} \quad 2.0\text{ T}$$

6. (a) As magnetic force always acts perpendicular to magnetic field, magnetic field must be along x-axis.

$$F_1 \quad qv_1B\sin{}_1$$

$$B \quad \frac{F_1}{qv_1B\sin{}_1} \quad \frac{5\sqrt{2} \quad 10^{\ 3}}{1 \quad 10^{\ 6} \quad 10^6 \quad \frac{1}{\sqrt{2}}}$$

$$B \quad 10^{\ 3}\text{ T}$$

or $\quad \mathbf{B} \quad (10^{\ 3}\text{ T})\hat{\mathbf{i}}$

(b) $F_2 \quad qv_2B\sin{}_2$

$$1 \quad 10^{\ 6} \quad 10^6 \quad 10^{\ 3} \quad \sin 90$$

$$10^{\ 3}\text{ N}$$

$$F_2 \quad 1\text{ mN}$$

7. Let $\mathbf{B} \quad B_x\,\hat{\mathbf{i}} \quad B_y\,\hat{\mathbf{j}} \quad B_z\,\hat{\mathbf{k}}$

(a) $\mathbf{F} \quad q(\mathbf{v} \quad \mathbf{B})$

$$7.6 \quad 10^{\ 3}\,\hat{\mathbf{i}} \quad 5.2 \quad 10^{\ 3}\,\hat{\mathbf{k}}$$

$$7.8 \quad 10^{\ 6} \quad 3.8 \quad 10^3(B_z\,\hat{\mathbf{i}} \quad B_x\,\hat{\mathbf{k}})$$

$$B_x \quad 0.175\text{ T}, B_z \quad 0.256\text{ T}$$

(b) Cannot be determined by this information.

(c) As $\mathbf{F} \quad q(\mathbf{v} \quad \mathbf{B})$

$$\mathbf{F} \quad \mathbf{B}$$

Hence, $\mathbf{B}\ \mathbf{F} \quad 0$

8. $\mathbf{B} \quad B\,\hat{\mathbf{i}}$

(a) $\mathbf{v} \quad v\,\hat{\mathbf{j}}$

$$\mathbf{F} \quad q(\mathbf{v} \quad \mathbf{B}) \quad qvB\,\hat{\mathbf{k}}$$

(b) $\mathbf{v} \quad v\,\hat{\mathbf{j}}$

$$\mathbf{F} \quad q(\mathbf{v} \quad \mathbf{B}) \quad qvB\,\hat{\mathbf{j}}$$

(c) $\mathbf{v} \quad v\,\hat{\mathbf{i}}$

$$\mathbf{F} \quad q(\mathbf{v} \quad \mathbf{B}) \quad 0$$

(d) $\mathbf{v} \quad v\cos 45\ \hat{\mathbf{i}} \quad v\cos 45\ \hat{\mathbf{k}}$

$$\mathbf{F} \quad q(\mathbf{v} \quad \mathbf{B}) \quad \frac{qvB}{\sqrt{2}}\,\hat{\mathbf{j}}$$

(e) $\mathbf{v} \quad v\cos 45\ \hat{\mathbf{j}} \quad v\cos 45\ \hat{\mathbf{k}}$

$$\mathbf{F} \quad q(\mathbf{v} \quad \mathbf{B}) \quad \frac{qvB}{\sqrt{2}}(\quad \hat{\mathbf{j}} \quad \hat{\mathbf{k}})$$

$$\frac{qvB}{\sqrt{2}}(\hat{\mathbf{j}} \quad \hat{\mathbf{k}})$$

9. $r \quad \dfrac{mv}{qB} \quad \dfrac{\sqrt{2mk}}{eB} \quad \dfrac{\sqrt{2meV}}{eB}$

$$B \quad \sqrt{\frac{2mV}{e}}r$$

$$\sqrt{\frac{2 \quad 9.1 \quad 10^{\ 31} \quad 2 \quad 10^3}{1.6 \quad 10^{\ 19}}} \quad 0.180$$

$$0.36 \quad 10^{4}\ \text{T}$$
$$B \quad 3.6 \quad 10^{4}\ \text{T}$$

10. (a) $r \quad \frac{mv}{qB} \quad v \quad \frac{qBr}{m}$

$$\frac{1.6 \quad 10^{19} \quad 2.5 \quad 6.96 \quad 10^{3}}{3.34 \quad 10^{27}}$$

$$8.33 \quad 10^{5}\ \text{ms}^{1}$$

(b) $t \quad \frac{T}{2} \quad \frac{m}{qB}$

$$\frac{3.14 \quad 3.34 \quad 10^{27}}{1.6 \quad 10^{19} \quad 2.5}$$

$$2.62 \quad 10^{8}\ \text{s}$$

(c) $k \quad eV \quad \frac{1}{2}mv^2$

$$V \quad \frac{mv^2}{2e}$$

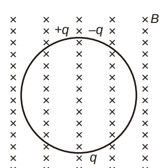
$$\frac{3.34 \quad 10^{27} \quad (8.33 \quad 10^{5})^2}{2 \quad 1.6 \quad 10^{19}}$$

$$7.26 \quad 10^{3}\ \text{V}$$
$$7.26\ \text{kV}$$

11. (a) q. As initially particle is neutral, charge on two particles must be equal and opposite.

(b) The will collide after completing half rotation, *i.e.*,

$$t \quad \frac{T}{2} \quad \frac{m}{qB}$$



12. Here, $r \quad \frac{10.0}{2} \quad 5.0$ cm,

(a) $r \quad \frac{mv}{qB} \quad B \quad \frac{mv}{qr}$

$$\frac{9.1 \quad 10^{31} \quad 1.41 \quad 10^{6}}{1.6 \quad 10^{19} \quad 5 \quad 10^{2}}$$

$$1.6 \quad 10^{4}\ \text{T}$$

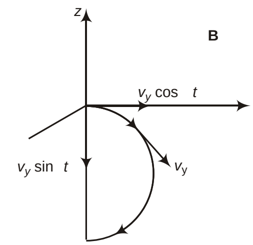
By Fleming's left hand rule, direction of magnetic field must be inward.

(b) $t \quad \frac{T}{2} \quad \frac{m}{qB}$

$$\frac{3.14 \quad 9.1 \quad 10^{31}}{1.6 \quad 10^{19} \quad 1.6 \quad 10^{4}}$$

$$1.1 \quad 10^{7}\ \text{s}$$

13. The component of velocity along the magnetic field (*i.e.*, v_x) will remain unchanged and the proton will move in a helical path.



At any instant,

Components of velocity of particle along Y-axis and Z-axis

$$v_y \quad v_y \cos \quad v_y \cos \quad t$$

and $$v_z \quad v_z \sin \quad v_z \sin \quad t$$

where, $$\frac{qB}{m}$$

$$\mathbf{v} \quad v_x \hat{\mathbf{i}} \quad v_y \cos \quad t\,\hat{\mathbf{j}} \quad v_z \sin \quad t\,\hat{\mathbf{k}}$$

14. For the electron to hit the target, distance GS must be multiple of pitch, *i.e.*,

$$GS \quad np$$

For minimum distance, $n \quad 1$

$$GS \quad p \quad \frac{2 \quad mv\cos}{qB}$$

$$p \quad \frac{2 \quad \sqrt{2\,mk}\cos 60}{qB} \qquad (mv \quad \sqrt{2\,mk})$$

$$B \quad \frac{2 \quad \sqrt{2\,mk}\cos 60}{qp}$$

$$\frac{2 \quad 3.14 \quad \sqrt{2 \quad 9.1 \quad 10^{31} \quad 2 \quad 1.6 \quad 10^{16}} \quad \frac{1}{2}}{1.6 \quad 10^{19} \quad 0.1}$$

$$B \quad 4.73 \quad 10^{4}\ \text{T}$$

15. (a) From Question 5 (c)

Introductory Exercise 23.2

$$\frac{L}{R} \quad \sin \qquad L \quad R\sin$$

$$R\sin 60 \quad \frac{R}{2}$$

$$L \quad \frac{mv}{2qB} \quad \frac{mv_0}{2qB_0}$$

(b) Now, $L \quad 2.1L \quad 1.05R$

As $L \quad R$,

Particle will describe a semicircle and move out of the magnetic field moving in opposite direction, *i.e.,*

$$v \quad v \quad v_0\,\hat{\mathbf{i}}$$

and $$t \quad \frac{T}{2} \quad \frac{m}{qB_0}$$

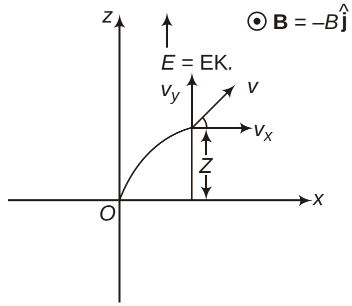
16. $\mathbf{v} \quad (50 \text{ ms}^{\ 1})\hat{\mathbf{i}}, \mathbf{B} \quad (2.0 \text{ mT})\hat{\mathbf{j}}$

As particle move with uniform velocity,

$$\mathbf{F} \quad q(\mathbf{E} \quad \mathbf{v} \quad \mathbf{B}) \quad 0$$

$$\mathbf{E} \quad \mathbf{B} \quad \mathbf{v} \qquad (0.1\,\text{N/C})\hat{\mathbf{k}}$$

17. If v be the speed of particle at point (0, y, z) then by work-energy theorem,



$$W \quad K \quad \frac{1}{2}mv^2$$

But work done by magnetic force is zero,

hence, network done   work done by electric force

$$qEZ$$

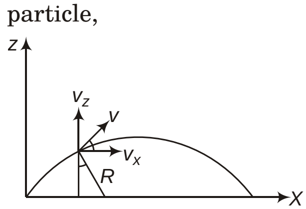
$$qE_0Z \quad \frac{1}{2}mv^2$$

$$v \quad \sqrt{\frac{2qE_0Z}{m}}$$

As the magnetic field is along Y-axis, particle will move in XZ-plane.

The path of particle will be a cycloid. In this case, instantaneous centre of curvature of the particle will move along X-axis.

As magnetic force provides centripetal force to the particle,



$$qvB_0 \quad \frac{mv^2}{R}$$

$$v \quad \frac{qB_0R}{m}$$

$$v_x \quad v\cos \quad \frac{qB_0R\cos}{m}$$

$$\frac{qB_0Z}{m} \qquad (\because R\cos \quad Z)$$

Now, $$v_z \quad \sqrt{v^2 \quad v_x^2} \quad \sqrt{\frac{2qE_0Z}{m} \quad \frac{q^2B_0^2Z^2}{m^2}}$$

18. Given, $\mathbf{E} \quad E\hat{\mathbf{j}}, \mathbf{B} \quad B\hat{\mathbf{k}},$

$$\mathbf{v} \quad v\cos \quad \hat{\mathbf{j}} \quad v\sin \quad \hat{\mathbf{k}}$$

As protons are moving undeflected,

$$\mathbf{F} \quad 0 \quad e(\mathbf{E} \quad \mathbf{v} \quad \mathbf{B}) \quad 0$$

$$e(E\hat{\mathbf{j}} \quad vB\cos \quad \hat{\mathbf{j}}) \quad 0$$

or $$v \quad \frac{E}{B\cos}$$

Now, if electric field is switched off

$$p \quad \frac{2 \quad mv\sin}{qB} \quad \frac{2 \quad mE\tan}{qB^2}$$

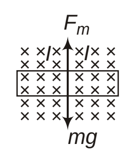
(Component of velocity along magnetic field $v_z \quad v\sin$)

19. $F \quad IlB\sin$

$$I \quad \frac{F}{lB\sin} \quad \frac{0.13}{0.2 \quad 0.067 \quad \sin 90}$$

9.7 A

20. For no tension in springs



$$F_m \quad mg$$

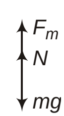
$$IlB \quad mg$$

$$I \quad \frac{mg}{lB} \quad \frac{13.0 \quad 10^{\ 3} \quad 10}{62.0 \quad 10^{\ 2} \quad 0.440}$$

0.48 A

By Fleming left hand rule, for magnetic force to act in upward direction, current in the wire must be towards right.

21. (a) FBD of metal bar is shown in figure, for metal to be in equilibrium,



$$F_m \quad N \quad mg$$

$$F_m \quad mg \quad N$$

$$IlB \quad m \quad N$$

$$\frac{V}{R}lB \quad mg \quad N$$

$$V \quad \frac{R}{lB}(mg \quad N)$$

For largest voltage,

$N \quad 0$

$$V \quad \frac{Rmg}{lB} \quad \frac{25 \quad 750 \quad 10^{3} \quad 9.8}{50.0 \quad 10^{2} \quad 0.450}$$

$$817.5 \text{ V}$$

(b) If $I\,lB \quad mg$

$$I\,lB \quad mg \quad ma$$

$$a \quad \frac{I\,lB \quad mg}{m} \quad \frac{V\,lB}{Rm} \quad g$$

$$\frac{817.5 \quad 50 \quad 10^{2} \quad 0.45}{2 \quad 750 \quad 10^{3}} \quad 9.8$$

$$112.8 \text{ m/s}^2$$

22. $I \quad 3.50 \text{ A}, l \quad (1.00 \text{ cm})\hat{\mathbf{i}}$

$$l \quad (1.00 \quad 10^{2} \text{ m})\hat{\mathbf{i}}$$

(a) $\mathbf{B} \quad (0.65 \text{ T})\hat{\mathbf{j}}$

$$\mathbf{F}_m \quad I(\mathbf{l} \quad \mathbf{B}) \quad (0.023 \text{ N})\hat{\mathbf{k}}$$

(b) $\mathbf{B} \quad (0.56 \text{ T})\hat{\mathbf{k}}$

$$\mathbf{F}_m \quad I(\mathbf{l} \quad \mathbf{B}) \quad (0.0196 \text{ N})\hat{\mathbf{j}}$$

(c) $\mathbf{B} \quad (0.33 \text{ T})\hat{\mathbf{i}}$

$$\mathbf{F}_m \quad I(\mathbf{l} \quad \mathbf{B}) \quad 0$$

(d) $\mathbf{B} \quad (0.33 \text{ T})\hat{\mathbf{i}} \quad (0.28 \text{ T})\mathbf{k}$

$$\mathbf{F}_m \quad I(\mathbf{l} \quad \mathbf{B}) \quad (0.0098 \text{ N})\hat{\mathbf{j}}$$

(e) $\mathbf{B} \quad (0.74 \text{ T})\hat{\mathbf{j}} \quad (0.36 \text{ T})\hat{\mathbf{k}}$

$$\mathbf{F}_m \quad I(\mathbf{l} \quad \mathbf{B}) \quad (0.0259 \text{ N})\hat{\mathbf{k}} \quad (0.0126 \text{ N})\hat{\mathbf{j}}$$
$$(0.0126 \text{ N})\hat{\mathbf{j}} \quad (0.0259 \text{ N})\hat{\mathbf{K}}$$

23. $\mathbf{B} \quad (0.020 \text{ T})\hat{\mathbf{j}}$

$\mathbf{l}_1 \quad \mathbf{ab} \quad (40.0 \text{ cm})\hat{\mathbf{j}}$

$$(40.0 \quad 10^{2} \text{ m})\hat{\mathbf{j}}$$

$\mathbf{F}_1 \quad I(\mathbf{l}_1 \quad \mathbf{B}) \quad 0$

$\mathbf{l}_2 \quad \mathbf{bc} \quad (40.0 \text{ cm})\hat{\mathbf{k}}$

$$(400 \quad 10^{2} \text{ m})\hat{\mathbf{k}}$$

$\mathbf{F}_2 \quad I(\mathbf{l}_2 \quad \mathbf{B}) \quad (0.04 \text{ N})\hat{\mathbf{i}}$

$\mathbf{l}_3 \quad \mathbf{cd} \quad (40 \quad 10^{2})\hat{\mathbf{i}} \quad (40 \quad 10^{2} \text{ m})\hat{\mathbf{j}}$

$\mathbf{F}_3 \quad I(\mathbf{l}_3 \quad \mathbf{B}) \quad (0.04 \text{ N})\hat{\mathbf{k}}$

$\mathbf{l}_4 \quad \mathbf{da} \quad (40 \quad 10^{2} \text{ m})\hat{\mathbf{i}} \quad (40 \quad 10^{2} \text{ m})\hat{\mathbf{k}}$

$\mathbf{F}_4 \quad I(\mathbf{l}_4 \quad \mathbf{B}) \quad (0.04 \text{ N})\hat{\mathbf{i}} \quad (0.04 \text{ N})\hat{\mathbf{k}}$

24. $\mathbf{M} \quad IA\hat{\mathbf{M}}$

$$0.20 \quad (8.0 \quad 10^{2})^2(0.60\hat{\mathbf{i}} \quad 0.80\hat{\mathbf{j}})$$

$$(40.2 \quad 10^{4})(0.60\hat{\mathbf{i}} \quad 0.80\hat{\mathbf{j}})\text{A-m}^2$$

$\mathbf{B} \quad (0.25 \text{ T})\hat{\mathbf{i}} \quad (0.30 \text{ T})\hat{\mathbf{k}}$

(a) $\mathbf{M} \quad \mathbf{B}$

$$(40.2 \quad 10^{4})(\quad 0.24\hat{\mathbf{i}} \quad 0.18\hat{\mathbf{j}} \quad 0.2\hat{\mathbf{k}})$$

$$(\quad 9.6\hat{\mathbf{i}} \quad 7.2\hat{\mathbf{j}} \quad 8.0\hat{\mathbf{k}}) \quad 10^{4} \text{ N-m.}$$

(b) $U \quad \mathbf{M}\,\mathbf{B} \quad (40.2 \quad 10^{4})(0.15) \text{ J}$

$$6.0 \quad 10^{4} \text{ J}$$

25. Consider the wire is bent in the form of a loop of N turns,

Radius of loop, $r \quad \frac{L}{2 \quad N}$

Magnetic dipole moment associated with the loop

$$M \quad NiA \quad Ni \quad r^2 \quad \frac{iL^2}{4 \quad N^2}$$

$$MB \sin 90 \quad \frac{iL^2B}{4 \quad N}$$

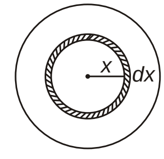
Clearly is maximum, when $N \quad 1$

and the maximum torque is given by

$$_m \quad \frac{iL^2B}{4}$$

26. Consider the disc to be made up of large number of elementary rings. Consider on such ring of radius x and thickness dx.

Charge on this ring,



$$dq \quad \frac{q}{R^2} \quad 2 \quad x\,dx \quad \frac{2q}{R^2}x\,dx$$

Current associated with this ring,

$$di \quad \frac{dq}{T} \quad \frac{dq}{2} \quad \frac{q}{R^2} x\,dx$$

Magnetic moment of this ring

$$dM \quad x^2 di \quad \frac{q}{R^2} x^3 dx$$

Magnetic moment of entire disc,

$$M \quad dM \quad \frac{q}{R^2} {}_0^R x^3 dx \quad \frac{1}{4} \quad qR^2 \qquad \ldots(i)$$

Magnetic field at the centre of disc due to the elementary ring under consideration

$$dB \quad \frac{{}_0 di}{2x} \quad \frac{{}_0 \quad q^2}{2 \quad R^2} dx$$

Net magnetic field at the centre of the disc,

$$B \quad dB \quad \frac{{}_0 \quad q}{2 \quad R^2} {}_0^R dx \quad \frac{{}_0 \quad q}{2 \quad R}$$

$$\frac{M}{B} \quad \frac{R^3}{2 \quad {}_0}$$

27. (a) By principle of conservation of energy,

Gain in KE Loss in PE

KE PE cos ME

$$f \cos \quad 1 \quad \frac{K}{\text{ME}} \quad 1 \quad \frac{0.80 \quad 10^{\quad 3}}{0.02 \quad 52 \quad 10^{\quad 3}}$$

$$\frac{10}{13}$$

$$\cos^{\ 1} \frac{10}{13} \quad 76.7$$

(b) $\cos^{\ 1} \frac{10}{13} \quad 76.7$

Entire KE will again get converted into PE

28. $U \quad U_2 \quad U_1 \qquad MB \quad (\quad MB)$

$2\,MB$

$2 \quad 1.45 \quad 0.835 \qquad 2.42$ J

29. (a) $T \quad \frac{2 \quad r}{v} \quad \frac{2 \quad 3.14 \quad 5.3 \quad 10^{\ 11}}{2.2 \quad 10^6}$

$1.5 \quad 10^{\ 16}$ s

(b) $i \quad \frac{e}{T} \quad \frac{1.6 \quad 10^{\ 19}}{1.5 \quad 10^{\ 16}} \quad 1.1 \quad 10^{\ 3}$A

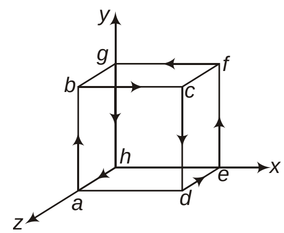
1.1 mA

(c) $M \qquad r^2 i$

$3.14 \quad (5.3 \quad 10^{\ 11})^2 \quad 1.1 \quad 10^{\ 3}$

$9.3 \quad 10^{\ 24}$ A-m^2

30. Suppose equal and opposite currents are flowing in sides $a\,d$ and $e\,h$, so that three complete current carrying loops are formed,



$$\mathbf{M}_{abcd} \qquad i\,l^2\,\hat{\mathbf{k}}$$

$$\mathbf{M}_{efgh} \quad i\,l^2\,\hat{\mathbf{k}}$$

$$\mathbf{M}_{adeh} \quad i\,l^2\,\hat{\mathbf{j}}$$

Total magnetic moment of the closed path,

$$\mathbf{M} \quad \mathbf{M}_{abcd} \quad \mathbf{M}_{efgh} \quad \mathbf{M}_{adeh} \quad i\,l^2\,\hat{\mathbf{j}}$$

31. Circuit is same as in Q.30

$$\mathbf{M} \quad i\,l^2\,\hat{\mathbf{j}} \quad \hat{\mathbf{j}}$$

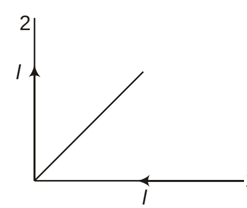
$$\mathbf{B} \quad 2\,\hat{\mathbf{j}}$$

$$\mathbf{M} \quad \mathbf{B} \quad 0$$

32. $B_1 \quad \frac{{}_0}{4} \quad \frac{I}{r}$

$$B_2 \quad \frac{{}_0}{4} \quad \frac{I}{r}$$

Here, B_1 and B_2 are perpendicular to each other, hence,



$$B \quad \sqrt{B_1^2 \quad B_2^2}$$

$$\frac{{}_0}{4} \quad \frac{\sqrt{2}I}{r} \quad \frac{10^{\ 7} \quad \sqrt{2} \quad 5}{35 \quad 10^{\ 2}}$$

$2.0 \quad 10^{\ 6}$ T

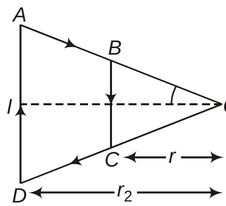
$2.0 \quad$ T

33. Clearly $BOC \sim \quad AOB$

$$\frac{r_2}{r_6} \quad \frac{AD}{BC}$$

$r_2 \quad 2r$

100 mm



and AD $2BC$ 200 mm

$$\cos^{1}\frac{r}{\frac{BC}{2}} \quad 45$$

$$B_{BC} \quad \frac{\ _0}{4}\frac{I}{r}[\sin 45 \quad \sin 45\ ]\frac{\sqrt{2}\,I}{r}$$

$$\frac{\ _0}{4} \qquad \text{(outwards)}$$

$$B_{AD} \quad \frac{\ _0}{4}\frac{I}{r_2}(\sin 45 \quad \sin 45\ )$$

$$\frac{\ _0}{4}\frac{\sqrt{2}\,I}{r_2} \qquad \text{(inwards)}$$

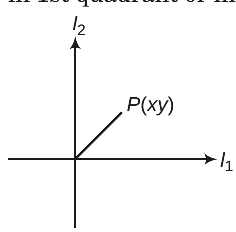
Net magnetic field at O.

$$B \quad B_{BC} \quad B_{AD} \quad \frac{\sqrt{2}\ \ _0 I}{4}\ \frac{1}{r_1}\ \ \frac{1}{r_2}$$

$$\sqrt{2} \quad 10^{\ 7} \quad \sqrt{2} \quad \frac{1}{50 \quad 10^{\ 3}} \quad \frac{1}{100 \quad 10^{\ 3}}$$

$$2 \quad 10^{\ 6}\,\text{T} \quad 2 \quad \text{T} \qquad \text{(outwards)}$$

34. Let us consider a point $P(x, y)$ where magnetic field is zero. Clearly the point must lie either in 1st quadrant or in 3rd quadrant.



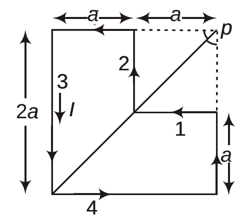
$$B \quad \frac{\ _0}{4}\frac{2I_1}{y} \quad \frac{\ _0}{4}\frac{2I_2}{x} \quad 0$$

$$I_1 x \quad I_2 y$$

$$y \quad \frac{I_1}{I_2} \quad x$$

35. 45

$$B_1 \quad B_2 \quad \frac{\ _0}{4}\frac{I}{a}(\sin \qquad \sin\ )$$



$$\frac{\ _0}{4}\frac{I}{a\sqrt{2}} \qquad \text{(inwards)}$$

$$B_3 \quad B_4 \quad \frac{\ _0}{4}\frac{I}{\sqrt{2}a}(\sin 0 \quad \sin 0)$$

$$\frac{\ _0}{4}\frac{I}{2a\sqrt{2}} \qquad \text{(outwards)}$$

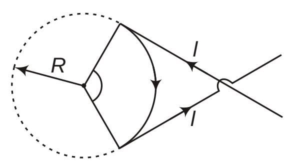
Net magnetic field at P

$$B \quad B_1 \quad B_2 \quad (B_3 \quad B_4)$$

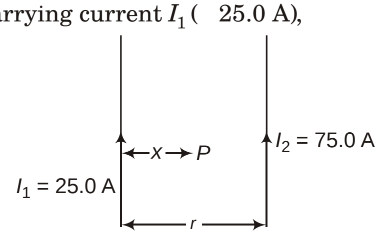
$$\frac{\ _0}{4}\frac{I}{\sqrt{2}a} \qquad \text{(inwards)}$$

36. $B \quad 2 \quad \frac{\ _0}{4}\frac{I}{R} \quad \frac{\ _0 I}{2R} \quad \frac{\ }{2} \quad 0$

2 rad.



37. (a) Consider a point P in between the two conductors at a distance x from conductor carrying current I_1 (25.0 A),



Magnetic field at P

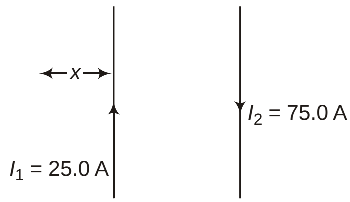
$$B \quad \frac{\ _0}{4}\frac{I_1}{x} \quad \frac{\ _0}{4}\frac{I_2}{r \quad x} \quad 0$$

$$\frac{I_1}{x} \quad \frac{I_2}{r \quad x}$$

$$\frac{r \quad x}{x} \quad \frac{I_2}{I_1}$$

$$x \quad \frac{I_1}{I_1 \quad I_2}r \quad \frac{25.0}{100.0} \quad 40 \quad 10\ \text{cm}$$

(b) Consider a point Q lying on the left of the conductor carrying current I_1 at a distance x from it.



$$B \quad \frac{_0}{4} \frac{I_1}{x} \quad \frac{_0}{4} \frac{I_2}{r \quad x} \quad 0$$

$$\frac{I_1}{x} \quad \frac{I_2}{r \quad x}$$

$$x \quad \frac{I_1}{I_2 \quad I_1} r \quad \frac{25.0}{50.0} \quad 40$$

$$20 \text{ cm}$$

38. $B \quad \frac{_0}{4} \frac{2N \quad r^2 I}{(r^2 \quad x^2)^{3/2}}$

But, $x \quad R$

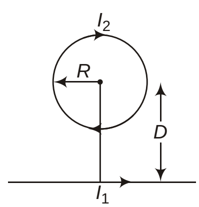
$$B \quad \frac{_0 NI}{4\sqrt{2} r} \quad N \quad \frac{4\sqrt{2}\, Br}{_0 I}$$

$$\frac{4\sqrt{2} \quad 6.39 \quad 10^{\quad 4} \quad 6 \quad 10^{\quad 2}}{4 \quad 10^{\quad 7} \quad 2.5}$$

$$N \quad 69$$

39. For magnetic field at the centre of loop to be zero, magnetic field due to straight conductor at centre of loop must be outward, hence I_1 must be rightwards.

At the centre of the loop



$$B \quad B_1 \quad B_2$$

$$\frac{_0}{4} \frac{2I_1}{D} \quad \frac{_0 I_2}{2R} \quad 0$$

$$I_1 \quad \frac{D}{R} I_2$$

40. (a) $B \quad \frac{_0 NI}{2R} \quad I \quad \frac{2BR}{_0 N}$

$$\frac{2 \quad 0.0580 \quad 2.40 \quad 10^{\quad 2}}{4 \quad 10^{\quad 7} \quad 800}$$

$$I \quad 2.77 \text{ A}$$

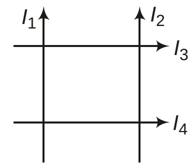
(b) On the axis of coil,

$$B \quad \frac{_0}{4} \frac{2\,NIA}{(r^2 \quad x^2)^{3/2}}$$

$$\frac{B_C}{B} \quad \frac{(r^2 \quad x^2)^{3/2}}{r^3} \quad \left(\frac{r^2 \quad x^2}{r^2}\right)^{3/2} \quad 2$$

$$x \quad 0.0184 \text{ m}$$

41. Let the current I_2 (I) upwards



$$B \quad B_1 \quad B_2 \quad B_3 \quad B_4$$

$$\frac{_0}{4} \frac{2}{r} [\quad I_1 \quad I_2 \quad I_3 \quad I_4] \quad 0$$

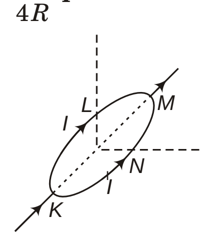
$$I_2 \quad I_1 \quad I_3 \quad I_4$$

$$10 \quad 8 \quad 20$$

$$2 \text{ A}$$

Negative sign indicates that current I is directed downwards.

42. $\mathbf{B}_{KLM} \quad \frac{_0 I}{4R} \hat{\mathbf{i}}$



$$\mathbf{B}_{KNM} \quad \frac{_0 I}{4R} \hat{\mathbf{j}}$$

$$\mathbf{B} \quad \mathbf{B}_{KLM} \quad \mathbf{B}_{KNM} \quad \frac{_0 I}{4R} (\quad \hat{\mathbf{i}} \quad \hat{\mathbf{j}})$$

(a) $\mathbf{F} \quad q(\mathbf{v} \quad \mathbf{B}) \quad \frac{_0 Iqv}{4R} \hat{\mathbf{k}}$

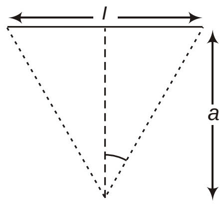
(b) $\mathbf{l}_1 \quad \mathbf{l}_2 \quad 2R\hat{\mathbf{k}}$

$$\mathbf{F}_1 \quad I(\mathbf{l}_1 \quad \mathbf{B}) \quad 2IRB\,\hat{\mathbf{i}}$$

$$\mathbf{F}_2 \quad I(\mathbf{l}_2 \quad \mathbf{B}) \quad 2IRB\,\hat{\mathbf{i}}$$

$$\mathbf{F} \quad \mathbf{F}_1 \quad \mathbf{F}_2 \quad 4IRB\,\hat{\mathbf{i}}$$

43. (a) Length of each side



$$l \quad \frac{2\ \ r}{n}$$

$$\overline{}\ \ n$$

$$a \quad \frac{l}{2}\cot \qquad \frac{r}{n}\cot$$

$$B \quad n \quad \frac{\ \ 0}{4}\ \frac{i}{a}(2\sin\ \ )$$

$$\frac{\ \ 0}{4}\ \frac{2n^2\sin}{r\cot}$$

$$\frac{{}_0\, i\, n^2 \sin^2 \frac{}{n}}{2\ \ {}^2 r\cos\frac{}{n}}$$

(b) $\lim_{n} B \quad \lim_{n} \frac{{}_0 i\, n^2 \sin^2 \frac{}{n}}{2\ \ {}^2 r\cos\frac{}{n}}$

$$\lim_{n\ \ 0} \quad \frac{{}_0 i}{2r}$$

44. $\circ\,\mathbf{B}\ \mathbf{dl} \quad 3.83 \quad 10^{\ 7}$ T-m

(a) By Ampere's circuital law

$\circ\,\mathbf{B}\ \mathbf{dl} \quad {}_0 I$

$$I \quad \frac{1}{0}\circ\,\mathbf{B}\ \mathbf{dl} \quad \frac{1}{4\quad 10^{\ 7}} \quad 3.83 \quad 10^{\ 7}$$

0.3A

(b) If we integrate around the curve in the opposite direction, the value of line integral will become negative, *i.e.*,

3.83 $\quad 10^{\ 7}$ T-m.

45. $\circ\,\mathbf{B}\ \mathbf{dl} \quad {}_0 I$

As the path is taken counter-clockwise direction, $\circ\,\mathbf{B}\ \mathbf{dl}$ will be positive if current is outwards and will be negative if current is inwards.

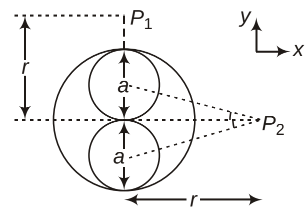
$\circ_a\,\mathbf{B}\ \mathbf{dl} \quad 0$

$\circ_b\,\mathbf{B}\ \mathbf{dl} \quad {}_0 I_1 \quad 5.0 \quad 10^{\ 6}$ T-m

$\circ_c\,\mathbf{B}\ \mathbf{dl} \quad {}_0(I_2 \quad I_1) \quad 2.5 \quad 10^{\ 6}$ T-m

$\circ_d\,\mathbf{B}\ \mathbf{dl} \quad {}_0(I_2 \quad I_3 \quad I_1) \quad 5.0 \quad 10^{\ 6}$ T-m

46.



Current density

$$J \quad \frac{I}{a^2 \quad 2\ \ \frac{a}{2}^{2}} \quad \frac{2I}{a^2}$$

Let us consider both the cavities are carrying equal and opposite currents with current density J.

Let B_1, B_2 and B_3 be magnetic fields due to complete cylinder, upper and lower cavity respectively.

(a) At point P_1

$$\mathbf{B}_1 \quad \frac{\ 0}{4}\ \frac{2I_1}{r}\hat{\mathbf{i}} \quad \frac{\ 0}{4}\ \frac{2J\quad a^2}{r}\hat{\mathbf{i}}$$

$$\frac{{}_0 I}{r}\hat{\mathbf{i}}$$

$$\mathbf{B}_2 \quad \frac{\ 0}{4}\ \frac{2I_2}{r\quad \frac{a}{2}}\hat{\mathbf{i}} \quad \frac{\ 0}{4}\ \frac{2J\quad \frac{a}{2}^{\ 2}}{r\quad \frac{a}{2}}\hat{\mathbf{i}}$$

$$\frac{{}_0 I}{4\quad r\quad \frac{a}{2}}\hat{\mathbf{i}}$$

$$\mathbf{B}_3 \quad \frac{\ 0}{4}\ \frac{2I_3}{r\quad \frac{a}{2}}\hat{\mathbf{i}} \quad \frac{0}{4\quad r\quad \frac{a}{2}}\hat{\mathbf{i}}$$

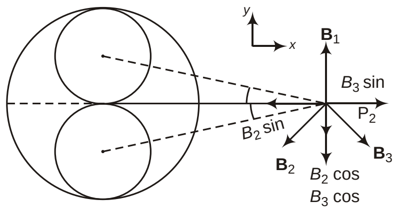
$$\mathbf{B} \quad \mathbf{B}_1 \quad \mathbf{B}_2 \quad \mathbf{B}_3$$

$$\frac{{}_0 I}{4}\quad \frac{4}{r} \quad \frac{1}{r\quad \frac{a}{2}} \quad \frac{1}{r\quad \frac{a}{2}}\ \hat{\mathbf{i}}$$

$$\mathbf{B} \quad \frac{{}_0 I}{4\ r}\ \frac{2r^2\quad a^2}{4r^2\quad a^2}\ \hat{\mathbf{i}}$$

(**B**) $\frac{{}_0 I}{4\ r}\ \frac{2r^2\quad a^2}{4r^2\quad a^2}$, towards left.

(b) At point P_2



$$\mathbf{B}_1 \quad \frac{{}_0}{4}\ \frac{2I_1}{r}\hat{\mathbf{j}} \quad \frac{{}_0 I}{r}\hat{\mathbf{j}}$$

$$\mathbf{B}_2 \quad \frac{{}_0}{4}\ \frac{2I_2}{\sqrt{r^2 \quad \frac{a^2}{4}}}[\quad \sin \quad \hat{\mathbf{i}} \quad \cos \quad \hat{\mathbf{j}}]$$

$$\frac{{}_0 I}{2\ \sqrt{4r^2 \quad a^2}}[\sin \quad \hat{\mathbf{i}} \quad \cos \quad \hat{\mathbf{j}}]$$

$$\mathbf{B}_3 \quad \frac{{}_0}{4}\ \frac{2I_3}{\sqrt{r^2 \quad \frac{a^2}{4}}}[\sin \quad \hat{\mathbf{i}} \quad \cos \quad \hat{\mathbf{j}}]$$

$$\frac{{}_0 I}{2\ \sqrt{4r^2 \quad a^2}}[\sin \quad \hat{\mathbf{i}} \quad \cos \quad \hat{\mathbf{j}}]$$

$$\mathbf{B} \quad \mathbf{B}_1 \quad \mathbf{B}_2 \quad \mathbf{B}_3$$

$$\frac{{}_0 I}{2}\ \frac{2}{r}\ \frac{2\cos}{\sqrt{4r^2 \quad a^2}}\ \hat{\mathbf{j}}$$

but, cos $\frac{r}{\sqrt{r^2 \quad \frac{a^2}{4}}} \quad \frac{2r}{\sqrt{4r^2 \quad a^2}}$

$$\mathbf{B} \quad \frac{{}_0 I}{2}\ \frac{2}{r}\ \frac{4r}{4r^2 \quad a^2}\ \hat{\mathbf{j}}$$

$$\frac{{}_0 I}{4\ r}\ \frac{2r^2 \quad a^2}{4r^2 \quad a^2}\ \hat{\mathbf{j}}$$

(**B**) $\frac{{}_0 I}{4\ r}\ \frac{2r^2 \quad a^2}{4r^2 \quad a^2}$, upwards.

47. Let us first find magnetic field due a current carrying infinite plate.

Consider a rectangular amperian loop ($WXYZ$) as shown in Fig. 1.

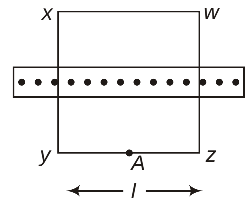


Fig.1

$$\oint_{WXYZ} \mathbf{B}\ \mathbf{dl} \qquad {}_0\ l$$

$$\int_W^X \mathbf{B}\ \mathbf{dl} \quad \int_X^Y \mathbf{B}\ \mathbf{dl} \quad \int_Y^Z \mathbf{B}\ \mathbf{dl} \quad \int_Z^W \mathbf{B}\ \mathbf{dl} \qquad {}_0\ l$$

$$Bl \quad 0 \quad Bl \quad 0 \quad {}_0\ l$$

$$B \quad \frac{1}{2}\ {}_0$$

In Fig. 2.

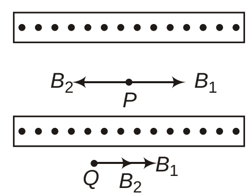


Fig.2

At point P,

$$B_1 \quad B_2 \quad \frac{1}{2}\ {}_0$$

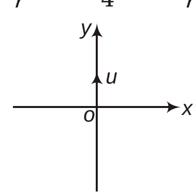
$$B \quad B_1 \quad B_2 \quad 0,$$

At point Q,

$$B_1 \quad B_2 \quad \frac{1}{2}\ {}_0$$

$$B \quad B_1 \quad B_2 \qquad {}_0$$

48. $\mathbf{B} \quad \frac{{}_0}{4}\ \frac{I\,\mathbf{dl} \quad \mathbf{r}}{r^3} \quad \frac{{}_0}{4}\ \frac{q(\mathbf{v} \quad \mathbf{r})}{r^3}$



$$\mathbf{v} \quad (8.00 \quad 10^6\ \text{ms}\ {}^{1})\hat{\mathbf{j}}$$

(a) $\mathbf{r} \quad (0.500\ \text{m})\hat{\mathbf{i}}$

$$\mathbf{B} \quad \frac{{}_0}{4}\ \frac{q(\mathbf{v} \quad \mathbf{r})}{r^3}$$

$$\frac{10^{\ 7}\ \ 6.00\ \ 10^{\ 6}[(8.00\ \ 10^{6}\,\hat{\mathbf{j}})\ \ (0.500)\,\hat{\mathbf{i}}\,]}{(0.500)^{3}}$$

$\mathbf{B}\quad (1.92\ \ 10^{\ 5}\,\mathrm{T})\,\hat{\mathbf{k}}$

(b) $\mathbf{r}\quad (0.500\ \mathrm{m})\,\hat{\mathbf{j}}$

$$\mathbf{B}\quad \frac{0}{4}\ \frac{q(\mathbf{v}\quad \mathbf{r})}{r^{3}}\quad 0$$

(c) $\mathbf{r}\quad (0.500\ \mathrm{m})\,\hat{\mathbf{k}}$

$$\mathbf{B}\quad \frac{0}{4}\ \frac{q(\mathbf{v}\quad \mathbf{r})}{r^{3}}\quad (1.92\ \ 10^{\ 5}\,\mathrm{T})\,\hat{\mathbf{i}}$$

(d) $\mathbf{r}\quad (0.50\ \mathrm{m})\,\hat{\mathbf{j}}\ \ 0.500\ \mathrm{m}\,\hat{\mathbf{k}}$

$$\mathbf{B}\quad \frac{0}{4}\ \frac{q(\mathbf{v}\quad \mathbf{r})}{r^{3}}\quad (1.92\ \ 10^{\ 5}\,\mathrm{T})\,\hat{\mathbf{i}}$$

49. $q\quad 4.80\ \mathrm{C}\quad 4.80\ \ 10^{\ 6}\,\mathrm{C}$

$\mathbf{v}\quad (6.80\ \ 10^{5}\ \mathrm{m/s})\,\hat{\mathbf{i}}$

(a) $\mathbf{r}\quad (0.500\ \mathrm{m})\,\hat{\mathbf{i}}$

$$\mathbf{B}\quad \frac{0}{4}\ \frac{q(\mathbf{v}\quad \mathbf{r})}{r^{3}}\quad 0$$

(b) $\mathbf{r}\quad (0.500\ \mathrm{m})\,\hat{\mathbf{j}}$

$$\mathbf{B}\quad \frac{0}{4}\ \frac{q(\mathbf{v}\quad \mathbf{r})}{r^{3}}\quad (1.3\ \ 10^{\ 6}\,\mathrm{T})\,\hat{\mathbf{k}}$$

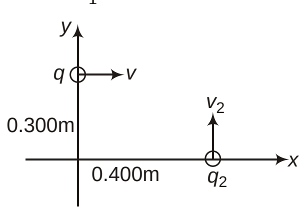
(c) $\mathbf{r}\quad (0.500\ \mathrm{m})\,\hat{\mathbf{i}}\ \ (0.500\ \mathrm{m})\,\hat{\mathbf{j}}$

$$\mathbf{B}\quad \frac{0}{4}\ \frac{q(\mathbf{v}\quad \mathbf{r})}{r^{3}}\quad (1.31\ \ 10^{\ 6}\,\mathrm{T})\,\hat{\mathbf{k}}$$

(d) $\mathbf{r}\quad (0.500\ \mathrm{m})\,\hat{\mathbf{k}}$

$$\mathbf{B}\quad \frac{0}{4}\ \frac{q(\mathbf{v}\quad \mathbf{r})}{r^{3}}\quad (1.31\ \ 10^{\ 6}\,\mathrm{T})\,\hat{\mathbf{j}}$$

50. $\mathbf{B}_1\quad \frac{0}{4}\ \frac{q_1(\mathbf{v}_1\quad \mathbf{r}_2)}{r_1^{3}}$



$$\mathbf{B}_1\quad \frac{10^{\ 7}\ \ 4.00\ \ 10^{\ 6}[(2.00\ \ 10^{5}\,\hat{\mathbf{i}})\ \ (\ \ 0.300\,\hat{\mathbf{j}})]}{(0.300)^{3}}$$

$(8.89\ \ 10^{\ 7}\,\mathrm{T})\,\hat{\mathbf{k}}$

$$\mathbf{B}_2\quad \frac{0}{4}\ \frac{q_2(\mathbf{v}_2\quad \mathbf{r}_2)}{r_2^{3}}$$

$$\mathbf{B}_2\quad \frac{10^{\ 7}\ \ (\ \ 1.5\ \ 10^{\ 6})[(8.00\ \ 10^{5}\,\hat{\mathbf{i}})\ \ (\ \ 0.400\,\hat{\mathbf{j}})]}{(0.400)^{2}}$$

$(7.5\ \ 10^{\ 7}\,\mathrm{T})\,\hat{\mathbf{k}}$

$\mathbf{B}\quad \mathbf{B}_1\quad \mathbf{B}_2\quad (16.4\ \ 10^{\ 6}\,\mathrm{T})\,\hat{\mathbf{k}}$

$(1.64\ \ 10^{\ 6}\,\mathrm{T})\,\hat{\mathbf{k}}$

or $\quad B\ \ 1.64\ \ 10^{\ 6}\,\mathrm{T}$ (inwards)

51. Magnetic force per unit length on the conductor AB,

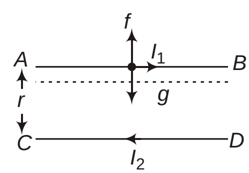
$$f\quad \frac{0}{4}\ \frac{2I_1I_2}{r}$$

For equilibrium

$$f\quad \frac{m}{l}g\qquad g$$

$$g\quad \frac{0}{4}\ \frac{2I_1I_2}{r}\qquad \text{...(i)}$$

Suppose wire AB is depressed by x,



Net force on unit length of wire AB

$$a\quad g\quad f$$

$$\frac{0}{4}\ \frac{2I_1I_2}{r}\qquad \frac{0}{4}\ \frac{2I_1I_2}{r\quad x}$$

$$\frac{0}{4}\ \frac{2\,I_1I_2\ \ x}{r(r\quad x)}$$

If $x\quad r$

$$a\qquad \frac{{}_0I_1I_2}{2r^{2}}\,x$$

$$a\qquad \frac{{}_0I_1I_2}{2\ \ r^{2}}\,x\qquad \text{...(ii)}$$

General equation of SHM

$$a \quad {}^2 x \qquad \ldots\text{(ii)}$$

Hence, motion of wire AB will be simple harmonic.

From Eqs. (i) and (ii),

$$\sqrt{\frac{{}_0 I_1 I_2}{2 \ r^2}}$$

$$T \ \frac{2}{\ } \quad 2\sqrt{\frac{2 \ r^2}{{}_0 I_1 I_2}} \quad 2\sqrt{\frac{r}{g}}$$

$$2 \quad 3.14\sqrt{\frac{0.01}{9.8}}$$

$$0.2 \text{ s}$$

52. (a) $f \quad \frac{\ _0}{4} \ \frac{2I_1 I_2}{r}$

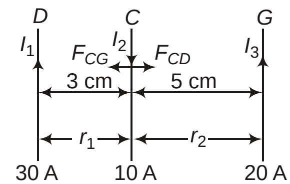
$$I_2 \quad \frac{f\ r}{\frac{\ _0}{4}\ 2I_1}$$

$$\frac{4.00 \quad 10^{\ 5} \quad 2.50 \quad 10^{\ 2}}{10^{\ 7} \quad 2 \quad 0.600}$$

$$8.33 \text{ A}$$

(b) As the wires repel each other, current must be in opposite directions.

53. $f_{CD} \quad \frac{\ _0}{4} \ \frac{2\, I_1 I_2}{r_1}$



$$f_{CG} \quad \frac{\ _0}{4} \ \frac{2\, I_2 I_3}{r_2}$$

$$f \quad f_{CD} \quad f_{CG}$$

$$f \quad f_{CD} \quad f_{CG} \quad \frac{\ _o}{4} \ 2I_2 \ \frac{I_1}{r_1} \ \frac{I_3}{r_2}$$

$$10^{\ 7} \quad 2 \quad 10 \ \frac{30}{3 \quad 10^{\ 2}} \quad \frac{20}{5 \quad 10^{\ 2}}$$

$$f \quad 12 \quad 10^{\ 4} \text{ N} \quad 1.2 \quad 10^{\ 3} \text{ N/m}$$

$$F \quad f\ l \quad 1.2 \quad 10^{\ 3} \quad 25 \quad 10^{\ 2}$$

$$3 \quad 10^{\ 4} \text{ N}$$

54. Force per unit length on wire MN

$$f_{MN} \quad \frac{\ _0}{4} \ \frac{2I_1 I_2}{a}$$

$$F \quad f_{MN} \quad L \quad \frac{\ _0 I_1 I_2 L}{2 \ a}$$

Torque acting on the loop is zero because magnetic field is parallel to the area vector.

Objective Questions (Level 1)

1. Fact

2. $T \ \frac{2 \ m}{qB}$ is independent of speed.

3. Outside the wire

$B \ \frac{\ _0}{4} \ \frac{2I}{r}$ where, r is distance from the centre.

4. The path will be parabola if force acting on the particle is constant in magnitude as well as in direction.

5. $B \ \frac{\ _0}{4} \ \frac{2I}{r}$

$$_0 \ \frac{4 \ rB}{2I}$$

Units of $_0$ $\frac{\text{m} \quad \text{Wb/m}^2}{\text{A}}$

$$\text{Wbm}^{\ 1}\text{A}^{\ 1}$$

6. Fact

7. $\mathbf{M} \quad i\,\mathbf{A}$, where $\mathbf{A}$ Area vector.

8. Force acting on a closed current carrying loop is always zero.

9. $M \quad NIA$

10. $\mathbf{a} \quad \mathbf{B} \quad \mathbf{a}\ \mathbf{B} \quad 0$

$$(x\,\hat{\mathbf{i}} \quad \hat{\mathbf{j}} \quad \hat{\mathbf{k}})\ (2\,\hat{\mathbf{i}} \quad 3\,\hat{\mathbf{j}} \quad 4\,\hat{\mathbf{k}}) \quad 2x \quad 3 \quad 4 \quad 0$$

$$x \quad 0.5$$

12. A current carrying closed loop never experiences a force magnetic field.

13. $r \quad \frac{mv}{qB} \quad \frac{P}{qB}$,

$$P \quad mv \quad \text{momentum.}$$

$$r \quad \frac{1}{q}$$

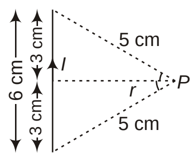
$$\frac{r_p}{r} \quad \frac{q}{q_p} \qquad r_P : r \quad 2:1$$

14. $W \quad MB(\cos \;_1 \quad \cos \;_2)$

Here, $\;_1 \quad , \;_2$

$$W \quad MB(\cos \quad \cos(\quad))$$
$$MB(1 \quad \cos \;)$$

15. $B_P \quad \frac{_0}{4} \frac{I}{r}(2\sin \;)$



$$r \quad \sqrt{5^2 \quad 3^2} \quad 4 \text{ cm}$$
$$4 \quad 10^{\ 2} \text{ m}$$

$\sin \quad \frac{3}{5}$

$$B_P \quad \frac{10^{\ 7} \quad 50 \quad 2 \quad \frac{3}{5}}{4 \quad 10^{\ 2}}$$
$$1.5 \quad 10^{\ 4} \text{ T}$$
$$1.5 \text{ gauss.}$$

16. Magnetic field on the axis of current carrying circular loop,

$$B_1 \quad \frac{_0}{4} \frac{2M}{(r^2 \quad x^2)^{3/2}} \qquad \text{...(i)}$$

Magnetic field at the centre of current carrying circular loop,

$$B_2 \quad \frac{_0}{4} \frac{2M}{r^3} \qquad \text{...(ii)}$$

From Eqs. (i) and (ii),

$$\frac{B_2}{B_1} \quad \frac{(r^2 \quad x^2)^{3/2}}{r^3}$$
$$\frac{(3^2 \quad 4^2)^{3/2}}{3^3}$$
$$\frac{125}{27}$$
$$B_2 \quad \frac{125}{27} \quad 54 \quad 150 \quad \text{T}$$

17. $\mathbf{F} \quad I(\mathbf{l} \quad \mathbf{B}) \quad I(\mathbf{ba} \quad \mathbf{B})$

$$I(\mathbf{ab} \quad \mathbf{B}) \quad I(\mathbf{B} \quad \mathbf{ab})$$

18. Kinetic energy of electron,

$$K \quad \frac{1}{2}mv^2 \quad eV$$

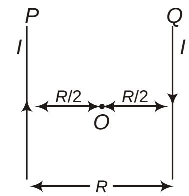
$$v \quad \sqrt{\frac{2eV}{m}}$$

Magnetic force,

$$F_m \quad evB\sin$$
$$F_m \quad v \quad F_m \quad \sqrt{v}$$

Hence, if potential difference is doubled, force will become $\sqrt{2}$ times.

19. Magnetic field at O due to P,



$$B_1 \quad \frac{_0}{4} \frac{2I}{R/2} \quad \frac{_0 I}{R} \qquad \text{(inwards)}$$

Magnetic field at O due to Q,

$$B_2 \quad \frac{_0}{4} \frac{2I}{R/2} \quad \frac{_0 I}{R} \qquad \text{(inwards)}$$

Net magnetic field at O,

$$B \quad B_1 \quad B_2 \quad \frac{2 \;_0 I}{R}$$

20. As solved in Question 16,

$$\frac{B_2}{B_1} \quad \frac{x^2 \quad R^2}{R^2}^{3/2}$$
$$\frac{x^2 \quad R^2}{R^2}^{3/2} \quad 8$$
$$\frac{x^2 \quad R^2}{R^2} \quad 4$$
$$x \quad \sqrt{3}\,R$$

21. Component of velocity of particle along magnetic field, *i.e.*,

$$v_y \quad \frac{qE}{m}t \qquad Et$$

is not constant, hence pitch is variable.

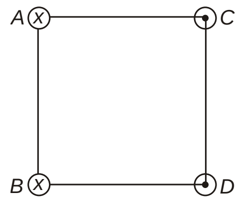
22. $r \quad \frac{mv}{qB} \quad \frac{\sqrt{2mK}}{qB}$

Now, $R \quad \frac{\sqrt{2mK}}{eB}$

$$R \quad \frac{\sqrt{2m(2K)}}{e(3R)} \quad \frac{\sqrt{2}}{3}R$$

23. Same as question 1. Introductory exercise 23.6.

Note. Her diagram is wrong correct diagram should be



24. $r \quad \frac{mv}{qB} \quad \frac{\sqrt{2\,mK}}{qB} \quad \frac{\sqrt{2\,mqV}}{qB}$ $[K \quad qV]$

$$r \quad \sqrt{\frac{2\,mV}{q}} \quad \frac{1}{B}$$

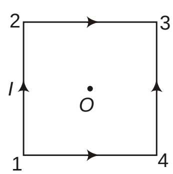
25. Magnetic field due to a conductor of finite length.

$$B \quad \frac{\ _0}{4} \frac{I}{r}(\sin \qquad \sin \ )$$

Here, $\quad _2, \quad _1$ and $r \quad a$

$$B \quad \frac{_0 I}{2a}(\sin \ _1 \quad \sin \ _2)$$

26. In case C, magnetic field of conductor 1-2 and 2-3 at O is inward while those of 3-4 and 4-1 at O is outward, hence net magnetic field at O in this case is zero.

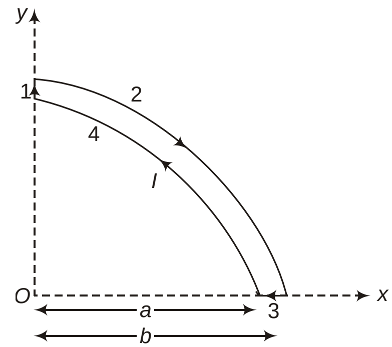


27. $\mathbf{dF} \quad I(\mathbf{dl} \quad \mathbf{B})$

But $\mathbf{B} \,||\, \mathbf{dl}$ at every point,

hence, $\mathbf{dF} \quad 0.$

28. $B_1 \quad B_3 \quad 0$ (Magnetic field on the axis of current carrying straight conductor is zero)



$$\mathbf{B}_2 \quad \frac{1}{4} \quad \frac{_0 I}{2b} \quad \hat{\mathbf{k}} \qquad \frac{_0 I}{8b} \hat{\mathbf{k}},$$

$$\mathbf{B}_3 \quad \frac{1}{4} \quad \frac{_0 I}{2a} \quad \hat{\mathbf{k}} \qquad \frac{_0 I}{8a} \hat{\mathbf{k}}$$

$$\mathbf{B} \quad \mathbf{B}_1 \quad \mathbf{B}_2 \quad \mathbf{B}_3 \quad \mathbf{B}_4$$

$$\frac{_0 I}{8} \quad \frac{1}{a} \quad \frac{1}{b} \quad \hat{\mathbf{k}}$$

29. Current associated with electron,

$$I \quad \frac{q}{T} \quad ef$$

$$B \quad \frac{_0 I}{2R} \quad \frac{_0 ef}{2R}$$

30. Same as question 1(a). Introductory Exercise 23.5.

31. At point 1,

Magnetic field due to inner conductor is non-zero, but due to outer conductor is zero.

Hence, $B_1 \quad 0$

At point 2,

Magnetic field due to both the conductors is equal and opposite.

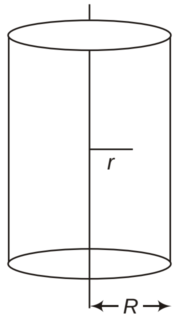
Hence, $B_2 \quad 0$

32. Apply Fleming's left hand rule or right hand thumb rule.

33. Magnetic field due to straight conductors at O is zero because O lies on axis of both the conductors.

Hence, $B \quad \frac{\ }{2} \quad \frac{_0 I}{2x} \quad \frac{_0 I}{4 \ x}$

34. Inside a solid cylinder having uniform current density,



$$B \quad \frac{{}_0 Ir}{2 \quad R^2}$$

Here, $r \quad R \quad x$

$$B \quad \frac{{}_0 I(R \quad x)}{2 \quad R^2}$$

35. Magnetic force is acting radially outward on the loop.

JEE Corner

Assertion and Reason

1. For parabolic path, acceleration must be constant and should not be parallel or antiparallel to velocity.

2. By Fleming's left hand rule.

3. Magnetic force on upper wire must be in upward direction, hence current should be in a direction opposite to that of wire 1.

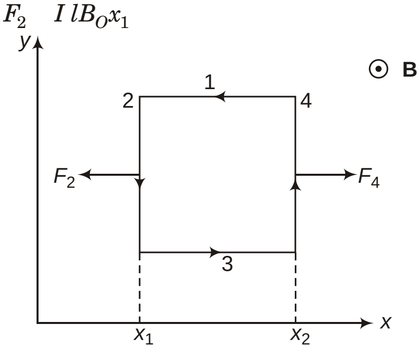
Reason is also correct but does not explain Assertion.

4. $\quad MB \sin$

90

$MB \quad 0$

5. $F_2 \quad I\,lB_O x_1$



$$F_4 \quad I\,lB_0 x_2$$

$$F_4 \quad F_2$$

Hence, net force is along X-axis.

6. Radii of both is different because mass of both is different

$$r \quad \frac{mv}{qB} \quad \frac{\sqrt{2\,meV}}{e\,B}$$

7. For equilibrium

$\mathbf{F}_e \quad \mathbf{F}_m \quad 0$

$$q\,\mathbf{E} \qquad q(\mathbf{v} \quad \mathbf{B})$$

$$\mathbf{E} \qquad \mathbf{v} \quad \mathbf{B} \quad \mathbf{B} \quad \mathbf{v}$$

8. $P_m \quad \mathbf{F}_m \; \mathbf{v}$

As $\mathbf{F}_m$ is always perpendicular to $\mathbf{v}$,

$$\mathbf{P}_m \quad 0$$

Again, $P_e \quad \mathbf{F}_e \; \mathbf{v}$, may or may not be zero.

9. Reason correctly explains Assertion.

10. Magnetic force cannot change speed of particle as it is always perpendicular to the speed of the particle.

11. $a \quad \frac{v^2}{R}$

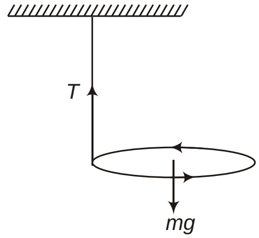
but R also depends on v.

$$a \quad \frac{F_m}{m} \quad \frac{qvB}{m}$$

$$a \quad v$$

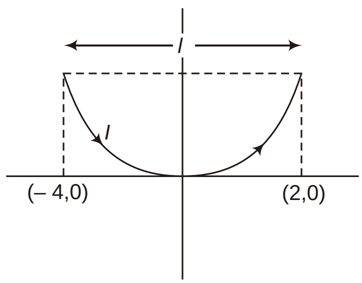
Objective Questions (Level 2)

1. For net torque to be zero.



$$IAB_0 \quad mgR$$
$$I \quad \frac{mgR}{AB_0} \quad \frac{mgR}{R^2B_0}$$
$$\frac{mg}{RB_0}$$

2. As it is clear from diagram,



Effective length of wire,

$$\mathbf{l} \quad (4\text{ m})\hat{\mathbf{i}}$$
$$\mathbf{F} \quad I(\mathbf{l} \quad \mathbf{B})$$
$$\mathbf{a} \quad \frac{\mathbf{F}}{m} \quad \frac{I}{m}(\mathbf{l} \quad \mathbf{B})$$
$$\frac{2}{0.1}(4\hat{\mathbf{i}} \quad (\quad 0.02\hat{\mathbf{k}})) \quad 1.6\hat{\mathbf{j}}\text{ m/s}^2$$

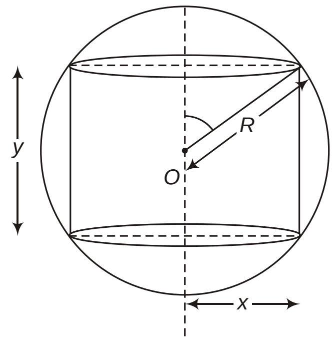
3. Impulse Change in momentum

$$I\, lB\, dt \quad mv \quad 0$$
$$lB \; dq \quad mv$$
$$dq \quad \frac{mv}{lB} \quad \frac{m\sqrt{2gh}}{lB}$$

4. Consider the sphere to be made up of large number of hollow, coaxial cylinder of different height and radius. Consider one such cylinder of radius x, height y and thickness.

Now, $y \quad 2R\cos \quad , x \quad R\sin \quad , dx \quad R\cos \quad d$

Charge on this cylinder,



$$dq \quad \frac{q}{\frac{4}{3} \quad R^3}(2 \quad yx\,dx)$$
$$3q\cos^2 \quad \sin \quad d$$

Current associated with this cylinder,

$$di \quad \frac{dq}{T} \quad \frac{dq}{2} \quad \frac{3 \quad q}{2}\cos^2 \quad \sin \quad d$$

Magnetic moment associated with this cylinder,

$$dM \quad di\,A \quad \frac{3q}{2}\cos^2 \quad \sin \quad d \qquad x^2$$
$$dM \quad \frac{3}{2}R^2 \quad qA\cos^2 \quad \sin^3 \quad d$$
$$M \qquad dM \quad \frac{3}{2}R^2 q \int_{\;2}^{0} \cos^2 \quad \sin^3 \quad d$$
$$\frac{3}{2}R^2 \quad q \int_{/2}^{0} \cos^2 \quad (1 \quad \cos^2 \quad)\sin \quad d$$
$$\frac{3}{2}R^2 \quad q \left[\frac{\cos^3}{3} \quad \frac{\cos^5}{5}\right]_{/2}^{0}$$
$$\frac{1}{5}R^2 \quad q$$

5. As solved in question 5(c). Introductory Exercise 23.2.

$$\frac{L}{R} \quad \sin$$

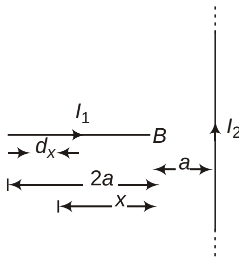
Here, $L \quad d, R \quad \frac{mV}{qB}$

$$\frac{qBd}{mV} \quad \sin$$

or $\frac{q}{m} \quad \frac{V\sin}{Bd}$

6. Force on portion AC will more compared to that on portion CB.

7. Consider an elementary portion of the wire carrying current I_1 of length dx at a distance x from end B.



Force on this portion

$$dF \quad I_1 dx\, B$$

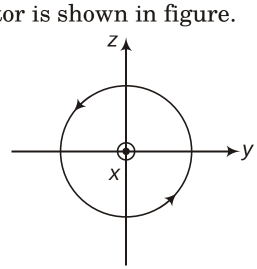
$$\frac{_0}{4} \frac{2 I_1 I_2}{a \quad x} dx$$

Total force on wire AB

$$F \quad dF \quad \frac{_0}{4}\, 2I_1 I_2 \;{}_a^{2a} \frac{dx}{a \quad x}$$

$$\frac{_0 I_1 I_2}{2} \ln 3$$

8. Magnetic field line due to current carrying conductor is shown in figure.



9. $$B_1 \quad \frac{_0}{4} \frac{2\, IA_1}{(x_1^2 \quad r_1^2)^{3/2}}$$

$$\frac{_0}{4} \frac{2I \quad r_1^2}{(x_1^2 \quad r_1^2)^{3/2}}$$

$$B_2 \quad \frac{_0}{4} \frac{2I \quad r_2^2}{(x_2^2 \quad r_2^2)^{3/2}}$$

$$\frac{B_1}{B_2} \quad \frac{r_1^2 (x_2^2 \quad r_2^2)^{3/2}}{r_2^2 (x_1^2 \quad r_1^2)^{3/2}}$$

But, $\quad r_1 \quad x_1 \tan$

and $\quad r_2 \quad x_2 \tan$

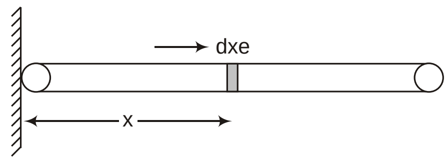
$$\frac{B_1}{B_2} \quad 2$$

10. $b \quad a$ must be less than or equal to radius of circular path,

i.e., $\quad b \quad a \quad \frac{mv}{qB}$

or $\quad v \quad \frac{qB(b \quad a)}{m}$

11. Consider an elementary portion of length dx at a distance x from the pivoted end.



Charge on this portion

$$dq \quad \frac{q}{l} dx$$

Current associated with this portion

$$di \quad \frac{dq}{T} \quad \frac{qf}{l} dx$$

Magnetic moment of this portion

$$dM \quad x^2 di \quad \frac{qf}{l} x^2 dx$$

$$M \quad \frac{qf}{l} \;{}_0^l\, x^2 dx \quad \frac{1}{3} \quad qfl^2$$

12. At $x \quad 0, y \quad 2$ m

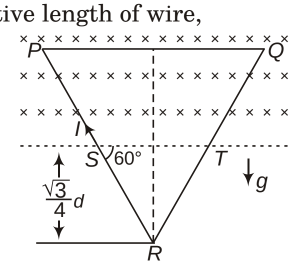
Effective length of wire

$$l \quad (4\text{ m})\hat{\mathbf{j}}$$

$$\mathbf{F}_m \quad I(\mathbf{l} \quad \mathbf{B}) \quad 3(4\hat{\mathbf{j}} \quad 5\hat{\mathbf{k}})$$

$$60\,\hat{\mathbf{i}}\text{ N}$$

13. Effective length of wire,



$$l \quad ST \quad 2 \quad \frac{\sqrt{3}}{4} a \quad \cot 60$$

$$\frac{a}{2}$$

For equilibrium, $I\,lB \quad Mg$

$$I \quad \frac{2Mg}{lB}$$

14. For particle not collide with the solenoid, radius of path of particle half or radius of solenoid.

$$\frac{mv}{qB} \quad \frac{r}{2}$$

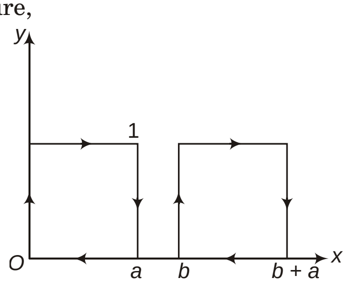
But $B \quad {}_0 n\, i$

$$v \quad \frac{rqB}{2m} \quad \frac{{}_0 qr\, n\, i}{2m}$$

16. Magnetic force cannot do work on charged particle, hence its energy will remain same, so that remains same.

Again, magnetic force is always along the string, it will never produce a torque hence, T will also remain same.

17. Let the x-coordinates of loops be as shown in figure,



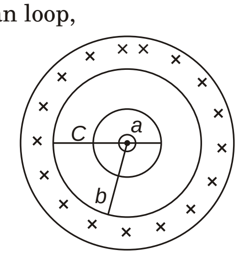
then, $F_1 \quad Ia\,(B_0 a) \quad 0 \quad I\,a^2 B_0$

$F_2 \quad Ia\,(B_0\,(b \quad a)) \quad Ia\,(B_0 b)$

$I\,a^2 B_0$

$F_1 \quad F_2 \quad 0$

18. Consider an amperian loop of radius $x\,(b \quad x \quad c)$, threaded by current the amperian loop,



$$I \quad I \quad \frac{x^2 \quad b^2}{c^2 \quad b^2} I$$

$$\frac{c^2 \quad x^2}{c^2 \quad b^2} I$$

$$I \quad \frac{{}_0 I}{2\ x} \quad \frac{{}_0 I\,(c^2 \quad x^2)}{2\ x\,(c^2 \quad b^2)}$$

19. As $\mathbf{E} \quad \mathbf{v} \quad \mathbf{B}$

Net force on the particle must be zero.

20. Consider an elementary portion of length dy at $y \quad y$ on the wire.

Force on this portion,

$$dF \quad I\,(\mathbf{dy} \quad \mathbf{B})$$

Here, $\mathbf{dy} \quad dy\,\hat{\mathbf{j}}$ (Current is directed along negative y-axis).

$$dF \quad I\,\{dy\,\hat{\mathbf{j}}(0.3\,y\,\hat{\mathbf{i}} \quad 0.4\,y\,\hat{\mathbf{j}})\}$$

$$2 \quad 10^{\ 3}(\quad 0.3\,y\,dy\,\hat{\mathbf{k}})$$

Total force on the wire,

$$F \quad dF \quad 2 \quad 10^{\ 3} \ {}_0^1(\quad 0.3\,y\,dy\,\hat{\mathbf{k}})$$

$$F \quad (3 \quad 10^{\ 4}\,\hat{\mathbf{k}})\ \text{N}$$

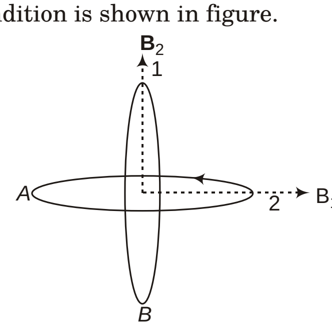
21. $\mathbf{E} \quad \mathbf{v} \quad \mathbf{B}$

$$|\mathbf{E}| \quad vB \quad \frac{rqB}{m} B$$

$$\frac{(5 \quad 10^{\ 2})(20 \quad 10^{\ 6})(0.1)^2}{(20 \quad 10^{\ 9})}$$

$$\mathbf{E} \quad 0.5\ \text{V/m} \qquad (1 \quad \text{g} \quad 10^{\ 9}\text{kg})$$

22. Condition is shown in figure.



$$B_1 \quad \frac{{}_0 I_1}{2R_1}$$

$$B_2 \quad \frac{{}_0 I_2}{2R_2}$$

$$B \quad \sqrt{B_1^2 \quad B_2^2}$$

$$\frac{{}_0}{2}\sqrt{\ \frac{I_1}{R_1}^{2} \quad \frac{I_2}{R_2}^{2}}$$

$$\frac{4 \quad 10^{7}}{2}\sqrt{\left(\frac{5}{\frac{5}{\sqrt{2}} \quad 10^{2}}\right)^{2} \quad \left(\frac{5\sqrt{2}}{5 \quad 10^{2}}\right)^{2}}$$

$$\frac{4 \quad 10^{7} \quad 2}{2 \quad 10^{2}} \quad 4 \quad 10^{5}\,\mathrm{T}$$

23. Initially, net force on the particle is zero. Hence,

$$V \quad \frac{E}{B}$$

Now, if electric field is switched off.

$$r \quad \frac{mv}{qB} \quad \frac{E}{SB^2} \qquad \frac{q}{m} \quad S$$

24. For equilibrium,

$f \quad \dfrac{mg}{l}$ [f magnetic force per unit length on the conductors]

$$\frac{_0}{4}\ \frac{2I_1I_2}{r} \qquad g$$

$$r \quad \frac{_0}{4}\ \frac{2\,I_1I_2}{g}$$

$$\frac{10^{7} \quad 2 \quad 100 \quad 50}{0.01 \quad 10}$$

$$0.01\,\mathrm{m}$$

Clearly, equilibrium of conductor B is unstable.

25. If $\mathbf{B}_1, \mathbf{B}_2$ and $\mathbf{B}_3$ be magnetic fields at the given point due to the wires along x, y and z axis respectively, then

$$\mathbf{B}_1 \quad \frac{_0}{4}\ \frac{2I}{a}\,\hat{\mathbf{j}}$$

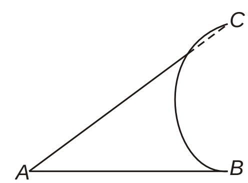
$$\mathbf{B}_2 \quad \frac{_0}{4}\ \frac{2I}{a}\,\hat{\mathbf{i}}$$

$$\mathbf{B}_3 \quad 0$$

$$\mathbf{B} \quad \mathbf{B}_1 \quad \mathbf{B}_2 \quad \mathbf{B}_3 \quad \frac{_0 i}{2\ a}(\hat{\mathbf{j}} \quad \hat{\mathbf{i}})$$

26. Effective length, $l \quad AC \quad \sqrt{4^2 \quad 3^2}$

$$5\,\mathrm{m}$$



$$F \quad I\,lB \quad 2 \quad 5 \quad 2 \quad 20\,\mathrm{N}$$

27. At point P,

$$E \quad \frac{1}{4 \quad _0}\ \frac{qx}{(R^2 \quad x^2)^{3/2}}$$

$$B \quad \frac{_0}{4}\ \frac{2\,iA}{(R^2 \quad x^2)^{3/2}}$$

Hence, $i \quad \dfrac{q}{T} \quad \dfrac{qv}{2\ R}$

and $A \quad R^2$

$$\frac{E}{B} \quad \frac{1}{_0\ _0}\ \frac{1}{v} \quad \frac{c^2}{v} \qquad c \quad \frac{1}{_0\ _0}$$

More than One Correct Options

1. $B_1 \quad \dfrac{_0N_1I_1}{2R_1} \quad \dfrac{4 \quad 10^{7} \quad 50 \quad 2}{2 \quad 5 \quad 10^{2}}$

$$4 \quad 10^{4}\,\mathrm{T}$$

$B_2 \quad \dfrac{_0N_2I_2}{2R_2} \quad \dfrac{4 \quad 10^{7} \quad 100 \quad 2}{2 \quad 10 \quad 10^{2}}$

$$4 \quad 10^{4}\,\mathrm{T}$$

If current is in same sense,

$$B \quad B_1 \quad B_2 \quad 8 \quad 10^{4}\,\mathrm{T}$$

And if current is in opposite sense,

$$B \quad B_1 \quad B_2 \quad 0$$

2. $\mathbf{F} \quad \mathbf{F}_e \quad \mathbf{F}_m \quad q(\mathbf{E} \quad \mathbf{v} \quad \mathbf{B})$

If $\mathbf{F} \quad 0$

Either, $\mathbf{E} \quad \mathbf{v} \quad \mathbf{B}$,

$\mathbf{E} \quad 0, \mathbf{B} \quad 0$

or $\mathbf{E} \quad 0$, or $\mathbf{v} \quad \mathbf{B} \quad 0$

Again, If $\mathbf{v} \quad \mathbf{B} \quad 0$

Either $\mathbf{B} \quad 0$

or 0, *i.e.*, $\mathbf{v} \parallel \mathbf{B}$.

3. The particle will describe a circle in x-y plane with radius,

$$r \quad \frac{mv}{qB} \quad \frac{1 \quad \sqrt{8^2 \quad 6^2}}{1 \quad 2} \quad 5\text{ m}$$

and $T \quad \frac{2 \quad m}{qB} \quad \text{s} \quad 3.14\text{ s}$

4. $MB \sin$

$U \quad pE \cos$

80

Hence, $0, U \quad pE$ maximum.

As PE (U) is maximum, equilibrium is unstable.

5. Fact.

6. Upward and downward components of force will cancel each other while leftward force is more than rightward force, hence net force is leftwards.

7. $\mathbf{F} \quad q\,\mathbf{E} \quad q(\mathbf{v} \quad \mathbf{B})$

$$q\{E_0\,\hat{\mathbf{k}} \quad (v\,\hat{\mathbf{j}}) \quad (B_0\,\hat{\mathbf{i}})\}$$

$$q(E_0 \quad vB_0)\,\hat{\mathbf{k}}$$

If $v \quad \frac{E_0}{B_0}$, particle will deflect towards positive z-axis.

If $v \quad \frac{E_0}{B_0}$, particle will deflect towards negative z-axis.

If $v \quad \frac{E_0}{B_0}$, particle will move undeflected and its KE will remain constant.

8. $K \quad eV \quad K \quad V$ will become double

$R \quad \frac{\sqrt{2mK}}{qB} \quad R \quad \sqrt{K}$ will become $\sqrt{2}$ times.

$\frac{qB}{2 \quad m}$ is independent of kinetic energy.

9. Use right hand thumb rule.

10. For cd to be in equilibrium, force on it must be repulsive while for ab to be in equilibrium, force on it must be attractive.

Equilibrium of cd will be stable while that of ab will be unstable.

Match the Columns

1. (a r), (b q), (c p), (d r)

$\mathbf{F}_m \quad q(\mathbf{v} \quad \mathbf{B}) \quad e(\mathbf{v} \quad \mathbf{B})$

and $\mathbf{F}_m \quad q\,\mathbf{E} \quad e\,\mathbf{E}$

2. (a r), (b s), (c q), (d p)

As $\mathbf{F}_m \quad q(\mathbf{v} \quad \mathbf{B})$

By Fleming's left hand rule, positively charged particles deflects towards left and negatively charged particles deflects towards right.

Again, $r \quad \frac{mv}{qB} \quad \frac{\sqrt{2\,mK}}{qB}$

$$r \quad \frac{\sqrt{m}}{q}$$

3. (a p, s), (b p, q), (c p, r), (d p, s)

Whenever a closed current carrying loop is placed in uniform magnetic field, net force experienced by it is zero.

Also $PE \sin$

is maximum if 90, *i.e.*, in case (b) only.

And $U \quad PE \cos$

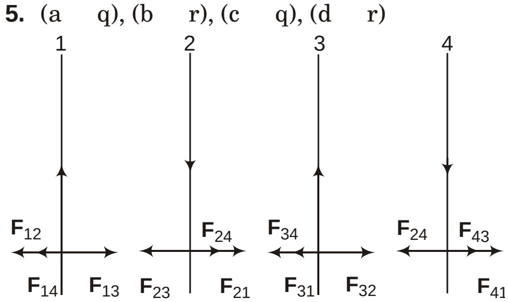
U is positive if is obtuse, *i.e.*, in cases (a) and (d).

and U is minimum if 0, *i.e.*, in case (c).

4. (a q), (b r), (c s), (d s)

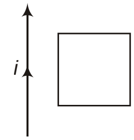
Use right hand thumb rule.

5. (a q), (b r), (c q), (d r)



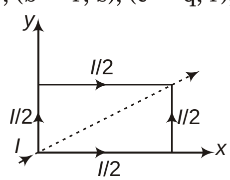
Direction of different forces on different wires is shown in figure.

6. (a q, s), (b p, r), (c p, r), (d q, s)



When the current is increased or the loop is moved towards the wire, magnetic flux linked with the loop increases. As a result of this, induced current will produce in the loop to decrease the magnetic field. Because initial magnetic flux linked with the loop is inward, induced magnetic flux will be outward and induced current will be anti-clockwise and *vice-versa*.

7. (a r, s), (b r, s), (c q, r), (d p, r)



Effective lengths of two conductors,

$$l_1 \quad l_2 \quad l\hat{\mathbf{i}} \quad l\hat{\mathbf{j}}$$

If $\mathbf{B} \quad B_0 \hat{\mathbf{i}}$

$$\mathbf{F} \quad \frac{I}{2}(\mathbf{l}_1 \quad \mathbf{B}) \quad \frac{I}{2}(\mathbf{l}_2 \quad \mathbf{B}) \quad B_0 I l \hat{\mathbf{k}}$$

0, because lines of action of force on the two wires are equal and opposite.

If $\mathbf{B} \quad B_0 \hat{\mathbf{j}}$

$$\mathbf{F} \quad B_0 I l \hat{\mathbf{k}}$$

Again, lines of action of force on the two wires are equal and opposite.

0

If $\mathbf{B} \quad B_0(\hat{\mathbf{i}} \quad \hat{\mathbf{j}})$

$$\mathbf{F} \quad 0$$

0

If $\mathbf{B} \quad B_0 \hat{\mathbf{k}}$

$$\mathbf{F} \quad B_0 I l(\hat{\mathbf{i}} \quad \hat{\mathbf{j}})$$

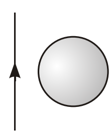
$$|\mathbf{F}| \quad \sqrt{2} B_0 I l$$

0

24 Electromagnetic Induction

Introductory Exercise 24.1

1. Magnetic field inside the loop due to current carrying conductor is inwards.



As the current in the conductor increases, magnetic flux linked with the loop increases as a result of which, induced current will produce in the loop to produce an outward magnetic field, *i.e.*, induced current will be anti-clockwise.

2. No.

Emf is induced if the field is time varying.

3. $\frac{d\ \ _B}{dt}$ induced emf

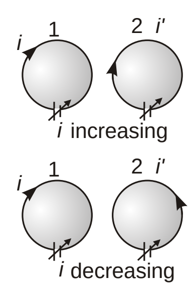
$$\frac{d\ \ _B}{dt} \quad [V] \quad [ML^2T^{\ 3}I^{\ 1}]$$

Introductory Exercise 24.2

1. If the outward magnetic flux increases, induced current will be in such a way that it produces inwards magnetic flux, *i.e.,* it will be clockwise.

2. Magnetic flux linked with the coil will not change, hence induced current will be zero.

3. If the current in coil 1 (clockwise) increases, outward magnetic flux linked with the coil 2 increases and the coil 2 will produce induced current in clockwise direction to oppose the change in magnetic flux linked with it.



Hence, if the current in coil 1 increases, induced current will be in same sense and *vice-versa*.

Introductory Exercise 24.3

1. $_B \quad BS \quad B_0 S e^{\ at}$

$$e \quad \frac{d\ \ _B}{dt} \quad a B_0 S e^{\ at}$$

2. No.

As, $F_m \quad i l B \quad 0$

Because, $i \quad 0$ as the circuit is not closed. As net force acting on the bar is zero, no external force is required to move the bar with constant velocity.

3. $|e| \quad \frac{\quad_2 \quad\quad_1}{t}$

But, $\quad_1 \quad NB_1A\cos \quad , \quad_2 \quad NB_2A\cos$

$$|e| \quad \frac{NA\cos \quad (B_2 \quad B_1)}{t}$$

$$A \quad \frac{|e|t}{N(B_2 \quad B_1)\cos}$$

$$\frac{80.0 \quad 10^{\;3} \quad 0.4}{50 \quad (600 \quad 10^{\;6} \quad 200 \quad 10^{\;6}) \quad \frac{\sqrt{3}}{2}}$$

$$1.85 \text{ m}^2$$

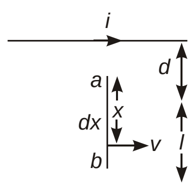
Side of square, $a \quad \sqrt{A} \quad 1.36 \text{ m}$

Total length of wire $\quad 50 \quad 4a$

$$50 \quad 4 \quad 1.36 = 272 \text{ m}$$

4. (a) Consider an elementary portion of length dx of the bar at a distance x from end a.

Magnetic field at this point,



$$B \quad \frac{\;_0}{4} \quad \frac{2i}{a \quad x}$$

Induced emf in this portion,

$$de \quad B\,dxv \quad \frac{\;_0}{4} \quad \frac{2vi}{d \quad x}dx$$

5. (a) EMF induced in the bar ab,

$$e \quad\quad de \quad \frac{\;_0}{4} \quad 2vi \int_0^l \frac{dx}{d \quad x}$$

$$\frac{\;_0}{4}2vi[\ln(d \quad x)]_0^l$$

$$\frac{\;_0 vi}{2}\ln\frac{d \quad l}{d}$$

$$\frac{\;_0 vi}{2}\ln \quad 1 \quad \frac{l}{d}$$

(b) Magnetic field in the region ab is inwards, hence by Fleming's left hand rule, positive charge will move up and a will be at higher potential.

Or

Use Fleming's right hand rule.

(c) No.

As flux linked with the square loop will remain same.

Introductory Exercise 24.4

1. Potential difference across an inductor,

$$V \quad L\frac{di}{dt} \quad L\frac{d}{dt}(3t\sin t)$$

$$3L[\sin t \quad\quad t\cos t]$$

Introductory Exercise 24.5

1. (a) Total number of turns on the solenoid,

$$N \quad \frac{l}{d} \quad \frac{40 \quad 10^{\;2}}{0.10 \quad 10^{\;2}}$$

$$400$$

$$L \quad \frac{\;_0 N^2 A}{l}$$

$$\frac{4 \quad\quad 10^{\;7} \quad (400)^2 \quad 0.90 \quad 10^{\;4}}{40 \quad 10^{\;2}}$$

$$4.5 \quad 10^{\;5} \text{ H}$$

(b) $\quad e \quad\quad L\frac{di}{dt}$

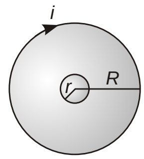
$$4.5 \quad 10^{\;5} \quad \frac{0 \quad 10}{0.10}$$

$$4.5 \quad 10^{\;3} \text{ V}$$

$$4.5 \text{ mV}$$

Introductory Exercise 24.6

1. Consider a current i is flowing in the outer loop.



Magnetic field at the centre of the loop.

$$B \quad \frac{_0 i}{2\,R}$$

As $R \quad r$, magnetic field inside smaller loop may assumed to be constant.

Hence, magnetic flux linked with the smaller loop,

$$_m \quad B \quad r^2 \quad \frac{_0\, r^2 i}{2R}$$

$$M \quad \frac{_m}{i} \quad \frac{_0 r^2}{2R}$$

Introductory Exercise 24.7

1. (a) $V_0 \quad i_0 R \quad 36 \quad 10^{\;3} \quad 175 \quad 6.3$ V

(b) $i \quad i_0(1 \quad e^{\;t/\;})$

where, $\quad \frac{L}{R}$

Now, at $t \quad 58 \quad$ s

$$i \quad 4.9 \text{ mA}$$

$$4.9 \quad 36(1 \quad e^{\;58/\;})$$

$$e^{\;58/} \quad \frac{31.1}{36}$$

$$397 \quad \text{s}$$

$$\frac{L}{R} \quad 397 \quad \text{s}$$

$$L \quad 175 \quad 397 \quad 10^{\;6}$$

$$69 \text{ mH}$$

(c) $\quad 397 \quad$ s

2. $$[L] \quad \frac{[e]}{\frac{di}{dt}} \quad \frac{[V][t]}{[i]}$$

and $$[R] \quad \frac{[V]}{[i]}$$

$$\frac{L}{R} \quad \frac{[L]}{[R]} \quad [\text{T}]$$

3. (a) Initially

$$E \quad L\frac{di}{dt}$$

$$\frac{di}{dt} \quad \frac{E}{L}$$

$$\frac{12.0}{3.00} \quad 4 \text{ A/s}$$

(b) $\quad E \quad V_L \quad V_R$

$$E \quad L\frac{di}{dt} \quad iR$$

$$\frac{di}{dt} \quad \frac{1}{L}[E \quad iR]$$

$$\frac{1}{3.00} \quad [12 \quad 1 \quad 7]$$

$$\frac{di}{dt} \quad \frac{5}{3} \quad 1.67 \text{ A/s}$$

(c) $$\quad \frac{L}{R} \quad \frac{3}{7}$$

$$i \quad i_0(1 \quad e^{\;t/\;})$$

$$\frac{E}{R}(1 \quad e^{\;t/\;}) \quad \frac{12}{7}(1 \quad e^{\;1.4/3})$$

$$i \quad 0.639 \text{ A}$$

(d) $i_0 \quad \frac{E}{R} \quad \frac{12}{7} \quad 1.71$ A

4. (a) $P \quad Ei \quad \frac{E^2}{R}(1 \quad e^{\;t/\;})$

$$\frac{(12)^2}{7}(1 \quad e^{\;7t/3}) \quad 20.6(1 \quad e^{\;2.33t})\text{ W}$$

(b) Rate of dissipation of energy,

$$P_R \quad i^2 R \quad i_0^2 R(1 \quad e^{\;7t/R})^2$$

$$20.6(1 \quad e^{\;2.33t})^2 \text{ W}$$

(c) Rate of increase of magnetic energy

$$P_L \quad ei \quad L\frac{di}{dt}i$$

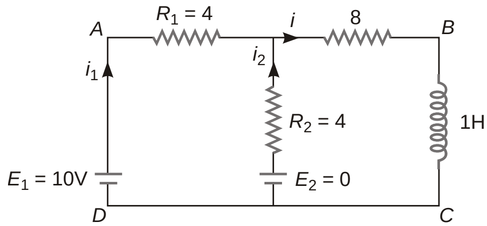
$$20.6(e^{\;2.33t} \quad e^{\;4.67t})\text{ W}$$

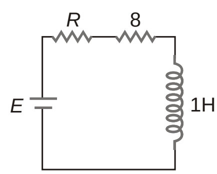
(d) Clearly, $P \quad P_R \quad P_L$

5. No.

$E \quad V_L \quad V_R$ and V_R cannot be negative in RL circuit.

6. Consider the system as a combination of two batteries (E_1 10 V and E_2 0) as shown





$$E \quad \frac{E_1 R_2 \quad E_2 R_1}{R_1 \quad R_2} \quad 5\text{ V}$$

$$R \quad \frac{R_1 R_2}{R_1 \quad R_2} \quad 2$$

$$i_0 \quad \frac{E}{R \quad 8} \quad \frac{5}{10} \quad 0.5\text{ A}$$

$$\frac{L}{R \quad 8} \quad \frac{1}{10}$$

$$i \quad i_0(1 \quad e^{\ t/\ })$$

$$i \quad 0.5(1 \quad e^{\ 10t})\text{ A}$$

Current through inductor

$$i \quad 2.5(1 \quad e^{\ 10t})\text{ A}$$

In loop *ABCDA*

$$i_1 R_1 \quad 8i \quad L\frac{di}{dt} \quad E_1 \quad 0$$

$$i_1 \quad 4 \quad 8 \quad 0.5(1 \quad e^{\ 10t}) \quad 1(5e^{\ 10t}) \quad 10 \quad 0$$

$$i_1 \quad (1.5 \quad 0.25e^{\ 10t})\text{ A}$$

Introductory Exercise 24.8

1. $$[C] \quad \frac{[q]}{[V]} \quad \frac{[i][T]}{[V]}]$$

$$[L] \quad \frac{[e]}{\frac{di}{dt}} \quad \frac{[V][T]}{[i]}$$

$$[\sqrt{LC}] \quad [\sqrt{L}\sqrt{C}] \quad [\text{T}]$$

2. In LC oscillations, magnetic energy is equivalent to kinetic energy in spring block system.

$$i \quad \frac{dq}{dt} \qquad v \quad \frac{dx}{dt}$$

Also L is equivalent to inertia (m) in electricity, hence

Magnetic energy $\frac{1}{2}Li^2$ is equivalent to kinetic energy $\frac{1}{2}mv^2$.

3. In LC oscillations,

(a) $$\frac{di}{dt} \quad \frac{1}{LC}q \quad q \quad LC\frac{di}{dt}$$

$$|q| \quad 18 \quad 10^{\ 6} \quad 0.75 \quad 3.40$$

$$46.5 \quad 10^{\ 6}\text{ C}$$

$$46.5 \quad \text{C}$$

(b) $$e \quad L\frac{di}{dt} \quad L \quad \frac{1}{LC}q$$

$$\frac{q}{C} \quad \frac{4.8 \quad 10^{\ 4}}{18 \quad 10^{\ 6}} \quad 23.3\text{ V}$$

4. $i_0 \quad q_0$

where, $$\frac{1}{\sqrt{LC}}$$

$$V_0 \quad \frac{q_0}{C} \quad \frac{i_0}{C}$$

$$V_0 \quad i_0\sqrt{\frac{L}{C}} \quad 0.1 \quad \sqrt{\frac{20 \quad 10^{\ 3}}{0.5 \quad 10^{\ 6}}}$$

$$20\text{ V}$$

Introductory Exercise 24.9

1. (a) $B \quad _0 ni$

$$_m \quad NBA \quad _0 n\ NAi$$

$$e \quad \frac{d\ _m}{dt} \quad _0 nNA\frac{di}{dt}$$

$$4 \quad 10^{\ 7} \quad \frac{25}{0.01} \quad 10 \quad 5.0 \quad 10^{\ 4} \quad (\quad 0.2)$$

$3.14 \quad 10^{\ 6}$ V

$3.14 \quad$ V

(b) $E \quad \frac{e}{2\ R} \quad \frac{3.14 \quad 10^{\ 6}}{2 \quad 3.14 \quad 25 \quad 10^{\ 2} \quad 10}$

$2 \quad 10^{\ 7}$ V/m

2. $B \quad (2.00t^3 \quad 4.00t^2 \quad 0.8)$ T

$\frac{dB}{dt} \quad (6.00t^2 \quad 8.00t)$ T/s

From, $t \quad 0$ to $t \quad 1.33$ s, $\frac{dB}{dt}$ is negative, hence B is decreasing in that interval.

For $t \quad 1.33$ s, $\frac{dB}{dt}$ is positive, hence B is increasing for $t \quad 1.33$ s.

(a) For point P_2,

induced emf, $V_2 \quad \frac{d\ _{m_2}}{dt} \quad R^2 \frac{dB}{dt}$

Induced electric field at P_2,

$E \quad \frac{V_2}{2\ r_2} \quad \frac{R^2}{2r_2} \frac{dB}{dt}$

$\frac{R^2}{2r_2}(6.00t^2 \quad 8.00t)$

$F \quad eE \quad \frac{R^2}{2r_2}(6.00t^2 \quad 8.00t)$

$8.0 \quad 10^{\ 21}$ N

As magnetic field is increasing in this region, induced electric field will be anti-clockwise and hence, electron will experience force in clockwise sense, *i.e.*, downward at P_2.

(b) For point P_1,

Induced emf, $V_1 \quad \frac{d\ _{m_1}}{dt} \quad r_1^2 \frac{dB}{dt}$

Induced electric field at P_1,

$E \quad \frac{V_1}{2\ r_1} \quad \frac{1}{2} r_1 \frac{dB}{dt}$

$\frac{1}{2} r_1 (6.00t^2 \quad 8.00t) \quad 0.36$ V/m

At, $t \quad 2.00$ s

magnetic field is increasing, hence, induced electric field will be anti-clockwise, *i.e.*, upward at P_1 and perpendicular to r_1.

AIEEE Corner

Subjective Questions (Level 1)

1. $e \quad \frac{\ _2 \quad _1}{t} \quad \frac{B(A_2 \quad A_1)}{t}$

$A_1 \quad r^2 \quad 3.14 \quad (0.1)^2$

$3.14 \quad 10^{\ 2} \quad 0.0314$

$A_2 \quad a^2 \quad \frac{2\ r}{4}^{\ 2}$

$\frac{2 \quad 3.14 \quad 0.1}{4}^{\ 2} \quad 0.025$

$e \quad \frac{100(0.025 \quad 0.0314)}{0.1}$

6.4 V

2. $_1 \quad NBA \quad 500 \quad 0.2 \quad 4 \quad 10^{\ 4}$

0.04 Wb

$_2 \quad NBA \quad 0.04$ Wb

Average induced emf,

$e \quad \frac{(\ _2 \quad _1)}{t}$

Average induced current,

$i \quad \frac{e}{R} \quad \frac{(\ _2 \quad _1)}{Rt}$

Charge flowing through the coil

$q \quad i \quad t$

$q \quad \frac{(\ _2 \quad _1)}{R} \quad \frac{(\quad 0.04 \quad 0.04)}{50}$

$\frac{0.08}{50} \quad 1.6 \quad 10^{\ 3}$ C

1.6 mC $\quad$ 1600 $\quad$ C

3. $_1 \quad NBS, \ _2 \quad NBS$

Induced emf,

$e \quad \frac{(\ _2 \quad _1)}{t} \quad \frac{2NBS}{t}$

Induced current

$i \quad \frac{e}{R} \quad \frac{2NBS}{Rt}$

Charge flowing through the coil,

$q \quad i \quad t \quad \frac{2NBS}{R}$

$B \quad \frac{qR}{2NS} \quad \frac{4.5 \quad 10^{\ 6} \quad 40}{2 \quad 60 \quad 3 \quad 10^{\ 6}}$

$0.5\ \text{T}$

4. $\mathbf{B} \quad (4.0\,\hat{\mathbf{i}} \quad 1.8\,\hat{\mathbf{k}}) \quad 10^{\ 3}\ \text{T},$

$\mathbf{S} \quad (5.0 \quad 10^{\ 4}\,\hat{\mathbf{k}})\ \text{m}^2$

$\mathbf{B}\ \ \mathbf{S} \qquad 9.0 \quad 10^{\ 7}\ \text{Wb}$

5. $e \quad Blv \quad 1.1 \quad 0.8 \quad 5 \quad 4.4\ \text{V}$

By Fleming's right hand rule, north end of the wire will be positive.

6. $A \qquad r^2 \quad 3.14 \quad (12 \quad 10^{\ 2})^2 \quad 0.045\ \text{m}^2$

(a) For $t \quad 0$ to $t \quad 2.0$ s

$$\frac{dB}{dt} \quad \text{slope} \quad \frac{0.5 \quad 0}{2.0 \quad 1} \quad 0.25\ \text{T/s}$$

$$e \quad \frac{d\ \ _m}{dt} \quad A\frac{dB}{dt}$$

$$0.045 \quad 0.25 \qquad 0.011\ \text{V}$$

$|e| \quad 0.011\ \text{V}$

(b) For, $t \quad 2.0$ s to $t \quad 4.0$ s

$$\frac{dB}{dt} \quad \text{slope} \quad 0\ e \quad 0$$

(c) For, $t \quad 4.0$ s to $t \quad 6.0$ s

$$\frac{dB}{dt} \quad \text{slope} \quad \frac{0 \quad 0.5}{6.0 \quad 4.0} \qquad 0.25$$

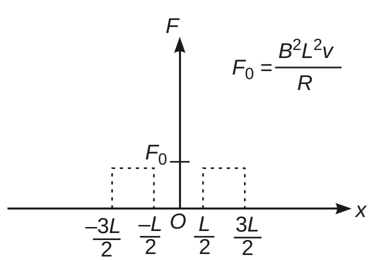
$$e \quad \frac{d\ \ _m}{dt} \qquad A\frac{dB}{dt} \quad 0.11\ \text{V}$$

7. (a) When magnetic flux linked with the coil changes, induced current is produced in it, in such a way that, it opposes the change.

Magnetic flux linked with the coil will change only when coil is entering in (from $x \quad \frac{3L}{2}$ to $x \quad \frac{L}{2}$) or moving (from $x \quad \frac{L}{2}$ to $x \quad \frac{3L}{2}$) of the magnetic field.

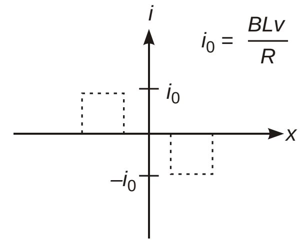
Because, of induced current, an opposing force act on the coil, which is given by

$$F \quad ilB \quad \frac{BLv}{R}BL \quad \frac{B^2L^2v}{R}$$

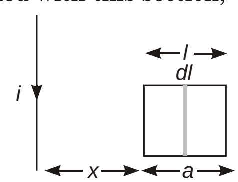


Hence, equal force in direction of motion of coil is required to move the block with uniform speed.

(b) When the coil is entering into the magnetic field, magnetic flux linked with the coil increases and the induced current will produce magnetic flux in opposite direction and will be counter-clockwise and *vice-versa*.



8. Consider an elementary section of length dl of the frame as shown in figure. Magnetic flux linked with this section,



$$d\ \ _m \quad BdB \quad \frac{_0}{4}\ \frac{2i}{x \quad l}\,adl$$

Total magnetic flux linked with the frame,

$$_m \qquad d\ \ _m \quad \frac{_0ai}{2}\ \ _0^a\frac{dl}{x \quad l}$$

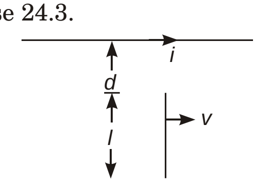
$$\frac{_0ai}{2}[\ln(x \quad a) \quad \ln x]$$

Induced emf

$$e \quad \frac{d\ \ _m}{dt} \qquad \frac{_0ai}{2} \quad \frac{1}{x \quad a} \quad \frac{1}{x}\ \frac{dx}{dt}$$

$$\frac{_0a^2i}{2\ x(x \quad a)}v \quad \frac{_0a^2iv}{2\ x(x \quad a)}$$

9. As solved in Qusetion 4. Introductory Exercise 24.3.



$$e \quad \frac{{}_0 iv}{2} \ln \; 1 \quad \frac{l}{d}$$

Here, $\quad i \quad 10 \;\text{A}$

$\quad v \quad 10 \;\text{ms}^{\;1}$

$l \quad 10.0\,\text{cm} \quad 1.0\,\text{cm} \quad 9.0\,\text{cm}$

$d \quad 1.0\,\text{cm}$

$$e \quad \frac{4 \quad 10^{\;7} \quad 10 \quad 10}{2} \ln \; 1 \quad \frac{9.0}{1.0}$$

$$e \quad (2 \quad 10 V) \ln (10)\,\text{V}$$

10. Induced current

$$i \quad \frac{e}{R} \quad \frac{Blv}{R}$$

Force needed to move the rod with constant speed Magnetic force acting on the rod

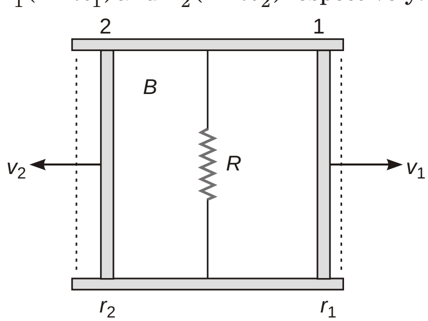
ie., $\quad F \quad i\,lB \quad \frac{Blv}{R} lB$

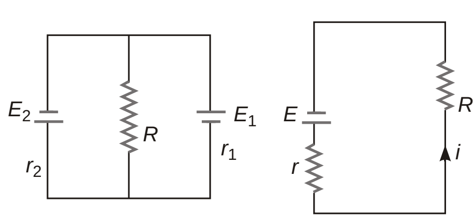
$$\frac{B^2 l^2 v}{R} \quad \frac{(0.15)^2 \quad (50 \quad 10^{\;2})^2 \quad 2}{3}$$

$$F \quad 0.00375$$

11. Suppose the magnetic field is acting into the plane of paper.

Rods 1 and 2 can be treated as cells of emf E_1 (Blv_1) and E_2 (Blv_2) respectively.





Now, $E_1 \quad Blv_1 \quad 0.010 \quad 10.0 \quad 10^{\;2} \quad 4.00$

$\quad 0.004\,\text{V}$

$E_2 \quad Blv_2 \quad 0.010 \quad 10 \quad 0 \quad 10^{\;2} \quad 8.00$

$\quad 0.008\,\text{V}$

Effective emf

$$E \quad \frac{E_2 r_1 \quad E_1 r_2}{r_1 \quad r_2}$$

$$\frac{0.008 \quad 15.0 \quad 0.004 \quad 10.0}{15.0 \quad 10.0}$$

$$0.0032\,\text{V}$$

$$r \quad \frac{r_1 r_2}{r_1 \quad r_2} \quad \frac{15 \quad 10}{25} \quad 6$$

$$i \quad \frac{E}{R \quad r} \quad \frac{0.0032}{5 \quad 6} \quad 0.003\,\text{A} \quad 0.3\,\text{mA}$$

12. (a) $e \quad L\frac{di}{dt} \quad 0.54 \quad (\quad 0.030)$

$$1.62 \quad 10^{\;2}\,\text{V}$$

(b) Current flowing from b to a is decreasing, hence, a must be at higher potential.

13. (a) $i \quad 5 \quad 16t, |e| \quad 10\text{mV} \quad 10 \quad 10^{\;3}\,\text{V}$

$$|e| \quad L\frac{di}{dt} \quad 10 \quad 10^{\;3} \quad L\frac{d}{dt}(5 \quad 16t)$$

$$L \quad \frac{10 \quad 10^{\;3}}{16} \quad 0.625\,\text{mH}$$

(b) at $t \quad 1\,\text{s}$

$$i \quad 5 \quad 16(1) \quad 21\,\text{A}$$

Energy stored in the inductor,

$$U \quad \frac{1}{2}Li^2 \quad \frac{1}{2} \quad 0.625 \quad 10^{\;3} \quad (21)^2$$

$$0.138\,\text{J}$$

$$P \quad \frac{dU}{dt} \quad Li\frac{di}{dt} \quad 0.625 \quad 10^{\;3} \quad 21 \quad 16$$

$$0.21\,\text{W}$$

14. From $t \quad 0$ to $t \quad 2.0\,\text{ms}$

$$\frac{V \quad 0}{t \quad 0} \quad \frac{5.0 \quad 0}{2.0 \quad 10^{\;3}} \quad 0$$

$$V \quad 2500\,t$$

$$L\frac{di}{dt} \quad 2500\,t$$

$$di \quad \frac{2500}{L} \quad tdt$$

$$\int_0^i di \quad \frac{2500}{L} \int_0^t tdt$$

$$i \quad \frac{1250}{L} t^2$$

at $\quad t \quad 2.0\,\text{ms}$

$$i \quad \frac{1250}{150 \quad 10^{\;3}} \quad (2.0 \quad 10^{\;3})^2$$

$$3.33 \quad 10^{\;2}\,\text{A}$$

From t 2.0 ms to t 4.0 ms

$$\frac{V \quad 5.0}{t \quad 2.0 \quad 10^{\ 3}} \quad \frac{0 \quad 0.50}{(4.0 \quad 2.0) \quad 10^{\ 3}}$$

$$V \quad 2500(t \quad 2.0 \quad 10^{\ 3}) \quad 5.0$$
$$2500\,t \quad 10.0$$

$$L\frac{di}{dt} \quad 2500\,t \quad 10.0$$

$$di \quad \frac{1}{L}(\quad 2500\,t \quad 10.0)\,dt$$

$$i \quad \frac{1}{L}[\quad 1250\,t^2 \quad 10.0\,t]$$

at t 4 s

$$i \quad \frac{1}{150 \quad 10^{\ 3}}[\quad 1250 \quad (4.0 \quad 10^{\ 3})^2$$
$$10.0(4.0 \quad 10^{\ 3})]$$
$$3.33 \quad 10^{\ 2}\ \text{A}$$

15. (a) $|e| \quad L\frac{di}{dt} \quad L \quad \frac{|e|}{di/dt} \quad \frac{0.0160}{0.0640}$

$$0.250\ \text{H}$$

(b) Flux per turn

$$\frac{Li}{N} \quad \frac{0.250 \quad 0.720}{400}$$
$$4.5 \quad 10^{\ 4}\ \text{Wb}$$

16. $|e| \quad M\frac{di}{dt} \quad M\frac{i_2 \quad i_1}{t}$

$$50 \quad 10^{\ 3} \quad M\frac{12 \quad 4}{0.5}$$

$$M \quad \frac{50 \quad 10^{\ 3} \quad 0.5}{8} \quad 3.125 \quad 10^{\ 3}\ \text{H}$$
$$3.125\ \text{mH}$$

If current changes from 3 A to 9 A in 0.02 s.

$$|e| \quad M\frac{di}{dt} \quad M\frac{i_2 \quad i_1}{t}$$
$$3.125 \quad 10^{\ 3}\frac{9 \quad 3}{0.02}$$
$$0.9375\ \text{V}$$

17. (a) Magnetic flux linked with secondary coil,

$$_{m_2} \quad M\,i_1$$
$$M \quad \frac{_2}{i_1} \quad \frac{6.0 \quad 10^{\ 3} \quad 1000}{3} \quad 2\ \text{H}$$

(b) $e \quad \frac{d\ _{m_2}}{dt} \quad M\frac{d\,i_1}{dt}$

$$2\ \frac{0 \quad 3}{0.2} \quad 30\ \text{V}$$

(c) $L \quad \frac{_{m_1}}{i_1} \quad \frac{600 \quad 5 \quad 10^{\ 3}}{3} \quad 1\ \text{H}$

18. (a) $|e| \quad M\frac{di}{dt} \quad 3.25 \quad 10^{\ 4} \quad 830$

$$0.27\ \text{V}$$

As, $\frac{di}{dt}$ is constant, induced emf is constant.

(b) Coefficient of mutual induction remains same whether current flows in first coil or second.

Hence, $|e| \quad M_1\frac{di}{dt} \quad 0.27$ V

19. (a) Magnetic flux linked with the secondary coil,

$$_2 \quad Mi_1$$
$$M \quad \frac{_2}{i_1} \quad \frac{0.0320 \quad 400}{6.52}$$
$$1.96\ \text{H}$$

(b) $_1 \quad Mi_2 \quad 1.96 \quad 2.54 \quad 4.9784$ Wb

Flux per turn through primary coil

$$\frac{_1}{N_1} \quad \frac{4.9784}{700}$$
$$7.112 \quad 10^{\ 3}\ \text{Wb/turn.}$$

20. Same as Question 2. Introductory Exercise 24.4

21.

$$i \quad i_0(1 \quad e^{\ t/\ })$$
$$\frac{E}{R}(1 \quad e^{\ \frac{Rt}{L}})$$
$$\frac{di}{dt} \quad \frac{E}{L}e^{\ \frac{Rt}{L}}$$

Power supplied by battery,

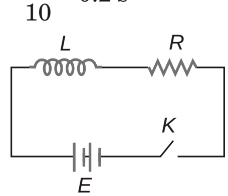
$$P \quad Ei \quad \frac{E^2}{R}(1 \quad e^{\ \frac{Rt}{L}})$$

Rate of storage of magnetic energy

$$P_1 \quad Li\frac{di}{dt} \quad \frac{E^2}{R}(1 \quad e^{\ \frac{Rt}{L}})e^{\ \frac{Rt}{L}}$$

$$\frac{P_1}{P} \quad e^{\ \frac{Rt}{L}} \quad e^{\ \frac{10 \quad 0.1}{1}} \quad e^{\ 1} \quad 0.37$$

22. (a) $\frac{L}{R} \quad \frac{2}{10} \quad 0.2$ s



(b) $i_0 \quad \frac{E}{R} \quad \frac{100}{10} \quad 10\text{ A}$

(c) $i \quad i_0(1 \quad e^{\frac{t}{}})$

$$i \quad 10(1 \quad e^{\frac{1}{0.2}})$$

$$10(1 \quad e^{5}) \quad 9.93\text{ A}$$

23. (a) Power delivered by the battery,

$$P \quad Ei \quad \frac{E^2}{R}(1 \quad e^{\frac{Rt}{L}})$$

$$\frac{(3.24)^2}{12.8}(1 \quad e^{\frac{12.8 \quad 0.278}{3.56}})$$

$$0.82(1 \quad e^{1}) \quad 0.518\text{ W}$$

$$518\text{ mW}$$

(b) Rate of dissipation of energy as heat

$$P_2 \quad i^2R \quad \frac{E^2}{R}(1 \quad e^{\frac{Rt}{L}})^2$$

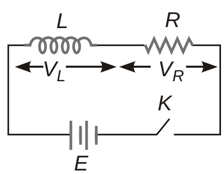
$$0.82(1 \quad e^{1})^2 \quad 0.328\text{ W}$$

$$328\text{ mW}$$

(c) Rate of storage of magnetic energy

$$P_1 \quad P \quad P_2 \quad 190\text{ mW}$$

24. $E \quad V_L \quad V_R \quad L\frac{di}{dt} \quad iR$



(a) Initially, $i \quad 0$

$$\frac{di}{dt} \quad \frac{E}{L} \quad \frac{6.00}{2.50} \quad 2.40\text{ A/s}$$

(b) When, $i \quad 0.500\text{ A}$

$$\frac{di}{dt} \quad \frac{E \quad iR}{L} \quad \frac{6.00 \quad 0.500 \quad 8.00}{2.50}$$

$$0.80\text{ A/s}$$

(c) $i \quad \frac{E}{R} \quad 1 \quad e^{\frac{Rt}{L}}$

$$\frac{6.00}{8.00} \quad 1 \quad e^{\frac{8.00 \quad 0.250}{2.5}}$$

$$0.750(1 \quad e^{0.8}) \quad 0.413\text{ A}$$

(d) $i_0 \quad \frac{E}{R} \quad \frac{6.00}{8.00} \quad 0.750\text{ A}$

25. (a) $i \quad i_0 \quad 1 \quad e^{\frac{Rt}{L}}$

But $i \quad \frac{i_0}{2}$

$$\frac{i_0}{2} \quad i_0 \quad 1 \quad e^{\frac{Rt}{L}}$$

$$e^{\frac{Rt}{L}} \quad \frac{1}{2}$$

$$t \quad \frac{L}{R}\ln 2 \quad \frac{1.25 \quad 10^{3}}{50.0} \quad 0.693$$

$$17.3 \quad 10^{6} \quad 17.3 \quad \text{s}$$

(b) $U \quad \frac{1}{2}Li^2 \quad \frac{1}{2} \quad \frac{1}{2}L\,i_0^2$

$$i \quad \frac{1}{\sqrt{2}}i_0$$

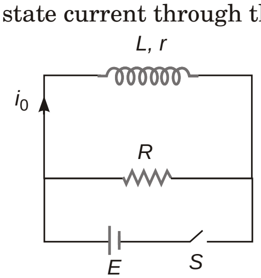
$$i_0 \quad 1 \quad e^{\frac{Rt}{L}} \quad \frac{i_0}{\sqrt{2}}$$

$$e^{\frac{Rt}{L}} \quad \frac{\sqrt{2} \quad 1}{\sqrt{2}}$$

$$t \quad \frac{L}{R}\ln\frac{\sqrt{2}}{\sqrt{2} \quad 1}$$

$$30.7 \quad \text{s}.$$

26. Steady state current through the inductor



$$i_0 \quad \frac{E}{r}$$

When the switch S is open

$$\frac{L}{R \quad r}$$

(a) $i \quad i_0\, e^{t/}$

$$i \quad \frac{E}{r}e^{\frac{(R \quad r)}{L}}$$

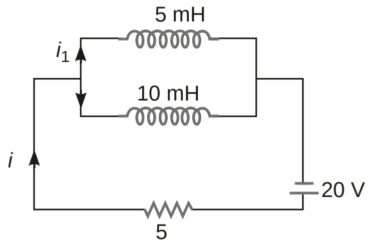
(b) Amount of heat generated in the solenoid

$$H \quad {}_0 \, i^2r\,dt \quad i_0^2r \, {}_0 \, e^{2t/} \, dt$$

$$\frac{E^2}{r} \quad \frac{}{2}[e^{2t/}]_0$$

$$\frac{(R \quad r)E^2}{2rL}$$

27. At any instant of time,



$$L_1 \frac{di_1}{dt} \quad L_2 \frac{di_2}{dt}$$

$$L_1 i_1 \quad L_2 i_2$$

$$i_1 \quad 2i_2 \qquad \text{...(i)}$$

In steady state,

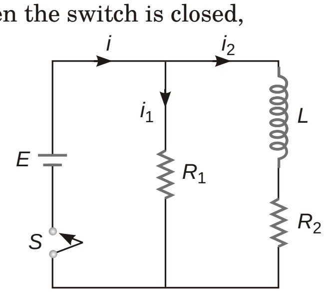
inductors offer zero resistance, hence

$$i \quad \frac{20}{5} \quad 4\text{ A}$$

But $\quad i_1 \quad i_2 \quad i$

$$i_2 \quad \frac{4}{3}\text{A}, \ i_1 \quad \frac{8}{3}\text{A}$$

28. When the switch is closed,

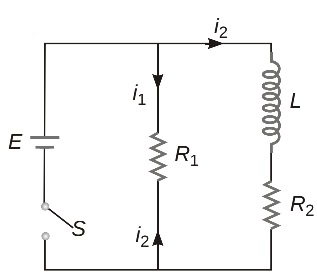


$$i_2 \quad \frac{E}{R_2}(1 \quad e^{\ R_2 t/L})$$

$$\frac{di_2}{dt} \quad \frac{E}{L} e^{\ R_2 t/L}$$

Potential difference across L

$$V \quad L\frac{di_2}{dt} \quad E e^{\ R_2 t/L} \quad (12 e^{\ 5t})\text{ V}$$



When the switch S is open, current i_2 flows in the circuit in clockwise direction and is given by

$$i_2 \quad i_0 e^{\ t/}$$

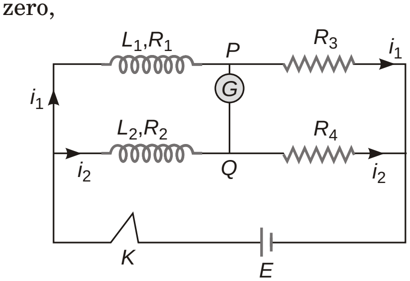
Here, $\quad i_2 \quad \frac{E}{R_2}$

$$\frac{L}{R_1 \quad R_2}$$

$$i_2 \quad \frac{E}{R_2} e^{\ \frac{R_1 \quad R_2}{L} \ t}$$

$$\frac{12}{2} e^{\ 10t} \quad (6 e^{\ 10t})\text{ A}$$

29. For current through galvanometer to be zero,



$$V_P \quad V_Q$$

$$L_1 \frac{di_1}{dt} \quad i_1 R_1 \quad L_2 \frac{di_2}{dt} \quad i_2 R_2 \qquad \text{...(i)}$$

Also, $\quad i_1 R_3 \quad i_2 R_4 \qquad$ ...(ii)

From Eqs.(i) and (ii),

$$\frac{L_1 \frac{di_1}{dt} \quad i_1 R_1}{i_1 R_3} \quad \frac{L_2 \frac{di_2}{dt} \quad i_2 R_2}{i_2 R_4} \qquad \text{...(iii)}$$

In the steady state,

$$\frac{di_1}{dt} \quad \frac{di_2}{dt} \quad 0$$

$$\frac{R_1}{R_3} \quad \frac{R_2}{R_4} \quad \frac{R_1}{R_2} \quad \frac{R_3}{R_4}$$

Again as current through galvanometer is always zero.

$$\frac{i_1}{i_2} \quad \text{constant}$$

or $$\frac{di_1 / dt}{di_2 / dt} \quad \text{constant}$$

or $$\frac{\frac{di_1}{dt}}{\frac{di_2}{dt}} \quad \frac{i_1}{i_2} \qquad \text{...(iv)}$$

From Eqs. (iii) and (iv),

$$\frac{L_1}{L_2} \quad \frac{R_3}{R_4} \quad \frac{R_1}{R_2}$$

30. (a) In LC circuit

Maximum electrical energy   Maximum magnetic energy

$$\frac{1}{2}CV_0^2 \quad \frac{1}{2}Li_0^2$$

$$L \quad C\left(\frac{V_0}{i_0}\right)^2 \quad 4 \quad 10^{\ 6}\left(\frac{1.50}{50 \quad 10^{\ 3}}\right)^2$$

$$3.6 \quad 10^{\ 3}\ \text{H}$$

$$L \quad 3.6\ \text{mH}$$

(b) $f \quad \dfrac{1}{2\ \sqrt{LC}}$

$$\frac{1}{2 \quad 3.14\sqrt{3.6 \quad 10^{\ 3} \quad 4 \quad 10^{\ 6}}}$$

$$1.33 \quad 10^3\ \text{Hz}$$

$$1.33\ \text{kHz}$$

(c) Time taken to rise from zero to maximum value,

$$t \quad \frac{T}{4} \quad \frac{1}{4f} \quad \frac{1}{4 \quad 1.33 \quad 10^3}$$

$$3 \quad 10^{\ 3}\ \text{s} \quad 3\ \text{ms.}$$

31. (a) $\quad 2\ f \quad 2 \quad 3.14 \quad 10^3$

$$6.28\ \text{rad/s}$$

$$T \quad \frac{1}{f} \quad \frac{1}{10^3} \quad 10^{\ 3}\ \text{s} \quad 1\ \text{ms}$$

(b) As initially charge is maximum, (*i.e.., it is extreme position for charge).*

$$q \quad q_0 \cos \quad t$$

$$q_0 \quad CV_0 \quad 1 \quad 10^{\ 6} \quad 100$$

$$10^{\ 4}$$

$$q \quad [10^{\ 4}\cos(6.28 \quad 10^3)t]\ \text{C.}$$

(c) $\dfrac{1}{\sqrt{LC}}$

$$L \quad \frac{1}{{}^2C} \quad \frac{1}{(6.28 \quad 10^3)^2 \quad 10^{\ 6}}$$

$$2.53 \quad 10^{\ 3}$$

$$L \quad 2.53\ \text{mH}$$

(d) In one quarter cycle, entire charge of the capacitor flows out.

$$i \quad \frac{q}{t} \quad \frac{4CV}{T}$$

$$\frac{4 \quad 10^{\ 6} \quad 100}{10^{\ 3}} \quad 0.4\ \text{A}$$

32. (a) $V_0 \quad \dfrac{q_0}{C} \quad \dfrac{5.00 \quad 10^{\ 6}}{4 \quad 10^{\ 4}}$

$$1.25 \quad 10^{\ 2}\ \text{V} \quad 12.5\ \text{mV}$$

(b) Maximum magnetic energy   Maximum electric energy

$$\frac{1}{2}Li_0^2 \quad \frac{q_0^2}{2C}$$

$$i_0 \quad \frac{q_0}{\sqrt{LC}}$$

$$i_0 \quad \frac{5.00 \quad 10^{\ 6}}{\sqrt{0.090 \quad 4 \quad 10^{\ 4}}} \quad 8.33 \quad 10^{\ 4}\ \text{A}$$

(c) Maximum energy stored in inductor,

$$\frac{1}{2}L\,i_0^2$$

$$\frac{1}{2} \quad 0.0900 \quad (8.33 \quad 10^{\ 4})^2$$

$$3.125 \quad 10^{\ 8}\ \text{J}$$

(d) By conservation of energy,

$$\frac{q^2}{2C} \quad \frac{1}{2}Li^2 \quad \frac{1}{2}Li_0^2$$

But $i \quad \dfrac{i_0}{2}$

$$\frac{q^2}{2C} \quad \frac{3}{8}Li_0^2$$

$$q \quad \frac{i_0}{2}\sqrt{3LC} \quad \frac{\sqrt{3}}{2}q_0$$

$$\frac{1.732}{2} \quad 5.00 \quad 10^{\ 6}$$

$$4.33 \quad 10^{\ 6}\ \text{C}$$

$$U_m \quad \frac{1}{2}Li^2 \quad \frac{1}{4}\ \frac{1}{2}Li_0^2$$

$$7.8 \quad 10^{\ 9}\ \text{J}$$

33. (a) $\quad \dfrac{1}{\sqrt{LC}} \quad \dfrac{1}{\sqrt{2.0 \quad 10^{\ 3} \quad 5.0 \quad 10^{\ 6}}}$

$$10^4\ \text{rad/s}$$

$$\frac{di}{dt} \quad {}^2Q$$

$$(10^4)^2 \quad 100 \quad 10^{\ 6} \quad 10^4\ \text{A/s}$$

(b) $i \quad \sqrt{Q_0^2 \quad Q^2}$

$$10^4\sqrt{(200 \quad 10^{\ 6})^2 \quad (200 \quad 10^{\ 6})^2} \quad 0$$

(c) $i_0 \quad Q_0 \quad 10^4 \quad 200 \quad 10^{\ 6} \quad 2\ \text{A}$

(d) $i \quad \sqrt{Q_0^2 \quad Q^2}$

$$\frac{i_0}{2} \quad \sqrt{Q_0^2 \quad Q^2}$$

$$\frac{Q_0}{2} \quad \sqrt{Q_0^2 \quad Q^2}$$

$$Q \quad \frac{\sqrt{3}}{2} Q_0 \quad \frac{1.73 \quad 200 \quad 10^{\ 6}}{2}$$

$$173 \quad \text{C}$$

34. As initially charge is maximum

$$q \quad q_0 \cos \quad t$$

and $\quad |i| \quad i_0 \sin \quad t$

where, $\quad \frac{1}{\sqrt{LC}} \quad \frac{1}{\sqrt{3.3 \quad 840 \quad 10^{\ 6}}}$

$$19 \text{ rad./s}$$

$i_0 \quad q_0 \quad 19 \quad 105 \quad 10^{\ 6}$

$\quad 2.0 \quad 10^{\ 3} \text{ A} \quad 2.0 \text{ mA}$

At $t \quad 2.00$ ms

(a) $U_e \quad \frac{q^2}{2C} \quad \frac{q_0^2}{2C}(\cos^2 \quad t)$

$$\frac{(105 \quad 10^{\ 6})^2}{2 \quad 840 \quad 10^{\ 6}}[\cos^2 (38 \text{ rad})]$$

$U_e \quad 6.55 \quad 10^{\ 6} \text{ J} \quad 6.55 \quad \text{J}$

(b) $U_m \quad \frac{1}{2}Li^2 \quad \frac{1}{2}Li_0^2 (\sin \quad t)$

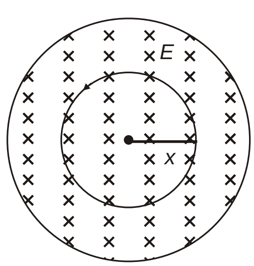
$$\frac{1}{2} \quad 3.3 \quad (2 \quad 10^{\ 3})^2 \sin^2(38 \text{ rad})$$

$0.009 \quad 10^{\ 6} \text{ J} \quad 0.009 \quad \text{j}$

(c) $U \quad \frac{q_0^2}{2C} \quad \frac{1}{2}Li_0^2$

$6.56 \quad 10^{\ 6} \text{ J} \quad 6.56 \quad \text{J}$

35. As the inward magnetic field is increasing, induced electric field will be anticlockwise.



At a distance x from centre of the region,

Magnetic flux linked with the imaginary loop of radius x

$$_m \quad x^2 B$$

$$e \quad \frac{d_{\ m}}{dt} \quad x^2 \frac{dB}{dt}$$

Induced electric field,

$$E \quad \frac{e}{2 \quad x} \quad \frac{1}{2} x \frac{dB}{dt}$$

At a,

$$E \quad \frac{1}{4} r \frac{dB}{dt}, \text{ towards left.}$$

At b ,

$$E \quad \frac{1}{2} r \frac{dB}{dt}, \text{ upwards.}$$

At c,

$$E \quad 0$$

36. Inside the solenoid,

$$B \quad _0 ni$$

$$\frac{dB}{dt} \quad _0 n \frac{di}{dt}$$

Inside the region of varying magnetic field

$$E \quad \frac{1}{2} r \frac{dB}{dt} \quad \frac{1}{2} \quad _0 nr \frac{di}{dt}$$

(a) $r \quad 0.5$ cm $\quad 5.0 \quad 10^{\ 3}$ m

$$E \quad \frac{1}{2} \quad _0 rn \frac{di}{dt}$$

$$\frac{1}{2} \quad 4 \quad 10^{\ 7} \quad 5.0 \quad 10^{\ 3} \quad 900 \quad 60$$

$$1.7 \quad 10^{\ 4} \text{ V/m}$$

(b) $r \quad 1.0$ cm $\quad 1.0 \quad 10^{\ 2}$ m

$$E \quad \frac{1}{_0} rn \frac{di}{dt}$$

$$\frac{1}{2} \quad 4 \quad 10^{\ 3} \quad 5.0 \quad 10^{\ 3} \quad 900 \quad 60$$

$$3.4 \quad 10^{\ 4} \text{ V/m}$$

AIEEE Corner

Objective Questions (Level 1)

1. $V \quad L\dfrac{di}{dt}$

$[L] \quad \dfrac{[V][T]}{[i]} \quad \dfrac{[ML^2T^{\ 3}A^{\ 1}][T]}{[A]}$

$[ML^2T^{\ 2}A^{\ 2}]$

2. $M \quad n_1n_2$

3. Both will tend to oppose the magnetic flux changing with them by increasing current in opposite direction.

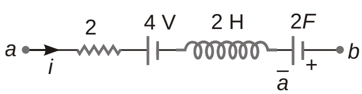
4. Moving charged particle will produced magnetic field parallel to ring, Hence

$_m \quad 0$

Velocity of particle increases continuously due to gravity.

5. Induced electric field can exist at a point where magnetic field is not present, i.e., outside the region occupying the magnetic field.

6. At, $t \quad 1$ s



$q \quad 4t^2 \quad 4\,C$

$i \quad \dfrac{dq}{dt} \quad 8t \quad 8\,A$

$\dfrac{di}{dt} \quad 8$ A/s

As, $\dfrac{di}{dt} \quad \dfrac{d^2q}{dt}$ Positive

Charge in capacitor is increasing, current i must be towards left.

$V_{ab} \quad 2I \quad 4 \quad L\dfrac{di}{dt} \quad \dfrac{q}{C}$

$2 \quad 8 \quad 4 \quad 2 \quad 8 \_ \dfrac{4}{2} \quad 30\,V$

7. $|e| \quad M\dfrac{di}{dt} \quad M\dfrac{d}{dt}(i_0 \sin \quad t)$

$Mi_0 \cos \quad t$

Maximum induced emf $\quad Mi_0$

$100 \quad 0.005 \quad 10$

5

8. $\dfrac{1}{2}Li_0^2 \quad \dfrac{1}{2}CV_0^2 \quad i_0\sqrt{\dfrac{L}{C}} \quad 2 \quad \sqrt{\dfrac{2}{4 \quad 10^{\ 6}}}$

$\sqrt{2} \quad 10^3$ V

9. $e \quad \dfrac{1}{2}B\,l^2$, is independent of t.

10. $|e| \quad \dfrac{d}{dt} \quad \dfrac{}{t}$

$|e|t \quad iRt$

$10 \quad 10^{\ 3} \quad 0.5 \quad 5$

$25 \quad 10^{\ 3}$ Wb

25 mWb.

11. As inward magnetic field is increasing, induced electric field must be anti-clockwise.

Hence, direction of induced electric field at P will be towards and electron will experience force towards right (opposite to electric field).

12. $at(\quad t) \quad a\ t \quad at^2$

$|e| \quad \dfrac{d}{dt} \quad a \quad 2at$

$i \quad \dfrac{|e|}{R} \quad \dfrac{a \quad 2at}{R}$

$H \quad _0\ i^2R\,dt \quad _0\ \dfrac{(a \quad 2at)^2}{R}dt$

$\dfrac{1}{R}\ \dfrac{(a \quad 2\,at)^3}{3 \quad (\quad 2a)}\ _0$

$\dfrac{1}{6Ra}[\quad a^{3\ \ 3} \quad a^{3\ \ 3}]$

$\dfrac{a^{2\ \ 3}}{3R}$

13. $E \quad L\dfrac{di}{dt}$

14. $V_{BA} \quad L\dfrac{di}{dt} \quad 15 \quad iR$

$5 \quad 10^{\ 3}(\quad 10^3) \quad 15 \quad 5 \quad 1$

15 V

15. $\dfrac{di}{dt} \quad 10$ A/s, at $t \quad 0, i \quad 5$A

$\dfrac{di}{dt} \quad 10$ A/s

$$V_A \quad V_B \quad iR \quad L\frac{di}{dt} \quad E \quad 0$$

$$5 \quad 3 \quad 1 \quad 10 \quad 10 \quad 15\text{ V}$$

16. $\frac{di}{dt}_{\max} \quad \frac{d^2q}{dt}_{\max} \quad {}^2q_0 \quad \frac{q_0}{LC}$

17. $V \quad L\frac{di}{dt}$

18. $_m \quad BA\cos$

$$e \quad \frac{d_m}{dt} \quad BA\sin \quad \frac{d}{dt}$$

$$iR \quad BA\sin \quad \frac{d}{dt}$$

$$\frac{dq}{dt}R \quad BA\sin \quad \frac{d}{dt}$$

$$dq \quad \frac{BA}{R}\sin \quad d$$

$$q \quad \frac{BA}{R}\,{}^{3\ /2}_{\ /2}\sin \quad d \quad 0$$

19. $\mathbf{A} \quad ab\,\hat{\mathbf{k}}, \mathbf{B} \quad 20t\,\hat{\mathbf{i}} \quad 10t^2\,\hat{\mathbf{j}} \quad 50\,\hat{\mathbf{k}}$

$$_m \quad \mathbf{B} \quad \mathbf{A} \quad 50\,ab$$

$$e \quad \frac{d_m}{dt} \quad 0$$

20. $E \quad V_b \quad iR$

$V_b \quad E \quad iR \quad 200 \quad 20 \quad 1.5 \quad 170\text{ V}$

21. $\frac{V_s}{V_p} \quad \frac{N_s}{N_p} \quad V_s \quad \frac{1}{2} \quad 290 \quad 10\text{ V}$

$$\frac{i_p}{i_s} \quad \frac{N_s}{N_p}$$

$$i_s \quad \frac{N_p}{N_s}i_p \quad 2 \quad 4 \quad 8\text{ A}$$

22. V_r 0, hence magnetic flux linked with the coil remain same.

$$e \quad \frac{d}{dt} \quad 0$$

23. $s \quad \frac{1}{2}at^2$

Due to change in magnetic flux linked with the ring, magnet experiences an upward force, hence,

$$a \quad g$$

$$s \quad \frac{1}{2}gt^2 \quad s \quad 5\text{ m}$$

24. $V_A \quad V_B \quad L\frac{di}{dt} \quad t$

25. $i_0 \quad \frac{E}{R} \quad \frac{12}{0.3} \quad 40\text{ A}$

$$U_0 \quad \frac{1}{2}Li_0^2 \quad \frac{1}{2} \quad 50 \quad 10^{\ 3} \quad (40)^2$$

$$40\text{ J}$$

26. $i \quad i_0 \quad 1 \quad e^{\ \frac{t}{}} \quad \frac{E}{R} \quad 1 \quad e^{\ \frac{Rt}{L}}$

$$\frac{di}{dt} \quad \frac{E}{L}e^{\ \frac{Rt}{L}}$$

$$V_L \quad L\frac{di}{dt} \quad Ee^{\ \frac{Rt}{L}}$$

at t 0

$$V_L \quad E \quad 20\text{ V}$$

at t 20 ms

$$V_L \quad Ee^{\ \frac{R\ \ 20\ \ 10^{\ 3}}{L}} \quad 5 \quad 20e^{\ \frac{R}{50L}}$$

$$\frac{R}{50L} \quad \ln 4 \quad R \quad (100\ln 4)$$

27. $|i| \quad \frac{|e|}{R} \quad \frac{1}{R}\frac{d}{dt} \quad \frac{1}{R}NA\frac{dB}{dt}$

$$\frac{10 \quad 10 \quad 10^{\ 4}}{20} \quad 10^8 \quad 10^{\ 4}$$

$$5\text{ A}$$

28. In the steady state, inductor behaves as short circuit, hence entire current flows through it.

29. $_m \quad AB\cos$

But, 90

$$_m \quad 0$$

30. $i \quad \frac{|e|}{R} \quad \frac{1}{R}\frac{d_m}{dt}$

$$\frac{dq}{dt} \quad \frac{nBA}{R}\frac{d}{dt}(\cos \quad)$$

$$\frac{nBA}{R}\sin \quad \frac{d}{dt}$$

$$dq \quad \frac{nBA}{R}\sin \quad d$$

$$Q_1 \quad \frac{nBA}{R}\,{}_0\sin \quad d \quad \frac{2nBA}{R}$$

$$Q_2 \quad \frac{nBA}{R}\,{}^{\ 2}_{0}\sin \quad d \quad 0$$

$$\frac{Q_2}{Q_1} \quad 0$$

31. According to Lenz's law, induced current always opposes the cause producing it.

32. $i \quad i_0 \; 1 \quad e^{\frac{t}{}} \quad \frac{E}{R} \; 1 \quad e^{\frac{Rt}{L}}$

$$\frac{15}{5} \; 1 \quad e^{\frac{5 \;\; 2}{10}} \quad 3\,(1 \quad e^{\;1})$$

$$3 \;\; 1 \quad \frac{1}{e} \;\; \text{A}$$

33. Velocity of AB is parallel to its length.

34. Velocity of rod is parallel to its length.

35. $V_c \quad V_a \quad V_c \quad V_b \quad BRV$

and $\qquad V_a \quad V_b \quad 0$

36. Induced current always opposes the cause producing it.

37. $E \qquad \frac{d}{dt}$

38. Magnetic flux linked with the coil does not change, hence

$$i \quad \frac{e}{R} \quad \frac{1}{R}\frac{d}{dt} \quad 0$$

39. $e \quad Blv\cos \quad \frac{1}{2}Bl^2 \;\; \cos \qquad \because v \quad \frac{l}{2}$

As $|\cos \quad|$ varies from 0 to 1

e varies from 0 to $\frac{1}{2}B\,l^2$.

JEE Corner

Assertion and Reason

1. Magnetic flux linked with the coil is not changing with time, hence induced current is zero.

2. Both Assertion and Reason are correct but Reason does not explain Assertion.

3. Induced electric field is non-conservative but can exert force on charged particles.

4. $i \quad 2t \quad 8$

$\frac{di}{dt} \quad 2$

$V_a \quad V_b \quad L\frac{di}{dt} \quad 2 \quad 2 \quad 4\,\text{V}$

5. $\frac{di}{dt}_{\text{max}} \qquad (i_{\text{max}}) \quad 1 \quad 2 \quad 2\,\text{A/s}$

6. $V_a \quad V_b \quad V_c \quad V_a$

$V_c \quad V_a \quad V_b$

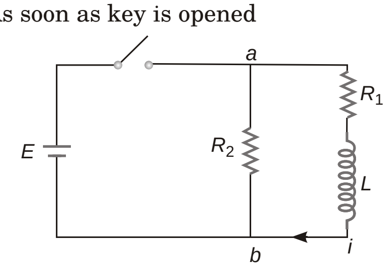
7. Fact.

8. $L \qquad {}_r \;\; {}_0 n^2 lA$, for ferromagnetic substance,

$${}_r \quad g$$

and L does not depends on i.

9. As soon as key is opened



$$i \quad i_0 \quad \frac{E}{R_1}$$

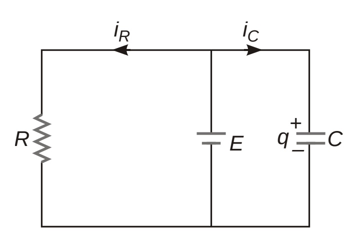
10. Inductors oppose change in current while resistor does not.

Objective Questions (Level 2)

1. By conservation of energy

$$\frac{1}{2}L\,i_0^2 \quad \frac{1}{2}mv_0^2$$

$$i_0 \quad \sqrt{\frac{m}{k}}v_0$$



2. Wire AB behaves as a cell of emf, $E \quad Blv$

$$i_R \quad \frac{E}{R} \quad \frac{Blv}{R}$$

$$i_c \quad 0$$

$$U_c \quad \frac{1}{2}CE^2 \quad \frac{1}{2}CB^2l^2v^2$$

3. Apply Fleming's left hand rule.

4. For SHM,

$$v \quad A\cos \quad t$$

$$e \quad Blv \quad Bl \quad A\cos \quad t$$

$$e \quad \begin{matrix} e_0 \cos \quad t & \text{for } nT \quad t \quad (2n \quad 1)\frac{T}{2} \\ e_0 \cos \quad t & \text{for } \frac{(2n \quad 1)T}{2} \quad t \quad nT \end{matrix}$$

5. $_m \quad BA$

At any instant when wires have moved through a distance x,

$$A \quad (a \quad 2x)^2$$

$$_m \quad B(a \quad 2x)^2$$

$$|e| \quad \frac{d \;_m}{dt} \quad 4B(a \quad 2x)\frac{dx}{dt}$$

$$4B(a \quad 2x)v_0$$

$$|i| \quad \frac{|e|}{R} \quad \frac{4B(a \quad 2x)v_0}{4(a \quad 2x)} \quad \frac{Bv_0}{}$$

6. $A \quad l^2$

$$\frac{dA}{dt} \quad 2l\frac{dl}{dt} \quad 2l \quad \frac{dl}{dt}$$

$$_m \quad BA$$

$$e \quad \frac{d \;_m}{dt} \quad B\frac{dA}{dt} \quad 2Bl$$

at $\quad l \quad a$

$$e \quad 2a \quad B$$

7. At this instant, direction of motion of wire PQ is perpendicular to its length.

$$e \quad Blv$$

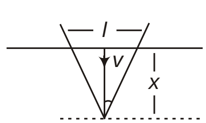
8. $q \quad CV \quad CBlv$

$$20 \quad 10^{\;6} \quad 0.5 \quad 0.1 \quad 0.2$$

$$0.2 \quad \text{C}$$

Plate A is positive while plate B is negative.

9. $_m \quad BA \quad B \;\frac{1}{2}lx$



But $l \quad 2x \tan$

$$_m \quad B\tan \quad x^2$$

$$e \quad \frac{d \;_m}{dt} \quad 2B\tan \quad x\frac{dx}{dt}$$

$$2B\tan \quad vx$$

$$R \quad rl \quad r(2x\tan \quad)$$

where, r resistance per unit length of the conductor.

$$i \quad \frac{e}{R} \quad \frac{Bv}{r} \quad \text{constant.}$$

10. $_m \quad BA\cos \quad BA\cos \quad t$

$$e \quad \frac{d \;_m}{dt} \quad BA\sin \quad t$$

But $\quad A \quad b^2$

$$e \quad b^2B \quad \sin \quad t$$

11. Induced emf

$$e \quad a^2\frac{dB}{dt} \quad (1)^2 \quad 2 \quad 10^{\;3}$$

$$2 \quad 10^{\;3}\,\text{V}$$

$$W \quad qe \quad 1 \quad 10^{\;6} \quad 2 \quad 10^{\;3}$$

$$2 \quad 10^{\;9}\,\text{J}$$

12. In the steady state, current through capacitor $\;0$.

$$i_L \quad \frac{20}{5} \quad 4\,\text{A}$$

$$_1 \quad 0, \quad _2 \quad i_L L \quad 4 \quad 500 \quad 10^{\;2}$$

$$2\,\text{Wb}$$

$$_2 \quad _1 \quad 2\,\text{Wb.}$$

13. $\frac{1}{2}Li^2 \quad \frac{1}{2}\,\frac{1}{2}Li_0^2$

$$i \quad \frac{i_0}{\sqrt{2}}$$

$$i_0 \;\; 1 \quad e^{\;\;t} \quad \frac{i_0}{\sqrt{2}}$$

$$e^{\;t/} \quad \frac{\sqrt{2} \quad 1}{\sqrt{2}}$$

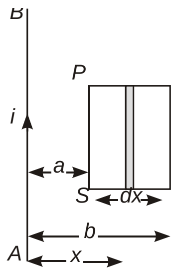
$$t \quad \ln\frac{\sqrt{2}}{\sqrt{2} \quad 1}$$

$$\frac{L}{R}\ln\frac{\sqrt{2}}{\sqrt{2} \quad 1}$$

14. $B \quad \frac{_0 i}{2 \quad a}$

$$F \quad qvB \quad \frac{_0 iqv}{2 \quad a}$$

15. Consider an elementary section of loop of width dx at a distance x from wire AB

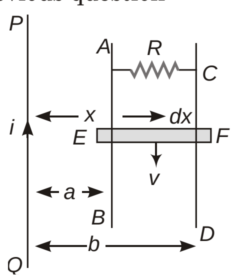


$$d\ _m \quad BdA \quad \frac{_0 i}{2\ x} C\, dx$$

$$_m \quad \frac{_0 iC}{2} \int_a^b \frac{dx}{x} \quad \frac{_0 iC}{2} \ln \frac{b}{a}$$

$$M \quad \frac{_m}{i} \quad \frac{_0 C}{2} \ln \frac{b}{a}$$

16. From previous question



$$_m \quad \frac{_0 iy}{2} \ln \frac{b}{a}$$

$$e \quad \frac{d\ _m}{dt} \quad \frac{_0 i \ln \frac{b}{a}}{2} \frac{dy}{dt}$$

$$e \quad \frac{_0 iv}{2} \ln \frac{b}{a}$$

$$i \quad \frac{e}{R} \quad \frac{_0 iv}{2\ R} \ln \frac{b}{a}$$

Consider an elementary portion of length dx of the rod at a distance, x from the wire PQ.

Force on this portion,

$$dF \quad i\, dxB$$

$$i \frac{_0}{4} \frac{2i}{x} dx$$

$$F \quad i \frac{_0}{4}\ 2i \int_a^b \frac{dx}{x}$$

$$\frac{_0 iv}{2\ R} \ln \frac{b}{a} \quad \frac{_0 i}{2} \ln \frac{b}{a}$$

$$\frac{1}{vR} \quad \frac{_0 iv}{2} \ln \frac{b}{a} \quad ^2$$

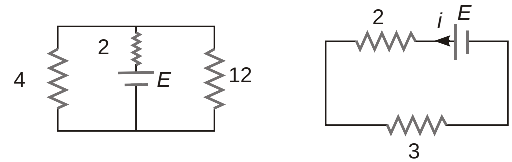
17. $E \quad \frac{1}{2} r \frac{dB}{dt} \qquad E \quad r$

18. Induced current opposes change in magnetic flux.

19. $V_L \quad E \quad iR$

20. The rod can be assumed as a cell of emf $E \quad Blv$

The equivalent circuit is shown in figure,



$$i \quad \frac{E}{2\quad 3} \quad \frac{Blv}{5} \quad \frac{0.50 \quad 0.25 \quad 4}{5}$$

0.1 A

21. Outside the region of magnetic field, induced electric field,

$$E \quad \frac{r^2}{2R} \frac{dB}{dt} \quad \frac{Br^2}{2R}$$

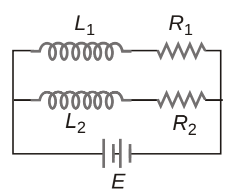
$$F \quad qE$$

$$qER \quad \frac{1}{2} qBr^2$$

22. $V_A \quad V_0 \quad B(2R)V$

$$V_A \quad V_0 \quad 2BRV$$

23. $L_1 \quad \frac{L}{1}, L_2 \quad \frac{L}{1}$



$$R_1 \quad \frac{R}{1}, R_2 \quad \frac{R}{1}$$

$$\frac{1}{L_e} \quad \frac{1}{L_1} \quad \frac{1}{L_2}$$

$$\frac{1}{L} \quad \frac{1}{L}$$

$$\frac{1)}{L} \quad \frac{1}{} \quad \frac{1}{1}$$

$$L_e \quad \frac{L}{(\quad 1)^2}$$

Similarly, $R_e \quad \frac{R}{(\quad 1)^2} \qquad \frac{L_e}{R_e} \quad \frac{L}{R}$

24. $i \quad i_0 e^{\ t/}$

$$Bi_0 \quad i_0 e^{\ T/}$$

$$\frac{T}{\ln \frac{1}{B}}$$

25. Given, $i_0^2 R \quad P, \frac{L}{R}$

when, choke coil is short circuited,

Total heat produced Magnetic energy stored in the choke coil

$$\frac{1}{2} L i_0^2 \quad \frac{1}{2}(R \ ) \frac{P}{R} \quad \frac{1}{2} P$$

26. $i \quad i_0 e^{\frac{Rt}{L}}$

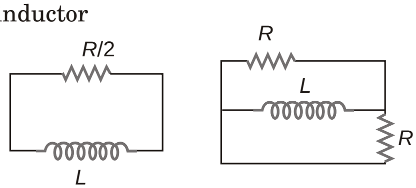
For current to be constant

$$i \quad i_0$$

$$e^{\frac{Rt}{L}} \quad 1$$

$\frac{Rt}{L} \quad 0$ not possible.

27. To final time constant, short the battery and find effective resistance in series with inductor

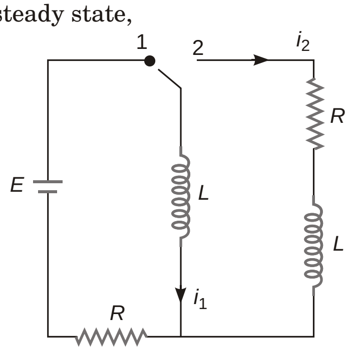


$$R_e \quad \frac{R}{2}$$

$$\frac{L}{R_e} \quad \frac{2L}{R}$$

28. When switch is at position 1.

In steady state,



$$i_1 \quad \frac{E}{R}$$

$$i_2 \quad 0$$

When switch is thrown to position 2.

$$i_1 \quad \frac{E}{R}, i_2 \quad \frac{E}{R}$$

29. $\frac{1}{2} L i^2 \quad \frac{1}{4} \ \frac{1}{2} L \, i_0^2$

$$i \quad \frac{i_0}{2}$$

$$i_0 \ 1 \quad e^{\frac{t}{}} \quad \frac{i_0}{2}$$

$$t \quad \ln 2$$

$$t \quad \frac{L}{2} \ln 2$$

30. At the moment when switch is thrown to position 2,

current in capacitor current in inductor just before throwing the switch to position 2,

$$i_c \quad \frac{E}{R}$$

31. Initially, inductor offers infinite resistance, hence,

$$i \quad 0 \text{ and } \frac{di}{dt} \quad \text{maximum}$$

$$E \quad V_L \quad V_C \quad V_R$$

But $\quad V_C \quad V_R \quad 0$

$$V_L \quad E$$

32. Same as Q.12 objective Questions (Level 2).

33. Let V_0 Potential of metallic rod,

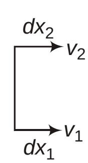
$$V_B \quad V_0 \quad B(2R)V \quad 2BR^2 \qquad \ldots\text{(i)}$$

$$V_0 \quad V_C \quad B(2R)V \quad 2BR^2 \qquad \ldots\text{(ii)}$$

Adding Eqs. (i) and (ii), we get

$$V_B \quad V_C \quad 4B \ R^2$$

34. $e \quad Blv_c$



$$v_c \quad \frac{v_1 \quad v_2}{2}$$

$$e \quad \frac{1}{2} Bl(v_1 \quad v_2)$$

or

$$e \quad B\frac{dA}{dt}$$

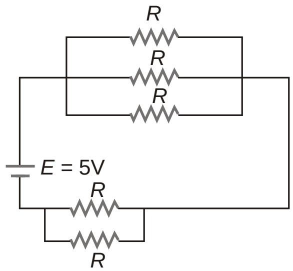
$$dA \quad \frac{1}{2} l(dx_1 \quad dx_2)$$

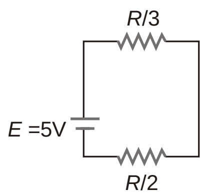
$$e \quad \frac{1}{2} Bl \ \frac{dx_1}{dt} \quad \frac{dx_2}{dt}$$

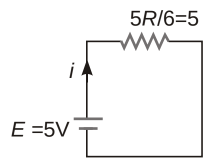
$$\frac{1}{2} Bl(v_1 \quad v_2)$$

35. Initially, capacitor offer zero resistance and inductor offers infinite resistance.

Effective circuit is given by

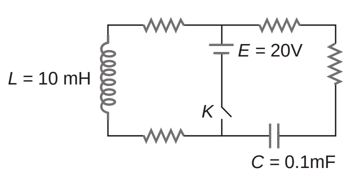


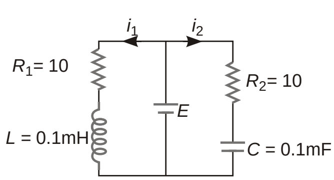




$$i \quad \frac{E}{R} \quad 1\,\text{A}$$

36 . $i_1 \quad \frac{E}{R_1} \quad 1 \quad e^{\frac{R_1 t}{L}}, i_2 \quad \frac{E}{R_2} \quad e^{\frac{t}{R_2 C}}$





$$i \quad i_1 \quad i_2$$

$$\frac{E}{R_1} \quad 1 \quad e^{\frac{R_1 t}{L}} \qquad \frac{E}{R_2} e^{\frac{t}{R_2 C}}$$

at $t \quad 10^{\ 3} \ln 2$

$$i \quad \frac{20}{10} \quad 1 \quad e^{\frac{10 \quad 10^{\ 3} \ln 2}{10 \quad 10^{\ 3}}} \qquad \frac{20}{10} e^{\frac{10^3 \ln 2}{10 \quad 0.1 \quad 10^{\ 3}}}$$

$$2 \quad 1 \quad \frac{1}{2} \qquad 2 \quad \frac{1}{2} \qquad 2\,\text{A}$$

37. $|i| \quad \frac{|e|}{R} \quad \frac{A}{R}\frac{dB}{dt}$

$$\frac{B_0 A}{R} \quad \frac{B_0[(2b)^2 \quad a^2]}{R}$$

$$\frac{B_0(4b^2 \quad a^2)}{R}$$

As inward magnetic field is increasing, net current must be anticlockwise. Hence current in inner circle will be clockwise.

38. From Q. 48 Subjective Questions (Level 1).

$$_m \quad \frac{_0\, ai}{2} \ln \ 1 \quad \frac{a}{x}$$

Case 1

$$x \quad b, a \quad a$$

$$_{m_1} \quad \frac{_0\, ai}{2} \ln \ 1 \quad \frac{a}{b}$$

$$\frac{_0\, ai}{2} \ln \ \frac{b \quad a}{b}$$

Case 2

$$x \quad b \quad a$$

$$a \quad a$$

$$_{m_2} \quad \frac{_0\, ai}{2} \ln \ 1 \quad \frac{a}{b \quad a}$$

$$\frac{_0 ai}{2} \ln \ \frac{b}{b \quad a}$$

$$e \qquad \frac{_{m_2} \qquad _{m_1}}{t}$$

$$e \qquad \frac{e}{R} \qquad \frac{_{m_2} \qquad _{m_1}}{R\, t}$$

$$q \qquad i \quad t \qquad \frac{_{m_2} \qquad _{m_1}}{R}$$

$$\frac{_0\, ai}{2 \ R} \quad \ln \ \frac{b \quad a}{b} \qquad \ln \frac{b}{b \quad a}$$

$$\frac{_0 ai}{2 \ R} \ln \ \frac{b}{b^2 \quad a^2}$$

$$|q| \quad \frac{_0 ai}{2 \ R} \ln \ \frac{b}{b^2 \quad a^2}$$

39. Magnetic flux linked with the coil.

$$_m \quad nBA \quad \frac{_0 n\, iA}{2r}$$

$$|e| \quad \frac{d\ _m}{dt}$$

$$iR \quad \frac{d\ _m}{dt}$$

$$\frac{dq}{dt}R \quad \frac{d_{\ m}}{dt} \quad dq \quad \frac{1}{R}d_{\ m}$$

$$q \quad \frac{_0 nA}{2rR}\int_0^{i} di \quad \frac{_0 n\, iA}{2rR}$$

40. Induced electric field inside the region of varying magnetic fields,

$$E \quad \frac{1}{2}r\frac{dB}{dt} \quad \frac{1}{2}r(6t^2 \quad 2x) \quad 3r(t^2 \quad x)\ \text{V/m}$$

At, t 2.0 s and r $\frac{R}{2}$ 1.25 cm

$$1.25 \quad 10^{\ 2}\ \text{m}$$

$$E \quad 3 \quad 1.25 \quad 10^{\ 2} \quad (4 \quad x)$$

$$0.3\ \text{V/m}$$

$$F \quad eE \quad 1.6 \quad 10^{\ 19} \quad 0.3$$

$$48 \quad 10^{\ 21}\ \text{N}$$

41. $E \quad \frac{1}{2}r\frac{dB}{dt} \qquad E \quad r$

42. As inward magnetic field is increasing, induced electric field must be anticlockwise.

43. $e \quad \frac{d_{\ m}}{dt} \quad a^2\frac{dB}{dt} \quad a^2B_0$

44. $E \quad \frac{e}{2\ a} \quad \frac{1}{2}aB_0$

45. $qEa \quad i$

$$\frac{qEa}{ma^2} \quad \frac{q\ \ \frac{1}{2}aB_0a}{ma^2}$$

$$\frac{qB_0}{2m}$$

46. $P \qquad (\ t) \quad i^{\ 2}\ t$

$$ma^2 \quad \frac{q^2B_0^2}{m^2}t$$

At t 1 s

$$P \quad \frac{q^2B_0^2a^2}{4m}$$

47. $i \quad \frac{e}{R} \quad \frac{A}{R}\frac{dB}{dt}$

$\frac{dB}{dt}$ 2 T/s, A 0.2 0.4 0.08 m^2

$$i \quad \frac{0.08}{1 \quad 1.0} \quad 2 \quad 16\ \text{A} \qquad [\because R \quad r \quad (b \quad 2l)]$$

As outward magnetic field is increasing, induced current must be clockwise.

48. $e \quad B\frac{dA}{dt} \quad A\frac{dB}{dt} \quad Blv \quad A\frac{dB}{dt}$

At t 2 s,

$$B \quad 4\ \text{T},\ A \quad 0.2 \quad (0.4 \quad vt) \quad 0.06\ \text{m}^2$$

$$v \quad 5\ \text{cm/s} \quad 0.05\ \text{m/s}$$

$$e \quad 4 \quad 0.2 \quad 0.05 \quad 0.06 \quad 2$$

$$0.04 \quad 0.12 \quad 0.08\ \text{V}$$

49. $F \quad ilB \quad \frac{e}{R}lB$

$$\frac{0.08}{1 \quad 0.8} \quad 0.2 \quad 4$$

$$0.008\ \text{N}$$

50. When terminal velocity is attained,

power delivered by gravity power dissipated in two resistors

$$mgv \quad 0.76 \quad 1.2$$

$$v \quad \frac{1.96}{0.2 \quad 9.8} \quad 1\ \text{m/s}$$

51. $e \quad Blv \quad 0.6 \quad 1 \quad 1 \quad 0.6\ \text{V}$

$$P_1 \quad \frac{e^2}{R_1}$$

$$R_1 \quad \frac{e^2}{P_1} \quad \frac{(0.6)^2}{0.76} \quad 0.47$$

52. $P_2 \quad \frac{e^2}{R_2}$

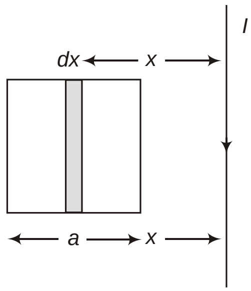
$$R_2 \quad \frac{e^2}{P_2} \quad \frac{(0.6)^2}{1.2} \quad 0.3$$

More than One Correct Options

1. $e \quad B \frac{1}{2} v \quad \frac{1}{2} BLv$

By Fleming's left hand rule, P must be positive w.r.t. Q.

2. $d_{\ m} \quad BdA \quad Ba\,dx$



$$\frac{_0 a\, i}{2\ x} dx$$

$$_m \quad \frac{_0 a\, i}{2\ i} \ln 2$$

$$M \quad \frac{_m}{i} \quad \frac{_0 a}{2} \ln 2$$

If the loop is brought close to the wire, upward magnetic flux linked with the loop increases, hence induced current will be clockwise.

3. Li Henry-Ampere.

$$L \quad \frac{V}{di/dt} \quad \frac{V\,dt}{di} \quad \frac{\text{Volt-second}}{\text{Ampere}}$$

4. $\frac{L}{R} \quad 1\text{ s}$

$$i \quad i_0(1 \quad e^{\ t/\ }) \quad \frac{E}{R}(1 \quad e^{\ t/\ })$$

$$4(1 \quad e^{\ t})$$

At $t \quad \ln 2$,

$$i \quad 2A$$

Power supplied by battery, $P \quad EI \quad 16$ J/s.

Rate of dissipation of heat in across resistor

$$i^2R \quad 8\text{ J/s}$$

$$V_R \quad iR \quad 4\text{ V}$$

$$V_a \quad V_b \quad E \quad V_R \quad 4\text{ V}$$

5. In both the cases, magnetic flux linked with increases, so current i_2 decreases in order to oppose the change.

6. $_1 \quad BA \quad 4 \quad 2 \quad 8\text{ Wb}, \quad _2 \quad 0$

$$e \quad \frac{_2 \quad _1}{t} \quad \frac{8}{0.1} \quad 80\text{ V}$$

$$i \quad \frac{e}{R} \quad \frac{80}{4} \quad 20\text{ A}$$

$$q \quad it \quad 20 \quad 0.1 \quad 2\text{ C}$$

Current is not given as a function of time, hence heat produced in the coil cannot be determined.

7. In LC oscillations,

$$\frac{1}{\sqrt{LC}}, f \quad \frac{}{2} \quad \frac{1}{2\ \sqrt{LC}}$$

$$T \quad \frac{1}{f} \quad 2\ \sqrt{LC}$$

$$i_0 \quad q_0 \quad \frac{q_0}{\sqrt{LC}}$$

$$\left.\frac{di}{dt}\right|_{\max} \quad q_0 \quad \frac{q_0}{LC}$$

$$(V_L)_{\max} \quad L \left.\frac{di}{dt}\right|_{\max} \quad \frac{q_0}{C}$$

8. If magnetic field increases, induced electric field will be anticlockwise and *vice-versa*.

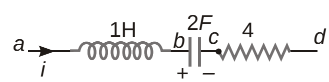
9. $q \quad 2t^2$

$$i \quad \frac{dq}{dt} \quad 4t$$

$$\frac{di}{dt} \quad 4\text{ A/s}$$

As $\frac{dq}{dt}$ Positive

Charge on the capacitor is increasing, hence current flows from a to b.



$$t \quad 1\text{ s}, q \quad 2\text{ C}, \ i \quad 4\text{ A}$$

$$\frac{di}{dt} \quad 4\text{ A/s}$$

$$V_a \quad V_b \quad L\frac{di}{dt} \quad 1 \quad 4 \quad 4\text{ V}$$

$$V_b \quad V_c \quad \frac{q}{c} \quad \frac{2}{2} \quad 1\text{ V}$$

$$V_c \quad V_d \quad iR \quad 4 \quad 4 \quad 16\text{ V}$$

$$V_a \quad V_d \quad 4 \quad 1 \quad 16 \quad 21\text{ V}$$

10. $V_a \quad V_b \quad \frac{1}{2} Bl^2$

$$V_c \quad V_b \quad \frac{1}{2} Bl^2$$

$$V_a \quad V_c \quad 0$$

[Direction of velocity of rod a-c is parallel to length a-c]

Match the Columns

1. $[B] \quad \frac{[F]}{[i][l]} \quad \frac{[\mathrm{MLT}^{\ 2}]}{[\mathrm{A}][\mathrm{L}]}$

$[\mathrm{ML}^0\mathrm{T}^{\ 2}\mathrm{A}^{\ 1}]$

$[L] \quad \frac{[V][dt]}{[di]} \quad \frac{[\mathrm{ML}^2\mathrm{T}^{\ 3}][\mathrm{T}]}{[\mathrm{A}]}$

$[\mathrm{ML}^2\mathrm{T}^{\ 2}\mathrm{A}^{\ 2}]$

$[LC] \quad [\mathrm{T}^{\ 2}]$

$[\ _m] \quad [B][S]$

$[\mathrm{ML}^0\mathrm{T}^{\ 2}\mathrm{A}^{\ 1}][\mathrm{L}^2] \quad [\mathrm{ML}^2\mathrm{T}^{\ 2}\mathrm{A}^{\ 1}]$

2. $i \quad i_0(1 \quad e^{\ t/\ })$

$\frac{L}{R} \quad 1\ \mathrm{s}$

$i_0 \quad \frac{E}{R} \quad 5\ \mathrm{A}$

$V_R \quad iR \quad E(1 \quad e^{\ t})$

$V_L \quad E \quad V_R \quad Et^{\ t}$

At $t \quad 0$,

$V_L \quad E \quad 10\ \mathrm{V}, V_R \quad 0$

at $t \quad 1\ \mathrm{s}$

$V_L \quad E(1 \quad e^{\ 1}) \quad 1 \quad \frac{1}{e} \quad 10\ \mathrm{V}$

$V_R \quad \frac{10}{e}\ \mathrm{V}$

3. In LC oscillations,

$\frac{1}{\sqrt{LC}} \quad \frac{1}{\sqrt{1 \quad \frac{1}{4}}} \quad 2\ \mathrm{rad/s}$

$q_0 \quad 4\ \mathrm{C}$

$i_0 \quad q_0 \quad 8\ \mathrm{A}$

$\frac{di}{dt}_{\max} \quad {}^2q_0 \quad 16\ \mathrm{A/s}.$

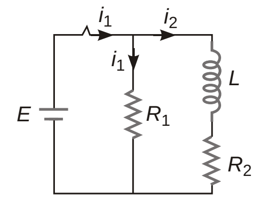
When, $q \quad 2\ \mathrm{C}$

$V_L \quad V_C \quad \frac{q}{C} \quad 8\ \mathrm{V}$

When, $\frac{di}{dt} \quad \frac{1}{2}\ \frac{di}{dt}_{\max} \quad 8\ \mathrm{A/s}.$

$V_C \quad V_L \quad L\frac{di}{dt} \quad 1 \quad 8 \quad 8\ \mathrm{V}$

4. $i_1 \quad \frac{E}{R_1} \quad \frac{9}{6} \quad 1.6\ \mathrm{A}$



$i_2 \quad \frac{E}{R_2}(1 \quad e^{\ \frac{R_2 t}{L}}) \quad 3(1 \quad e^{\ t/3})$

At $t \quad (\ln 2)\ \mathrm{s}$

$V_L \quad E \quad i_2R_2 \quad qe^{\ t/3} \quad \frac{q}{2^{1/3}}$

$V_{R_2} \quad i_2R_2 \quad q(1 \quad e^{\ t/3})$

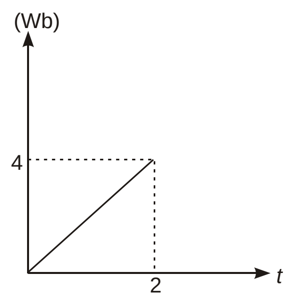
$q \ \ 1 \quad \frac{1}{2^{1/3}}$

$V_{R_1} \quad i_1R_1 \quad 9\ \mathrm{V}$

$V_{bc} \quad V_L \quad V_{R_2} \quad 9\ \mathrm{V}$

(a s), (b s), (c p), (d p).

5. Induced emf



$|e| \quad$ slope of $\ \ - t$ graph

$\frac{4 \quad 0}{2 \quad 0} \quad 2\ \mathrm{V}$

$|i| \quad \frac{|e|}{R} \quad \frac{2}{2} \quad 1\ \mathrm{A}$

$|q| \quad |i|t \quad 1 \quad 2 \quad 2\ \mathrm{C}$

As current i is constant

$H \quad i^2Rt \quad (1)^2 \quad 2 \quad 2 \quad 4\mathrm{J}$

25 Alternating Current

Introductory Exercise 25.1

1. $R \quad \frac{V_{DC}}{I} \quad \frac{100}{10} \quad 10$

$Z \quad \frac{V_{AC}}{I} \quad \frac{150}{10} \quad 15$

$X_L \quad \sqrt{Z^2 \quad R^2} \quad \sqrt{(15)^2 \quad (10)^2}$

$5\sqrt{5}$

$L \quad \frac{X_L}{} \quad \frac{X_L}{2 \quad f} \quad \frac{5\sqrt{5}}{2 \quad 3.14 \quad 50}$

$0.036\,\text{H}$

$V_L \quad IX_L \quad 50\sqrt{5}\ \text{V}$

$111.8\ \text{V}$

2. For phase angle to be zero,

$X_L \quad X_C$

$L \quad \frac{1}{C}$

$L \quad \frac{1}{{}^2C} \quad \frac{1}{(2 \quad f)^2 C}$

$\frac{1}{(360)^2 \quad 10^{\ 6}}$

$7.7\ \text{H}$

As $\quad X_L \quad X_C$

$Z \quad R$

$I \quad \frac{V}{Z} \quad \frac{120}{20} \quad 6\ \text{A}$

Introductory Exercise 25.2

1. Resonating frequency,

${}_r \quad \frac{1}{\sqrt{LC}} \quad \frac{1}{\sqrt{0.03 \quad 2 \quad 10^{\ 6}}}$

$\frac{10^4}{\sqrt{6}}$

$f_r \quad \frac{{}_r}{2} \quad \frac{10^4}{2 \quad 3.14 \quad \sqrt{6}}$

$1105\ \text{Hz}$

Phase angle at resonance is always 0 .

2. Resistance of arc lamp,

$R \quad \frac{V_{DC}}{I}$

$\frac{40}{10} \quad 4$

Impedance of series combination,

$Z \quad \frac{V_{AC}}{I} \quad \frac{200}{10} \quad 20$

Power factor $\quad \cos \quad \frac{R}{Z} \quad \frac{4}{20} \quad \frac{1}{5}$

AIEEE Corner

Subjective Questions (Level-1)

1. (a) $X_L = \omega L = 2\pi fL$

$= 2 \times 3.14 \times 50 \times 2$

$= 628\ \Omega$

(b) $X_L = \omega L \Rightarrow L = \dfrac{X_L}{\omega}$

$= \dfrac{X_L}{2\pi f} = \dfrac{2}{2 \times 3.14 \times 50}$

$= 6.37$ mH

(c) $X_C = \dfrac{1}{\omega C} = \dfrac{1}{2\pi fC}$

$= \dfrac{1}{2 \times 3.14 \times 50 \times 2 \times 10^{-6}}$

$= 1592\ \Omega \approx 1.59$ kΩ

(d) $X_C = \dfrac{1}{\omega C} \Rightarrow C = \dfrac{1}{\omega X_C}$

$= \dfrac{1}{2 \times 3.14 \times 50 \times 2} = 1.59$ mF

2. (a) $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$= \sqrt{R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2}$

$= \sqrt{(300)^2 + \left(400 \times 0.25 - \dfrac{1}{400 \times 8 \times 10^{-6}}\right)^2}$

$= 367.6\ \Omega$

$I_0 = \dfrac{V_0}{Z} = \dfrac{120}{367.6} = 0.326$ A

(b) $\phi = \tan^{-1}\dfrac{X_L - X_C}{R}$

$= \tan^{-1}\dfrac{212.5}{300} = 35.3°$

As $X_C > X_L$ voltage will lag behind current by 35.3°.

(c) $V_R = I_0 R = 0.326 \times 300 = 97.8$ V,

$V_L = I_0 X_L = 32.6$ V

$V_C = I_0 X_C = 0.326 \times 312.5$

$= 101.875$ V $\neq 120$ V

3. (a) Power factor at resonance is always 1, as $Z = R$, Power factor $= \cos\phi = \dfrac{R}{Z} = 1$.

(b) $P = \dfrac{I_0 E_0 \cos\phi}{2} = \dfrac{E_0^2}{2R}$

$= \dfrac{(150)^2}{3 \times 150} = 75$ W

(c) Because resonance is still maintained, average power consumed will remain same, *i.e.*, 75 W.

4. (a) As voltage is lag behind current, inductor should be added to the circuit to raise the power factor.

(b) Power factor $= \cos\phi = \dfrac{R}{Z}$

$Z = \dfrac{R}{\cos\phi} = \dfrac{60}{0.720} = \dfrac{250}{3}$

$X_C = \sqrt{Z^2 - R^2}$

$= \sqrt{\left(\dfrac{250}{3}\right)^2 - (60)^2}$

$= 58\ \Omega$

$C = \dfrac{1}{\omega X_C}$

$= \dfrac{1}{2\pi f X_C}$

$= \dfrac{1}{2 \times 3.14 \times 50 \times 58}$

$= 54\ \mu$F

For resonance,

$\omega_r = \dfrac{1}{\sqrt{LC}}$

$L = \dfrac{1}{\omega_r^2 C}$

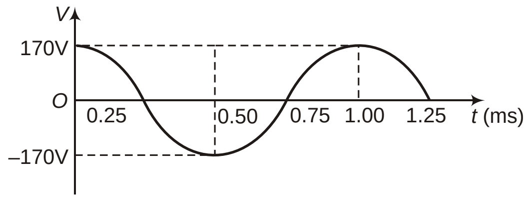
$= \dfrac{1}{(2\pi f)^2 C}$

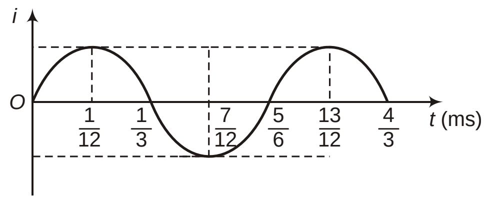
$L = \dfrac{1}{(2 \times 3.14 \times 50)^2 \times 54 \times 10^{-6}}$

$= 0.185$ H

5. $V(t) \quad 170 \sin (6280t \quad\; / 3)$ volt

$i(t) \quad 8.5 \sin (6280t \quad\; /2)$ amp.





(b) $f \quad \frac{}{2} \quad \frac{6280}{2 \quad 3.14} \quad 1000 \text{ Hz}$

1 kHz

(c) $\quad \frac{}{2} \quad \frac{}{3} \quad \frac{}{6}$

$\cos \quad \cos \frac{}{6} \quad \frac{\sqrt{3}}{2}$

As phase of i is greater than V, current is leading voltage.

(d) Clearly the circuit is capacitive in nature, we have

$\cos \quad \frac{R}{Z}$

$\frac{\sqrt{3}}{2} \quad \frac{R}{Z} \quad Z \quad \frac{2}{\sqrt{3}} R$

Also, $\quad Z \quad \frac{V_0}{i_0} \quad \frac{170}{8.5} \quad 20$

$R \quad \frac{\sqrt{3}}{2} Z \quad 10\sqrt{3}$

Again, $\quad Z \quad \sqrt{R^2 \quad X_C^2} \quad X_C \quad \sqrt{Z^2 \quad R^2}$

$\sqrt{400 \quad 300} \quad 10$

$X_C \quad \frac{1}{C} \quad \frac{1}{X_C} \quad \frac{1}{6280 \quad 10}$

$15.92 \quad \text{F}$

6. $I \quad \frac{V}{X_L} \quad \frac{V}{L}$

(a) $\quad 100 \text{ rad/s}$

$I \quad \frac{60}{100 \quad 5} \quad 0.12 \text{ A}$

(b) $\quad 1000 \text{ rad/s}$

$I \quad \frac{60}{1000 \quad 5} \quad 1.2 \quad 10^{\;\;2} \text{ A}$

(c) $\quad 10000 \text{ rad/s}$

$I \quad \frac{60}{10000 \quad 5} \quad 1.2 \quad 10^{\;\;3} \text{ A}$

7. $V_R \quad (2.5 \text{ V}) \cos [(950 \text{ rad/s}) t]$

(a) $I \quad \frac{V_R}{R}$

$\frac{(2.5 \text{ V}) \cos [(950 \text{ rad/s}) t]}{300}$

$(8.33 \text{ mA}) \cos [(950 \text{rad/s}) t]$

(b) $X_L \quad L \quad 950 \quad 0.800$

760

(c) $V_L \quad I_0 X_L \cos (\quad t \quad\; /2)$

$V_L \quad I_0 X_L \sin \quad t$

$6.33 \sin [(950 \text{ rad/s}) t] \text{V}$

8. Given, $L \quad 0.120$ H, $R \quad 240 \quad$, $C \quad 7.30 \quad$ F, $I_{\text{rms}} \quad 0.450$ A, $f \quad 400$ Hz

$X_L \quad L \quad 2 \; fL$

$2 \quad 3.14 \quad 400 \quad 0.120$

301.44

$X_C \quad \frac{1}{C} \quad \frac{1}{2 \; f C}$

$\frac{1}{2 \quad 3.14 \quad 400 \quad 7.3 \quad 10^{\;\;6}}$

54.43

(a) $\cos \quad \frac{R}{Z} \quad \frac{R}{\sqrt{R^2 \quad (X_L \quad X_C)^2}}$

$\frac{240}{\sqrt{(240)^2 \quad (301.44 \quad 54.43)^2}}$

0.697

$\cos^{\;\,1}(0.697) \quad 45.8$

(b) $Z \quad \sqrt{R^2 \quad (X_L \quad X_C)^2}$

$\sqrt{(240)^2 \quad (301.44 \quad 54.43)^2} \quad 344$

(c) $V_{\text{rms}} \quad I_{\text{rms}} Z \quad 0.450 \quad 344$

$154.8 \text{ V} \quad 155 \text{ V}$

(d) $P_{av} \quad V_{\text{rms}} I_{\text{rms}} \cos$

$155 \quad 0.450 \quad 0.697 \quad 48.6 \text{ W}$

(e) $P_R \quad I_{\text{rms}}^2 R \quad (0.450)^2 \quad 240 \quad 48.6 \text{ W}$

(f) and (g) Average power associated with inductor and capacitor is always zero.

Objective Questions (Level-1)

1. In an AC circuit, cos is called power factor.

2. DC ammeter measures charge flowing in the circuit per unit time, hence it measures average value of current, but average value of AC over a long time is zero.

3. $$Z \quad \sqrt{R^2 \quad (X_L \quad X_C)^2}$$
$$\sqrt{R^2 \qquad L \quad \frac{1}{C}}^{\,2}$$

Hence, for $X_L \quad X_C$, Z decreases with increase in frequency and for $X_L \quad X_C$, Z increases with increase in frequency.

4. As voltage leads current and $\frac{\quad}{2}$, hence either circuit contains inductance and resistance or contains inductance, capacitance and resistance with $X_L \quad X_C$.

5. RMS value of sine wave AC is $0.707\, I_0$, but can be different for different types of AC's.

6. $P \quad I_v E_v \cos \qquad 0$

7. $Z \quad \sqrt{R^2 \quad (X_L \quad X_C)^2}$

8. $P \quad \frac{V_0 I_0}{2}$ [V_0 and I_0 are peak voltage and current through resistor only]

9. $V_{rms} \quad \frac{V_0}{\sqrt{2}} \quad 170\text{ V}$

$$f \quad \frac{\quad}{2} \quad \frac{120}{2 \quad 3.14} \quad 19\text{ Hz}$$

10. Current is maximum at

$$_r \quad \frac{1}{\sqrt{LC}} \quad \frac{1}{\sqrt{0.5 \quad 8 \quad 10^{\;\,6}}}$$
$$500\text{ rad/s.}$$

11. $P \quad \frac{I_0 E_0 \cos}{2}$

$$\frac{100 \quad 100}{2} \cos \frac{\quad}{3} \quad 10^{\;\,3} \quad 2.5\text{ W}$$

12. $X_C \quad \frac{1}{C}$ if 0, *i.e.*, for DC

13. $V \quad 10 \cos 100 \quad t$

at $t \quad \frac{1}{600}$ s,

$$V \quad 10 \cos 100 \quad \frac{1}{600}$$
$$10 \cos \frac{\quad}{6} \quad 10 \quad \frac{\sqrt{3}}{2} \quad 5\sqrt{3}\text{ V}$$

14. For purely resistive circuit 0.

15. $X_C \quad \frac{1}{C} \quad X_C \quad \frac{1}{\quad}$ or $X_C \quad \frac{1}{f}$

16. $$\sin \quad \frac{X}{Z} \quad \frac{1}{\sqrt{3}}$$
$$\sin^{\;1} \frac{1}{\sqrt{3}}$$

17. $\frac{3}{2}$, $P \quad \frac{I_0 E_0}{2} \cos \qquad 0$

18. $R \quad \frac{V_{DC}}{I_{DC}} \quad 100$

$$Z \quad \frac{V_{AC}}{I_{AC}} \quad \frac{100}{0.5} \quad 200$$
$$X_L \quad \sqrt{Z^2 \quad R^2} \quad 100\sqrt{3}$$
$$L \quad \frac{X_L}{\quad} \quad \frac{X_L}{2 \ f} \quad \frac{100\sqrt{3}}{2 \quad 50}$$
$$\frac{\sqrt{3}}{\quad} \text{ H}$$

19. $I_{rms} \quad \frac{V_{rms}}{X_C} \quad CV_{rms}$

$$100 \quad 1 \quad 10^{\;\,6} \quad \frac{200\sqrt{2}}{\sqrt{2}}$$
$$I_{rms} \quad 20\text{ mA}$$

20. $V \quad \sqrt{V_R^2 \quad V_L^2} \quad \sqrt{(20)^2 \quad (15)^2}$

$$25\text{ V}, V_0 \quad 25\sqrt{2}\text{ V}$$

21. $P \quad \frac{I_0 V_0 \cos}{2} \quad 0$

$$\cos \quad 0$$
$$90$$

22. R is independent of frequency.

23. L is very high so that circuit consumes less power.

24. $\tan \quad \frac{X_L}{R} \quad \tan 45 \quad \frac{X_L}{100}$

$X_L \quad 100$

$L \quad 100$

$L \quad \frac{100}{2 \quad 3.14 \quad 10^3} \quad 16\,\text{mH}$

25. The minimum time taken by it in reaching from zero to peak value $\frac{T}{4}$

$\frac{1}{4f} \quad \frac{1}{4 \quad 50} \quad \frac{1}{200} \quad 5\,\text{ms}$

26. $\quad 60$

$P \quad \frac{I_0 V_0 \cos}{2} \quad \frac{4 \quad 220 \quad \frac{1}{2}}{2}$

$220\,\text{W}$

JEE Corner

Assertion and Reasons

1. X_C and X_L can be greater than Z because

$$Z \quad \sqrt{R^2 \quad (X_L \quad X_C)^2}$$

Hence, $V_C \quad IX_C$ and $V_L \quad IX_L$ can be greater than $V \quad IZ$.

2. At resonance $X_L \quad X_C$, with further increase in frequency, X_L increases but X_C decreases hence voltage will lead current.

3. $f_r \quad \frac{1}{2 \quad \sqrt{LC}}$, if dielectric slab is inserted between the plates of the capacitor, its capacitance will increase, hence, f_r will decrease.

4. $q \quad$ Area under graph

$\frac{1}{2} \quad 4 \quad (2 \quad 3) \quad \frac{1}{2} \quad 4 \quad (2 \quad 4)$

$22\,\text{C}$

Average current $\frac{q}{t} \quad \frac{22}{6} \quad 3.6\,\text{A}$

5. On inserting ferromagnetic rod inside the inductor, X_L and hence V_L increase. Due to this current will increase if it is lagging and *vice-versa*.

6. $V_R \quad V_L \quad V_C \quad R \quad X_L \quad X_C$

Hence, $\quad 0$ and I is maximum.

as $Z \quad \sqrt{R^2 \quad (X_L \quad X_C)^2}$ is minimum.

7. $I \quad I_L \quad I_C \quad 0$

8. $P \quad I_{\text{rms}}^2 R \quad (\sqrt{2})^2 \quad 10 \quad 20\,\text{W}$

9. Inductor coil resists varying current.

10. $I_0 \quad \frac{E_0}{\sqrt{R^2 \quad ^2L^2}}, \quad \tan^{1} \frac{L}{R}$

11. At resonance, current and voltage are in same phase and $I_0 \quad \frac{V_0}{R}$. Hence, I_0 depends on R.

Objective Questions (Level-2)

Single Correct Options

1. For parallel circuit

$$\tan^{1} \frac{1/X_L}{1/R} \quad \tan^{1} \frac{4}{3}$$

$$53$$

2. Current will remain same in series circuit given by

$I \quad I_0 \sin (\quad t \quad)$

$I_0 \sin \quad t \quad \tan^{1} \frac{X_L}{R}$

3. $R \quad R_1 \quad R_L \quad 10$

$X_L \quad L \quad 10 \quad ,$

$X_C \quad \frac{1}{C} \quad 10$

Reading of ammeter

$$I_{rms} \quad \frac{V_{rms}}{R} \quad \frac{10\sqrt{2}}{10}$$

$$\sqrt{2}\text{ A} \quad 1.4\text{ A}$$

Reading of voltmeter,

$$V \quad I_{rms}R_L \quad 5.6\text{ V}$$

4. $X_C \quad \dfrac{1}{C} \quad \dfrac{1}{2 \quad 5 \quad 10^3 \quad \frac{1}{} \quad 10^{\ 6}}$

$$100$$

$$I_R \quad \frac{V}{R} \quad \frac{200}{100} \quad 2\text{ A}$$

$$I_C \quad \frac{V}{X_C} \quad \frac{200}{100} \quad 2\text{ A}$$

[Question is wrong. It should be choose the correct statement].

5. Let $i \quad i_1 \quad i_2$

where, $i_1 \quad 5\text{ A}, i_2 \quad 5\sin 100 \quad t\text{ A}$

Average value of $i_1 \quad 5\text{ A}$

Average value of $i_2 \quad 0$

Average value of $i \quad 5\text{ A}$

Another method

$$i \quad 5 \ 1 \quad \cos \ \frac{}{2} \quad 100 \quad t$$

$$5 \ 2\cos^2 \ \frac{}{4} \quad 50 \quad t$$

$$10\cos^2 \ \frac{}{4} \quad 50 \quad t$$

Average value of $\cos^2 \ \dfrac{}{4} \quad 50 \quad t \quad \dfrac{1}{2}$

average value of $i \quad \dfrac{10}{2} \quad 5\text{ A}.$

6. As voltage is leading with current, circuit is inductive, and as $\dfrac{}{4}, X_L \quad R$

or $\quad L \quad \dfrac{R}{} \quad \dfrac{R}{100}$

7. As $X_C \quad X_L$ voltage will lag with current.

Again $V \quad \sqrt{V_R^2 \quad (V_L \quad V_C)^2} \quad 10\text{ V}$

$$V \quad V_C$$

and $\quad \cos \quad \dfrac{R}{Z} \quad \dfrac{V_R}{V} \quad \dfrac{4}{5}$

Hence, a, b and c are wrong.

8. For parallel RLC circuit,

$$I \quad \sqrt{I_R^2 \quad (I_C \quad I_L)^2}$$

$$I \quad \sqrt{\frac{V_0}{R}^{\ 2} \quad \frac{V_0}{X_C} \quad \frac{V_0}{X_L}^{\ 2}}$$

$$V_0\sqrt{\frac{1}{R^2} \quad C \quad \frac{1}{L}^{\ 2}}$$

9. $V \quad \sqrt{V_L^2 \quad V_R^2} \quad 72.8\text{ V}$

$$\tan^{\ 1}\frac{V_L}{V_R} \quad \tan^{\ 1}\frac{2}{7}$$

10. Clearly P is capacitor and Q is resistor, as, $V_P \quad V_Q, X_C \quad R$.

When connected in series,

$$Z \quad \sqrt{X_C^2 \quad R^2} \quad \sqrt{2}R$$

and $\dfrac{}{4}$, leading.

$I \quad \dfrac{1}{4\sqrt{2}}$ A, leading in phase by $\dfrac{}{4}$.

11. $I \quad \sqrt{I_R^2 \quad (I_C \quad I_L)^2}$

Here, $I_C \quad I$ or $I_L \quad I$

12. $I \quad I_L \quad I_C \quad 0.2\text{ A}$

13. For a pure inductor voltage leads with current by $\dfrac{}{2}$.

14. $V_R \quad IR \quad 220\text{V}$

Hence it is condition of resonance, i.e.,

$$V_L \quad V_C \quad 200\text{ V}$$

15. $\dfrac{H_1}{H_2} \quad \dfrac{I_{DC}^2R}{I_{rms}^2R} \quad \dfrac{I^2}{(I/\sqrt{2})^2} \quad 2$

16. $H \quad I_{rms}^2R \quad \dfrac{I_0^2R}{2} \quad \dfrac{V_0^2R}{2(R^2 \quad {}^2L^2)}$

17. $V_L \quad IX_L \quad I \ L$

$$V_C \quad IX_C \quad \frac{I}{C}$$

If is very small,

$$V_L \quad 0, V_C \quad V_0 .$$

18. Resistance of coil, $R \quad \dfrac{V}{I} \quad 4$

When connected to battery

$$I \quad \frac{V}{R \quad r} \quad \frac{12}{4 \quad 4} \quad 1.5\text{ A}$$

19. $V_R \quad \sqrt{V^2 \quad V_C^2} \quad 6\,\text{V}$

$$\tan^{\ 1} \frac{V_C}{V_R} \quad \tan^{\ 1} \frac{4}{3}$$

20. $V_C \quad \sqrt{V^2 \quad V_R^2} \quad 16\,\text{V}$

21. $I \quad I_0 \sin \quad \frac{}{2} t$

$I \quad I_0$ at $\frac{}{2} \qquad \frac{3}{2}$

$t \quad 1\,\text{s}$

22. $I_0 \quad \frac{V_0}{\sqrt{2}\,R}$

$X_C \quad \frac{\sqrt{3}}{C} \quad \sqrt{3}R$

$I_0 \quad \frac{V_0}{2R} \quad \frac{I_0}{\sqrt{2}}$

23. $R \quad \frac{V_{\text{DC}}}{I_{\text{DC}}} \quad \frac{12}{4} \quad 3$

24. $X_L \quad \sqrt{Z_1^2 \quad R^2} \quad \sqrt{(5)^2 \quad (3)^2}$

4

$X_C \quad \frac{1}{C}$

$$\frac{1}{50 \quad 2500 \quad 10^{\ 6}} \quad 8$$

$Z \quad \sqrt{R^2 \quad (X_L \quad X_C)^2} \quad 5$

Average power $\quad I_{\text{rms}}^2 R \quad \frac{V_{\text{rms}}^2 R}{Z^2}$

$$\frac{(12)^2 \quad 3}{(5)^2} \quad 17.28\ \text{W}$$

25. Already $X_C \quad X_L$, with increase in , X_C further decrease in , X_C increases and X_L decreases, hence, I will decrease.

26. For maximum current

$$_r \quad \frac{1}{\sqrt{LC}} \quad \frac{1}{\sqrt{1 \quad 10^{\ 6} \quad 4.9 \quad 10^{\ 3}}}$$

$$\frac{10^5}{7}\ \text{rad/s.}$$

27. In resonance,

$$Z \quad \sqrt{R_P^2 \quad X_C^2} \quad 77$$

28. In resonance, cos 1.

More than One Correct Answers

1. $V_R^2 \quad V_L^2 \quad 10000$ ...(i)

$V_L \quad V_C \quad 120$ ...(ii)

$V_R^2 \quad (V_L \quad V_C)^2 \quad (130)^2 \quad 16900$ ...(iii)

On solving

$V_r \quad 50\,\text{V}, V_L \quad 86.6\,\text{V}, V_C \quad 206.6\,\text{V}$

and $\quad \cos \quad \frac{V_R}{V} \quad \frac{50}{130} \quad \frac{5}{15}$

As $V_C \quad V_L$, circuit is capacitive in nature.

2. $i \quad 3 \sin \quad t \quad 4 \cos \quad t$

$R \sin (\quad t \quad)$

$R \quad 5$ and $\quad \tan^{\ 1} \frac{4}{3}$

$i_m \quad \frac{2\,i_0}{} \quad \frac{2R}{} \quad \frac{10}{}$

If $\quad V \quad V_m \sin \quad t$

current will lead with the voltage.

If $\quad V \quad V_m \cos \quad t$

current will lag with voltage.

3. $I \quad \frac{P}{V} \quad 1\,\text{A}, R \quad \frac{V}{I} \quad 60$

For AC,

$$Z \quad \frac{100}{1} \quad 100$$

X_C or $X_L \quad \sqrt{Z^2 \quad R^2} \quad 80$

$L \quad \frac{X_L}{} \quad \frac{80}{2 \quad 50} \quad \frac{4}{5}\,\text{H}$

or $\quad C \quad \frac{1}{X_C} \quad \frac{1}{2 \quad 50 \quad 80} \quad \frac{125}{}\ \text{F}$

or $\quad R \quad R \quad \frac{V}{I}$

$R \quad 100 \quad 60 \quad 40$

4. $\cos \quad \frac{R}{Z} \quad \begin{matrix} 1 & \text{if} & R & Z \\ 0 & \text{if} & R & 0 \end{matrix}$

5. As $X_L \quad X_C$, voltage will lead with the current.

$$Z \quad \sqrt{R^2 \quad (X_L \quad X_C)^2} \quad 10\sqrt{2}$$

$$\tan^{1}\frac{X_L \quad X_C}{R} \quad \frac{}{4} \quad 45$$

$$\cos \quad \frac{R}{Z} \quad \frac{1}{\sqrt{2}}$$

6. As $X_L \quad X_C$, $\quad _r$

with increase in , X_L and hence, Z will increase while with decrease in , Z will first decrease and then increase.

7. $X_c \quad \frac{V_C}{I} \quad 50$

$$V_R \quad IR \quad 80\,\text{V}$$

$$V_L \quad IX_L \quad 40\,\text{V}$$

$$V_{\text{rms}} \quad \sqrt{V_R^2 \quad (V_L \quad V_C)^2} \quad 100\,\text{V},$$

$$V_0 \quad 100\sqrt{2}\,\text{V}$$

8. $I \quad \dfrac{V}{\sqrt{R^2 \quad L \quad \dfrac{1}{C}^{\,2}}}$

with change in L or C I may decrease or increase depending on effect on $L \quad \frac{1}{C}$.

Match the Columns

1. (a) (p, r), (b) (q, r), (c s), (d) (p)

Concept based insertion.

2. (a) (p, s) current and voltage are in same phase so either $X_C \quad 0, X_L \quad 0$

or $X_C \quad X_L \quad 0$.

(b) (q)

$$I \quad I_0 \cos \quad t$$

$$I_0 \sin \quad t \quad \frac{}{2}$$

$$90 \quad R \quad 0$$

(c) (r, s) current is leading with voltage by $\frac{}{6}$, either $X_L \quad 0$ or $X_C \quad X_L$

but X_C and R are non-zero.

(d) (s) current lags with voltage by $\frac{}{6}$, R and X_L are both non-zero.

3. (a) (q, s), (b) (r, s), (c) (r, s), (d) (r, s).

$$I \quad \frac{V}{Z} \text{ and } P \quad \frac{V^2 r}{Z^2}$$

with increase in L, C or f, Z may increase or decrease, hence power and current.

4. (a q),

$$R \quad \frac{V_R}{I} \quad \frac{40}{2} \quad 20$$

(b p)

$$V_C \quad IX_C \quad 2 \quad 30 \quad 60\,\text{V}$$

(c r)

$$V_L \quad IX_C \quad 2 \quad 15 \quad 30\,\text{V}$$

(d s)

$$V \quad \sqrt{V_R^2 \quad (V_L \quad V_C)^2}$$

$$50\,\text{V}$$

5. (a s) R is independent of f.

(b p) $X_C \quad \frac{1}{f}$

(c r) $X_L \quad \frac{1}{f}$

(d q)

$$Z \quad \sqrt{R^2 \quad L \quad \frac{1}{C}^{\,2}}$$

i.e., first decreases then increases.