

Class-XII

MHT-CET

Study Material

PHYSICS

Booklet-2

(Solutions)

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Hints & Solutions

9 Current Electricity

Exercise 1 : WARM-UP
Topic-wise MCQs

1. **(a)** Kirchhoff ' s first law deals with conservation of electrical charge & the second law deals with conservation of electrical energy.

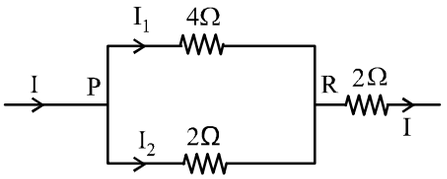
2. **(c)** The current in the circuit is

$$I = \frac{E}{R} = \frac{12-4}{8+1+1} = \frac{8}{10} = 0.8\ A$$

$\therefore$ The potential difference between points P and Q is

$V_{PQ} = IR = 0.8 \times 8 = 6.4\ V$

3. **(d)** The equivalent circuit diagram is



$$\therefore\ I_1 = \left(\frac{2}{4+2}\right) I = \frac{1}{3} \times 6 = 2A$$

$$I_2 = \left(\frac{4}{4+2}\right) I = \frac{2}{3} \times 6 = 4A$$

4. **(d)** Ohm's law is applicable to conductor because *V–I* relationship is linear for conductor.

5. **(a)** For ohmic devices, $V \propto I \qquad (\because V = IR)$

$\therefore$ Graph (a) represents the correct *I–V* characteristics.

6. **(c)**

7. **(d)** $I = n\,e\,A\,v_d = 2 \times 10^{21} \times 1.6 \times 10^{-19} \times 10 \times 0.25 \times 10^{-3}$

$$= 2 \times 1.6 \times 0.25 = \frac{8}{10} = 0.8\ A$$

8. **(a)** Power, $P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P}$

i.e., $R \propto \frac{1}{P}$

i.e., the resistance of 25 W bulb is greater than 100 W bulb.

Heat produced by the bulbs, $H = I^2Rt$.

Since the bulbs are connected in series, current remains same.

i.e., $H \propto R$

i.e., The heat produced by 25 W bulb is greater and hence it will glow brighter.

9. **(c)** $P = V^2 / R$

$\Rightarrow\ R = V^2 / P = 4 \times 10^4 / 100 = 400\ \Omega.$

$S = 10^4 / 200 = 0.5 \times 10^2 = 50\ \Omega.$

$R / S = 8$

10. **(a)** Resistance of filament of electric bulb

$$R = \frac{V^2}{P} = \frac{(200)^2}{50} = \frac{40000}{50} = 800\Omega$$

Therefore power dissipation of the bulb,

$$P = \frac{\left(V_{applied}\right)^2}{R} = \frac{(100)^2}{800} = 12.5\ watt$$

11. **(d)**

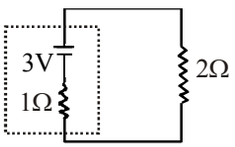
12. **(d)** $I = \frac{E}{R+r}$, Internal resistance (r) is zero,

$I = \frac{E}{R} =$ constant.

13. **(c)**

14. **(c)** Kirchoff's junctions rule is based on conservation of charges.

15. **(a)** The circuit can be redrawn as



Current, $i = \frac{E}{R_{eq}} = \frac{3}{1+2} = 1A$

Terminal potential difference, $V = E - Ir = 3 - 1 \times 1 = 2V$

16. **(b)**

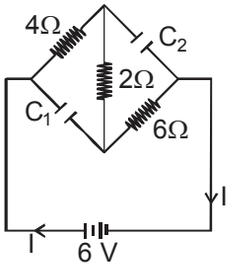
17. **(b)** If we apply Kirchhoff's loop rule to the loop BCDEB in clockwise direction the changes in potential across R_3 and R_4 are negative. Therefore $i_3 R_3$ and $i_3 R_4$ should have negative sign. But for this clockwise direction we are moving in a direction opposite to i_2 across R_2. Current flows from higher potential to lower potential but we are moving from lower potential to higher potential *i.e.*, potential is increasing. So the change in potential is positive. Therefore $i_2 R_2$ has positive sign.

18. **(c)** Kirchhoff's junction rule states that the algebraic sum of all currents into and out of any branch point is zero : $\Sigma I = 0$. By convention, the sign of current entering a junction is

positive and current leaving a junction is negative.
$4A+5A-6A+I_{AB}=0$, therefore $I_{AB}=-3A$. The wire between points A and B carries a current of 3A away from the junction.

19. **(a)**

20. **(d)**



Equivalent Resistance in steady state $R_{eq}=4+2+6=12\Omega$

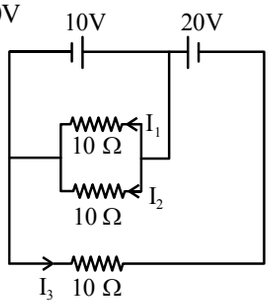
Current, $I=\frac{V}{R_{eq}}=\frac{6}{12}=0.5A$

Potential across C_1 is $V_1=(4+2)I=6\times0.5=3V$
Potential across C_2 is $V_2=(6+2)I=8\times0.5=4V$

$$\frac{q_1}{q_2}=\frac{C_1V_1}{C_2V_2}=\frac{1}{2}$$

21. **(c)** We have $10I_1=10I_2=10V$
$\Rightarrow I_1=I_2=1A$
and, $-10V+20V-10I_3=0$
[By KVL in largest loop]
$\Rightarrow 10V=10I_3 \Rightarrow I_3=1A$

So, $\left|\frac{I_1+I_3}{I_2}\right|=\frac{1+1}{1}=2$

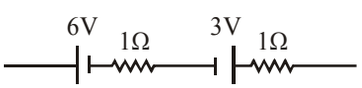


22. **(d)** The given combination consists of two batteries in parallel and resultant of these two in series with third one. For parallel combination, we can apply

$$E_{eq}=\frac{\frac{E_1}{r_1}-\frac{E_2}{r_2}}{\frac{1}{r_1}+\frac{1}{r_2}}=\frac{\frac{10}{2}-\frac{4}{2}}{\frac{1}{2}+\frac{1}{2}}=\frac{6}{2}=3V$$

Further, $\frac{1}{r'_{eq}}=\frac{1}{r_1}+\frac{1}{r_2}=\frac{1}{2}+\frac{1}{2}=1\Rightarrow r'_{eq}=1\Omega$

Now, this is in seris with third one, i.e.,



$\Rightarrow r_{eq}=1+1=2\Omega$ and $E_{eq}=6-3=3V$

23. **(b)** The deflection in galvanometer will not be changed due to interchange of cells and the galvanometer.

24. **(c)** From meter bridge principle

$$\frac{X}{R}=\frac{l_1}{100-l_1}$$

$$\frac{2}{3}=\frac{l_1}{100-l_1}$$

$\Rightarrow 200-2l_1=3l_1$

$$l_1=\frac{200}{5}=40\text{ cm}$$

25. **(b)** For meter bridge,

$$\frac{P}{Q}=\frac{\ell}{100-\ell}\Rightarrow Q\propto\frac{100-\ell}{\ell}$$

$$\therefore\ \frac{Q_2}{Q_1}=\frac{100-\ell_2}{\ell_2}\times\frac{\ell_1}{100-\ell_1}=\frac{100-\ell_2}{\ell_2}\times\frac{50}{50}$$

$$\Rightarrow\ \frac{4Q_1}{Q_1}=\frac{100-\ell_2}{\ell_2}\therefore\ \ell_2=20\text{cm}$$

26. **(a)** L = 20 cm ; L' = 40 cm

Using $\frac{R_1}{R_2}=\frac{L}{100-L}=\frac{20}{100-20}=\frac{20}{80}\Rightarrow R_2=4R_1$

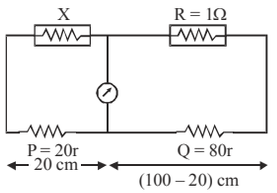
$$\frac{R_1'}{R_2'}=\frac{L'}{100-L'}=\frac{40}{100-40}=\frac{40}{60}=\frac{2}{3}$$

Here $R_1'=R_1+15$ and $R_2'=R_2=4R_1$

$$\frac{R_1+15}{4R_1}=\frac{2}{3}$$

$3R_1+45=8R_1 \Rightarrow R_1=9\Omega$ Smaller resistance

27. **(a)** Let unknown resistance be X. Then condition of Wheatstone's bridge gives $\frac{X}{R}=\frac{20r}{80r}$, where r is resistance of wire per cm.



$$\therefore X=\frac{20}{80}\times R=\frac{1}{4}\times1=0.25\Omega$$

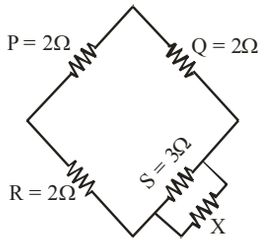
28. **(d)**

29. **(b)** The deflection in galvanometer will not changed due to interchange of battery and the galvanometer.

30. **(d)**

31. **(a)** In meter bridge experiment, it is assumed that the resistance of the L shaped plate is negligible, but actually it is not so. The error created due to this is called end error. To remove this the resistance box and the unknown resistance must be interchanged and then the mean reading must be taken.

32. **(b)** Let X be the resistance with which S is to be shunted for the bridge to be balanced.



Then, for balanced Wheatstone's bridge

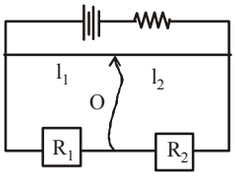
$$\frac{P}{Q}=\frac{R}{\frac{SX}{S+X}} \quad (\because \text{S and X are in parallel})$$

Substituting the given values, we get

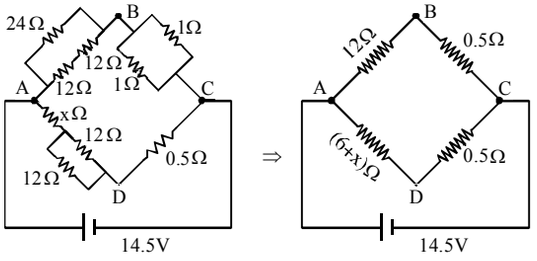
$$\frac{2\Omega}{2\Omega}=\frac{2\Omega}{\frac{(3\Omega)X}{3\,\Omega+X}} \quad \text{or} \quad X(3\,\Omega-2\,\Omega)=(2\,\Omega)\,(3\,\Omega)$$

$$X=\frac{(2\Omega)(3\Omega)}{1\Omega}=6\Omega$$

33. **(b)** Since $R_t = R_0 (1 + \alpha t)$ so, R_1 increases and then l_1 increases when metal wire is heated. The null point shift to the right.



34. **(c)** Solving resistance in series and parallel,



Using balanced condition of Wheatstone Bridge

$$\frac{12}{6+x}=\frac{0.5}{0.5}\Rightarrow x=6\Omega$$

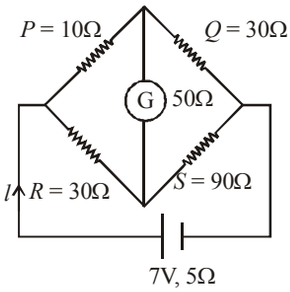
35. **(d)** From Kirchhoff's voltage law, KVL,

$V_1+V_2-V_3=0\Rightarrow V_1+V_2=V_3$

36. **(d)** $\frac{P}{Q}=\frac{l}{(100-l)}$ or $P=\frac{l}{100-l}\times Q=\frac{20}{80}\times 1=0.25\Omega.$

37. **(c)**

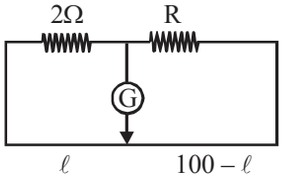
38. **(b)**



$$\therefore R_{eff}=\frac{(P+Q)(R+S)}{(P+Q)+(R+S)}=\frac{40\times 120}{120+40}=\frac{4800}{160}=30\Omega$$

$$\therefore \text{Current, } I=\frac{7}{30+5}\left(\because I=\frac{E}{R+r}\right)=\frac{7}{35}=0.2\,\text{A}$$

39. **(a)**



Condition for Wheatstone Bridge is, $\frac{R_1}{R_2}=\frac{\ell}{100-\ell}$

In Ist case $\frac{2}{R}=\frac{40}{60}\Rightarrow R=3\Omega$

on shunting with 2Ω resistance $R'=\frac{2\times 3}{2+3}=1.2\Omega$

Applying condition of Wheatstone Bridge

$$\frac{2}{1.2}=\frac{\ell}{100-\ell}\Rightarrow \ell=\frac{200}{3.2}=62.5\text{cm}$$

Balance length changes by $62.5 - 40 = 22.5$ cm

40. **(b)** Given,

Resistance in the left gap, $P = 4\Omega$

From the balancing condition of meter bridge

$$\frac{P}{Q}=\frac{l_1}{100-l_1}=\frac{40\text{ cm}}{100\text{ cm}-40\text{ cm}}$$

$$\frac{4}{Q}=\frac{40}{60}\Rightarrow\frac{4}{Q}=\frac{2}{3}$$

$\Rightarrow Q = 6\,\Omega$

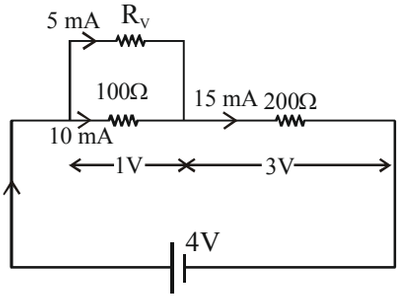
When unknown resistance x is connected in series with P, then

$$\frac{4+x}{6}=\frac{80}{100-80}=\frac{80}{20} \Rightarrow \frac{4+x}{6}=4$$

$\Rightarrow 4+x=24$

$\Rightarrow x=20\,\Omega$

41. (b)



$3=200\times i \Rightarrow i=15\text{ mA}$

$1=100\times i_1 \Rightarrow i_1=10\text{ mA}$

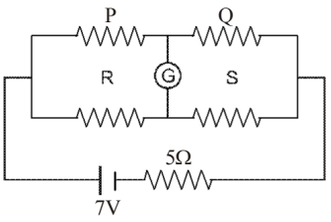
Then, $i-i_1=15-10=5\text{ mA}$

$$\therefore R_v=\frac{1}{5\text{mA}}=\frac{1}{5\times10^{-3}}=200\,\Omega$$

42. (c)

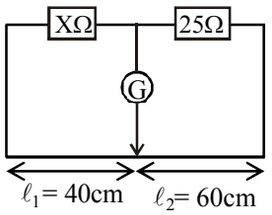
43. (a) Given : $V=7\text{ V}$

$r=5\Omega$



$$R_{eq}=\frac{40\times120}{40+120}\,\Omega;\ I=\frac{V}{R}=\frac{7}{5+\frac{40\times120}{40+120}}=0.2\text{ A}$$

44. (d)



From the balancing condition of meter bridge

$$\frac{X}{\ell_1}=\frac{25}{100-\ell_1}$$

In first case, $\frac{X}{r\ell_1}=\frac{25}{r\ell_2}$ ...(i)

In second case, $\frac{X}{2r\ell'_1}=\frac{25}{2r\ell'_2}$ ...(ii)

From (i) and (ii)

$\ell'_1=\ell_1=40$ cm

45. (c) For null point in balanced condition,

$$\frac{P}{Q}=\frac{\ell_1}{100-\ell_1} \qquad \therefore \quad \frac{4.5}{60}=\frac{R}{40}$$

Also, $R=\frac{\rho\ell}{A}=\frac{\rho\ell}{\pi r^2}\Rightarrow 4.5\times40=\rho\times\frac{0.1}{\pi\times7\times10^{-8}}\times60$

$\therefore\ \rho=66\times10^{-7}\,\Omega\text{m}$

46. (c) Initially at null deflection $\frac{R_1}{R_2}=\frac{2}{3}$ ...(i)

Finally at null deflection, when null point is shifted

$$\frac{R_1+10}{R_2}=1\Rightarrow R_1+10=R_2 \qquad ...(ii)$$

Solving equations (i) and (ii) we get, $\frac{2R_2}{3}+10=R_2$

$10=\frac{R_2}{3}\Rightarrow R_2=30\Omega\ \&\ R_1=20\Omega$

Now if required resistance is R then

$$\frac{\frac{30\times R}{30+R}}{30}=\frac{2}{3}\Rightarrow R=60\Omega$$

47. (b) $\frac{P}{Q}=\frac{R}{S}$ where $S=\frac{S_1S_2}{S_1+S_2}$.

48. (b) For potentiometer we know that, $\frac{E_1}{E_2}=\frac{l_1}{l_2}$

Here, $E_1=V$, $E_2=1.5$ V and $l_1=\frac{l}{3}$

$$\therefore \frac{V}{1.5V}=\frac{l/3}{l_2}\ \ l_2=\frac{l}{3}\times1.5=\frac{l}{2}.$$

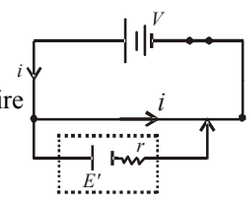
49. (d) From the principle of potentiometer, $V\propto l$

$\Rightarrow \frac{V}{E}=\frac{l}{L}$; where

V = emf of battery,

E = emf of standard cell.

L = length of potentiometer wire



$$V=\frac{El}{L}=\frac{30E}{100}$$

50. **(b)** $r = \frac{\ell_1 - \ell_2}{\ell_2} \times R\Omega$

Here, $\ell_1 = 125$ cm, $\ell_2 = 100$ cm, $R = 2\Omega$.

$\therefore\ r = 0.5\Omega$

51. **(b)** $\theta = \frac{NiAB}{C} \Rightarrow \theta \propto N$ [Number of turns]

52. **(b)** $i = \frac{C\theta}{NAB} \Rightarrow i \propto \theta$

53. **(d)** The coil of a moving coil galvanometer is wound over metallic frame to provide electromagnetic damping so it becomes dead beat galvanometer.

54. **(d)** Current senstivity is given by :

$$\frac{\phi}{1} = \frac{NBA}{k}$$

Since $\frac{\phi}{I} \propto N$ so current sensitivity is increased.

Voltage senstivity is given by :

$$\frac{\phi}{V} = \frac{NBA}{k} \times \frac{1}{R}$$

Since $R \propto N$. $\therefore\ \phi/V$ is not depend on N.

55. **(a)** Resistance is given by : $R = \frac{V}{I} - G$

$$R = \frac{20}{5 \times 10^{-3}} - 50 = 4000 - 50 = 3950\Omega$$

56. **(b)** For full scale deflection current is given by :

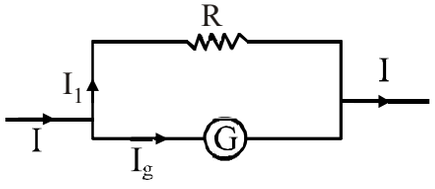
$$30I = \frac{3}{50 + 2950} = \frac{3}{3000} \Rightarrow I = \frac{1}{3000}\text{A}$$

If an additional series resistance is connected current is given by,

$$20I = \frac{3}{50 + 2950 + R} \Rightarrow 20 \times \frac{1}{30000} = \frac{3}{3000 + R}$$

$$\Rightarrow R = 1500\Omega$$

57. **(None)**

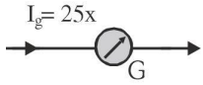


$$I_1 R = I_g G \Rightarrow \frac{95}{100} IR = \frac{51}{100} G \Rightarrow R = \frac{G}{19}$$

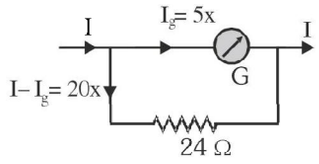
Resistance of ammeter, $R_a = \frac{RG}{R+G} = \frac{\frac{G^2}{19}}{\frac{20G}{19}} = \frac{G}{20}$

58. **(d)** For moving coil galvanometer,

Let x = current/division



After applying shunt



$\therefore\ V_G = V_S$

Now, $5x \times G = 20x \times 24$

$G = 4 \times 24 = 96\Omega$

59. **(c)** [Hint $\Rightarrow S \times (I - I_g) = R_g \times I_g$]

60. **(b)** $I_g = 0.1I$, $I_s = 0.9I$; $S = I_g\ R_g / I_s$

$= 0.1 \times 900 / 0.9 = 100\Omega$.

61. **(c)** $I_g = 10 \times 10^{-3}/5 = 2 \times 10^{-3}$ A;

$$R = \frac{V}{I_g} - R_g = \frac{1}{2 \times 10^{-3}} - 5 = 495\Omega.$$

62. **(c)**

63. **(b)** In moving coil galvanometer

$BINA = K\theta$

$$A = \frac{K\theta}{NIB} = \frac{4 \times 10^{-5} \times 0.05}{200 \times 10 \times 10^{-3} \times 10^{-2}} = \frac{20 \times 10^{-7}}{2 \times 10^{-2}}$$

$$= \frac{10 \times 10^{-7}}{10^{-2}} = 10^{-4}\text{m}^2 = 1\text{ cm}^2$$

64. **(c)** $I = \frac{2}{10} = 0.2$ A

$$\therefore\ \frac{V}{L} = \frac{IR}{L} = 0.2 \times \frac{10}{4} = 0.5\text{ V/m}$$

Exercise 2 : ACCELERATOR
Topic-wise MCQs

1. **(b)** $P = \frac{V^2}{R}$ or $R = \frac{V^2}{P}$

For heater resistance, $R_h = \frac{(220)^2}{500} = 96.8\,\Omega$

For bulb resistance, $R_b = \frac{(220)^2}{100} = 484\ \Omega$

Current in the circuit when both are connected in series

$$I = \frac{V}{R_b + R_h} = \frac{220}{484 + 96.8} = 0.38\ A$$

(i) Power consumed by heater
$= I^2R_h = (0.38)^2 \times 96.8 = 13.98\ W$

(ii) Power consumed by bulb
$= I^2R_b = (0.38)^2 \times 484 = 69.89\ W$

2. **(c)** Resistance of bulb,

$$R_b = \frac{v^2}{P} = \frac{120 \times 120}{60} = 240\Omega$$

As the bulb should glow properly,

$$\therefore\ I = \frac{P}{V} = \frac{60}{120} = \frac{1}{2}A\ \ \therefore\ R + R_b = \frac{V}{I} = \frac{220}{1/2} = 440$$

$$\therefore\quad R = 440 - R_b = 440 - 240 = 200\Omega$$

3. **(c)** $R = \frac{\rho \ell_1}{A_1}$, now $\ell_2 = 2\ell_1$

$$A_2 = \pi(r_2)^2 = \pi(2r_1)^2 = 4\pi r_1^2 = 4A_1$$

$$\therefore\quad R_2 = \frac{\rho(2\ell_1)}{4A_1} = \frac{\rho\ell}{2A} = \frac{R}{2}$$

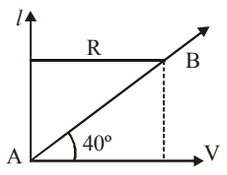
$\therefore$ Resistance is halved, but specific resistance remains the same.

4. **(d)** $R = \frac{\rho l}{\pi r^2}$. But $m = \pi r^2 ld\ \therefore \pi r^2 = \frac{m}{ld}$

$$\therefore\ R_1 = \frac{\rho l_1^2 d}{m_1},\ R_2 = \frac{\rho l_2^2 d}{m_2};\ R_3 = \frac{\rho l_3^2 d}{m_3}$$

$$R_1 : R_2 : R_3 = \frac{l_1^2}{m_1} : \frac{l_2^2}{m_2} : \frac{l_3^2}{m_3} = 125 : 45 : 3$$

5. **(d)** The *V-l* graph for a conductor is as shown in the figure



According to Ohm's law, we get

Current, $I = \frac{V}{R}$

Also, slope AB = resistance $R = \frac{V}{l}$

$$\Rightarrow \frac{1}{\tan 40^\circ} = R = \frac{V}{l} \text{ or } R = \cot 40^\circ$$

6. **(b)** Resistance $R = \frac{\rho l}{A}$

$$\Rightarrow R = \frac{\rho l}{\pi r^2} \Rightarrow R \propto \frac{l}{r^2}$$

Volume of wire remains constant,
$V_i = V_f$

$$\pi r^2 l = \pi \frac{r^2}{4} l'$$

$$l' = 4l$$

$$\frac{R'}{R} = \left(\frac{4l}{\frac{r^2}{4}}\right)\frac{r^2}{l} = 16 \Rightarrow R' = 16R$$

Hence, x = 16

7. **(a)** Resistance, $R_1 = \rho\frac{L_1}{A_1}$

$$R_2 = \rho\left(\frac{3L_1}{A_1/3}\right) = 9\rho\frac{L_1}{A_1} \qquad \therefore \frac{R_2}{R_1} = \frac{9\rho\frac{L_1}{A_1}}{\rho\frac{L_1}{A_1}} = 9:1$$

8. **(d)** Resistance

$$R = \frac{\rho\ell}{A} = \frac{\rho V}{A^2} \text{or}, R \propto \frac{1}{(r^2)^2}$$

$$\therefore \frac{R_A}{R_B} = \frac{r_B^4}{r_A^4} \Rightarrow \frac{R_A}{2} = \left[\frac{4\times10^{-3}}{2\times10^{-3}}\right]^4 \qquad \therefore R_A = 32\ \Omega$$

9. **(a)** Power, $P = \frac{V^2}{R}$

$$\% \text{ decrease in power} = \frac{\Delta P}{P} \times 100 = \frac{2\Delta V}{V} \times 100$$

($\because$ Resistance of the bulb is constant)

$= 2 \times 2.5\% = 5\%$

10. **(c)** Power is, $P = \frac{v^2}{R} \Rightarrow P = \frac{v^2}{I\ell}A \Rightarrow P \propto \frac{1}{\ell}$

Also, power $P = I^2Rt \qquad \therefore P \propto t$

$$P \propto \frac{1}{\ell}$$

$$\frac{P_1}{P_2} = \frac{t_2}{t_1} = \frac{15}{20} = \frac{\ell_2}{\ell_1} \qquad \therefore\ \ell_2 = \frac{3}{4}\ell_1$$

Thus length should be decreased by $\frac{3}{4}$ times.

11. **(a)** Resistance of Heater is,

$$R_h = \frac{V^2}{P} = \frac{(100)^2}{1000} = 10\Omega$$

Voltage drop across heater is,

Also, $V = \sqrt{PR}$

$V = \sqrt{62.5 \times 10} = 25\,V$

Current through 10Ω resistance

$$i_1 = \frac{75}{10} = 7.5A,$$

Current through heater is

$$i_h = \frac{25}{10} = 2.5\,A.$$

Using Kirchoff's law

$i_R = i_1 - i_h = 5$

$$R = \frac{V}{CR}\frac{25}{5} = 5\Omega$$

12. **(a)** Resistance, $R = \dfrac{1}{\text{slope of } I - V \text{ graph}}$

$$\therefore \quad R_1 = \frac{1}{\tan 45°} = 1\Omega, T = 100°C$$

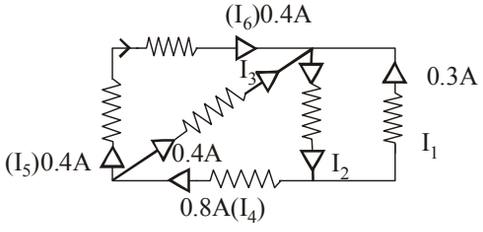
$$\therefore \quad R_2 = \frac{1}{\tan 30°} = \sqrt{3}\Omega, T_2 = 400°C$$

$\therefore$ The temperature coefficient of resistance is

$$\alpha = \left(\frac{R_2 - R_1}{R_1}\right).\frac{1}{\Delta T} = \left(\frac{\sqrt{3}-1}{1}\right) \times \frac{1}{(400-100)}$$

$\approx 3 \times 10^{-3}\,°C^{-1}$

13. **(b)**



From KCL, $I_3 = 0.8 - 0.4 = 0.4\,A$

$I_2 = 0.4 + 0.4 + 0.3 = 1.1\ A$

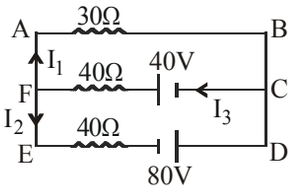
and $I_6 = 0.4\,A$

14. **(b)** Given, $E_1 = 1V, E_2 = 2V, E_3 = 3V, r_1 = 1\Omega$, $r_2 = 1\Omega$ and $r_3 = 1\Omega$. Here, $V_{AB} = V_{CD}$ because $i = 0$

$$V_{AB} = V_{CD} = \frac{\frac{E_1}{r_1}+\frac{E_2}{r_2}+\frac{E_3}{r_3}}{\frac{1}{r_1}+\frac{1}{r_2}+\frac{1}{r_3}} = \frac{\frac{1}{1}+\frac{2}{1}+\frac{3}{1}}{\frac{1}{1}+\frac{1}{1}+\frac{1}{1}} = \frac{6}{3} = 2V$$

15. **(a)**

16. **(b)**



Applying 1st law of Kirchoff's, $I_3 = I_1 + I_2$ …(i)

Applying 2nd law of Kirchhoff in Mesh ABCFA

$-30I_1 + 40 - 40I_3 = 0$ …(ii)

in Mesh FCDEF

$40I_3 - 40 - 80 + 40I_2 = 0$ …(iii)

putting I_3 from (i) in (ii) and (iii) we get

$-30I_1 + 40 - 40I_1 - 40I_2 = 0$

or, $-70I_1 - 40I_2 = -40$

or, $7I_1 + 4I_2 = 4$ …(iv)

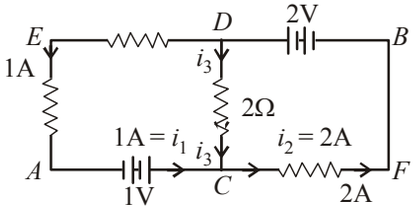
and $40I_1 + 40I_2 - 40 - 80 + 40I_2 = 0$

or, $40I_1 + 80I_2 = 120$ or, $4I_1 + 8I_2 = 12$

or, $2I_1 + 4I_2 = 6$ …(v)

$(iv)-(v)$ gives $5I_1 = -2$ $I_1 = -0.4$ A

17. **(d)**



Let us assume the potential at $A = V_A = 0$

Using Kirchoff's junction rule at C, we get

$i_1 + i_3 = i_2$

$1A + i_3 = 2\ A \Rightarrow i_3 = 2A$

Now using Kirchoff's loop law along $ACDB$

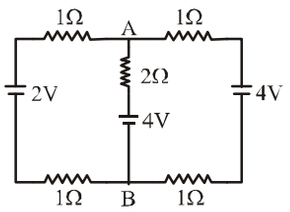
$V_A + 1 + i_3(2) - 2 = V_B$

$\Rightarrow V_A + 1 + i_3(1) - 2 = V_B$

$\Rightarrow V_B - V_A = 3 - 2 = 1$ volt

18. **(d)** Applying parallel combination of batteries

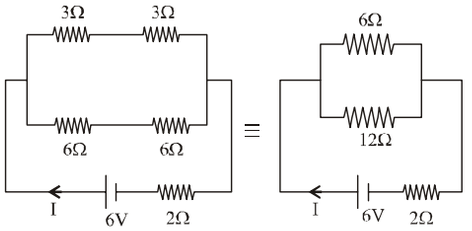
$$\frac{\frac{E_1}{1+1}+\frac{E_2}{2}+\frac{E_3}{1+1}}{\frac{1}{1+1}+\frac{1}{2}+\frac{1}{1+1}}$$



$$\Rightarrow \frac{\frac{2}{2}+\frac{4}{2}+\frac{4}{2}}{\frac{1}{2}+\frac{1}{2}+\frac{1}{2}} = \frac{5\times 2}{3}$$

$$= \frac{10}{3} = 3.3 \text{ Volt}$$

19. **(a)** Balanced wheat stone bridge in circuit so there is no current in 5Ω resistor so it can be removed from the circuit.



The equivalent resistance will be

$$R_{eq} = \frac{6\times 12}{6+12} + 2 = 6\ \Omega$$

Now, apply K.V.L, we have

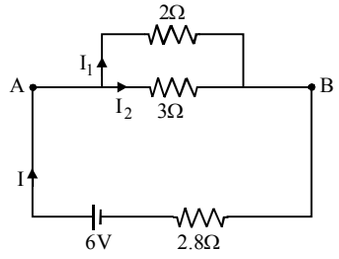
$$I = \frac{V}{R_{eq}} = \frac{6}{6} = 1A$$

20. **(a)**

21. **(a)**

22. **(d)** Kirchhoff's first law is based on conservation of charge and Kirchhoff's second law is based on conservation of energy.

23. **(c)** At steady state the capacitor will be fully charged and thus there will be no current in the 1Ω resistance. So the effective circuit becomes

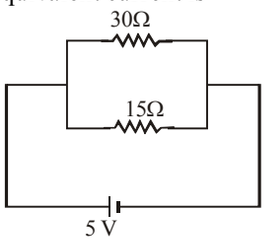


Net current from the 6V battery,

$$I = \frac{6}{\left(\frac{2\times 3}{2+3}\right)+\frac{2.8}{1}} = \frac{6}{1.2+2.8} = \frac{3}{2} = 1.5A$$

Between A and B, voltage is same in both resistances,
$2I_1 = 3I_2$ where $I_1 + I_2 = I = 1.5$
$\Rightarrow \quad 2I_1 = 3(1.5 - I_1) \Rightarrow I_1 = 0.9A$

24. **(b)** The network of resistors is a balanced wheatstone bridge. The equivalent current is



$$R_{eq} = \frac{15\times 30}{15+30} = 10\ \Omega \Rightarrow I = \frac{V}{R} = \frac{5}{10} = 0.5\ A$$

25. **(a)**

26. **(a)** You precise measurement, we always take P and Q approx equal and small.

27. **(c)** At D, we have null point

So, $\frac{S}{30} = \frac{R}{70} \Rightarrow \frac{S}{30} = \frac{5600}{70} \Rightarrow S = \frac{3}{7}\times 5600 = 2400\ \Omega$

28. **(b)** After applying the condition of wheatstone bridge and adding the end correction

$$\frac{15}{43+2} = \frac{R}{102-45} \Rightarrow \frac{15}{45} = \frac{R}{57} \quad \therefore R = 19\Omega$$

29. **(d)**

30. **(a)**

31. **(b)** The working principle of meter bridge is

$$\frac{R}{S} = \frac{l}{100-l} \qquad \ldots(i)$$

When S' is connected in parallel with S we obtain equivalent resistance S_{eq} of S and S' which is less than S. Thus if the value of denominator of L.H.S. of eq. (i) decreases then value of denominator of R.H.S. of eq. (i) also decreases.

For this to happen the null point shifts to the right of D.

32. **(c)** At $t_1 = 0°C$, $l_1 = 50cm$, $S = 4\Omega$
By meter-bridge principle,

$$\frac{X_1}{S} = \frac{l_1}{100-l_1} \Rightarrow \frac{X_1}{4} = \frac{50}{100-50} \quad \therefore X_1 = 4\Omega$$

At $t_2 = 100°C$, $l_2 = 60$ cm, $S = 4\Omega$

$$\therefore \quad \frac{X_2}{S} = \frac{l_2}{100-l_2} \Rightarrow \frac{X_2}{4} = \frac{60}{100-60} \quad \therefore X_2 = 6\Omega$$

The temperature coefficient of the coil is

$$\alpha = \left(\frac{X_2 - X_1}{X_1}\right).\frac{1}{\Delta t} = \left(\frac{6-4}{4}\right)\times\frac{1}{100} = 0.005\ °C^{-1}$$

33. **(b)** Given, balance point from one end, $\ell_1 = 20$ cm
From the condition for balance of metre bridge, we have

$$\frac{55}{R} = \frac{\ell_1}{100-\ell_1} \Rightarrow \frac{55}{R} = \frac{20}{80} \Rightarrow R = 220\Omega$$

34. **(b)** For the given meter bridge

$\frac{R}{S}=\frac{\ell_1}{100-\ell_1}$ Where, ℓ_1 = balancing length

$\Rightarrow \quad \frac{R}{S}=\frac{25}{75}=\frac{1}{3}$ ...(i)

New resistance,

$$R'=\frac{\rho\frac{\ell}{2}}{\frac{A}{4}}=\rho\frac{\ell\times 2}{A} \qquad \left(\because R=\rho\frac{\ell}{A}\right)$$

$\Rightarrow \quad R'=2R$

$\frac{R'}{S}=\frac{\ell_2}{100-\ell_2} \Rightarrow \quad \frac{2R}{S}=\frac{\ell_2}{100-\ell_2}$

$\Rightarrow \quad 2\times\frac{1}{3}=\frac{\ell_2}{100-\ell_2}$ Using (i)

$\Rightarrow \quad \ell_2=40\,\text{cm}$

35. **(c)** From the balanced wheat stone bridge

$\frac{R_1}{R_2}=\frac{\ell_1}{\ell_2}$ where $\ell_2=100-\ell_1$

In the first case $\frac{X}{Y}=\frac{20}{80}$; $Y=4X$

In the second case

$\frac{4X}{Y}=\frac{\ell}{100-\ell}\Rightarrow\frac{4X}{4X}=\frac{\ell}{100-\ell} \quad \Rightarrow \ell=50$

36. **(b)** From the balancing condition of metre bridge

$\frac{R_1}{R_2}=\frac{\ell}{100-\ell}\Rightarrow\frac{2}{3}=\frac{\ell}{100-\ell}$

$\Rightarrow \ell=40\,\text{cm}$

When XΩ resistor is added to 3Ω balancing condition

$$\frac{2}{\left(\frac{3X}{3+X}\right)}=\frac{40+22.5}{60-22.5}=\frac{62.5}{37.5}=\frac{5}{3}\Rightarrow\frac{6}{5}=\frac{3x}{3+x}$$

$\Rightarrow 6+2X=5X\Rightarrow X=2$

37. **(c)** $I_s=\left(\frac{G}{S+G}\right)I=\frac{18}{20}\times 2=1.8\,A$

38. **(d)** $\frac{I_g}{I}=\frac{S}{S+G} \quad \therefore\frac{0.5}{I}=\frac{3}{45+3}=\frac{1}{16}$

$\therefore I=16\times 0.5=8A$

39. **(b)** The deflection is reduced to half

i.e. $\frac{I_g}{I}=\frac{1}{2}=\frac{S}{S+G} \quad \therefore\frac{1}{2}=\frac{40}{40+G}$

$\therefore G=40\,\Omega$

40. **(c)**

41. **(b)**

42. **(d)** $\frac{I_g}{I}=\frac{S}{S+G}=\frac{\frac{G}{n}}{\frac{G}{n}+G}=\frac{1}{1+n}$

43. **(a)** $\frac{I_g}{I}=\frac{s}{s+G}=\frac{2.5}{2.5+25}=\frac{2.5}{27.5}=\frac{1}{11}$

44. **(a)** Let E_A, E_B and E_C be the emf of three cells A, B and C respectively.

According to question

$E_A+E_B+E_C=kI_1=k\times 740$ ...(i)

$E_A+E_B=kI_2=k\times 440$ ...(ii)

$E_B+E_C=kI_3=k\times 540$ ...(iii)

Inserting the value of E_A+E_B from (ii) into (i), we get

$E_C=300k$

Inserting the value of E_B+E_C from (iii) into (i), we get

$E_A=200k$

Inserting this value of E_A into (ii), we get

$E_B=240k$

$\therefore \quad E_A:E_B:E_C=200k:240k:300k$

$=10:12:15=1:1.2:1.5$

45. **(a)**

46. **(c)** Balancing length l will give emf of cell

$\therefore E = Kl$

Here K is potential gradient.

If the cell is short circuited by resistance 'R'

Let balancing length obtained be l' then

$V = kl'$

$r=\left(\frac{E-V}{V}\right)R$

$\Rightarrow V = E - V \quad \Rightarrow \quad 2V = E$ [$\because$ $r = R$ given]

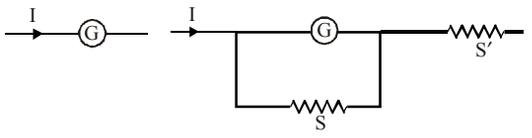
or, $2Kl' = Kl \quad \therefore \quad l' = \frac{l}{2}$

47. **(c)** $V=I_g(R+R_g)$

$\Rightarrow \quad R=\frac{V}{I_g}-R_g=\frac{100}{5\times10^{-3}}-50=19950\,\Omega$

48. **(c)** To keep the main current in the circuit unchanged, the resistance of the galvanometer should be equal to the net resistance.

$\therefore G=\left(\frac{GS}{G+S}\right)+S' \Rightarrow G-\frac{GS}{G+S}=S' \quad \therefore S'=\frac{G^2}{G+S}.$



49. **(a)** $I = \frac{E}{R_1 + R_2} = \frac{2}{1000} = \frac{1}{500} A$

$\therefore$ P.D. across the wire = $IR = \frac{10}{500} = \frac{1}{50} V$

$\therefore$ Potential gradient = $\frac{V}{L} = \frac{1}{50 \times 2} = 0.01$ V/m

50. **(c)** By Ohm's law, P.D. = V = IR = $\frac{I\rho L}{A}$

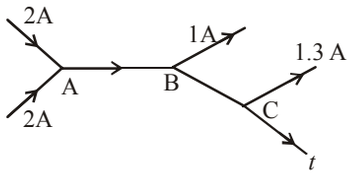
$\therefore$ Potential gradient $\frac{V}{L} = \frac{I\rho}{A}$

Exercise 3 : PREVIOUS YEARS MCQs

1. **(a)** According to Kirchhoff's first law

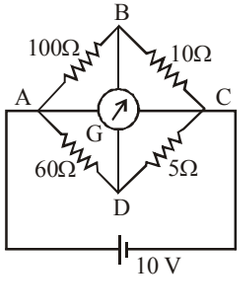
At junction A, $i_{AB} = 2 + 2 = 4$ A

At junction B, $i_{AB} = i_{BC} - 1 = 3$A



At junction C, $i = i_{BC} - 1.3 = 3 - 1.3 = 1.7$ amp

2. **(d)**



Current through the galvanometer,

$$I_G = \frac{V_B - V_D}{R_{BD}}$$

$$\frac{V_B - V_A}{100} + \frac{V_B - V_D}{15} + \frac{V_B - V_C}{10} = 0$$

$$\Rightarrow \frac{V_B - 10}{100} + \frac{V_B - V_D}{15} + \frac{V_B - 0}{10} = 0$$

$$\Rightarrow \frac{V_B - 10}{20} + \frac{V_B - V_D}{3} + \frac{V_B}{2} = 0$$

$$\Rightarrow 3V_B - 30 + 20V_B - 20V_D + 30V_B = 0$$

$$\Rightarrow 53V_B - 20V_D = 30 \quad ...(i)$$

Similarly,

$$\frac{V_D - 10}{60} + \frac{V_D - V_B}{15} + \frac{V_D - 0}{5} = 0$$

$$\Rightarrow V_D - 10 + 4V_D - 4V_B + 12V_D = 0$$

$$\Rightarrow -4V_B + 17V_D = 10 \quad ...(ii)$$

Solving equations (i) and (ii), we get

$V_B = 0.86$ V and $V_D = 0.79$ V

$$\therefore I_G = \frac{V_B - V_D}{R_{BD}} = \frac{0.86 - 0.79}{15} = \frac{0.07}{15}$$

$\therefore I_G = 4.87$ m A

3. **(a)** Sum of current at junction point will be zero:

$$\frac{x - 30}{10} + \frac{x - 12}{20} + \frac{x - 2}{30} = 0$$

$$\Rightarrow x\left(\frac{1}{10} + \frac{1}{20} + \frac{1}{30}\right) = \frac{30}{10} + \frac{12}{20} + \frac{2}{30}$$

$$\Rightarrow x\left(\frac{6 + 3 + 2}{60}\right) = \frac{180 + 36 + 4}{60}$$

$$\Rightarrow x = \frac{220}{11} = 20V$$

Hence, current through the 20Ω resistor will be

$$\frac{x - 12}{20} = \frac{20 - 12}{20} = \frac{2}{5} = 0.4A$$

4. **(c)** Electric current,

$i \propto \theta$ (angle of deflection)

$$\therefore \frac{i_2}{i_1} = \frac{\theta_2}{\theta_1} \Rightarrow \frac{i_2}{200\,\mu A} = \frac{\pi/10}{\pi/3} = \frac{3}{10} \qquad \left[\because 60° = \frac{\pi}{3}\right]$$

$\therefore i_2 = 60\,\mu A$

5. **(a)** The new balancing length L_2 is less than the original length L_1.

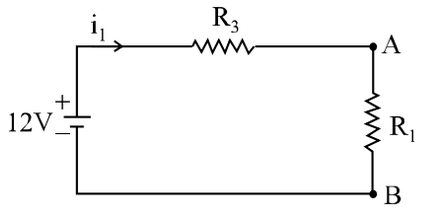
$L_2 = L_1 - 0.10\,L_1 = 0.90\,L_1$

Internal resistance

$$r = R\left(\frac{L_1}{L_2} - 1\right) = R\left(\frac{L_1}{0.9L_1} - 1\right) = R\left(\frac{10}{9} - 1\right) = \frac{R}{9}$$

6. **(None)**

7. **(a)** When switch S is open



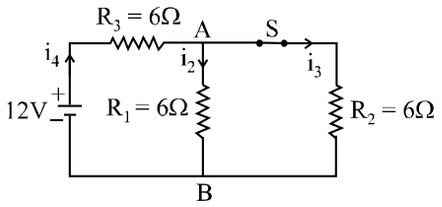
Net resistance = 6 + 6 = 12Ω

Current $i_1 = \frac{12V}{12\Omega} = 1A$

Potential across R_1 is

$V_{AB} = i_1 \times R_1 = 1 \times 6 = 6V$

After switch is closed



Total resistance is here

$= 6 + (6 \| 6) = 6 + \frac{6 \times 6}{6+6} = 6 + 3 = 9\Omega$

Current passing through cell $i_4 = \frac{V}{R_{Total}} = \frac{12}{9} = \frac{4}{3}A$

$\therefore \quad i_2 = i_3 = i_4 / 2 = \frac{4}{3 \times 2} = \frac{2}{3}A$

So, potential across R_1

$V'_{AB} = i_2 R_1 = \frac{2}{3} \times 6 = 4V$

So, change in potential of R_1 is

$= V'_{AB} - V_{AB} = 4 - 6 = -2V$

8. **(b)** For left most loop, by KVL

$2 + i_1 R - 2 = 0$

$\Rightarrow i_1 = 0$

For middle loop, by KVL

$2 + i_2 R - 2 - i_1 R = 0$

$\Rightarrow \quad i_2 R - i_1 R = 0 \Rightarrow i_2 = i_1 = 0$

For right most loop, by KVL

$2 + i_3 R - 2 - i_2 R = 0$

$\Rightarrow \quad i_3 = i_2$

$\Rightarrow i_3 = 0$

9. **(d)** From the given circuit

$V_A - V_B = 1 \times 1.5 = 1.5\,V$

Here, $V_B = 0$

So, $V_A = 1.5\,V$

Consider a point p between B and C

$V_B - V_p = 2.5 \times 1 = 2.5\,V$

$V_C - V_p = V_C - (-2.5)$

$\Rightarrow \quad V_C + 2.5 = 2 \Rightarrow V_C = 2 - 2.5 \Rightarrow V_C = -0.5\,V$

10. **(a)** For series combination of resistors,

$V = IRs = I(2R) = 2 \times 2R = 4R$

For parallel combination of resistors,

$I = \frac{V}{R_P} = \frac{4R}{\left(\frac{R \times R}{R+R}\right)} = 8A$

$\therefore$ Current through each resistor is $I' = \frac{I}{2} = 4A$

11. **(c)** Initial will point is at $\ell_1 = 20cm$

after shunting S with 60Ω, null point shifts by 5 cm to the right, so new null point is:

$\ell_2 = 25$ cm

$\frac{R}{S} = \frac{\ell_1}{100 - \ell_1} \Rightarrow \frac{20}{80} = \frac{1}{4} = \frac{\ell_1}{100 - \ell_1} \Rightarrow R = \frac{S}{4}$ ... (i)

$\frac{1}{S'} = \frac{1}{S} + \frac{1}{60} \Rightarrow S' = \frac{60S}{S+60}$

New null point $\ell_2 = 25$ cm

$\frac{R}{S'} = \frac{25}{75} = \frac{1}{3} \Rightarrow R = \frac{S'}{3}$ ... (ii)

From equation (i) $R = \frac{S}{4}$

from equation (ii) $R = \frac{1}{3} \times \frac{60S}{S+60}$

$\frac{S}{4} = \frac{1}{3} \times \frac{60S}{S+60} \Rightarrow \frac{1}{4} = \frac{60}{3(S+60)} = \frac{20}{S+60}$

$(S + 60) = 80 \Rightarrow S = 20\Omega$

Now from (i)

$R = \frac{S}{20} = \frac{20}{4} = 5\Omega$

Hence final answer is

$\boxed{S = 20\Omega,\ R = 5\Omega}$

12. **(b)** Give, area of cross-section = $6 \times 10^{-7}\ m^2$

Potential difference per unit length = 0.15 V/m

From ohm's law V = IR ...(i)

Resistivity, $\rho = \frac{RA}{L}$

$R = \frac{\rho L}{A}$ ...(ii)

From eq(i) and eq (ii)

$V = I\left(\frac{\rho L}{A}\right)$

$$\Rightarrow \quad \rho = \frac{VA}{IL}$$

$$\Rightarrow \quad \rho = \frac{A}{I}\left(\frac{V}{L}\right) = \frac{6\times10^{-7}\times0.15}{0.3} = 3\times10^{-7}\,\Omega m$$

13. (a) Total potential drop across the entire wire is

$v_t = IR = I \times 5$

But this must be equal to the terminal voltage of the cell

$$IR = V_{term} = E\times\frac{R}{R+r}$$

$$\text{So, } I = \frac{E}{R+r},\ V_{wire} = IR = \frac{ER}{R+r}$$

Potential difference between 660 cm is 1.1V (Given)

$$\text{potential gradient} = \frac{\text{Total potential drop across 1000}}{1000}$$

So, potential difference across 660 cm

$$V = \frac{IR}{1000}\times660 \Rightarrow 1.1 = \frac{IR\times660}{1000}$$

$$I = \frac{1}{3}A$$

Internal resistance of EMF

$$I = \frac{E}{R+r} \Rightarrow \frac{1}{3} = \frac{2.2}{5+r}$$

$r = 1.6\Omega$

14. (d) Right gap = two equal resistors in series

Balancing point is at 50 cm meaning both sides have equal resistance.

Case- 1: Right gap $(R_R) = R + R = 2R$

Left gap $(R_L) = 2R$

Case 2 : One of the resistors from the right gap is removed, and connected in parallel with the resistor in the left gap.

Right gap: only resistor R

Left gap: Now two resistors: 2R and R connected in parallel

Now, Total resistance in left gap:

$$\frac{1}{R_L} = \frac{1}{2R} + \frac{1}{R} \Rightarrow R_L = \frac{2R}{3}$$

using meter bridge principle

$$\frac{R_L}{R_R} = \frac{\ell}{100-\ell} \Rightarrow \frac{2R/3}{R} = \frac{\ell}{100-\ell}$$

$$\Rightarrow \quad \ell = 40\,cm$$

15. (a) From wheat stone bridge, we have

$$\frac{R_1}{R_3} = \frac{L}{K}$$

$P = I^2R$

$$\frac{P_3}{P_1} = \frac{I^2R_3}{I^2R_1} = \frac{K}{L}$$

16. (b) For the given metre bridge,

$$\frac{R}{S} = \frac{\ell_1}{\ell_2} = \frac{40}{60} = \frac{2}{3} \qquad ...(i)$$

When the wire in the left gap is stretched to double of its length, then

$R' = (2)^2R = 4R$

$\therefore$ New balancing length is given by

$$\frac{R'}{S} = \frac{\ell}{100-\ell} \Rightarrow \frac{4R}{S} = \frac{\ell}{100-\ell}$$

$$\Rightarrow 4\times\frac{2}{3} = \frac{\ell}{100-\ell}\left[\text{From eq(i)}\right] \Rightarrow 800 - 8\ell = 3\ell$$

$$\therefore\ \ell = \frac{800}{11}\,cm$$

17. (a)

18. (a) Cells are in series as positive terminal of one cell connected with the negative terminal of other cell.

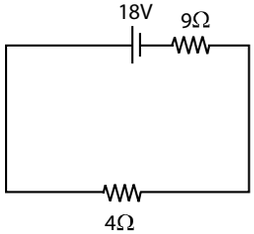
$Eq = E_1 + E_2$

$= 12 + 6 = 18\ V$

$req = r_1 + r_2$

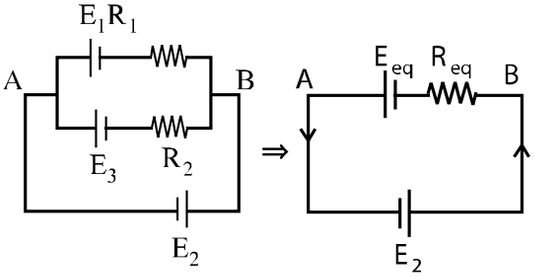
$= 6 + 3$

$= 9\ \Omega$



$$\text{Now, } I = \frac{E}{R+r} = \frac{18}{9+4} = \frac{18}{13} = 1.3 \simeq 1\,A$$

19. (d)



$$E_{eq} = \frac{\frac{E_1}{R_1}+\frac{E_3}{R_2}}{\frac{1}{R_1}+\frac{1}{R_2}} = \frac{E_1R_2+E_3R_1}{R_1+R_2} = \frac{2\times4+2\times4}{42+4} = 2V$$

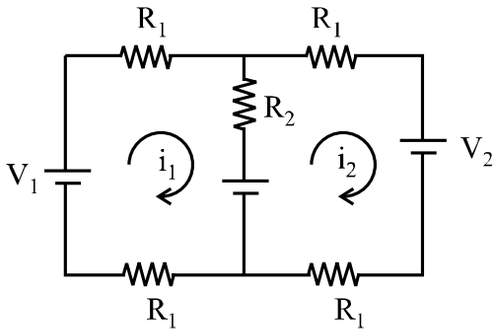
$$R_{eq} = \frac{R_1R_2}{R_1+R_2} = \frac{4\times4}{4\times4} = 2\Omega$$

$$-E_2 + iR_{eq} - E_{eq} = 0$$

$$i = \frac{E_2+E_{eq}}{R_{eq}} = \frac{2+2}{2} = 2A$$

Hence, the current flowing through E_2 is 2A from B to A

20. (a)



By Mesh law

Loop 1 : $i_1R_1 + (i_1-i_2)R_2 + V_2 + i_1R_1 - V_1 = 0$

$i_1\beta R + (i_1-i_2)\gamma R + \alpha V + i_1\beta R - V = 0$ ...(i)

Loop 2 : $i_2R_1 + V_2 + i_2R_1 - V_2 + (i_2-i_1)R_2 = 0$

$\Rightarrow \quad i_2\beta R + V_2 + i_2\beta R - V_2 + (i_2-i_1)\gamma R = 0$

$\Rightarrow \quad 2i_2\beta R + (i_2-i_1)\gamma R = 0$ ...(ii)

Solving (i) & (ii), we get

$$i_2 = \frac{-(\alpha-1)}{4\beta(\beta-\gamma)}\frac{\gamma V}{R}\cdot \text{As } I = -i_2$$

$$\text{So, } I = \frac{(\alpha-1)\gamma}{4\beta(\beta+\gamma)}\frac{V}{R}$$

21. (d) Apply the Kirchoff law

$-12 + 500i + 100i = 0$

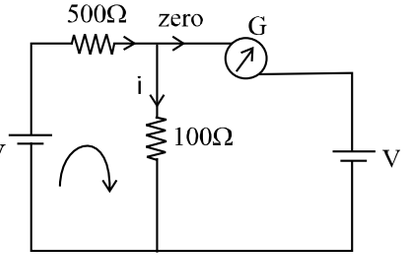
$600i = 12$

$i = \dfrac{12}{600}$

$= 0.02\,A$

$V = iR = 100\times0.02$

$= 2V$



22. (d) Apply the KVL in given circuit

$-6 + 2\times2 = 0$

$V_{BA} = -2V$

23. (c) In meter bridge experiment,

$$\frac{9}{x} = \frac{1}{100-1} \qquad \text{...(i)}$$

$$\text{Again, } \frac{x}{9} = \frac{1+10}{100-(1+10)} = \frac{1+10}{90-1} \qquad \text{...(ii)}$$

Multiplying eq(i) and (ii), we get

$$\frac{1(1+10)}{(100-1)(90-1)} = 1 \Rightarrow l^2 + 10\,\ell = 9000 - 190l + l^2$$

$\therefore \quad l = 45\,cm$

$\therefore$ From eq(i)

$$\frac{9}{x} = \frac{45}{55} \Rightarrow x = 11\Omega$$

24. (a) $\dfrac{E_1}{E_2} = \dfrac{\ell_1-\ell_2}{\ell_1+\ell_2}$

$\ell_1 = 160\,cm,$

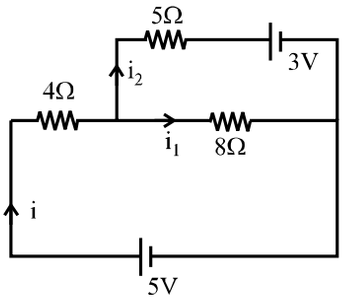
$$\ell_2 = \ell_1 - \ell\times\frac{75}{100} = 160 - 160\times\frac{75}{100} = 40\,cm$$

$E_1 = 1.2V, E_2 = ?$

$$\therefore \frac{E_1}{E_2} = \frac{\ell_1-\ell_2}{\ell_1+\ell_2} \Rightarrow \frac{1.2}{E_2} = \frac{160-40}{160+40}$$

$$\therefore E_2 = \frac{1.2\times200}{120} = 2V$$

25. (d)



By KVL

$4i + 8i_1 - 5 = 0$ [In smaller loop]

$\Rightarrow \quad 4i_1 + 4i_2 + 8i_1 - 5 = 0 \Rightarrow 12i_1 + 4i_2 = 5$ ...(i)

and, $5i_2 + 3 - 8i_1 = 0$ [In bigger loop]

$5i_2 - 8i_1 = -3$

$$5i_2 - 8\left(\frac{5-4i_2}{12}\right) = -3 \qquad [\text{from (i)}]$$

$$5i_2 - \frac{2}{3}(5-4i_2) = -3$$

$$5i_2 - \frac{10}{3} + \frac{8}{3}i_2 = -3 \Rightarrow \frac{23}{3}i_2 = \frac{1}{3}$$

$$i_2 = \frac{1}{23} \Rightarrow \text{Current through } 5\Omega = \frac{1}{23}\text{A}$$

26. (a)

27. (d) We have

$$i = \frac{E}{R + r}$$

So, $1 = \frac{E}{2.5 + r}$ and $0.5 = \frac{E}{10 + r}$

$\Rightarrow \quad 2.5 + r = 0.5(10 + r) \Rightarrow 2.5 + r = 5 + 0.5\,r$

$\Rightarrow \quad 0.5\,r = 2.5 \Rightarrow r = 5\Omega.$

28. (a) In potentiometer, $A = 4\ cm^2 = 4 \times 10^{-4}\ m^2$

$I = 1A, k = 7.5\ Vm^{-1}$

$\therefore$ Potential gradient, $k = \frac{V}{l} = \frac{I_\delta}{A}$

$\therefore$ Resistivity $\delta = \frac{kA}{I} = \frac{7.5 \times 4 \times 10^{-4}}{1}$

$= 3 \times 10^{-3}\ \Omega m.$

29. (d)

30. (c) Given,

Length of potentiometer wire, $\ell = 2.5m$

Emf of cell, $E = 2.5V$

Potential gradient,

$$x = \frac{V}{L} = \frac{IR}{L} = \frac{2.5}{(242 + 8)} \times \frac{8}{2.5}$$

Potential difference between two points

Separated by

$$20cm = x \times \frac{20}{100} = \frac{2.5}{(242 + 8)} \times \frac{8}{2.5} \times 0.20$$

$= 0.0064 = 6.4\,mV$

31. (d)

32. (a) Given,

Drift velocity of charged particle, $V_d = 7.5 \times 10^{-4}$ m/s

Electric field, $E = 3 \times 10^{-10}\ Vm^{-1}$

Mobility, $\mu = \frac{V_d}{E} = \frac{7.5 \times 10^{-4}}{3 \times 10^{-10}} = 2.5 \times 10^6\ m^2V^{-1}s^{-1}$

33. (c) Resistance for ideal voltmeter $= \infty$ Resistance for ideal ammeter $= 0$

For I[st] circuit,

$$V_1 = i_1 \times 10 = \frac{10}{10} \times 10 = 10 \text{ volt}$$

For IInd circuit,

$$V_2 = i_2 \times 10 = \frac{10}{10} \times 10 = 10 \text{ volt}$$

$$V_1 = V_2 \text{ and, } i_1 = i_2 = \frac{10V}{10\Omega} = 1A$$

34. (d)

35. (b) This is a balanced wheatstone bridge condition,

$$\frac{5}{R} = \frac{\ell_1}{100 - \ell_1} \text{ and } \frac{5}{R/2} = \frac{1.6\ell_1}{100 - 1.6\ell_1} \Rightarrow R = 15\,\Omega$$

36. (b) Total resistance $R = (0.5\ \Omega/km) \times (150\ km) = 75\ \Omega$

Total voltage drop $= (8\ V/km) \times (150\ km) = 1200\ V$

$$\text{Power loss} = \frac{(\Delta V)^2}{R} = \frac{(1200)^2}{75}\text{W} = 19200\text{ W} = 19.2\text{ kW}$$

37. (d) Net Power, $P = 15 \times 45 + 15 \times 100 + 15 \times 10 + 2 \times 1000$

$= 15 \times 155 + 2000$ W

Power, $P = VI \Rightarrow I = \frac{P}{V}$

$$\therefore \quad I_{main} = \frac{15 \times 155 + 2000}{220} = 19.66\ A \approx 20A$$

38. (b) As $R \propto V^2/P$ or $R \propto 1/P$, so resistance of heater is less than that of fan.

39. (d) Given,

Power rating of resistor, $P = 320$ watts

Voltage, $V = 220$ volts

We know that power, $P = \frac{V^2}{R}$

$\therefore$ Resistance of resistor, $R = \frac{V^2}{P} = \frac{220 \times 220}{320}\Omega$

When the resistors are connected in series, then voltage across each resistor reduced to half.

Power in each resistor connected in series,

$$P_S = \frac{(V')^2}{R} = \frac{\left(\frac{110}{2}\right)^2}{R} = \frac{110 \times 110}{2 \times 2} \times \frac{P}{V^2}$$

$$= \frac{110 \times 110}{2 \times 2} \times \frac{320}{220 \times 220} = \frac{1}{4} \times \frac{1}{4} \times 320 = 20 \text{ watts}$$

10 Magnetic Field Due to Electric Current

Exercise 1 : WARM-UP
Topic-wise MCQs

1. **(b)** **2.** **(c)**

3. **(a)** We have,

$$r = \frac{mv}{qB} = \frac{\sqrt{2m(K.E)}}{qB}$$

$$r \propto \frac{\sqrt{m}}{q} \Rightarrow \frac{r_d}{r_p} = \sqrt{\frac{m_d}{m_p}} \times \frac{q_p}{q_d} = \sqrt{\frac{2}{1}} \times \frac{1}{1} = \frac{\sqrt{2}}{1}$$

4. **(c)** As Lorentz force is given by

$$\vec{F} = q\left(\vec{E} + \vec{V} \times \vec{B}\right) = q\vec{E} + q\left(\vec{V} \times \vec{B}\right)$$

$$\vec{F} = \vec{F}_E + \vec{F}_B$$

5. **(a)** We know, $\frac{mv^2}{R} = qvB$, For proton.

$$R_p = \frac{mv}{qB} = \frac{\sqrt{2m_pK}}{qB}$$

and for deuteron $R_d = \frac{\sqrt{2m_dK}}{qB}$

$$\Rightarrow \quad \frac{R_d}{R_p} = \sqrt{\frac{m_d}{m_p}} = \sqrt{2} \Rightarrow R_d = \sqrt{2}R_p$$

6. **(b)** $r = \frac{p}{qB} \Rightarrow p \propto q$ ($\because$ r and B are constantly)

$$\frac{p_p}{p_\alpha} = \frac{q_p}{q_\alpha} = \frac{q_p}{(2q_p)} = \frac{1}{2}$$

7. **(c)** $p = \frac{2\pi m}{Bq}(v\cos 45°) = \frac{2\pi m}{Bq}(v\sin 45°)$

$$\therefore \quad \frac{mv\sin 45°}{Bq} = \frac{p}{2\pi} = \text{radius of helix}$$

8. **(c)** By using $r = \frac{mv}{qB} = \frac{v}{\left(\frac{q}{m}\right)B} \Rightarrow r \propto \frac{1}{(q/m)}$

$$\because \quad \left(\frac{q}{m}\right)_{e^-} > \left(\frac{q}{m}\right)_{p^+} > \left\{\left(\frac{q}{m}\right)_d = \left(\frac{q}{m}\right)_\alpha\right\} \quad \therefore \quad R_d = R_\alpha$$

9. **(b)** Magnetic force on the charged particle q is

$\vec{F}_m = q\left(\vec{v} \times \vec{B}\right)$ or $F_m = qvB\sin\theta$

Where θ is the angle between $\vec{v}$ and $\vec{B}$.

The particle is moving and magnetic field is perpendicular to the velocity and in this case it will experience force.

10. **(c)** Due to perpendicular component the charged particle will describe a circular path and due to parallel component it will move forward direction along the magnetic field. Hence, it will follow a helical path.

11. **(d)** Circular path of radius r given by

$$r = \frac{mv}{eB} = \frac{v}{\frac{e}{m}B}$$

Where $\frac{e}{m}$ is the specific charge of the proton and v is its velocity.

$$\therefore \quad r = \frac{10^9\,\text{m s}^{-1}}{\left(10^{11}\,\text{C kg}^{-1}\right)\left(10^{-4}\,\text{Wb m}^{-2}\right)} = 100\,\text{m}$$

12. **(b)** Centripetal force = Lorentz force

$F_c = F_e$

$$\frac{mv^2}{r} = evB \Rightarrow r = \frac{mv}{eB}$$

If the magnetic field reduces to $\frac{B}{2}$ than the radius of circular path is given by :

$$r' = \frac{2mv}{eB} = 2r$$

13. **(a)** If the velocity component v_y is perpendicular to the magnetic field B, the magnetic force acts like a centripetal force qv_yB.

$$q\,v_y\,B = \frac{mv_y^2}{r} \quad \text{and} \quad v_y = \frac{qBr}{m}$$

$v_y = r\omega$

$$\omega = \frac{qB}{m}$$

Time taken for one revolution

$$T = \frac{2\pi}{\omega} = \frac{2\pi m}{qB}$$

The distance moved by a charged particle along the magnetic field.

$$x = vt = \frac{2\pi mv}{qB}$$

14. **(c)** In the uniform magnetic field, radius of the circular path is given by;

$$R = \frac{mv}{qB} = \frac{\sqrt{2m(K.E)}}{qB} \Rightarrow R \propto \frac{\sqrt{m}}{q};\ (\because \text{KE in same})$$

$$\therefore \frac{R_{\text{deutron}}}{R_{\text{proton}}} = \sqrt{\frac{m_d}{m_p}} \times \frac{q_p}{q_d} \qquad \because\ m_d = 2m_p \text{ and } q_d = q_p$$

$$\therefore \frac{R_d}{R_p} = \sqrt{\frac{2m_p}{m_p}} \times \frac{q_p}{q_p} = \sqrt{2} \qquad \therefore R_d : R_p = \sqrt{2} : 1$$

15. **(b)** Magnetic force acts perpendicular to the velocity. Hence speed remains constant.

16. **(c)** As $R = \frac{mv}{qB}$

$$\Rightarrow R \propto \frac{m}{q} \Rightarrow \frac{R_\alpha}{R_P} = \left(\frac{m_\alpha}{m_P}\right) \times \frac{q_P}{q_\alpha} \Rightarrow \frac{R_\alpha}{R_P} = \left(\frac{4}{1}\right) \times \frac{1}{2} = 2$$

17. **(b)**

18. **(a)** r = mv/Bq is same for both.

19. **(a)** Since magnetic force is always perpendicular to the velocity of electron, so it can only change the direction of velocity of electron, but it (the magnetic force) cannot accelerate or deaccelerate the electron.

20. **(c)**

21. **(c)** $Bqv = \frac{mv^2}{r}$ $or\, B = \frac{mv}{rq} = \frac{(9\times10^{-31})\times10^6}{0.1\times(1.6\times10^{-19})}$

$= 5.5 \times 10^{-5}$ T

22. **(b)** Due to perpendicular component both will execute circular motion for which $T = \frac{2\pi m}{qB}$. Since q is same, therefore $T \propto m$. Hence deuterium nucleus will travel more distance.

23. **(a)** Given, $\vec{E} = E\hat{k}$

$\vec{B} = B\hat{j}$, B = 12 mT = 12 × 10^{-3} T. Energy = 728 eV

$\text{Energy} = \frac{1}{2}mv^2$

$728\text{ eV} = \frac{1}{2}\times9.1\times10^{-31}\times v^2$

$728\times1.6\times10^{-19} = \frac{1}{2}\times9.1\times10^{-31}\times v^2$

$= v = \sqrt{\frac{2\times728\times1.6\times10^{-9}}{9.1\times10^{-31}}}$

we have, v = 16 × 10^6 m/s

E = vB ⇒ E = 16 × 10^6 × 12 × 10^{-3}

⇒ E = 192 × 10^3 V/m = 192 k Vm^{-1}

24. **(c)** E = vB = 2 × 10^3 × 1.5 = 3 × 10^3 V/m.

25. **(a)** Radius of path, $r = \frac{mv}{qB}$

Given, $r_a > r_b \Rightarrow \frac{m_a v_a}{qB} > \frac{m_b v_b}{qB}$ [$\because$ $q_a = q_b$ (given)]

$\Rightarrow m_a v_a > m_b v_b$

26. **(a)** Lorentz force, $\vec{F} = q\{\vec{E} + (\vec{v}\times\vec{B})\}$

$$\vec{v}\times\vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & 2 & 0 \\ 5 & 3 & 4 \end{vmatrix} = 8\hat{i} - 4\hat{j} - 7\hat{k}$$

$\vec{F} = 1(2\hat{i} - 3\hat{j} + 8\hat{i} - 4\hat{j} - 7\hat{k}) = (10\hat{i} - 7\hat{j} - 7\hat{k})$

27. **(b)** Given that uniform magnetic field, $\vec{B} = (2\hat{i} + 3\hat{j})$ T

Acceleration $\vec{a} = (\alpha\hat{i} - 4\hat{j})$ m/s^2

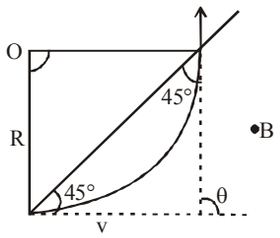
We know that

$F = q(\vec{v}\times\vec{B}) \Rightarrow m\vec{a} = q(\vec{v}\times\vec{B})$

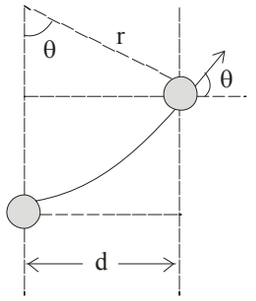
Here, $\vec{a} \perp \vec{B}$, so, $\vec{a}.\vec{B} = 0$

$(\alpha\hat{i} - 4\hat{j})(2\hat{i} + 3\hat{j}) = 0 \Rightarrow 2\alpha - 12 = 0 \Rightarrow \alpha = 6$

28. **(b)** Path of electron is shown. Deviation of electron will be θ = 90°.



29. **(b)** According to following figure, $\sin\theta = \frac{d}{r}$



Also, $r = \frac{\sqrt{2mK}}{qB} = \frac{1}{B}\sqrt{\frac{2mV}{q}}$ $\therefore$ $\sin\theta = Bd\sqrt{\frac{q}{2mV}}$

$= 0.51\times0.1\sqrt{\frac{1.6\times10^{-19}}{2\times1.67\times10^{-27}\times500\times10^3}} = \frac{1}{2} \Rightarrow \theta = 30°$

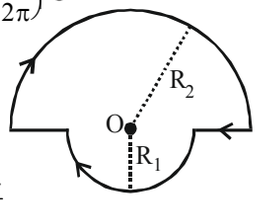
30. **(b)** $d\vec{B} = \frac{\mu_0}{4\pi}\frac{q(\vec{v}\times\vec{r})}{r^3}$ i.e. $\vec{B} \perp r\,\vec{v}$ & $\vec{r}$ both

31. **(d)** Ampere's circuital law holds for steady currents which are not accelerated with time.

32. **(a)** Here magnetic field at the centre (O) of a wire loop formed by two semicircular wires of radii R_1 and R_2

$\vec{B}_{centre} = \frac{\mu_0 i}{2R_2}\left(\frac{\pi}{2\pi}\right)\otimes + \frac{\mu_0 i}{2R_1}\left(\frac{\pi}{2\pi}\right)\otimes$

$= \left(\frac{\mu_0 i}{4R_2} + \frac{\mu_0 i}{4R_1}\right)\otimes$



$= \frac{4\pi\times10^{-7}\times4}{4\times4\pi} + \frac{4\pi\times10^{-7}\times4}{4\times2\pi}$

$= 3 \times 10^{-7}\,T = \alpha \times 10^{-7}\,T$ (given) $\therefore$ $\alpha = 3$

33. **(a)** Magnetic field at point A

$B_A = \frac{\mu_0 i}{2\pi r} + \frac{\mu_0(2i)}{2\pi(3r)} = \frac{5\mu_0 i}{6\pi r}$

Magnetic field at point C

$B_C = \frac{\mu_0(2i)}{2\pi r} + \frac{\mu_0 i}{2\pi(3r)} = \frac{7\mu_0 i}{6\pi r}$

$\therefore \frac{B_A}{B_C} = \frac{5}{7} = \frac{x}{7} \ \therefore x = 5$

34. **(b)** Magnetic field is given by $B = \frac{\mu_0 i}{2\pi r}$ *i.e.*, $B \propto \frac{1}{r}$ which implies that field has cylindrical symmetry.

35. **(a)** $B = \frac{\mu_0 I}{2\pi r} \Rightarrow B \propto \frac{1}{r}$

As the distance is increased to three times, the magnetic induction reduces to one third. Hence, $B = \frac{1}{3} \times 10^{-3}$ tesla $= 3.33 \times 10^{-4}$ tesla

36. **(d)** $l = 20$ cm, $I = \frac{3}{\pi^2}$ A

For circle, $l = 2\pi R \Rightarrow 20 \times 10^{-2} = 2\pi R$

$\therefore \ R = \frac{10^{-1}}{\pi}$ m

$\therefore$ Magnetic field at the centre of circle,

$$B = \frac{\mu_0 I}{2R} = \frac{4\pi \times 10^{-7} \times \frac{3}{\pi^2}}{2 \times \frac{10^{-1}}{\pi}} = 6 \times 10^{-6} \text{ T}$$

37. **(b)** Ampere's circuital law defined by $\oint B.dl = \mu_0 I$

38. **(a)** $B = \frac{\mu_0 I}{2r} \times \frac{\theta}{2\pi} = \frac{\mu_0 I \theta}{4\pi r}$

39. **(d)**

40. **(d)** According to Ampere's circuital law $\int \vec{B}.\vec{dl} = \mu_o I$

41. **(c)** $dB = \frac{\mu_0}{4\pi} \frac{IdI \sin\theta}{r^2}$

Here, $dI = \Delta x = 0.05$ *m*, $I = 10$ *A*, $r = 1$ *m*

$\sin\theta = \sin 90° = 1$,

$\therefore \ dB = 10^{-7} \times \frac{10 \times 0.05 \times 1}{(1)^2} = 0.50 \times 10^{-7} = 5.0 \times 10^{-8}$ T

42. **(a)**

43. **(b)**

44. **(a)** At equilibrium, $F_{magnetic} = mg$

$\Rightarrow$ $iLB = mg$ and $L = \frac{AR}{\rho}$

$\therefore B = \frac{mg\rho}{iAR} = \frac{0.5 \times 10 \times 2 \times 10^{-6}}{2 \times 10 \times 10^{-6} \times 1} = 0.5$T

45. **(a)** Magnetic field, $B_H = 3.5 \times 10^{-5}$ T, Current, $i = \sqrt{2}$ A

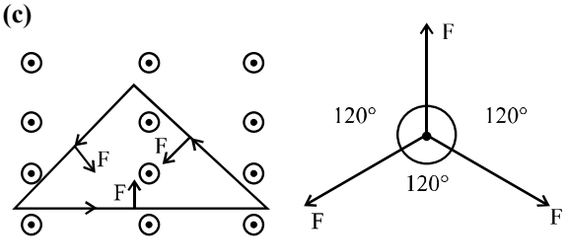
Force on the conductor, $F = i\ell B \sin\theta$

$$\frac{F}{\ell} = iB \sin 45° = \sqrt{2} \times 3.5 \times 10^{-5} \times \frac{1}{\sqrt{2}} = 35 \times 10^{-6} \text{ N/m}$$

46. **(c)** Magnetic field midway between the wires,

$$B_p = \left(\frac{\mu_0 i}{2\pi a}\right) \times 2 = \frac{4\pi \times 10^{-7} \times 10}{\pi \times \left(\frac{5}{2} \times 10^{-2}\right)} = 16 \times 10^{-5} = 160\mu\text{T}$$

47. **(c)**



As the three forces are at 120° w.r.t. each other as shown above, so $\vec{F}_{net} = 0$.

48. **(a)** Let current in second conductor be 'i', then current in first is '2i'.

$\frac{F}{1} = \frac{\mu_0}{2\pi} \frac{i_1 i_2}{d}$ or, $\frac{1}{50} = 2 \times 10^{-7} \times \frac{(2i)i}{0.2}$

$\Rightarrow \ 0.2 = 100 \times 10^{-7} \times 2 \times i^2$

$\Rightarrow \ i^2 = \frac{0.1}{10^{-5}} \Rightarrow \ i^2 = 10^4 \Rightarrow i = 100$A

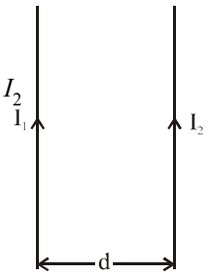
49. **(d)**

50. **(d)** Given, Force per unit length

$\frac{F}{\ell} = 4 \times 10^{-5}$ N/m

$I_1 = 0.5$A and the need to determine I_2

As we know that,



$f = \frac{\mu_0}{2\pi} \frac{I_1 I_2}{d}$, where $f = \frac{F}{L}$

$\therefore I_2 = (f) \times \frac{d \times 2\pi}{\mu_0 I_1}$

$= 4 \times 10^{-5} \times \frac{2.5 \times 10^{-2} \times 2\pi}{4\pi \times 10^{-7} \times 0.5}$

$= 2 \times 5 \times 10^{-7+7} = 10A$

51. **(c)**

52. **(c)**

53. **(b)** $F = iB\,l \sin\theta$. This is maximum when $\sin\theta = 1$ or $\theta = \pi/2$.

54. **(b)** $F = I\ell B \sin\theta = 3 \times 0.40 \times (500 \times 10^{-4}) \times \sin 30° = 3 \times 10^{-2}$ N.

55. **(a)** $F = IlB \sin\theta$ or $\sin\theta = \frac{F}{IlB}$

$\sin\theta = \frac{15}{10 \times 1.5 \times 2} = \frac{1}{2}$ or $\theta = 30°$

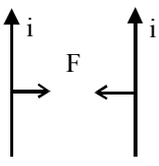
56. **(b)** $F = IlB \sin\theta$

Here, $\theta = 90°$, $I = 10$ *A*

$l = 8$ cm $= 8 \times 10^{-2}$ *m*, $B = 0.3$ *T*

$\therefore \ F = 10 \times 8 \times 10^{-2} \times 0.3 \times \sin 90° = 0.24$ *N*

57. **(b)** $\frac{F}{\ell} = \frac{\mu_0 i_1 i_2}{2\pi d} = \frac{\mu_0 i^2}{2\pi d}$



(attractive as current is in the same direction)

58. **(a)** **59.** **(c)** **60.** **(c)**

61. **(b)** $F = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r}\times \ell$

$= \frac{10^{-7}\times 2\times 10\times 2}{0.1}\times 2 = 8\times 10^{-5}$ N

62. **(a)** Given, length of wire X, ℓ_1 = 50 cm = 0.5 m
Length of wire Y, ℓ_2 = 5m
Distance between two wire, r = 5 cm = 5×10^{-2} m
Force of interaction = $I_1\, \ell_1\, B_{12}$

$= \frac{\mu_0 I_1 I_2}{2\pi r}.\ell_1 \quad \left(\therefore B_{12} = \frac{\mu_0 I_2}{2\pi r}\right)$

$= \frac{4\pi\times 10^{-7}\times 6\times 0.5}{2\pi\times 5\times 10^{-2}} = 1.2 \times 10^{-5}$ towards X

63. **(b)** $\theta = \frac{NiAB}{C} \Rightarrow \theta \propto N$ [Number of turns]

64. **(b)** $i = \frac{C\theta}{NAB} \Rightarrow i \propto \theta$

65. **(d)** The coil of a moving coil galvanometer is wound over metallic frame to provide electromagnetic damping so it becomes dead beat galvanometer.

66. **(d)** Current senstivity is given by :

$\frac{\phi}{1} = \frac{NBA}{k}$

Since $\frac{\phi}{I} \propto N$ so current sensitivity is increased.

Voltage senstivity is given by :

$\frac{\phi}{V} = \frac{NBA}{k}\times\frac{1}{R}$

Since $R \propto N$. $\therefore$ ϕ/V is not depend on N.

67. **(c)** Electric current,
$i \propto \theta$ (angle of deflection)

$\therefore \frac{i_2}{i_1} = \frac{\theta_2}{\theta_1} \Rightarrow \frac{i_2}{200\,\mu A} = \frac{\pi/10}{\pi/3} = \frac{3}{10} \quad \left[\because 60° = \frac{\pi}{3}\right]$

$\therefore i_2 = 60\ \mu A$

68. **(b)** In moving coil galvanometer
$BINA = K\theta$

$A = \frac{K\theta}{NIB} = \frac{4\times 10^{-5}\times 0.05}{200\times 10\times 10^{-3}\times 10^{-2}} = \frac{20\times 10^{-7}}{2\times 10^{-2}}$

$= \frac{10\times 10^{-7}}{10^{-2}} = 10^{-4}\,m^2 = 1\,cm^2$

Exercise 2 : ACCELERATOR
Topic-wise MCQs

1. **(d)** When a charged particle is kept stationary ($v = 0$) in the strong magnetic field, then no force acts on the charged particle.
i.e., $F = Bqv = Bq \times 0$
$F = 0$
Hence, when an electron is kept in a strong magnetic field, then electron remains stationary at same position.

2. **(c)** The magnetic field must be vertically upward to prevent the wire from falling under gravity. As the current in the horizontal wire is from north to south, so according to right hand screw rule the magnetic field should be from west to east, i.e., towards east.

3. **(b)** For circular path in magnetic field,

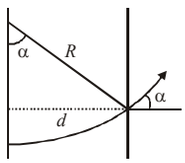
$mr\omega^2 = qvB \Rightarrow \omega^2 = \frac{qvB}{mr}$

As $v = r\omega \ \therefore \ \omega^2 = \frac{q(r\omega)B}{mr} \Rightarrow \omega = \frac{qB}{m}$
$\therefore$ If ν is frequency of roatation, then

$\nu = \frac{\omega}{2\pi} \Rightarrow \nu = \frac{qB}{2\pi m}$

4. **(c)** $r = \frac{1}{B}\sqrt{\frac{2mV}{q}}$ so, $\frac{R_1}{R_2} = \sqrt{\frac{m_x}{m_y}} \Rightarrow \frac{m_x}{m_y} = \left(\frac{R_1}{R_2}\right)^2$

5. **(d)** From figure, $\sin\alpha = d/R$



we know, $\frac{mv^2}{R} = qvB$

$\Rightarrow R = \frac{mv}{qB} \quad \therefore \quad \sin\alpha = \frac{dqB}{mv}$

$\sin\alpha = Bd\sqrt{\frac{q}{2mV}} \left[\because qV = \frac{1}{2}mv^2\right]$

6. **(c)** Time period of one revolution of proton, $T = \frac{2\pi m}{qB}$

Here, m = mass of proton
q = charge of proton
B = magnetic field.
Linear distance travelled in one revolution,
$p = T(v\cos\theta)$ (Here, v = velocity of proton)
$\therefore$ Length of region, $l = 10\times(v\cos\theta)T$

$\Rightarrow l = 10\times v\cos 60°\times\frac{2\pi m}{qB}$

$\Rightarrow l = \frac{10\pi mv}{qB} = \frac{10\times 3.14\times 1.67\times 10^{-27}\times 4\times 10^5}{1.6\times 10^{-19}\times 0.3}$

$\Rightarrow l = 0.44$ m

7. **(d)** As particle is moving along a circular path

$\therefore R = \frac{mv}{qB}$ ...(i)

Path is straight line, then
$qE = qvB$

$E = vB \Rightarrow v = \frac{E}{B}$ ....(ii)

From equation (i) and (ii)

$m = \frac{qB^2R}{E} = \frac{1.6\times 10^{-19}\times(0.5)^2\times 0.5\times 10^{-2}}{100}$

$\therefore m = 2.0 \times 10^{-24}$ kg

8. **(b)** According to the principal of circular motion in a magnetic field,

$F_c = F_m \Rightarrow \frac{mv^2}{R} = qVB \Rightarrow R = \frac{mv}{qB} = \frac{P}{qB} = \frac{\sqrt{2m \cdot K}}{qB}$

$R_\alpha = \frac{\sqrt{2(4m)K'}}{2qB}$; $\frac{R}{R_\alpha} = \sqrt{\frac{K}{K'}}$

but $R = R_\alpha$ (given)

Thus $K = K' = 1$ MeV

9. **(a)** Given, velocity of proton, $\boldsymbol{v} = 2\hat{i}$ m/s

Magnetic field, $B = (\hat{i} + 3\hat{j} + 4\hat{k})\mu$T

Electric field, $\boldsymbol{E} = 10\hat{i}\,\mu$ V/m

Charge on proton, $q = 1.6 \times 10^{-19}$ C

Lorentz force,

$\boldsymbol{F} = q\boldsymbol{E} + q(\boldsymbol{v} \times \boldsymbol{B}) = q\,[\boldsymbol{E} + (\boldsymbol{v} \times \boldsymbol{B})]$

$= 16 \times 10^{-19}\,[10 \times 10^{-6}\hat{i} + 2\hat{i} \times (\hat{i} + 3\hat{j} + 4\hat{k}) \times 10^{-6}]$

F = $1.6 \times 10^{-25} \times [10\hat{i} - 8\hat{j} + 6\hat{k}\,]$N

$|F| = 1.6 \times 10^{-25} \times \sqrt{(10)^2 + (-8)^2 + (6)^2} = 22.6 \times 10^{-25}$ N

10. **(a)** $F = qvB$, $E = \frac{1}{2}mv^2$

$F = qB\sqrt{\frac{2E}{m}} = 1.6 \times 10^{-19} \times 2.5$

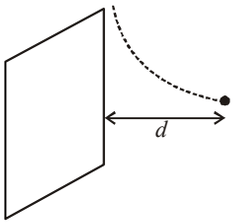
$\times\sqrt{\frac{2\times2\times10^6\times1.6\times10^{-19}}{1.67\times10^{-27}}}$

$F = 8 \times 10^{-12}$ N

11. **(c)** If $r \le d$, particle will not hit screen

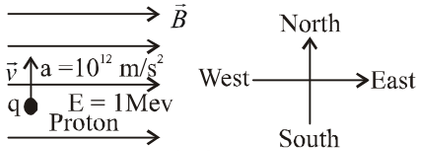
$r = \frac{mv}{qB_0}$ $\left[\because \frac{mv^2}{r} = qvB_0\right]$

Hence, minimum value of v for which the particle will not hit the screen.



$v = \frac{qB_0 d}{m}$

12. **(a)**



As we know, magnetic force $F = qvB = ma$

$\therefore\ \vec{a} = \left(\frac{qvB}{m}\right)$ perpendicular to velocity.

$\therefore$ Also $v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2\times e\times10^6}{m}}$

$\therefore\ a = \frac{qvB}{m} = \frac{eB}{m}\sqrt{\frac{2\times e\times10^6}{m}}$

$\therefore\ 10^{12} = \left(\frac{1.6\times10^{-19}}{1.67\times10^{-27}}\right)^{\frac{3}{2}} \cdot\sqrt{2}\times10^3 B$

$\therefore\ B \simeq \frac{1}{\sqrt{2}}\times10^{-3}T = 0.71$ mT (approx)

13. **(c)** $\mathrm{f} = \frac{1}{\mathrm{T}} = \frac{\mathrm{eB}}{2\pi\mathrm{m}}$ $\left[\because\ \mathrm{T} = \frac{2\pi\mathrm{m}}{\mathrm{qB}}\right]$

$= \frac{1.6\times10^{-19}\times10^{-4}}{2\pi\times9\times10^{-31}} = 2.8\times10^6$ Hz

14. **(c)** Electrostatic force, $\vec{\mathrm{F}}_1 = \mathrm{q}\vec{\mathrm{E}}$

Magnetic force, $\vec{\mathrm{F}}_2 = \mathrm{q}\left(\vec{\mathrm{V}}\times\vec{\mathrm{B}}\right)$

15. **(c)** Equating magnetic force to centripetal force,

$\frac{\mathrm{mv}^2}{\mathrm{r}} = \mathrm{qvB}\ \sin 90^\circ$

Time to complete one revolution,

$\mathrm{T} = \frac{2\pi\mathrm{r}}{\mathrm{v}} = \frac{2\pi\mathrm{m}}{\mathrm{qB}}$

16. **(c)**

17. **(b)** As, component of velocity v is along magnetic field $\boldsymbol{B}$. So, path is helical.

Radius of a helix

$r = \frac{mv_\perp}{Bq} = \frac{1.67\times10^{-27}\times2\times10^6\sin30^\circ}{0.104\times1.6\times10^{-19}}$

$\Rightarrow r = \frac{0.2}{2}\,\mathrm{m} = 0.1$ m

Time period,

$T = \frac{2\pi m}{Bq} = \frac{2\pi\times1.67\times10^{-27}}{0.104\times1.6\times10^{-19}} = 2\pi\times10^{-7}$ s

18. **(c)** For undeviated motion, $|\vec{\mathrm{F}}_\mathrm{e}| = |\vec{\mathrm{F}}_\mathrm{m}|$, which happened when $\vec{\mathrm{v}}, \vec{\mathrm{E}}$ and $\vec{\mathrm{B}}$ are mutually perpendicular to each other.

19. **(b)** Here, current cannot be in same direction in both wire because then, $B_p = 0$. So current should be in opposite direction.

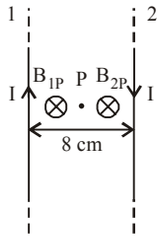
$B_p = B_{1p} + B_{2p}$

$B_p = 2\frac{\mu_0 I}{2\pi r}$

$300\times10^{-6} = 2\times2\times10^{-7}\times\frac{I}{4\times10^{-2}}$

$3\times10^{-4} = 10^{-5}\times I$

$I = 30\ A$



20. **(a)**

21. **(d)** $B_1 = -\frac{\mu_0 i_1}{2\pi r/2} + \frac{\mu_0 i_2}{2\pi r/2} = \frac{\mu_0}{\pi r}(i_2 - i_1)$

$= 6\times10^{-6}$T ...(i)

When the current is reversed in I_2,

$$B_2 = -\frac{\mu_0(i_1+i_2)}{2\pi r/2} = -\frac{\mu_0(i_1+i_2)}{\pi r} = 3\times10^{-5}\text{T} \quad ...(ii)$$

Dividing (ii) by (i) we get

$$\frac{-(i_1+i_2)}{i_2-i_1} = \frac{30}{6} = 5$$

$$-(i_1+i_2) = 5i_2 - 5i_1 \Rightarrow 6i_2 = 4i_1;\ \frac{i_1}{i_2} = \frac{3}{2}$$

22. **(a)** Magnetic field at P,

B_P = 2 (Magnetic field due to straight wire) + (Magnetic field due to semicircle)

$$B_P = 2\left(\frac{\mu_0 I}{4\pi r}\right) + \frac{\mu_0 I}{4r} \quad \therefore B_P = \frac{\mu_0 I}{2\pi r} + \frac{\mu_0 I}{4r} = \frac{\mu_0 I}{4\pi r}(2+\pi)$$

23. **(d)**

24. (c) $F = \frac{\mu_0}{2\pi}\left(\frac{i_1 i_2}{a} - \frac{i_1 i_2}{2a}\right)\times a = \frac{\mu_0 i_1 i_2}{4\pi}$

25. **(a)** Given, Current, I = 14A

Radius of semicircular arc, R = 2.2 cm = 2.2×10^{-2}m

Magnetic field at the centre of semicircular arc

$$B = \frac{\mu_0 I}{4R} = \frac{4\pi\times10^{-7}\times14}{4\times2.2\times10^{-2}} = \frac{4\times22\times10^{-7}\times14}{4\times7\times2.2\times10^{-2}} = 2\times10^{-4}\text{T}$$

26. **(c)** Using Ampere's circuital law, magnetic field for long straight wire of circular cross-section is given by

$$B = \frac{\mu_0 Ir}{2\pi a^2} \text{ (For } r < a) \ \therefore B \propto r$$

For r > a

$$B = \frac{\mu_0 I}{2\pi r} \ \therefore B \propto \frac{1}{r}$$

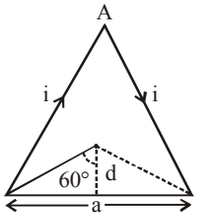
27. **(d)** $B = 3\left[\frac{\mu_0 i}{4\pi d}(\sin 60° + \sin 60°)\right]$

$$\tan 60° = \frac{a/2}{d}$$

put $a = 9\times10^{-2}\ m \Rightarrow d = \frac{9\times10^{-2}}{2\sqrt{3}}\ m$

$B = 3\times10^{-5}\ T$.

$\vec{B}$ is into the plane of triangle.



28. **(d)** Given : $I_A = 2$ A, $R_A = 2$ cm, $\theta_A = 2\pi - \frac{\pi}{2} = \frac{3\pi}{2}$

$I_B = 3$ A, $R_B = 4$ cm, $\theta_B = 2\pi - \frac{\pi}{3} = \frac{5\pi}{3}$

Using, magnetic field, $B = \frac{\mu_0 I\theta}{4\pi R}$

$$\frac{B_A}{B_B} = \frac{I_A}{I_B}\times\frac{\theta_A R_B}{\theta_B R_A} = \frac{2\times\frac{3\pi}{2}\times4}{3\times\frac{5\pi}{3}\times2} = \frac{6}{5}$$

29. **(c)** Magnetic field due to straight wire, $B = \frac{\mu_0 I}{2\pi r}$

Magnetic field at $\frac{a}{2}$ is,

$$B_{a/2} = \frac{\mu_0 I}{2\pi(a/2)} \ \therefore \ \frac{B_{a/2}}{B_{2a}} = \frac{1}{1} = 1:1$$

30. **(c)** From Ampere circuital law

$\oint \vec{B}.\vec{dl} = \mu_0 I_{enc}$

$B \times 2\pi R = \mu_0 I_{enc}$

$$B = \frac{\mu_0 I_{enc}}{2\pi R} = 2\times10^{-7}\times\frac{75}{3} = 5\times10^{-6}\text{ T}$$

The direction of field at the given point will be vertical up determined by the screw rule or right hand rule.

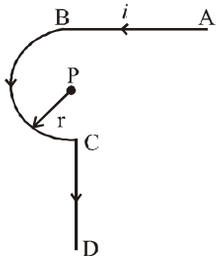
31. **(a)** The magnetic field at the point P is $B_P = B_{AB} + B_{BC} + B_{CD}$

$$B_{AB} = \frac{\mu_0 i}{4r}$$

$$B_{BC} = \frac{\mu_0 i}{4\pi r}\times\pi = \frac{\mu_0 i}{4r}$$

$$B_{CD} = 0$$

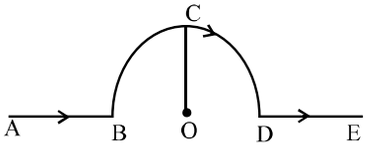
$$B_P = \left(\frac{\mu_0 i}{4r} + \frac{\mu_0 i}{4\pi r}\right) = \frac{\mu_0 i}{2r}\left(\frac{1}{2} + \frac{1}{2\pi}\right)$$



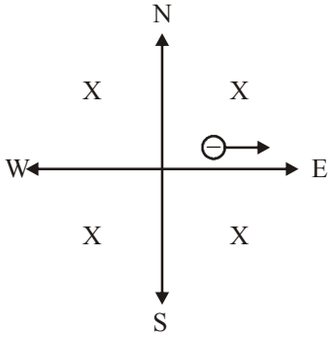
32. **(d)** For a point O $\vec{dl}$ and $\vec{r}$ for each element of the straigh segment AB and DE are parallel. Therefore, $\vec{dl}\times\vec{r} = 0$

Hence, magnetic field at O due to current through straight segments AB and DE is

$$\vec{B} = \int\frac{\mu_0}{4\pi}\frac{i\,\vec{dl}\times\vec{r}}{r^3} = 0$$



33. **(d)** Using the Fleming's left hand rule, the direction of force can be determined. According to it, the force experienced will be in south direction.



34. **(a)** **35.** **(d)**

36. **(a)** We have

$$\frac{F}{\ell} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{d} \Rightarrow F = \frac{\mu_0}{2\pi}\frac{I_1 I_2 \ell}{d}$$

So, $F \propto \frac{I_1 I_2}{d}$

$$\frac{F_2}{F_1} = \frac{\left(\frac{2I_1.2I_2}{d/2}\right)}{\left(\frac{I_1 I_2}{d}\right)} = 8 \Rightarrow F_2 = 8F_1$$

37. **(a)** We have

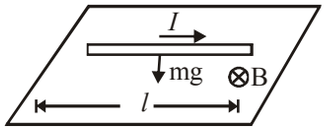
$$\frac{F}{l}=\frac{\mu_0}{2\pi}\frac{i_1 i_2}{r} \quad \Rightarrow \quad r=\frac{\mu_0}{2\pi}i_1 i_2\times\frac{l}{F}$$

$$\Rightarrow r=2\times10^{-7}\times25\times\frac{0.1}{10^{-5}}$$

$$=50\times10^{-7}\times10^{4}=50\times10^{-3}\,\text{m}=5\text{ cm}$$

38. **(a)** $I_1 I_2$ = Positive
(attract) F = Negative
$I_1 I_2$ = Negative
(repell) F = Positive
Hence, option (a) is the correct answer.

39. **(b)** A straight wire of mass 200 g and length 1.5 m carries a current of 2A. It is held in a mid-air by a uniform horizontal magnetic field. There is an upward force **F** of magnitude *IlB*. For mid-air suspension, this must be balanced by the force due to gravity as shown in figure.



$mg = Ilg$ [$\because$ m = 200 g = 0.2 kg]

$$\Rightarrow B=\frac{mg}{Il}=\frac{0.2\times9.8}{2\times1.5}=0.65\text{ T}$$

40. **(b)** Torque due to rectangular coil is given by
$\tau = BAIN\cos\theta$
$\theta = 30°$, $\tau_1 = BAIN\cos 30°$
Similarly, torque. when coil is making an angle of 60° is
$\tau_2 = BAIN\cos 60°$

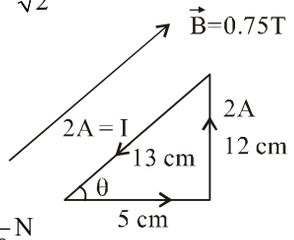
$$\text{So, } \frac{\tau_1}{\tau_2}=\frac{\cos30°}{\cos60°}\frac{\frac{\sqrt{3}}{2}}{\frac{1}{2}}$$

$$\frac{\tau_1}{\tau_2}=\frac{\sqrt{3}}{1};\ \tau_1:\tau_2=\sqrt{3}:1$$

41. **(d)** $\tau = MB\sin45° = N(iA)B\sin45°$

$$=100\times3(5\times2.5)\times10^{-4}\times1\times\frac{1}{\sqrt{2}}=0.27\text{ N-m}$$

42. **(c)** $\vec{F}=I(\vec{L}\times\vec{B})$
So, $|F| = ILB\sin\theta$
Force on 5 cm side is



$$|\vec{F}| = ILB\sin\theta$$

$$=(2)(5\times10^{-2})\times\frac{3}{4}\times\frac{12}{13}=\frac{9}{130}\text{N}$$

So, x = 9

43. **(a)** $\left(\frac{F}{\ell}\right)_a=\frac{\mu_0}{2\pi}\frac{i_a i_b}{d_1}-\frac{\mu_0}{2\pi}\frac{i_a i_c}{(d_2+d_1)}$

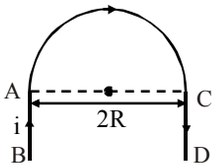
$$=\frac{\mu_0}{2\pi}\frac{i_a^2}{d_1}-\frac{\mu_0}{2\pi}\frac{4i_a^2}{3d_1}=\frac{\mu_0}{2\pi}\frac{i_a^2}{d_1}\left[1-\frac{4}{3}\right]$$

$$=\frac{\mu_0}{2\pi}\frac{i_a^2}{d_1}\times\frac{-1}{3}$$, –ve sign indicate repulsion

$$\text{So, } F=\left|\left(\frac{F}{\ell}\right)_a\right|\times\ell=\frac{\mu_0 i_a^2\ell}{6\pi d_1}$$

44. **(c)**

45. **(a)**



Force due to AB and CD will cancel each other.

Magnetic field is in $+\hat{k}$ direction
Effective length of semicircular loop, $l_{eff} = 2R$

$$\vec{F}=i\vec{l}\times\vec{B} \Rightarrow \vec{F}=il_{eff}B \Rightarrow \vec{F}=-2i\,RB\,\hat{j}$$

46. **(a)** Torque, $\tau = NIAB\sin\theta$
Torque is also given as, $\tau = K\theta$
on comparing, $NIAB\sin\theta = K\theta$

$$K=\frac{NIAB\sin\theta}{\theta}$$

$$K=\frac{100\times0.01\times0.01\times2\times10^{-4}}{0.05}=4\times10^{-5}\text{ N-m/rad.}$$

$= x\times10^{-5}$ N-m/rad (given) $\therefore$ x = 4

47. **(d)** $C\theta = NBiA\sin90°$

$$\text{or } 10^{-6}\left(\frac{\pi}{180}\right)=175B(10^{-3})\times10^{-4} \quad \therefore B=10^{-3}\text{ T}$$

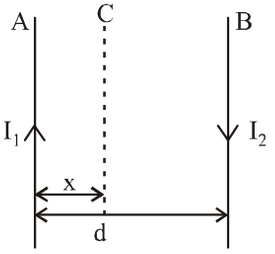
48. **(d)** As net force on the third wire C is zero.

$$\Rightarrow \vec{F}=\frac{\mu_0 I_1}{2\pi x}+\frac{\mu_0 I_2}{2\pi(d-x)}=0$$

$$\Rightarrow \frac{\mu_0 I_1}{2\pi x}=\frac{\mu_0 I_2}{2\pi(x-d)}$$

$$\Rightarrow I_1 x - I_1 d = I_2 x$$

$$x=\frac{I_1 d}{I_1-I_2}$$



Two cases may be possible if $I_1 > I_2$ or $I_2 > I_1$

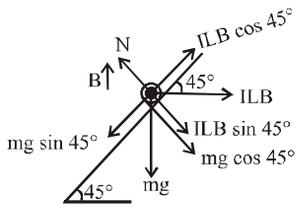
49. **(b)** Given, spring constant, $k = 10^{-8}$ N-m rad^{-1}
Number of turns, N = 100,
Area, $A = 1\text{ cm}^2 = (1\times10^{-2})^2\text{m}^2 = 1\times10^{-4}\text{ m}^2$
and magnetic field, B = 5 T

$$\therefore S_i=\frac{NBA}{k}=\frac{100\times5\times1\times10^{-4}}{10^{-8}}=5\times10^{6}\text{ A}^{-1}$$

50. **(b)** **51.** **(b)**

Exercise 3 : PREVIOUS YEARS MCQs

1. **(a)** Force, F = ILB sinθ
From figure, mg sin 45° = ILB cos 45°



$\therefore I = \left(\frac{m}{L}\right)\frac{g}{B} = \frac{(0.45)(10)}{0.15} = 30A$

2. **(c)** Electric current,
$i \propto \theta$ (angle of deflection)

$\therefore \frac{i_2}{i_1} = \frac{\theta_2}{\theta_1} \Rightarrow \frac{i_2}{200\,\mu A} = \frac{\pi/10}{\pi/3} = \frac{3}{10} \quad \left[\because 60° = \frac{\pi}{3}\right]$

$\therefore i_2 = 60\ \mu A$

3. **(b)** Magnetic force per unit length on wire PQ due to wire RS is given by

$\frac{F}{\ell} = \frac{\mu_o}{4\pi}\frac{2I_1I_2}{r}$

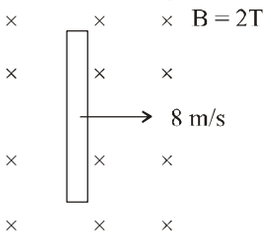
$\therefore \quad F_1 \propto I_1 I_2 \propto (I)^2$

When ammeter current reading is changed to 2I.

$F_2 \propto (2I)^2$

$\therefore \quad F_1 : F_2 = 1 : 4$

4. **(d)** Given, length, $\ell = 1m$



Velocity, v = 8 m/s

Magnetic Field, B = 2T

Induced emf across

the ends = $B v \ell$

$= 2 \times 8 \times 1 = 16$ V

5. **(c)** Given kinetic energy $k = \frac{1}{2}mv^2 = 8.35$ MeV

$= 8.35 \times 10^{-6} \times 1.6 \times 10 J^{-19}$ B = 10T, $\theta = 90°$, F = ?

$F = qVB \sin\theta$

$8.35 \times 10^6 \times 1.6 \times 10^{-19} J = \frac{1}{2} \times 1.67 \times 10^{-27} \times V^2$

$\therefore V^2 = \frac{2 \times 8.35 \times 10^6 \times 1.6 \times 10^{-19}}{1.67 \times 10^{-27}}$

$\sqrt{\frac{2 \times 16 \times 835 \times 10^{13}}{167}} = V$

$\therefore V = 4 \times 10^7$ m/s

$\therefore F = qvB \sin\theta = 1.6 \times 10^{-19} \times 4 \times 10^7 \times 10 \times 1$

$= 64 \times 10^{-12}$ N

6. **(b)** Formula for radius in magnetic field:

$r = \frac{mv}{qB}$

$K = \frac{1}{2}mV^2 \Rightarrow V = \sqrt{\frac{2K}{m}}$

Substitute into radius formula

$r = \frac{m \times \sqrt{\frac{2K}{m}}}{qB} \Rightarrow r \propto \frac{\sqrt{m}}{q}$

To find ratio:

$\frac{r_1}{r_2} = \frac{\sqrt{m_1}/q_1}{\sqrt{m_2}/q_2} = \frac{\sqrt{m_1}, q_2}{\sqrt{m_2}, q_1}$

Use: $m_1 : m_2 = 1 : 4$

$\Rightarrow \sqrt{m_1} : \sqrt{m_2} = 1 : 2$

Let specific charges be

$\frac{q_1}{m_1} = 2k, \frac{q_2}{m_2} = k$

$q_1 = 2km_1$ and $q_2 = km_2$

substitute:

$\frac{r_1}{r_2} = \frac{\sqrt{m_1} \times km_2}{\sqrt{m_2} \times 2km_1} = \frac{\sqrt{m_1} \times m_2}{2\sqrt{m_2} \times m_1}$

Put $m_1 = 1$, $m_2 = 4$

$\frac{r_1}{r_2} = \frac{1 \times 4}{2 \times 2 \times 1} = \frac{4}{4} = 1 : 1$

7. **(d)** The time period of revolution of the particle in a uniform magnetic field is

$T = \frac{2\pi m}{B\,q} \propto \frac{1}{q/m}$

$\therefore$ Time period decreases with increases of specific charge $\left(\frac{m}{m}\right)$ of the particle.

8. **(a)** Magnetic field due to a circular are

$B = \frac{\mu_o i}{4\pi R} \times \theta$

For semi circle $\theta = \pi$, so

$B = \frac{\mu_o i}{4\pi R} \times \pi = \frac{\mu_o i}{4R}$

For semi circle,

$$L = \pi R \Rightarrow R = \frac{L}{\pi}$$

$$B = \frac{\mu_o i\pi}{4R} = \frac{\mu_o i}{4 \times L} \times \pi = \frac{\mu_o i\pi}{4L}$$

$$\boxed{B = \frac{\mu_o i\pi}{4L}}$$

9. **(a)** Magnetic field at the center of a solenoid

$B_{center} = \mu_0 nI$

$\therefore B \propto nI$ or, $\frac{B_1}{B_2} = \frac{n_1 I_1}{n_2 I_2}$

Given $B_1 = 6.24 \times 10^{-2}$T, $n_1 = 400$ turns per unit length $I_1 = i$, $n_2 = 200$ turns per unit length,

$I_2 = \frac{i}{2}, B_2 = ?$

$$\frac{B_1}{B_2} = \frac{n_1 I_1}{n_2 I_2}$$

$$\therefore \frac{6.24 \times 10^{-2}}{B_2} = \frac{400 \times i}{200\frac{i}{2}} \therefore B_2 = \frac{6.24 \times 10^{-2}}{4}$$

$\therefore B_2 = 1.56 \times 10^{-2}$ T

10. **(c)** m = N.I.A (magnetic moment)

$A = \pi r^2 = \pi(0.02)^2 = \pi \times 4 \times 10^{-4}$

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

$m = 500 \times 15 \times 4\pi \times 10^{-4}$

$= 7500 \times 4\pi \times 10^{-4} = 30000 \times 10^{-4} \times \pi$

$m = 3\pi$ J / T

11. **(b)** $r = \frac{d}{2} = 0.6 \times 10^{-3}$m,

$$B = \frac{\mu_o I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 12}{2\pi \times 0.6 \times 10^{-3}}$$

$$B = \frac{48 \times 10^{-7}}{1.2 \times 10^{-3}} \Rightarrow B = \frac{48}{1.2} \times 10^{-4}$$

$= 40 \times 10\text{-}^{-4} = 4 \times 10^{-3}$ T

12. **(a)** Formula for magnetic field at the center of a long solenoid: $B = \mu_o$ nI

Substitute the values.

$B = 4\pi \times 10^{-7} \times 3500 \times 5 = 2.2 \times 10^{-2}$ T or 22 mT

13. **(d)** The magnetic field at a point inside a current carrying straight wire is

$$B_I = \left(\frac{\mu_o I}{2\pi R^2}\right) r$$

Here, r = 0.5a, R = a

$$\therefore B_I = \left(\frac{\mu_o I}{2\pi a^2}\right) \times 0.5a = \frac{\mu_o I}{4\pi a}$$

The magnetic field at a point outside a current carrying straight wire is

$$B_o = \frac{\mu_o I}{2\pi r} = \frac{\mu_o I}{2\pi(1.5a)} [\because r = 1.5a]$$

$$= \frac{\mu_o I}{3\pi a}$$

$$\therefore \frac{B_I}{B_o} = \frac{\mu_o I}{4\pi a} \times \frac{3\pi a}{\mu_o I} = \frac{3}{4}$$

14. **(a)**

15. **(c)** $B_c = \frac{\mu_o NI}{2R}$

$$B_a = \frac{\mu_o NIR^2}{2\left(x^2 + R^2\right)^{\frac{3}{2}}}$$

At x = R, $B_a = \frac{\mu_o NIR^2}{2\left(2R^2\right)^{\frac{3}{2}}} = \frac{\mu_o IN}{4\sqrt{2}R}$

$$= \frac{1}{2\sqrt{2}}\left(\frac{\mu_o IN}{2R}\right) = \frac{B_c}{2\sqrt{2}}$$

$$\therefore \frac{B_c}{B_a} = 2\sqrt{2}$$

16. **(c)** Given: $I_1 = 3A$, $I_2 = 4A$

$R = 2\pi$ cm $= 2\pi \times 10\text{-}^{-2}$m

The expression of Magnetic field of a coil

$$B = \frac{\mu_o I}{2R}$$

$$B_1 = \frac{\mu_o I_1}{2R} = \frac{\mu_o}{2} \times \frac{3}{2\pi \times 10^{-2}} = 3 \times 10^{-5} \text{T}$$

Similarly, $B_2 = \frac{\mu_o I_2}{2R} = \frac{\mu_o}{2} \times \frac{4}{2\pi \times 10^{-2}} = 4 \times 10^{-5}$ T

Net magnetic field at centre of a coil = $\sqrt{B_1^2 + B_2^2}$

$$= \sqrt{\left(3 \times 10^{-5}\right)^2 + \left(4 \times 10^{-5}\right)^2} = 5 \times 10^{-5} \text{T}$$

17. **(c)** Given, $\ell_1 = 10\text{cm} = 10 \times 10^{-2}$ m, i = 4A, B = ?

$$B = \frac{\mu_o i}{2\pi r} = \frac{4\pi \times 10^{-7} \times 4}{2\pi \times 10 \times 10^{-2}} = 8 \times 10^{-6}\,T = 8\,\mu T$$

18. **(c)** $F = iB\,l \sin\theta = 8 \times 0.15 \times 1 \times \sin 30°$

$$\boxed{F = 0.6\,N/m}$$

so option (c) is correct

19. **(b)** Circumference of the circular loop

$$2\pi r = L \Rightarrow r = \frac{L}{2\pi} = \frac{10}{2\pi} = \frac{5}{\pi}$$

Area of the loop-

$$A = \pi r^2 = \pi \times \left(\frac{5}{\pi}\right)^2 = \pi \times \frac{25}{\pi^2} = \frac{25}{\pi} m^2$$

maximum torque occurs when the angle between magnetic field and normal to the loops is 90°

$$\tau_{max} = IAB = 1 \times \frac{25}{\pi} \times 2\pi \times 10^{-4}$$

$$\boxed{\tau = 50 \times 10^{-4}\ Nm}$$

20. **(a)** For equilibrium: magnetic force balances weight per unit length

$BIL = mg$

$$I = \frac{mg}{BL}$$

Substitute given values.

$$I = \frac{0.12 \times 10}{0.5} = 2.4A$$

21. **(b)** S = 0.0625 div/μA

converted into a voltmeter to read up to V = 6V

$$\text{Current sensitivity} = \frac{\text{Number of divisions}}{I_g}$$

$$I_g = \frac{30}{0.0625} \Rightarrow I_g = 480\mu A = 480 \times 10^{-6} A$$

using ohm's law to find total resistance

$$V = I_g(R + R_g) \Rightarrow \frac{V}{I_g} = R + R_g$$

$$R_{total} = \frac{6}{480 \times 10^{-6}} = \frac{6}{4.8 \times 10^{-4}} = 12500\Omega$$

$$\boxed{R_{total} = 12.5\,k\Omega}$$

22. **(a)** Current sensitivity $(S) = \frac{\theta}{I} = \frac{NAB}{K}$

$$\frac{S_A}{S_B} = \frac{N_A A_A B_A}{N_B A_B B_B} \Rightarrow \frac{S_A}{S_B} = \frac{36 \times 2.4 \times 10^{-3} \times 0.25}{48 \times 4.8 \times 10^{-3} \times 0.5} = \frac{3}{16}$$

23. **(d)** To convert a galvanometer into a voltmeter.

We connect a series resistance R such that

$V = I(R + R_g) \Rightarrow 10 = 0.0005 \times (R + 15)$

Solve for R:

$$R + 15 = \frac{10}{0.0005} = 20000$$

$\Rightarrow R = 20000 - 15 = 19985\ \Omega$

24. **(b)** Give, velocity of proton = 8×10^5 m/s

Radius $r = 8.3 \times 10^{-2}$ m.

Radius of the circle, $r = \frac{mv}{qB}$

$$\Rightarrow B = \frac{mv}{rq} = \frac{1.66 \times 10^{-27} \times 8 \times 10^5}{8.3 \times 10^{-2} \times 1.6 \times 10^{-19}}$$

$$= \frac{13.28}{13.28} \times 10^{-1} = 100mT$$

25. **(b)** $\vec{F} = q.(\vec{v} \times \vec{B})$

A circular path in the horizontal place in a direction opposite to that of a negative charge with same speed.

26. **(b)** Using, time $t = \frac{2\pi m}{qB}$ as B is same so

$$t \propto \frac{m}{q} \quad \therefore \frac{t_p}{t_\alpha} = \frac{m_P}{m_\alpha} \times \frac{q_\alpha}{q_p} = \frac{1}{4} \times \frac{2}{1} = \frac{1}{2}$$

$\therefore\ t_p : t_\infty = 1 : 2$

27. **(d)** Given, number of turns, $N_A = 300$, $N_B = 200$

Magnetic moment ratio.

$M_A : M_B = 1:2$

Magnetic moment of a circular coil

$M = NIA$

$$\frac{M_A}{M_B} = \frac{N_A}{N_B}\frac{I_A}{I_B} \cdot \frac{R_A^2}{R_B^2}\ [I_A = I_B = I]$$

$$\frac{1}{2} = \frac{300}{200} \times \frac{R_A^2}{R_B^2}$$

$$R_A : R_B = 1 : \sqrt{3}$$

28. **(b)** Magnetic field on the axis of current carrying circular coil,

$$B = \frac{\mu_o i r^2}{2(x^2 + r^2)^{3/2}} \quad ...(i)$$

[Here r = radius of circular coil]

Magnetic field at the centre of current carrying circular coil,

$$B' = \frac{\mu_o i}{2r} \quad ...(ii)$$

Using (i) and (ii)

$$B' = \frac{B\left(x^2 + r^2\right)^{3/2}}{r^3}$$

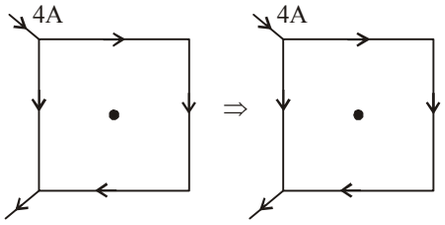
Substituting $x = \sqrt{2}d$ and $r = \frac{d}{2}$

$$B' = B\frac{\left[\left(\sqrt{2}d\right)^2 + \left(d/2\right)^2\right]^{3/2}}{\left(d/2\right)^3} = \frac{B\left[2d^2 + \frac{d^2}{4}\right]^{3/2}}{\frac{d^3}{8}}$$

$$B' = \frac{B\left(\frac{3d}{2}\right)^{2\times 3/2}}{\frac{d^3}{8}} = 27B$$

29. (a)

30. (d)



$$B_{oneside} = \frac{\mu_o I}{4\pi R} \times \frac{2}{\sqrt{2}} = \frac{\mu_o I}{2\pi R \times \sqrt{2}}$$

Current flows through two opposite arms of a square in opposite directions, the net magnetic field at the centre is zero due to cancellation.

31. (c) Magnetic field due to solenoid $B = \mu_o\, nI$

$$\text{or, } B = \mu_o \frac{N}{\ell} I = \frac{4\pi \times 10^{-7} \times 200 \times 2.5}{0.5} = 4\pi \times 10^{-4}\,T$$

32. (d) Given length of wire $30\sqrt{3}$cm

Uniform magnetic field = 2T

Current = 2A

A wire of length $30\sqrt{3}$cm is bent into an equilateral triangle. So, each side is

$$\frac{30\sqrt{3}}{3} = 10\sqrt{3}\text{ cm} = 0.1\sqrt{3}\text{ m}$$

Since triangle ABC is equilateral, angle between AC and side BC is 60°.

$$\vec{F} = I(\vec{L} \times \vec{B}) = IBL\sin\theta = 2 \times 2 \times 0.1\sqrt{3} \times \sin 60°$$

$$= 0.4 \times \sqrt{3} \times \frac{\sqrt{3}}{2} = 0.6\text{N}$$

33. (c) Two parallel long wires carry

$I_1 = 8A$, $I_2 = 10A$

Distance between wires, d = 9 cm.

Distance from the second wire, $r_2 = d - r = 9 - 4 = 5$ cm.

Magnetic field due to first wire

$$B_1 = \frac{\mu_o I_1}{2\pi r_1}$$

$$= \frac{4\pi \times 10^{-7} \times 8}{2\pi \times 4 \times 10^{-2}} = 4 \times 10^{-5}\,T$$

Magnetic field due to second wire

$$B_2 = \frac{\mu_o I_2}{2\pi r_2} = \frac{4\pi \times 10^{-7} \times 10}{2\pi \times 5 \times 10^{-2}} = 4 \times 10^{-5}\,T$$

Since the currents are in opposite directions, the magnetic fields add up.

$B_{net} = B_1 + B_2 = 4 \times 10^{-5} + 4 \times 10^{-5} = 8 \times 10^{-5}$T

34. (a) Given,

No of turns, n = 200

Area of coil, $A = 10 \times 10 = 100\text{ cm}^2$

Magnetic field, B = 2T

Current through the coil, I = 3 mA

Torque acting on the coil, $\tau = nIBA$

$\Rightarrow \tau = 200 \times 3 \times 10^{-3} \times 2 \times 100 \times 10^{-4} = 12 \times 10^{-3}$ Nm

35. (b) $\vec{B} = B_o\hat{j}, \vec{v} = v_o\hat{i}$

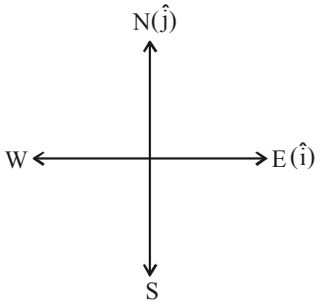
$\therefore$ Force on $\propto$-particle is

$$\vec{F} = q\left(\vec{v} \times \vec{B}\right) = q\left(v_o\hat{i} \times B_o\hat{j}\right) = qv_oB_o\hat{k}$$

$\therefore$ Centripetal force is along z-direction,

$\therefore$ The motion of $\propto$-particle will be a circle in xz-plane.

36. (a) For the freely falling electron.



$$\vec{v} = -v_o\hat{k}, \vec{B} = -B_o\hat{j}$$

$$\therefore \vec{F} = -e\left(\vec{v} \times \vec{B}\right) = -e\left[\left(-v_o\hat{k}\right) \times \left(-B_o\hat{j}\right)\right]$$

$$= -ev_oB_o\left(-\hat{i}\right) = ev_oB_o\hat{i} = ev_oB_o\,(\text{East})$$

$\therefore$ The electron is deflected towards east.

37. (c) The pitch of the helical path in uniform magnetic field is given by

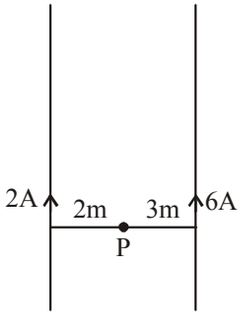
$$p = \frac{2\pi m}{qB}(v\cos\theta) \Rightarrow p \propto \frac{m}{q}$$

$$\therefore \quad \frac{p_1}{p_2} = \frac{m_1}{\frac{q_1}{m_2}{q_2}}$$

but, $m_1 = m$, $q_1 = 2q$
and $m_2 = 2m$, $q_2 = 3q$

$$\therefore \quad \frac{p_1}{p_2} = \frac{m}{\frac{2q}{2m}{3q}} = \frac{3}{4}$$

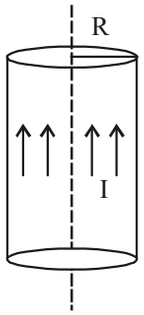
38. (b)



$I_1 = 2A$, $I_2 = 6A$
$r_1 = 2m$, $r_2 = 3m$
The resultant magnetic field at point P is

$$B = \frac{\mu_o}{2\pi}\left(\frac{I_2}{r_2} - \frac{I_1}{r_1}\right) = 2\times10^{-7}\left(\frac{6}{3} - \frac{2}{2}\right) = 2\times10^{-7}\,T$$

39. (d) R = 2mm,



$$\text{At } r_1 = 1mm, B_1 = \left(\frac{\mu_o I}{2\pi R^2}\right) r_1$$

$$\therefore \quad B_1 \propto \frac{r_1}{R^2}$$

$$\text{At } r_2 = 4mm, B_2 = \frac{\mu_o I}{2\pi r_2} \propto \frac{1}{r_2}$$

$$\therefore \quad \frac{B_1}{B_2} = \frac{r_1/R^2}{1/r_2} = \frac{r_1 r_2}{R^2} = \frac{1\times4}{(2)^2} = 1:1$$

40. (d)

11 Magnetic Material

Exercise 1 : WARM-UP
Topic-wise MCQs

1. **(a)** **2.** **(b)** **3.** **(a)** **4.** **(a)** **5.** **(b)**

6. **(c)** When wire is bent in the form of semi-circular arc then, $l = \pi r$
So, $r = l/\pi$
Distance between two end points of semi-circular wire
$= 2r = \frac{2l}{\pi}$
So, magnetic moment of semi-circular wire
$= m \times 2r = \frac{m \times 2l}{\pi}$
But, ml is magnetic moment of straight wire.
i.e $ml = M$
So, New magnetic moment $= \frac{2}{\pi}M$

7. **(d)**

8. **(c)** $\tau = MB \sin\theta = m \times (2\ell) \times B \sin\theta$
$= 10^{-4} \times 0.1 \times 30 \sin 30° = 1.5 \times 10^{-4}$ *Nm*

9. **(a)** As we know, torque, $\tau = MB \sin\theta$
Hence, rate of change of torque with deflection,
$\frac{d\tau}{d\theta} = MB \cos\theta.$
It will be maximum when $\cos\theta = 1$, i.e., $\theta = 0°$.

10. **(c)** Torque, $\tau = MB \sin\theta$
$\sin\theta = \frac{\tau}{MB} = \frac{0.3464}{2.0 \times 0.2}$
$\sin\theta = 0.866$
$\Rightarrow \theta = 60°$

11. **(d)** The torque acting on dipole,
$\vec{\tau} = \vec{M} \times \vec{B} = (25\hat{j}) \times (3\hat{i} + 18\hat{j})$
$= (25 \times 3)(-\hat{k}) + (25 \times 18)(0) \quad [\because \hat{j} \times \hat{j} = 0]$
$= -75\hat{k}$ N-m

12. **(b)** As breadth of each part is half the original breadth, therefore, pole strength becomes half (i.e. m/2).

13. **(a)** Magnetic field due to a long solenoid on its axis,
$B = \mu_0 n l_2$ ... (i)
Magnetic moment of a circular coil,
$M = NAl_1$ ... (ii)
Torque, $\tau = \boldsymbol{M} \times \boldsymbol{B}$
$\tau = MB \sin\theta = MB \quad [\because \theta = 90° \text{ (Given)}]$
$\tau = (NAl_1)(\mu_0 n l_2) \quad$ [using Eqs. (i) and (ii)]
$\Rightarrow l_2 = \frac{\tau}{NAl_1\mu_0 n} = \frac{1.5 \times 10^{-8}}{(10)(1 \times 10^{-6})\left(\frac{21}{44}\right)(4\pi \times 10^{-7})(10^3)}$
$= 2.5$ A

14. **(b)** $U = mB \cos\theta$
At stable equilibrium
$U = -mB \cos 0° = -mB$
At unstable equilibrium
$U = -mB \cos 180° = +mB$
$W = \Delta U = 2mB = 2\,(0.5)\,8 \times 10^{-2} = 8 \times 10^{-2}$J

15. **(a)** Given,
Magnetic moment of straight wire $= m \times l = 44$ Am^2
Initial length of wire = length of arc $= \pi R = l$
Effective length of semicircular arc, $l' = 2R \Rightarrow l' = \frac{2l}{\pi}$
Magnetic moment of arc
$= m \times l' = m \times \frac{2\ell}{\pi} = \frac{44 \times 2}{\pi} = \frac{88}{\pi} = 28$ Am^2

16. **(b)** Work done is equal to change in potential energy,
$W = U_f - U_i$
$W = (-\vec{\mu}.\vec{B})_f - (-\vec{\mu}.\vec{B})_i = 0 + (\vec{\mu}.\vec{B})_i$
$\Rightarrow W = (100 \times 5 \times 10^{-3} \times 1 \times 10^{-3}) \times 0.2$ J $= 100\ \mu$J

17. **(c)** Work required by an external torque to turn the magnet so as to align its magnetic moment normal to the field direction.
$W = -MB(\cos\theta_2 - \cos\theta_1) = -2 \times 0.3(\cos 90° - \cos 0°)$
$\therefore W = -0.6(0 - 1) = 0.6$J.

18. **(a)** We know that
$\tau = MB \sin\theta$
$\Rightarrow M = \frac{\tau}{B \sin 45°} = \frac{3.6 \times 10^{-5}}{28.3 \times 10^{-3} \times \frac{1}{\sqrt{2}}}$
$= 1.8 \times 10^{-3}$J T^{-1}

19. **(a)** **20.** **(a)**

21. **(a)** Magnetic field, $B = 200G = 200 \times 10^{-4}$ T
We have
Torque $\tau = mB\sin\theta$
$\Rightarrow 0.012 = m \times 200 \times 10^{-4} \times \sin 30°$
$\Rightarrow m = 0.012 \times 10^2 \Rightarrow m = 1.2$ Am^2

22. **(b)** $\tau = MB \sin\theta = 0.1 \times 3 \times 10^{-4} \sin 30°$
or $\tau = 1.5 \times 10^{-5}$ N–m.

23. **(c)**

24. **(c)** Torque on magnetic dipole
$\vec{M} = \vec{M} \times \vec{B} = MB \sin\theta = MB \sin 0 = 0$
Force due to field is also zero as forces on both poles are in opposite direction so cancel each other.

25. **(d)** Torque, $\tau = MB \sin\theta$
$\Rightarrow M = \frac{\tau}{B \sin\theta} = \frac{0.032}{0.16 \times \sin 30°} = \frac{0.032 \times 2}{0.16 \times 1} = 0.4$ J/T

26. **(a)** Given, $B = 600$ G
$G = 600 \times 10^{-4} = 6 \times 10^{-2}$ T
Now, torque, $\tau = MB \sin\theta$

$$M = \frac{\tau}{B\sin\theta} = \frac{0.03}{6\times10^{-2}\times\sin30^\circ} = \frac{0.03\times2}{6\times10^{-2}} = 1.0\ \text{A-m}^2$$

27. **(b)** The torque on the magnetic dipole,
$\tau = MB \sin\theta = 1.0 \times 0.5 \times \sin 45^\circ$

$$= 0.5\times\frac{1}{\sqrt{2}} = 0.35\ \text{J}$$

28. **(c)**

29. **(d)** Torque acting on the dipole,

$$\tau = M \times B = 10\hat{j}\times(2\hat{i}+3\hat{j})$$

$$= 20(\hat{j}\times\hat{i}) + 30(\hat{j}\times\hat{j}) = 20(-\hat{k}) = -20\hat{k}\ \text{N-m}$$

30. **(d)**

31. **(a)** We know that $\mu_r = 1 + x$
$=1 + 5500 = 5501$
$\therefore \mu = \mu_r\mu_0 = (5501) \times (4\pi \times 10^{-7})$
$= 6.9 \times 10^{-3}$

32. **(c)** Here, $H = 2 \times 10^3$ A m^{-1}, $B = 8\pi$ T, $\mu_0 = 4\pi \times 10^7$

Since $\mu_r = \frac{\mu}{\mu_0} = \frac{\mu H}{\mu_0 H} = \frac{B}{\mu_0 H}$

$$= \frac{8\pi}{4\pi\times10^{-7}\times2\times10^3} = 10^4$$

33. **(a)** $\mu = \mu_0\mu_r = (4\pi \times 10^{-7}) \times 2000 = 8\pi \times 10^{-4}$ S.I. units

34. **(b)** From $\mu_r = 1 + \chi_m$;
Magnetic susceptibility, $\chi_m = \mu_r - 1$
$\chi_m = 0.075 - 1 = -0.925$.

35. **(d)** Here, $\chi = -1$
Then, $\mu_r = 1 + \chi$
$\Rightarrow \mu_r = 1 + (-1) = 1 - 1 = 0$
Since, magnetic susceptibility of given material is less than one.
Hence, the given magnetic material is a diamagnetic material.

36. **(d)**

37. **(b)** On heating, different domains have net magnetisation in them which are randomly distributed. Thus, the net magnetisation of the substance due to various domains decreases to minimum.

38. **(d)** X = diamagnetic; Y = paramagnetic.

39. **(b)** **40.** **(a)** **41.** **(b)** **42.** **(b)** **43.** **(d)** **44.** **(c)**

45. **(b)** Beyond curie temperature, ferormagnetic material turns into paramagnetic material, as if ferromagnetic domains become random.

46. **(c)** **47.** **(a)** **48.** **(c)**

49. **(a)** $\chi = C\times\frac{1}{T} \Rightarrow C = \frac{0.4}{7\times10^{-3}} = 57\text{K}$

50. **(d)** For ferromagnetic substance $\chi >> 1$

51. **(c)** **52.** **(b)**

Exercise 2 : ACCELERATOR
Topic-wise MCQs

1. **(b)**

2. **(a)** In non-uniform magnetic field, a bar magnet experiences both force and torque.

3. **(b)** $M = IA$

$$= \frac{e}{T}\times\pi R^2$$

$$= \frac{e}{2\pi R}\times v\times\pi R^2$$

$$= \frac{evR}{2}$$

4. **(a)** We know that
$\tau = MB \sin\theta$

$$\Rightarrow M = \frac{\tau}{B\sin45^\circ} = \frac{3.6\times10^{-5}}{28.3\times10^{-3}\times\frac{1}{\sqrt{2}}} = 1.8 \times 10^{-3}\ \text{J T}^{-1}$$

5. **(a)** Torque $\tau = MB_H \sin\theta$

$$= 0.1\times10^{-3}\times4\pi\times10^{-3}\times\sin30^\circ = 10^{-7}\times4\pi\times\frac{1}{2}$$

$= 2\pi \times 10^{-7}$ N × m

6. **(a)** Given,
Magnet moment of bar magnet, $M = 10^{-4}$ Am^2
Magnetic field, $B = 12 \times 10^{-3}$ T
Torque on the bar magnet $T = MB \sin\theta$

$\Rightarrow \tau = 10^{-4} \times 12 \times 10^{-3} \times \frac{1}{2} = 6 \times 10^{-7}$ Nm

7. **(d)** The torque on a bar magnet in magnetic field is
$\tau = MB \sin\theta$

$$\therefore \frac{\tau_2}{\tau_1} = \frac{\sin\theta_2}{\sin\theta_1} = \frac{\sin45^\circ}{\sin30^\circ} = \frac{1/\sqrt{2}}{1/2} = \sqrt{2}$$

$\therefore \tau_2 = 1.414\ \tau_1$ $\therefore$ % change in τ,

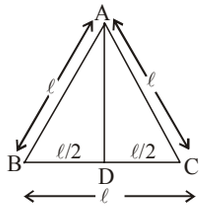
$$\Delta\tau\% = \frac{\tau_2 - \tau_1}{\tau_1}\times100 = \frac{1.414\tau_1 - \tau_1}{\tau_1}\times100$$

$= 41.4\%$ increases

8. **(a)**

9. **(b)** $\tau = MB \sin\theta$
$\tau = iAB \sin90^\circ$

$$\therefore A = \frac{\tau}{iB}$$



Also, A = 1/2 (BC) (AD)

$$\text{But } \frac{1}{2}(BC)(AD) = \frac{1}{2}(l)\sqrt{l^2 - \left(\frac{l}{2}\right)^2} = \frac{\sqrt{3}}{4}l^2$$

$$\Rightarrow \frac{\sqrt{3}}{4}(l)^2 = \frac{\tau}{Bi} \quad \therefore \quad l = 2\left(\frac{\tau}{\sqrt{3}\ B.i}\right)^{\frac{1}{2}}$$

10. **(a)** Given,
Moment of inertia of circular coil, $I = 0.8$ kg m^2
Magnetic moment of circular coil, $M = 20$ Am^2

Rotational kinetic energy of circular coil, $KE = \frac{1}{2}I\omega^2$

Here, ω = angular speed of coil
Potential energy of bar magnet = $-MB\cos\phi$
From energy conservation

$$\frac{1}{2}I\omega^2 = U_{in} - U_f = 0 - (-MB\cos 60°)$$

$$[\because U_i = -MB\cos 90° = 0]$$

$$\Rightarrow \frac{MB}{2} = \frac{1}{2}I\omega^2 \Rightarrow \frac{20\times 4}{2} = \frac{1}{2}(0.8)\omega^2$$

$$\Rightarrow 100 = \omega^2 \Rightarrow \omega = 10 \text{ rad/sec}$$

11. **(c)** Here, $\theta = 30°$, $\tau = 0.018$ N-m, $B = 0.06$ T
Torque on a bar magnet :

$$\tau = MB\sin\theta \Rightarrow 0.018 = M\times 0.06\times \sin 30°$$

$$\Rightarrow 0.018 = M\times 0.06\times\frac{1}{2} \Rightarrow M = 0.6 \text{ A-m}^2$$

Position of stable equilibrium ($\theta = 0°$)
Position of unstable equilibrium ($\theta = 180°$)
Minimum work required to rotate bar magnet from stable to unstable equilibrium

$$\Delta U = U_f - U_i = -MB\cos 180° - (-MB\cos 0°)$$

$$W = 2MB = 2\times 0.6\times 0.06 \Rightarrow W = 7.2\times 10^{-2}\text{J}$$

12. **(a)** Couple acting on a bar magnet of dipole moment M when placed in a magnetic field, is given by $\tau = MB\sin\theta$ where θ is the angle made by the axis of magnet with the direction of field.
Given the m = 5Am, $2\ell = 0.2$m, $\theta = 30°$
and B = 15 Wbm^{-2}

$$\therefore \tau = MB\sin\theta = (m\times 2\ell)\,B\sin\theta = 5\times 0.2\times 15\times\frac{1}{2}$$

= 7.5 Nm.

13. **(b)** Given,
Side of triangle, ℓ = 10 cm = 10×10^{-2} m
Magnetic field, B = 20 mT = 20×10^{-3} T
Current, I = 0.2 A

Area of equilateral triangle, $A = \frac{\sqrt{3}}{4}\ell^2$

$$\text{Torque, } \vec{\tau} = \vec{M}\times\vec{B} = MB\sin 90°$$

$$= IAB = \frac{I\sqrt{3}\ell^2}{4}B = \frac{0.2\times\sqrt{3}\times(10\times 10^{-2})^2}{4}\times 20\times 10^{-3}$$

$$\therefore \tau = \sqrt{3}\times 10^{-5}\text{ Nm}$$

14. **(b)**

15. **(d)** Diamagnetic substances do not have any unpaired electron. And they are magnetised in direction opposite to that of magnetic field. Hence, when they are brought to north or south pole of a bar magnet, they are repelled by poles.

16. **(b)** According to Curie's law, $\chi_m \propto \frac{1}{T}$

17. **(a)** There are some ferromagnetic materials in which the magnetisation disappears on the removal of external magnetic field such as soft ferromagnetic materials.

18. **(c)** Diamagnetic substance have a tendency to move away from stronger part to the weaker part of the field.

19. **(a)** Susceptibility (χ) of a diamagnetic material is negative

20. **(c)** The minimum temperature at which a ferromagnetic substance is converted into paramagnetic substance is defined as curie's law.

21. **(a)** Decreases

22. **(d)** According to Curie's law, $M = C\frac{B}{T}$

$$\Rightarrow \frac{M_1}{M_2} = \frac{B_1}{B_2}\times\frac{T_2}{T_1} \Rightarrow M_2 = \frac{B_2}{B_1}\times\frac{T_1}{T_2}\times M_1$$

Substitute the necessary values.

$$\Rightarrow M_2 = \frac{0.2}{0.6}\times\frac{4}{16}\times 8 = \frac{2}{3}\text{A m}^{-1}$$

23. **(c)** In a ferromagnetic material, below the curie temperature. Domain is defined as the region in which magnetic moment is aligned in such a way to produce saturated magnetization.

24. **(b)** Diamagnetic materials are repelled in an external magnetic field.
Bar *B* represents diamagnetic materials.

25. **(b)** A diamagnetic liquid moves from stronger part of magnetic field to weaker part.
Therefore, the meniscus of the level of solution will fall.

26. **(a)** $\chi_d < \chi_p < \chi_f$
For diamagnetic substance χ_d is small negative (10^{-5})
For paramagnetic substances χ_p is small and positive (10^{-3} to 10^{-5})
For ferromagnetic substanes χ_f is very large (10^3 to 10^5)

27. **(b)** Given, $\mu_r = 400$
$\therefore \quad \chi = \mu_r - 1 = 400 - 1 = 399$

28. **(b)** High permeability (easy to magnetize) and low retentivity (loses magnetism quickly when current stops).

Exercise 3 : PREVIOUS YEARS MCQs

1. **(b)**

2. **(b)** For a diamagnetic material, the value of μ_r is slightly less than one. For any material, the value of $\in_r$ is always greater than 1.

3. **(d)** A magnetic needle kept in non uniform magnetic field experience a force and torque due to unequal forces acting on poles.

4. **(a)** Work done from 0° to 45°:

$$W = MB(\cos 0° - \cos 45°)$$

$$= MB\left(1 - \frac{1}{\sqrt{2}}\right) \quad \text{... (1)}$$

Work done from 45° to 60°:

$$W_{add} = MB(\cos 45° - \cos 60°)$$

$$= MB\left(\frac{1}{\sqrt{2}} - \frac{1}{2}\right) \quad \text{... (2)}$$

From equ. (1), $MB = \frac{W}{1 - \frac{1}{\sqrt{2}}}$

Put this above expressions to eq. (2)

$$W_{add} = \frac{W}{1-\frac{1}{\sqrt{2}}}\left(\frac{1}{\sqrt{2}}-\frac{1}{2}\right)$$

$$W_{add} = \frac{W}{\sqrt{2}}$$

5. **(a)** For the short bar magnet,

$M = 10^4\ JT^{-1}$, $B = 4 \times 10^{-5}T$, $\theta_1 = 0°$, $\theta_2 = 60°$

$\therefore$ The work done in rotating the magnet in magnetic field from θ_1 to θ_2 is

$W = MB(\cos\theta_1 - \cos\theta_2)$

$= 10^4 \times 4 \times 10^{-5}(\cos 0° - \cos 60°)$

$$= 4\times10^{-1}\times\frac{1}{2} = 0.2J$$

6. **(d)** The expression of torque in terms of magnetic moment and magnetic field can be expressed as:

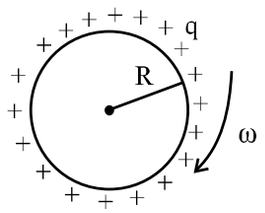
$\tau = MB\sin\theta$.

$$M = \frac{\tau}{B\sin\theta}$$

Substitute given values.

$$M = \frac{0.36}{2\times\sin 45°} = 0.36\ JT^{-1}$$

7. **(c)**



Magnetic moment,

$$M = \frac{q\omega}{2\pi}\times\pi R^2 = \frac{q\omega R^2}{2}$$

8. **(c)** $T_1 = 0.1s$, $B_H = 24\ \mu T = 24 \times 10^{-6}$ T, I = 18A,

$r = 20$ cm $= 20 \times 10^{-2}$ m

Magnetic field due to vertical wire,

$$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi\times10^{-7}\times18}{2\pi\times20\times10^{-2}} = 18\mu T$$

The time period of oscillation of magnet is

$$T = 2\pi\sqrt{\frac{I}{MB}} \Rightarrow T \propto \frac{1}{\sqrt{B}}$$

$$\therefore\ \frac{T_2}{T_1} = \sqrt{\frac{B_H}{B+B_H}} = \sqrt{\frac{24}{18+24}} = \frac{2}{\sqrt{7}}$$

$$\therefore\ T_2 = \frac{2}{\sqrt{7}}T_1 = \frac{2}{\sqrt{7}}\times0.1 = 0.076\ s$$

9. **(a)** The time period of a bar magnet in a magnetic field is

$$T = 2\pi\sqrt{\frac{I}{MB}} = 2\pi\sqrt{\frac{mk^2}{MB}} \Rightarrow T \propto \sqrt{m}$$

$$\therefore\ \frac{T_2}{T_1} = \sqrt{\frac{m_2}{m_1}} = \sqrt{\frac{9m_1}{m_1}} = 3 \quad \therefore\quad T_2 = 3T_1 = 3T$$

10. **(a)** Time period of suspended magnet in uniform magnetic field is

$$T_1 = 2\pi\sqrt{\frac{I}{MB}}$$

When the magnetic moment is reduced by 19%, then

$$T_2 = 2\pi\sqrt{\frac{I}{0.81MB}} = \frac{1}{0.9}\left(2\pi\sqrt{\frac{I}{MB}}\right) = \frac{T_1}{0.9}$$

$\therefore\quad T_2 = 1.11T_1$

$\therefore$ % increase in time period is

$$\Delta T\ \% = \left(\frac{T_2 - T_1}{T_1}\times100\right)\% = \left(\frac{1.11T_1 - T_1}{T_1}\right)\times100 = 11\%$$

11. **(c)** The coercivity of a ferromagnetic material is defined as negative field strength needed to bring the magnetic flux density (B) back to zero after saturation has been reached and the external field is reversed.

Curve cut the negative x-axis at point R.

12. **(c)** Given length of cube = 1.0 um $= 1 \times 10^{-6}$m,

$P = 9.3 \times 10^{-24}\ Am^2$, no. of atoms per cubic metre

$= 8.7 \times 10^{28}$, maximum possible magnetic dipole moment = ?

$$8.7\times10^{28} = \frac{n}{l^3}$$

$\therefore\ n = 8.7 \times 10^{28} \times (1 \times 10^{-6})^3 = 8.7 \times 10^{10}$

$\therefore$ Maximum possible magnetic dipole moment

$$= 8.7 \times 10^{10} \times 9.3 \times 10^{-24} \simeq 81\times10^{-14}\ Am^2$$

13. **(d)** The materials suitable for permanent magnets should have high retentivity and high coercivity.

14. **(b)** For iron specimen,

$$\mu = \left[\frac{0.4}{H} + 12\times10^{-4}\right]Hm^{-1},\ B = 1T$$

$\therefore\quad B = \mu H = 0.4 + (12 \times 10^{-4})H$

$\Rightarrow\quad 1 = 0.4 + 12 \times 10^{-4}\ H \ \therefore\quad H = 500\ Am^{-1}$

15. **(d)** Given, magnetic moment of the bar magnet, $M = 2.5\ Am^2$

Magnetic field, $B = 4 \times 10^{-5}\ T$

Work done, $W = MB(\cos\theta_1 - \cos\theta_2)$

$= 2.5 \times 4 \times 10^{-5}(\cos 0° - \cos 180°)$

$= 10 \times 10^{-5}(1 + 1) = 20 \times 10^{-5} J$

16. **(d)** The torque on a bar magnet in magnetic field is $\tau = MB \sin\theta$

$$\therefore \quad \frac{\tau_2}{\tau_1} = \frac{\sin\theta_2}{\sin\theta_1} = \frac{\sin 45°}{\sin 30°} = \frac{1/\sqrt{2}}{1/2} = \sqrt{2}$$

$\therefore \quad \tau_2 = 1.414\ \tau_1$

$\therefore$ % change in τ,

$$\Delta\tau\% = \frac{\tau_2 - \tau_1}{\tau_1} \times 100 = \frac{1.414\tau_1 - \tau_1}{\tau_1} \times 100$$

=41.4% increases

17. **(a)** Given,

Magnet moment of bar magnet, $M = 10^{-4}\ Am^2$

Magnetic field, $B = 12 \times 10^{-3}\ T$

Torque on the bar magnet $T = MB \sin\theta$

$$\Rightarrow \quad T = 10^{-4} \times 12 \times 10^{-3} \times \frac{1}{2}$$

$$= 6 \times 10^{-7}\ Nm$$

18. **(b)** Ferromagnetic substance has magnetic domains whereas paramagnetic substances have magnetic dipoles which get attracted to a magnetic field.

Diamagnetic substances do not have magnetic dipole but in the presence of external magnetic field due to their orbital motion of electrons these substances are repelled.

19. **(c)** Using $\mu_r = \frac{\mu}{\mu_o} = 1 + \chi_m$ where χ_m = magnetic

Susceptibility, $\frac{\mu}{\mu_o} = ?$

Given $\chi_m = 0.6$

$$\therefore \frac{\mu}{\mu_o} = 1 + \chi_m = 1 + 0.6 = \frac{16}{10} = \frac{8}{5} \qquad \therefore \mu : \mu_o = 8 : 5$$

20. **(a)** The time period of oscillation of a current carrying coil in external magnetic field is

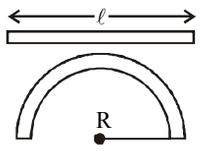
$$T = 2\pi\sqrt{\frac{I}{MB}} \Rightarrow T \propto \frac{I}{\sqrt{M}}$$

$$\therefore \quad \frac{T_2}{T_1} = \sqrt{\frac{M_1}{M_2}} = \sqrt{\frac{2.5}{10}} = \frac{1}{2}$$

$$\therefore \quad T_2 = \frac{T_1}{2} = \frac{T}{2}$$

21. **(b)** Given,

Magnetic moment of straight wire = $m \times l = 44\ Am^2$



Initial length of wire = length of arc = $\pi R = l$

Effective length of semicircular arc, $l' = 2R \Rightarrow l' = \frac{2l}{\pi}$

Magnetic moment of arc

$$= m \times l' = m \times \frac{2\ell}{\pi} = \frac{44 \times 2}{\pi} = \frac{88}{\pi} = 28\ Am^2$$

22. **(a)** External work done is given by:

$W_{ext} = \Delta U = U_2 - U_1$

$= -MB \cos 90 + MB \cos 0 = MB = NIAB$

$= 200 \times 100 \times 10^{-6} \times 2.5 \times 10^{-4} \times 1 = 5\mu J$

23. **(c)** Work done is equal to change in potential energy,

$W = U_f - U_i$

$W = -MB \cos 180° + MB \cos 90°$

$\Rightarrow W = (100 \times 5 \times 10^{-3} \times 1 \times 10^{-3}) \times 0.2\ J = 100\ \mu J$

24. **(b)** $U = -MB \cos\theta$

At stable equilibrium

$U = -MB \cos 0^0 = -MB$

At unstable equilibrium

$U = -MB \cos 180° = +MB$

$W = \Delta U = 2MB$

$= 2(0.5)\ 8 \times 10^{-2} = 8 \times 10^{-2} J$

25. **(a)** The percentage increase in magnetic field B is

$$\%\Delta B = \frac{B_{new} - B_{old}}{B_{old}} \times 100\%$$

$$= \frac{\mu ni - \mu_0 ni}{\mu_0 ni} \times 100\% = \frac{(\mu - \mu_0)}{\mu_0} \times 100\%$$

$$= \frac{(\mu_0\mu_r - \mu_0)}{\mu_0} \times 100\% = (\mu_r - 1) \times 100\%$$

$$= \chi \times 100\% \qquad [\because \chi = \mu_r - 1]$$

$$= 1.2 \times 10^{-3}\% = \frac{6}{5} \times 10^{-3}\%.$$

26. **(a)** Relative permeability

$\mu_r = (1 + \chi) \Rightarrow \chi = (\mu_r - 1)$

Also, $\mu = \mu_0\mu_r \Rightarrow \mu_r = \frac{\mu}{\mu_0}$

$\therefore$ Magnetic susceptibility $\chi = \left(\frac{\mu}{\mu_0} - 1\right)$

27. **(d)** When paramagnetic substances are placed in magnetic field, they align themselves along the directions of external magnetic field. For paramagnetic substance $\boxed{\chi > 0}$

28. **(a)** Coercivity is given by:

$$\Rightarrow H_0 = \frac{B}{\mu_0}$$

$$= \frac{\mu_0 ni}{\mu_o} = ni \quad \left[\because n = \frac{N}{\ell}\right]$$

$$5 \times 10^3 = \frac{150}{30} \times 100 \times i \Rightarrow i = 10A$$

29. **(c)** We know that when a bar magnet is placed in the magnetic field at an angle θ, then torque acting on the bar magnet $(\tau) = MB\sin\theta = \vec{M} \times \vec{B}$.

30. **(c)** Molecular bonding of O_2 based on orbitals show that O_2 is paramagnetic which is true experimentally.

31. **(a)** As susceptibility is positive and large, the given material is ferromagnetic.

32. **(c)** The susceptibility for a ferromagnetic material is large and positive *i.e.*, $\chi >> 1$.

33. **(a)** From the Curie's law

$$\chi = \frac{C}{T - T_C}, \chi_{Co} = \frac{C}{1600 - 1400} = \frac{C}{200}$$

$$\chi_{Fe} = \frac{C}{1600 - 1000} = \frac{C}{600}$$

$$\text{Ratio} = \frac{\chi_{Co}}{\chi_{Fe}} = \frac{C}{200} \times \frac{600}{C} = 3$$

34. **(d)** Paramagnetic substances have dipole moment > 0, i.e. $\mu_p \neq 0$, because of excess of electrons in its molecules spinning in the same direction.
Ferro-magnetic substances are very strong magnets and they also have permanent magnetic moment, i.e. $\mu_f \neq 0$.

35. **(d)** According to Curie's law,

$$\text{i.e., } \chi \propto \frac{1}{T} \quad \therefore \chi_2 = \chi_1 \frac{T_1}{T_2}$$

Here, $\chi_1 = 0.0075$
$T_1 = -73°C = (273 - 73)\ K = 200\ K$
$T_2 = -173°C = (273 - 173)\ K = 100\ K$

$$\therefore \chi_2 = (0.0075)\left(\frac{200K}{100K}\right) = 0.015$$

12 Electromagnetic Induction

Exercise 1 : WARM-UP
Topic-wise MCQs

1. **(a)** Faraday's law states that time varying magnetic flux can induce an e.m.f.

2. **(a)** **3.** **(c)** **4.** **(a)** **5.** **(d)**

6. **(d)** Given, $\phi = 3t^n - 2^n$, n = + ve constant

$\therefore$ The induced emf in the coil is

$$|e| = \frac{d\phi}{dt} = \frac{d}{dt}(3t^n - 2^n) = 3nt^{n-1}$$

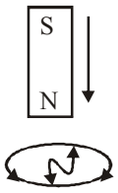
If $0 < n < 1$, then $e \neq 0$ and $|e| \propto \frac{1}{t}$

If $n = 1$, then $e = 3 \times 1 \times t^0 = 3$ = constant

If $n > 1$, then $|e| \propto t$, i.e., $|e|$ increase with time.

7. **(c)** **8.** **(b)**

9. **(c)** By Lenz's law, the direction of induced current in the loop will be anti-clockwise, because the induced current makes the ring, a magnetic dipole with its N-pole upward which opposes (repel) the N-pole of falling magnet.



10. **(a)** **11.** **(a)**

12. **(b)** Area coming out per second from the magnetic field is not constant for elliptical and circular loops, so induced emf, during the passage of these loops, out of the field region will not remain constant for the circular and the elliptical loops.

13. **(a)** $H = \frac{V^2 t}{R}$ and $V = -\frac{N(B_2 - B_1)A\cos\theta}{t}$

$$V = -\frac{1 \times (1-2) \times 0.01 \times \cos 0°}{10^{-3}} = 10\text{V}$$

$$\therefore \quad H = \frac{100 \times 10^{-3}}{0.01} = 10\text{J}$$

14. **(b)** When two coaxial coils having same current in same direction are brought to each other, then flux linkage to each other increases. So, by Lenz's law, the current in both coils decreases in order to oppose increase in flux linkage between them.

15. **(b)** **16.** **(a)** **17.** **(a)**

18. **(a)** $e = \frac{-n(\phi_2 - \phi_1)}{t}$

$$= \frac{-50(1 \times 10^{-6} - 31 \times 10^{-6})}{0.02} = 7.5 \times 10^{-2}\text{ V}$$

19. **(b)** The individual emf produced in the coil $e = \frac{-d\phi}{dt}$

$\therefore$ The current induced will be $i = \frac{|e|}{R} \Rightarrow i = \frac{1}{R}\frac{d\phi}{dt}$

But $i = \frac{dq}{dt} \Rightarrow \frac{dq}{dt} = \frac{1}{R}\frac{d\phi}{dt} \Rightarrow \int dq = \frac{1}{R}\int d\phi \Rightarrow q = \frac{BA}{R}$

20. **(a)** $e = \frac{d\phi}{dt} = \frac{d}{dt}(NBA) = NA\frac{dB}{dt}$

$$= 100 \times 0.1 \times 0.05 \times \left(\frac{0.1 - 0.05}{0.05}\right) = 0.5\text{ V}$$

21. **(c)** $i = \frac{e}{R} = \frac{\frac{nAdB}{dt}}{R} = \frac{20 \times (25 \times 10^{-4}) \times 1000}{100} = 0.5\text{A}$

22. **(c)** $i = \frac{\varepsilon}{R} = \frac{1}{R}\frac{d\phi}{dt}$

Here $df = B \times A = (2 \times 10^{-5}) \times (0.5 \times 10^{+3} \times 5)$

dt = time taken by the wire to fall at ground

$$= (2h/g)^{1/2} = (10/10)^{1/2} = 1\text{sec.}$$

$$\therefore \quad i = \frac{1}{2.5}\left[\frac{(2 \times 10^{-5}) \times (0.5 \times 10^3 \times 5)}{1}\right] = 0.02\text{ amp.}$$

23. **(a)** **24.** **(c)**

25. **(c)** As I increases, ϕ increases

$\therefore$ I_i is such that it opposes the increases in ϕ.

Hence, ϕ decreases (By Right Hand Rule). The induced current will be counterclockwise.

26. **(b)**

27. **(a)** As the magnetic field increases, its flux also increases into the page and so induced current in bigger loop will be anticlockwise. *i.e.*, from D to C in bigger loop and then from B to A in smaller loop.

28. **(b)**

29. **(d)** According to Lenz's law

30. **(c)** Use Lenz's law. Induced emf of the current opposes the change in flux through it.

31. **(b)** $\ell = 5$ cm

$$t = 1\text{ sec} \therefore V = \frac{0.05}{1} = 0.05\text{m/s.}$$

$$\text{And, } i = \frac{B\ell V}{R} \Rightarrow i = \frac{40 \times 0.05 \times 0.05}{10} = 0.01\text{A}$$

So, $F = Bi\ell = 40 \times 0.01 \times 0.05 \Rightarrow F = 0.02$ N

$\therefore$ $W = 0.02 \times \ell = 0.02 \times .05 \Rightarrow W = 1 \times 10^{-3}$ J

32. **(d)**

33. **(d)** $P = I^2R$ when I becomes half, then P becomes one-fourth, heat per unit time depends on square of I. When I is reduced P is substantially reduced.

34. **(a)** Induced emf, $e = -\frac{d\phi}{dt}$

35. **(b)** emf, $\varepsilon = -\frac{d\phi}{dt} = NAB\omega \sin(\omega t)$

emf is maximum when sin ωt = 1

$\varepsilon_{max} = NAB\omega$

$= 200 \times 0.2 \times 0.01 \times \pi = \frac{2\pi}{5} V = \frac{2\pi}{\beta} V$ (given)

$\therefore \beta = 5$

36. **(a)** Given,
Initial Magnetic field,
$B_i = 5000T$
Final Magnetic field,
$B_f = 3000T$

Radius, $r = \frac{0.02}{2} = 0.01$ m

From Faraday's law of electromagnetic induction

$$e = N\left(\frac{\Delta\phi}{\Delta t}\right) = N\,\frac{(\Delta B)A}{\Delta t} = \frac{N(B_f - B_i)\pi r^2}{\Delta t}$$

$$\Rightarrow \quad 22 = N\,\frac{2000\pi(0.01)^2}{2}$$

$\Rightarrow$ N = 70

37. **(a)** From Faraday's law of Induction
Induced

emf, $\varepsilon = -\left(\frac{d\phi}{dt}\right) = -\frac{d}{dt}(5t^2 - 36t + 1) = -(10t - 36)$

At t = 2, ε = –(10 × 2 – 36) = 16 V
Induced current,

$i = \frac{\varepsilon}{R} = \frac{16}{8} = 2$ A

38. **(b)**

39. **(c)** Average emf, $e = \frac{\text{Change in flux}}{\text{Time}} = -\frac{\Delta\phi}{\Delta t}$

$$= -\frac{0 - (4 \times (2.5 \times 2)\cos 60°)}{10} = +1V$$

40. **(b)** The charge through the coil = area of current-time ($i - t$) graph

$q = \frac{1}{2} \times 0.1 \times 4 = 0.2$ C

$q = \frac{\Delta\phi}{R}$ ∵ Change in flux ($\Delta\phi$) = $q \times R$

$q = 0.2 = \frac{\Delta\phi}{10}$, $\Delta\phi = 2$ weber

41. **(d)** $\phi = BA\cos\theta = 2.0 \times 0.5 \times \cos 60°$

$= \frac{2.0 \times 0.5}{2} = 0.5$ weber.

42. **(b)** **43.** **(d)** **44.** **(b)**

45. **(a)** $\phi = 5t^3 + 4t + 2t - 5$

$|e| = 15t^2 + 8t + 2 \quad \left[\because |e| = \frac{d\phi}{dt}\right]$

$R = 5\Omega$

So, $i = \frac{|e|}{R} = \frac{15t^2 + 8t + 2}{5} = 3t^2 + 1.6t + 0.4$

$= 3.2^2 + 1.6 \times 2 + 0.4 = 15.6$ A ($\because$ t = 2 sec)

46. **(a)** Induced e.m.f. $\varepsilon = \frac{d\phi}{dt} = \frac{dBA}{dt} = A_0\frac{dB}{dt}$

$$= A_0\left(\frac{4B_0 - B_0}{t}\right) = 3A_0B_0/t$$

47. **(c)** $\varepsilon = (5 \times 10^{-3})(1/0.1) = 0.05$ V.

48. **(a)** Change in flux = 2 B A N

$\therefore$ Induced e.m.f. $= \frac{2 \times 0.3 \times 200 \times 70 \times 10^{-4}}{0.1}$

49. **(b)** $\phi = 5t^2 + 3t + 16$

$|e| = \frac{d\phi}{dt} = \frac{d}{dt}[5t^2 + 3t + 16] = 10t + 3$

$|e|_{t=4} = 10(4) + 3 = 43$V

e = – 43Volts

50. **(b)** $\frac{d\phi}{dt} = \frac{(W_2 - W_1)}{t}$ $R_{tot} = (R + 4R)\Omega = 5R\ \Omega$

$i = \frac{nd\varphi}{R_{tot}dt} = \frac{-n(W_2 - W_1)}{5Rt}$.

($\because$ W_2 & W_1 are magnetic flux)

51. **(a)** $e = \frac{-d\phi}{dt} = \frac{-d}{dt}(6t^2 - 5t + 1) = -12t + 5$

e = – 12 (0.25) + 5 = 2 volt

$i = \frac{e}{R} = \frac{2}{10} = 0.2$A.

52. **(b)** Magnetic flux linked with the loop is $\phi = B\pi r^2$

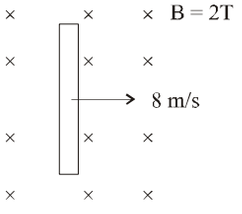
$|e| = \frac{d\phi}{dt} = B\pi \cdot 2r\frac{dr}{dt}$

When $r = 2$ cm, $\frac{dr}{dt} = 1$ mm s^{-1}

$e = 0.025 \times \pi \times 2 \times 2 \times 10^{-2} \times 10^{-3}$

$= 0.100 \times \pi \times 10^{-5} = \pi \times 10^{-6}$ V $= \pi\mu$V

53. **(d)** Given, length, ℓ = 1m
Velocity, v = 8 m/s
Magnetic Field, B = 2T
Induced emf across
the ends = Bvℓ
= 2 × 8 × 1 = 16 V



54. **(c)**

55. **(d)**

56. **(a)** Length of metal rod, l = 10 cm = 0.10 m
Induced emf = Blv

$0.08 = 0.4 \times 0.10 \times v \Rightarrow v = \frac{0.08}{0.4 \times 0.10}$ $\therefore$ $v = 2$ m/s

57. **(b)**

58. **(b)**

59. **(c)** Time taken by square loop to cross the magnetic field

$= \frac{50}{2} = 25s$

At t = 10 seconds, whole loop is inside magnetic field therefore flux will not change

$\therefore$ Induced emf, $e = \frac{d\phi}{dt} = 0$

60. **(c)**

61. **(d)** e = [Bvℓ]

$|e| = \begin{vmatrix} 3 & 3 & 2 \\ 1 & 2 & 0 \\ 0 & 0 & 1 \end{vmatrix}$ (as length of conductor is $0\hat{i} + 0\hat{j} + 1\hat{k}$)

$\therefore$ | e | = 3V

62. **(a)** If a wire, ℓ meter in length, moves perpendicular to a magnetic field of B weber/meter^2 with a velocity of v meter/second, then the e.m.f. induced in the wire is given by
V = B vℓ volt.
Here, B = 0.30×10^{-4} weber/meter^2,
v = 5.0 meter/second and ℓ = 10 meter.
$\therefore$ V = $0.30 \times 10^{-4} \times 5.0 \times 10 = 0.0015$ volt.

63. **(b)**

64. **(b)** emf induced between the two ends is given by

$e = \frac{1}{2} B_H \omega l^2 = \frac{1}{2} \times 0.2 \times 10^{-4} \times 5 \times 1^2$

$= 0.1 \times 10^{-4} \times 5 = 5 \times 10^{-5} = 50\,\mu V$

65. **(c)** The magnitude of induced e.m.f. is given by
|e| = Blv
v = 300 m/min = 5m/s

$\therefore$ $B = \frac{|e|}{lv} = \frac{2}{0.5 \times 5} = 0.8$ tesla

66. **(d)** No change in flux, hence no force required.

67. **(a)** **68.** **(d)**

69. **(d)** Since the magnetic field is uniform the flux f through the square loop at any time t is constant, because
f = B × A = B × L^2 = constant

$\therefore$ $\varepsilon = -\frac{d\phi}{dt} = $ zero

70. **(a)** In case of both the circular and the elliptical loops, the rate of change of area of the loops during their passage out of the field is not constant, hence induced emf will not remain constant for them.

71. **(d)**

72. **(a)**

73. **(c)** The induced emf in the coil is

$e = -L\left(\frac{\Delta l}{\Delta t}\right) = -L\left(\frac{l2 - l_1}{\Delta t}\right)$

$\Rightarrow 3.20 = L \times \frac{(10-2)}{0.1}$ $\therefore$ L = 0.04 H

74. **(b)** Mutual inductance of a pair of two coils depends on the relative position and orientation of two coils, other statements are incorrect.

75. **(b)** **76.** **(b)**

77. **(b)** The emf induced in the coil is given by

$\varepsilon = -L\frac{dl}{dt}$

$\therefore |\varepsilon| = 2 \times 10^{-3} \times 20 \times 10^{-3}$ V $= 40\,\mu$V

78. **(a)** $\therefore$ Induced emf in inductor is

$|\varepsilon| = L\frac{dl}{dt} = 10 \times \frac{2}{1 \times 10^{-3}} = 2 \times 10^4$ V

79. **(d)** The emf induced in a coil is given by,

$\varepsilon = -L\frac{\Delta i}{\Delta t}$ $\therefore \varepsilon = -\frac{60 \times 10^{-3} \times 1}{0.2} = 0.3$V

Induced current

$i = \frac{|\varepsilon|}{R} = \frac{0.3}{3} = 0.1$ A

80. **(a)**

81. **(d)** Emf induced in the coil,
$\varepsilon = 200 \sin 100\,\pi t$
Comparing with standard equation
$\varepsilon = \varepsilon_0 \sin \omega t$, we get
$\varepsilon_o = 200$, $\omega = 100\pi$ $\because$ BAN$\omega = \varepsilon_0$

$\therefore B = \frac{\varepsilon_0}{AN\omega} = \frac{200}{(0.25 \times 0.25) \times 1000 \times 100\,\pi} = 0.01$ T

82. **(c)** Since, coil rotates half revolution per second, hence frequency of rotation of coil,

$v = \frac{\frac{1}{2}}{1} = \frac{1}{2} = 0.5$ Hz

Emf induced,
$\varepsilon = \varepsilon_0 \sin \omega t = NBA\omega \sin \omega t$
$\varepsilon_{max} = \varepsilon_0 = NBA\omega$ ($\because \sin \omega t = 1$)
$= NBA(2\pi v)$ [$\because \omega = 2\pi v$]
$= 100 \times 0.01 \times 0.10 \times 2 \times 3.14 \times 0.5 = 0.314$ V
The maximum voltage is 0.314 V.

83. **(d)**

84. **(d)** If ε is the emf induced in the coil, then

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

$\Rightarrow \varepsilon = -NAB\frac{d}{dt}(\cos \omega t) = -NAB(-\sin \omega t)\,\omega$

$\varepsilon = NAB\omega \sin \omega t \quad \therefore \ \varepsilon_{max} = \varepsilon_0 = NAB\ \omega \times 1$

Therefore, ε would be maximum, hence current is maximum (as $i_0 = \varepsilon_0 / R$) when $\theta = 90°$, i.e., normal to plane of coil is perpendicular to the field or plane of coil is parallel to magnetic field.

85. (c)

86. (b) If resistance is constant (10 Ω), then steady current in the circuit $i = \frac{5}{10} = 0.5$ A. But resistance is increasing it means current through the circuit start decreasing. Hence, inductance comes in picture which induces a current in the circuit in the same direction of main current. So $i > 0.5$ A.

87. (d)

88. (b)

89. (a) Induced Emf is given as,

$$E_L = -L\frac{di}{dt} \Rightarrow 0.1 = \frac{(L)[+2-(-2)]}{0.2} \Rightarrow L = 5\text{mH}$$

90. (a) Given, $I = 3t + 8$, $\varepsilon = 12$ mV

$\therefore$ The marnitude of induced emf is

$$|\varepsilon| = \left|\frac{dI}{dt}\right| \Rightarrow 12 = L\left|\frac{d}{dt}(3t+8)\right| = L \times 3$$

$\therefore L = 4$mH

91. (d)

92. (b) Electric

flux, $\phi = Mi = Mi_0 \sin \omega t \quad [\because i = i_0 \sin \omega t]$

$$\therefore \ e = -M\frac{di}{dt} = -0.002(i_0 \omega \cos \omega t)$$

$e = i_0\omega\ (0.002) = (5)\ (50\pi)\ (0.002)$

$$e_{max} = \frac{\pi}{2}\text{V} = \frac{\alpha}{\pi}\text{V} \ \text{(given)} \quad \therefore \alpha = 2$$

93. (c)

94. (b) Magnetic flux, $\phi_B = B.A$

for solenoid, $B = \mu_0\ n\ I$

$\phi_B = \mu_0\ n\ I\ A$

The total magnetic flux associates with the solenoid

$\phi_B = \mu_0\ n\ I\ A \times N$

$N = n\ L = \mu\ n^2\ I\ A\ L$

$\phi = LI$

$\phi = LI = \mu_0\ n^2\ I\ A\ \ L$

Self-inductance, $L = \mu_0\ n^2\ A\ L$

95. (b) $\varepsilon = L\frac{di}{dt}$ or $8 = L\left[\frac{(4-2)}{0.05}\right]$

$$\therefore \ L = \frac{8 \times 0.05}{2} = 0.2 \text{ henry}$$

96. (b) Mutual Inductance of two coils

$$M = \sqrt{M_1 M_2} = \sqrt{2\text{mH} \times 8\text{mH}} = 4\text{mH}$$

97. (d) Given : $M = 0.75$ H and $\frac{dI}{dt} = \frac{0.5-0}{0.01} = 50$ A / s

$\therefore$ Average induced e.m.f. in secondary coil

$$e = M\frac{dI}{dt} = 0.75 \times 50 = 37.5 \text{ V}$$

98. (b) $L = \mu_0\ nI$

$$\therefore \ \frac{L_2}{L_1} = \frac{\mu}{\mu_0} \quad \text{.....}(\because \text{ n and I are same})$$

$\therefore \ L_2 = \mu_r L_1 = 900 \times 0.18 = 162$ mH

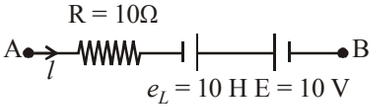
99. (a) $N\phi = LI$

$$\therefore \ \phi = \frac{LI}{N} = \frac{8\times10^{-3} \times 5\times10^{-3}}{400} = 10^{-7} = \frac{\mu_0}{4\pi}\text{ Wb}$$

100. (d) The emf across inductor is

$$e_L = \left|L\frac{dl}{dt}\right| = |5 \times (-2)| = 10\text{ V}$$

The equivalent circuit can be redrawn is



Applying Kirchhoff's law from point A to B,

$V_A - IR + e_L - E = V_B$

$\Rightarrow V_A - V_B = IR - e_L + E = 2 \times 10 - 10 + 10 = 20$ V

101. (b) Given $\frac{\ell_1}{\ell_2} = \frac{1}{2}$ and $\frac{N_1}{N_2} = \frac{1}{2}$ From

$$L = \frac{\mu_0 N^2 A}{\ell} \alpha \frac{N^2}{\ell}$$

we get, $\frac{L_1}{L_2} = \left(\frac{N_1}{N_2}\right)^2 \Big/ \left(\frac{\ell_1}{\ell_2}\right) = \frac{(1/2)^2}{1/2} = \frac{1}{2}$

102. (b) $\varepsilon = \frac{M}{dt}dI = 0.005 \times I_0 \cos\omega t \times \omega$ and $\varepsilon_{max} = 0.005 \times I_0 \times \omega$ $= 5\pi$

103. (c) $E = \frac{1}{2}Li^2 = \frac{1}{2} \times (100 \times 10^{-3}) \times 1^2 = 0.05$ J

104. (b)

105. (b) The self-inductance of a long solenoid of cross-sectional area A and length l, having n turns per unit length, filled the inside of the solenoid with a material of relative permeability is given by

$L = \mu_r\mu_0 n^2\ Al \qquad \therefore \quad n = N/l$

$$L = \mu_r\mu_0\left[\frac{N^2.A}{l.l}\right].l$$

$$L = \mu_r\mu_0\ [N^2A/l] \qquad \left(L \propto A, L \propto \frac{1}{l}\right)$$

As μ_r and N are constant here so, to increase L for a coil, area A must be increased and l must be decreased.

106. (b) The e.m.f. induced is directly proportional to rate at which flux is intercepted which in turn varies directly as the speed of rotation of the generator.

107. (b) As $\phi = NAB\cos 90° = 0$

$\varepsilon = \varepsilon_0 \sin 90° = \varepsilon_0$ = maximum

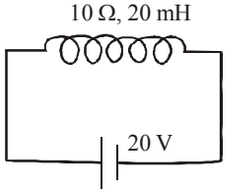
θ is the angle between the field and normal to the plane of the coil.

108. (d) Induced emf, $\varepsilon = -L\frac{dI}{dt} \Rightarrow 20 = -L\frac{(0-2)}{10^{-3}}$

Hence, inductance of the coil.

L = 10 mH

109. (a)



$$|e| = \frac{Ldi}{dt} = \frac{L(i_{initial} - 0)}{t} = \frac{LV}{Rt}$$

$$\therefore |e| = \frac{20\times10^{-3}\times20}{10\times100\times10^{-6}} = 400 \text{ V}$$

110. (d) According to Faraday's law of electromagnetic induction,

Induced emf, $e = \frac{Ldi}{dt}$

$$50 = L\left(\frac{5-2}{0.1\text{sec}}\right) \Rightarrow L = \frac{50\times0.1}{3} = \frac{5}{3} = 1.67 \text{ H}$$

111. (b) $L = \mu_0\frac{N^2}{l}A$

$$L' = \mu_0\frac{(2N)^2}{2l}A = 2\mu_0\frac{N^2}{l}A = 2L$$

112. (d)

113. (b) Self inductance $= \mu_0 n^2 AL = \mu_0 n^2(\ell\times b)\times L$

So, when all linear dimensions are increased by a factor of 2. The new self inductance becomes L′ = 8L.

114. (c) $\phi = LI \Rightarrow L = \frac{\phi}{I} = \frac{y}{x}$ henry

115. (d)

116. (c) $L = 2\text{mH}, i = t^2e^{-t}$

$$E = -L\frac{di}{dt} = -L[-t^2e^{-t} + 2te^{-t}]$$

when $e = 0$,

$-e^{-t}t^2 + 2te^{-t} = 0$ or, $2te^{-t} = e^{-t}t^2$

$\Rightarrow t = 2$ sec.

117. (c) A transformer is employed to obtain a Suitable A. C. voltage.

118. (b)

119. (a) Iron loss is the energy loss in the form of heat due to the formation of eddy currents in the iron core of the transformer.

120. (d) As primary coil made of thick copper wire has very less R. Therefore negligible power loss. Rest all options are reasons for power losses in a transformer.

Exercise 2 : ACCELERATOR
Topic-wise MCQs

1. (c) During the fall of ring, the magnetic flux associated with it increases out of the plane. By Lenz's law, a clockwise induced current is produced in the ring to oppose increase in magnetic flux through ring.

2. (a) The magnetic flux given by $\phi = \frac{2}{3}(9-t^2)$

when the flux becomes zero then $\phi = \frac{2}{3}(9-t^2) = 0$

t = 3 sec

The emf will be

$$e = \frac{-d\phi}{dt} = -\frac{2}{3}(0-2t) = \frac{4t}{3}$$

Heat produced in 3 sec $= \int_0^t \frac{e^2}{r}dt = \int_0^3 \frac{16t^2}{9\times8}dt = 2$ J

3. (b)

4. (a) From Lenz law direction of induced current can be found, induced current will oppose the decrease in outward magnetic field, by producing its own outward magnetic field.

5. (b)

6. (c) As $\phi = BA\cos\theta$

So, $\phi = \mu_0\mu_r\frac{N}{l}IA\cos0°$

$$\Rightarrow 4\pi\times10^{-6} = 4\pi\times10^{-7}\times\mu_r\times\frac{400}{0.4}\times0.4\times2\times10^{-4}$$

$$\Rightarrow \mu_r = 125$$

7. (b) As $\varepsilon|_{t=0.5\text{sec}} = -\frac{d\phi}{dt}$

$$= -A\frac{dB}{dt}\ [\because \theta = 0° \Rightarrow \cos\theta = 1]$$

$$= -\pi\times\left(\frac{10}{\sqrt{\pi}}\right)^2\times10^{-4}\times\frac{0-0.5}{0.5} = 10^{-2}\text{ V} = 10\text{ m V}$$

As $\frac{dB}{dt}$ = constant $\Rightarrow$ Induced emf will not change with time. So, $e|_{0.5\text{sec}} = e|_{0.25\text{sec}} = 10$ mV

8. (c) If plane of coil makes angle 60° with field, then angle between $\vec{B}$ and $\vec{A}$ at that instant is 30°

$$e = -\frac{Nd\phi}{dt} = -N\frac{d}{dt}(BA\cos\omega t) = NBA\omega\sin\omega t$$

$$= 600\times0.4\times70\times10^{-4}\times2\pi\times\frac{500}{60}\sin30° \simeq 44\text{ V}$$

9. (b) Induced emf is given by

$$|\varepsilon| = \left|-\frac{dt}{dt}\right| = \left|-\frac{dB.A}{dt}\right| = \frac{0.25\times0.2}{10^{-4}} = 500\text{ V}$$

Current, $I = \frac{V}{R} = \frac{500}{20} = 25A$

10. (a) Given : n = 10 turns, $R_{coil} = 20\Omega$, $R_G = 30\Omega$,

Total resistance in the circuit = 20 + 30 = 50Ω.

$A = 10^{-2}\ m^2$, $B = 10^{-2}\ T$, $\phi_1 = 0°$, $\phi_2 = 60°$

$$q = \frac{\phi_1 - \phi_2}{R} = \frac{BnA\cos\theta_1 - BnA\cos\theta_2}{R}$$

$$= \frac{BnA(\cos 0 - \cos 60)}{R} = \frac{BnA(1-0.5))}{R} = 1 \times 10^{-5}\ C$$

11. **(a)** Area of the loop = $0.1 \times 0.1 = 0.01\ m^2$

$$\varepsilon = -\frac{d\phi}{dt} = \frac{-d}{dt}(BA)$$

Magnitude of emf

$$\varepsilon = A\frac{dB}{dt} = (0.01 m^2)\,(0.02\ T/s) = 2\times10^{-4}\ V$$

Resistance of the loop is

$$R = \rho\frac{\ell}{A} = \frac{1.7\times10^{-8}\times40\times10^{-2}}{3.14\times10^{-6}} = 2.16 \times 10^{-3}\ \Omega$$

Current induced in the loop

$$I = \frac{\varepsilon}{R} = \frac{2\times10^{-4}\ V}{2.16\times10^{-3}\Omega} = 9.3\times10^{-2}\ amp.$$

12. **(a)**

13. **(b)** $\phi = \vec{B}\cdot\vec{A}$

$$= BA\cos 0° = 2\times\frac{1}{2}\times2\times1\times10^{-4} = 2 \times 10^{-4}\ Wb$$

14. **(d)**

15. **(a)** Given, magnetic field, B = 0.01T

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

$$Emf, e = -N\frac{d\phi}{dt} = -N\frac{d}{dt}(BA\sin\omega t) = -NBA\omega\cos\omega t$$

So, $e_{max} = NBA\omega = NBA(2\pi f)$

$$= 100\times0.01\times2\times10^{-2}\times2\times\frac{22}{7}\times50 = 6.28\ V.$$

16. **(b)** Induced emf is given by

$$|\varepsilon| = \left|-\frac{dt}{dt}\right| = \left|-\frac{dB.A}{dt}\right| = \frac{0.25\times0.2}{10^{-4}} = 500\ V$$

Current, $I = \frac{V}{R} = \frac{500}{20} = 25A$

17. **(a)** $\phi = 5t^3 + 4t + 2t - 5$

$$|e| = 15t^2 + 8t + 2 \quad \left[\because |e| = \frac{d\phi}{dt}\right]$$

$R = 5\Omega$

So, $i = \frac{|e|}{R} = \frac{15t^2+8t+2}{5} = 3t^2 + 1.6t + 0.4$

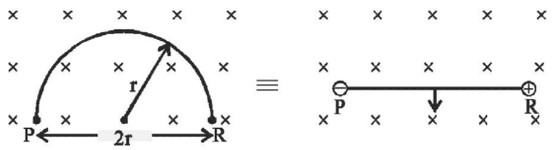
$= 3.2^2 + 1.6 \times 2 + 0.4 = 15.6\ A$ ($\because$ t = 2 sec)

18. **(d)** Rate of decrease of area of semicircular ring

$$= \frac{dA}{dt} = (2r)V$$

From Faraday's law of electromagnetic induction

$$e = -\frac{d\phi}{dt} = -B\frac{dA}{dt} = -B(2rV)$$



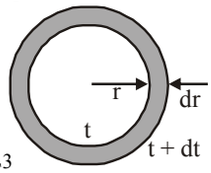
As induced current in ring produces magnetic field in upward direction hence R is at higher potential.

19. **(d)** Given that $\phi = at\,(T - t)$

Induced emf, $E = \frac{d\phi}{dt} = \frac{d}{dt}[at(T-t)]$

= at (0 – 1) + a (T – t) = a (T – 2t)

So, induced emf is also a function of time.



∴ Heat generated in time T is

$$H\int_0^T \frac{E^2}{R}dt = \frac{a^2}{R}\int_0^T (T-2t)^2\,dt = \frac{a^2T^3}{3R}$$

20. **(b)** Motional emf developed in the small element *dl* is given by

$de = B\,v\,dl$

Total emf :

$$\varepsilon = \int de = \int_0^L B\omega l\,dl = B\omega\int_0^L ldl = \frac{1}{2}B\omega L^2.$$

21. **(c)** Given, area of rectangular coil, $A = 14 \times 10^{-2}\ m^2$

Magnetic field, B = 3T

Number of turns, n = 100

$$\varepsilon_{max} = NAB\omega = 100\times14\times10^{-2}\times3\times\frac{360\times2\pi}{60} = 1584\ V$$

22. **(b)** $V_{centre} - V_{rim}$

$$= \frac{1}{2}BR^2\omega = \frac{1}{2}\times5\times10^{-3}\times(.05)\times(0.25)\times130$$

= 0.02 V = 20 mV

23. **(a)** According to right hand palm rule, the Lorentz force on free electrons in the conductor will be directed towards end B. Hence, the end A gets positively charged.

24. **(b)** When metal ball is passing through magnetic field, eddy current will produce and it will oppose the motion, so it will take more time.

25. **(a)** Vel. of coil $= \frac{1}{0.5} = 2m/s$

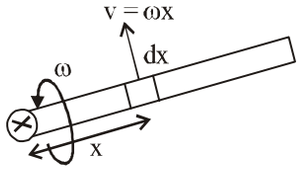
velocity of magnet $= \frac{2}{1} = 2m/s.$

As they are made to move in the same direction, their relative velocity is zero. Therefore, induced e.m.f. = 0.

26. **(a)** Potential difference between two faces perpendicular to x-axis

$$= l\ V.B = 2\times10^{-2}\,(6\times0.1) = 12mV$$

27. **(c)**



$$\Rightarrow \quad \int d\varepsilon = \int B(\omega x)\,dx \;\Rightarrow\; \varepsilon = B\omega\int_0^L x\,dx = \frac{B\omega L^2}{2}$$

28. **(d)** Magnetic energy stored in an inductor

$$U = \frac{1}{2}Li^2 = \frac{1}{2} \times 4 \times 10^{-6} \times (2)^2 = 8 \times 10^{-6}\ \text{J} = 8\ \mu\text{J}$$

29. **(c)** From question energy stored in inductor,
$U = 25 \times 10^{-3}$ J
Current, I = 60 mA

Energy stored in inductor $U = \frac{1}{2}LI^2$

$$25 \times 10^{-3} = \frac{1}{2} \times L \times (60 \times 10^{-3})^2$$

$$L = \frac{25 \times 2 \times 10^6 \times 10^{-3}}{3600} = 13.89\ \text{H}$$

30. **(c)** Magnetic flux $\phi = n\phi_0 = 500 \times 4 \times 10^{-3} = 2$ Wb
Magnetic flux, $\phi = LI$
$\therefore$ Self inductance of solenoid,

$$L = \frac{\phi}{I} = \frac{2}{2}\frac{\text{Wb}}{\text{A}} = 1\text{H}$$

31. **(b)** $\frac{dI}{dt} = \frac{4-3}{40-20} = \frac{1}{20}$
Induced emf is given by:

$$e = L\frac{dI}{dt} \Rightarrow e = \frac{6 \times 10^{-3}}{20} = 3 \times 10^{-4}\ \text{V}$$

32. **(a)** Magnetic energy per unit volume is given as :

$$U_B = \frac{1}{2}\frac{B^2}{\mu_0} = \frac{1}{2}\frac{(\mu_0 nI)^2}{\mu_0} = \frac{\mu_0 n^2 I^2}{2} \quad [\because B = \mu_0 nI]$$

$= 2\pi \times 10^{-7} \times (4 \times 10^3)^2 \times 1^2 = 3.2\pi$ J m^{-3}

33. **(a)** Induced $\text{emf} = \frac{\text{Mdi}}{\text{dt}} = \frac{.5 \times (7-3)}{.04} = 50\text{V}$

34. **(b)** According to faraday's law of electromagnetic induction, $e = \frac{-d\phi}{dt}$

$$L \times \frac{di}{dt} = 25 \Rightarrow L \times \frac{15}{1} = 25 \text{ or } L = \frac{5}{3}\text{H}$$

Change in the energy of the inductance,

$$\Delta E = \frac{1}{2}L\left(i_1^2 - i_2^2\right) = \frac{1}{2} \times \frac{5}{3} \times (25^2 - 10^2) = \frac{5}{6} \times 525 = 437.5\text{J}$$

35. **(d)** The rate of mutual inductance is given by

$$M = \mu_0 n_1 n_2 \pi r_1^2 \quad \text{...(i)}$$

The rate of self inductance is given by

$$L = \mu_0 n_1^2 \pi r_1^2 \quad \text{...(ii)}$$

Dividing (i) by (ii)

$$\Rightarrow \frac{M}{L} = \frac{n_2}{n_1}$$

36. **(c)** $L = \mu_0 n^2 A l$
$L \propto l$

$$\therefore \quad \frac{L_2}{L_1} = \frac{l_2}{l_1} \Rightarrow L_2 = 3L_1 \qquad [\because l_2 = 3l_1]$$

37. **(c)** Induced emf,

$$e = L\frac{dI}{dt} = L\frac{\Delta I}{\Delta t} = 8 \times 10^{-3} \times \frac{2}{0.1} = 16 \times 10^{-2}\ \text{V}$$

38. **(a)** $\phi_Q \propto i_P, \phi_p \propto i_Q \qquad \therefore \frac{\phi_Q}{\phi_P} = \frac{i_P}{i_Q}$

$$\phi_P = \frac{i_Q}{i_P}\phi_Q = \frac{2}{3} \times 10^{-3} = 6.67 \times 10^{-4}\ \text{Wb}$$

39. **(b)**

40. **(a)** Primary voltage $V_P = 220$ V
Secondary voltage $V_S = \frac{P}{i} = \frac{60}{0.11} = 545.45$ V
Hence step-up transformer.

41. **(d)** In step up transformer the output voltage is greater than input voltage because the number of turns is more at the output. Therefore $V_2 > V_1$
Input power is equal to output power.
$\therefore P_1 = P_2$
Hence (d) is correct.

42. **(d)** The transformer converts A.C. high voltage into A.C. low voltage, but it does not cause any change in frequency. The formula for voltage is

$$E_s = \frac{N_s}{N_p} \times E_p = \frac{5000}{500} \times 20 = 200\text{V}$$

Thus, output has voltage 200 V and frequency 50 Hz.

43. **(d)** A transformer is essentially an *AC* device. *DC* source so no mutual induction between coils
$\Rightarrow E_2 = 0$ and $I_2 = 0$

44. **(a)** Given:
Voltage in primary coil, $V_P = 200$ V
Current in primary coil, $i_p = 2$ A
Voltage in secondary coil, $V_s = 2000$ V
The relation for the current in the secondary coil is

$$\frac{V_s}{V_P} = \frac{i_p}{i_s} \Rightarrow \frac{2000}{200} = \frac{2}{i_s} = \frac{2 \times 200}{2000} = 0.2\ \text{A}$$

Exercise 3 : PREVIOUS YEARS MCQs

1. **(b)** $\frac{n_p}{n_s} = \frac{E_p}{E_s} = \frac{1}{25} \quad \therefore E_s = 25\ E_p$

But $E_s I_s = E_p I_p \Rightarrow I_p = \frac{E_S \times I_S}{E_p} \Rightarrow I_p = 50\text{A}$

2. **(a)** $\phi = 5t^3 + 4t + 2t - 5$

$$|e| = 15t^2 + 8t + 2 \qquad \left[\because |e| = \frac{d\phi}{dt}\right]$$

$R = 5\Omega$

So, $i = \frac{|e|}{R} = \frac{15t^2 + 8t + 2}{5} = 3t^2 + 1.6t + 0.4$

$= 3.2^2 + 1.6 \times 2 + 0.4 = 15.6$ A $\quad (\because t = 2$ sec)

3. **(b)** Mutual inductance depends on the relative position and orientation of the two coils.

4. **(a)** Given, resistance of coil = 16Ω

Magnetic flux, $\phi = 5t^2 + 4t + 2$

Induced emf is given by

$$\varepsilon = -\frac{d\phi}{dt}$$

Differentiate $\phi(t)$ $\frac{d\phi}{dt} = \frac{d}{dt}(5t^2 + 4t + 2) = 10t + 4$

Now substitute t = 6s

$$\frac{d\phi}{dt} = 10 \times 6 + 4 = 64$$

Induced emf, $|\varepsilon| = 64$ (in 10^{-3} weber/second)

$= 64 \times 10^{-3}$ volt

Use Ohm's law, $I = \frac{\varepsilon}{R} = \frac{64 \times 10^{-3}}{16} \Rightarrow I = 4$ mA

5. **(d)** Magnetic flux linked write a coil

$\phi = NB\cos\theta$

Since the magnetic field B is parallel to the area A

$\phi = NB \cos 90°$

$\phi = 0$

6. **(a)** Given,

Area of circular coil, $A = 3 \times 10^{-2}$ m^2

Number of turns, n = 900

Resistance, R = 1.8 Ω

Magnetic field, $B = 3.5 \times 10^{-5}$T

Change in flux, $\phi = 2BAN$

$= 2 \times 3.5 \times 10^{-5} \times 3 \times 10^{-2} \times 900 = 189 \times 10^{-5}$

$$\text{EMF, } E = \frac{d\phi}{dt} = \frac{189 \times 10^{-5}}{\frac{1}{2}} = 378 \times 10^{-5}\text{V}$$

Current,

$$I = \frac{E}{R} = \frac{378 \times 10^{-5}}{1.8} = 210 \times 10^{-5} = 2.1\text{mA}$$

7. **(b)** R = 8Ω, N = 250, $A = 1.2 \times 10^{-2}$m^2, B = 2T

Angle between plane of coil and $\vec{B}$

$$\theta_1 = \frac{\pi}{L},$$

So, normal makes angle $(\alpha_1) = \frac{\pi}{3}$

Final position: plane is parallel to magnetic field normal is perpendicular

$$\alpha_2 = \frac{\pi}{2}$$

$\Delta t = 100$ ms $= 0.1$S

Initial flux:

$$\phi_1 = NBA\cos\left(\frac{\pi}{3}\right) = 250 \times 2 \times (1.2 \times 10^{-2}) \times \frac{1}{2} = 3 \text{ Wb}$$

Final flux:

$$\phi_2 = NBA\cos\left(\frac{\pi}{2}\right) = 0$$

$$\varepsilon = \frac{|\phi_2 - \phi_1|}{\Delta t} = \frac{3-0}{0.1} = 30\text{V}$$

$$I = \frac{30}{8} = 3.75 \text{ Ampere}$$

8. **(c)** Given: Resistance R = 7.5 Ω, $\phi = 2t^2 + 3t - 2$,

t = 3s

Power = P = ?

$$e = -\frac{d\phi}{dt} = -\frac{d}{dt}(2t^2 + 3t - 2) = -(4t + 3)$$

$$\therefore |e| = 4 \times 3 + 3 - 15\text{V}$$

$$\therefore P = \frac{e^2}{R} = \frac{15 \times 15}{7.5} = 30\text{W}$$

9. **(a)** $\varepsilon = L\frac{dI}{dt} \Rightarrow L = \frac{\varepsilon \Delta t}{\Delta I}$

$$\Rightarrow \quad L = \frac{2.8 \times 10^{-3} \times 0.3}{5} = \frac{0.56 \times 10^{-3}}{5}$$

$$\Rightarrow \quad L = 1.12 \times 10^{-4} \Rightarrow \boxed{L = 112\ \mu\text{H}}$$

10. **(c)** For a coil, L = 80 mH = 80×10^{-3}H, I = 2.5A

$$\therefore \text{ Energy stored, } E = \frac{1}{2}LI^2 = \frac{1}{2} \times 80 \times 10^{-3} \times 2.5 \times 2.5$$

$= 0.25$ J

11. **(a)** For two coils,

M = 8mH, $I_1 = 12\sin 100t$

$$l_2 = M.\frac{dI_1}{dt} = M\frac{d}{dt}(12\sin 100t) = 1200M\cos 100t$$

$$\therefore \quad (l_2)_{max} = 1200M = 1200 \times 8 \times 10^{-3} = 9.6 \text{ V}$$

12. **(d)** Magnetic energy per unit volume

$$= \frac{B^2}{2\mu_r u_0} \Rightarrow U = \frac{B^2}{4\mu_0}V = \frac{B^2}{4\mu_0}A\ell \left[\because \mu_r = 2\right]$$

13. **(a)** Given,

Initial Magnetic field, $B_i = 5000$T

Final Magnetic field, $B_f = 3000$T

$$\text{Radius, } r = \frac{0.02}{2} = 0.01 \text{ m}$$

From Faraday's law of electromagnetic induction

$$e = -N\left(\frac{\Delta\phi}{\Delta t}\right) = -N\frac{(\Delta B)A}{\Delta t} = \frac{N(B_i - B_f)\pi r^2}{\Delta t}$$

$$\Rightarrow \quad 22 = N\frac{2000\pi(0.01)^2}{2} \quad \Rightarrow \quad N = 70$$

14. **(a)** Induced Emf is given as,

$E_L = -L\frac{di}{dt}$

$\Rightarrow 0.1 = \frac{(L)[+2-(-2)]}{0.2} \Rightarrow L = 5mH$

15. **(c)** Area of Loop (A) = $(side)^2 = (0.1)^2 = 0.01\ m^2$

Induced emf $= N\frac{d\phi}{dt}$

where $\phi = B.A$

$\frac{d\phi}{dt} = A.\frac{d_B}{dt} \Rightarrow emf = NA\frac{d_B}{dt}$

$emf = 100 \times 0.01 \times 0.7 = 0.7V$

16. **(b)** To find EMF;

Induced EMF (Faraday's Law):

$\varepsilon = \left|\frac{d\phi}{dt}\right|$

$\frac{d\phi}{dt} = \frac{d}{dt}(Sot^2 + 4) = 100t$

At t = 2s: $\varepsilon = 100 \times 2 = 200$ V

Use Ohm's law to find current

$I = \frac{\varepsilon}{R} = \frac{200}{200} = 1A$

17. **(d)** For metallic disc, r = 0.3m,w = 60 rad/s

$B = 5 \times 10^{-2}$ T

The emf induced between a point on rim and centre of the disc is

$e = \frac{1}{2}Bw\ell^2 = \frac{1}{2} \times 5 \times 10^{-2} \times 60 \times 0.3 \times 0.3$

= 0.135V

18. **(c)** Induced EMF $(E) = N \times \frac{d\phi}{dt}$

N = 45, $\Delta t = 220s$

$B_f = 0.70T$, $B_i = 0T$

$A = \pi \times (0.04)^2 = \pi \times 0.0016$

change in magnetic flux

$\frac{d\phi}{dt} = \frac{0.0016\pi \times 0.70}{220}$

$\varepsilon = \frac{45 \times 0.0016\pi \times 0.70}{220} = \frac{0.1583}{220}$

$\varepsilon = 7.2 \times 10^{-4}$ V

$\boxed{\varepsilon = 0.72mv}$

19. **(b)** Given, $\Delta I = 5 - 2 = 3A$, $\Delta t = 0.35$, e = 40 mv

= 40 10–3V

$e = \frac{-d}{dt} = -L\frac{dI}{dt}$

$\therefore L = \frac{40 \times 10^{-3}}{\frac{3}{0.3}} = 4 \times 10^{-3} = 4mH$

20. **(a)** Self inductance $(L) = \frac{\mu_o N^2 A}{\ell}$

$A = \pi \times (0.035)^2 = \pi \times 0.001225 \approx 3.85 \times 10^{-3}\ m^2$

$L = \frac{4\pi^2 \times 49}{0.4} \times 10^{-7}$

$L = 490 \times \pi^2 \times 10^{-7}$ H

$\boxed{L = 484\ \mu H}$

21. **(b)** When a coil is rotated in an uniform magnetic field, then Induced emf, e_{max} = N B A W

$= 50 \times 2 \times 10^{-2} \times 200 \times 10^{-4} \times 40 = 0.8$ V

22. **(c)** Given

Length of a × ℓe = 1.66m

Speed of train, v = 90 km $h^{-1} = \frac{90 \times 1000}{60 \times 60} = 25$ m/s

Vertical component of magnetic field, $Bv = 0.2 \times 10^{-4}$T

Emf induced, e = Bv ℓV

$= 0.2 \times 10^{-4} \times 1.66 \times 25$

$= 8.3 \times 10^{-4}$ V = 0. 83 mV

23. **(c)** Mutual inductance of two concentric circular coils of radii r_1 and r_2 $(r_1 << r_2) = M = \frac{\mu_0 \pi r_1^2}{2r_2}$

24. **(c)** Consider a small radial segment of dx at a distance from the centre of the disc.

Velocity of this segment, v = ωx

emf induced across this segment

$d\in = Blv = B\ x\omega\ dx$

Total emf induced across radius of disc r.

$\in = \int_0^r Bx\,\omega dx = \frac{B\omega r^2}{2}$

Here, B = 0.1 T w = 10 revolution/s = 20π rads.

r = 0.1 m

$\in = \frac{0.1 \times 20\pi \times (0.1)^2}{2} = \pi \times 0.1 \times 0.1$

$\in = 10\pi$ mv.

25. **(b)** Emf is related to mutual inductance

$\varepsilon = M\frac{dI}{dt} \Rightarrow 120 = M \times \frac{10-2}{0.2}$

Mutual inductance, $M = \frac{120 \times 0.2}{8} = 3H$

13 A.C. Circuits

Exercise 1 : WARM-UP
Topic-wise MCQs

1. **(b)** $V = V_0 \sin \omega t$

Voltage in r.m.s. value

$V_0 = \sqrt{2} \times 234\,V = 331$ volt

and $\omega t = 2\pi n t = 2\pi \times 50 \times t = 100\pi t$ **f**

Thus, the equation of line voltage is given by

$V = 331 \sin (100\,\pi\, t)$

2. **(d)** Alternating current cannot be measured by D.C. ammeter because average value of A.C. for complete cycle is zero.

3. **(a)** $E = 8 \sin \omega t + 6 \sin 2\omega t$

$\Rightarrow E_{peak} = \sqrt{8^2 + 6^2} = 10$ V

$E_{rms} = \dfrac{10}{\sqrt{2}} = 5\sqrt{2}$ V

4. **(b)** $\dfrac{I_0}{\sqrt{2}}$ = RMS current

5. **(c)** $i = 3 \sin \omega t + 4 \cos \omega t$

$= 5\left[\dfrac{3}{5}\sin \omega t + \dfrac{4}{5}\cos \omega t\right] = 5\,[\sin(\omega t + \delta)]$ ...(i)

$\Rightarrow$ rms value $= \dfrac{5}{\sqrt{2}}$ $\Rightarrow$ mean value $= \dfrac{\int_{T_1}^{T_2} i\,dt}{\int_{T_1}^{T_2} dt}$

$\therefore$ initial value is not given hence the mean value will be difference for various time intervals.

If voltage applied is $V = V_m \sin \omega t$ then i given by eq. (i) indicates that it is ahead of V by δ where $0 < \delta < 90°$ which indicates that the circuit contains R and C.

6. **(a)** **7.** **(d)**

8. **(d)** $R = 20\Omega$, $V = 200 \sin(10\pi t)$

$\therefore$ $I = \dfrac{V}{R} = 10 \sin(10\pi t)$ .....(i)

$\therefore$ $I_o = 10$, $I_{rms} = \dfrac{I_o}{\sqrt{2}} = \dfrac{10}{\sqrt{2}}$

$\therefore$ From equation (i),

$10 = 10\sin(10\pi t_1) \Rightarrow \sin(10\pi t_1) = \sin\dfrac{\pi}{2}$ $\therefore$ $t_1 = \dfrac{1}{20}$s

Again, $\dfrac{10}{\sqrt{2}} = 10\sin(10\pi t_2)$

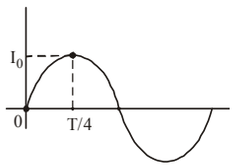
$\Rightarrow$ $\sin(10\pi t_2) = \sin\dfrac{\pi}{4}$ $\therefore$ $t_2 = \dfrac{1}{40}$s

$\therefore$ $\Delta t = t_1 - t_2 = \dfrac{1}{20} - \dfrac{1}{40} = \dfrac{1}{40} = 2.5 \times 10^{-2}$s

9. **(d)** We have

$\omega = 120\pi$

and, $T = \dfrac{2\pi}{\omega} = \dfrac{2\pi}{120\pi} = \dfrac{\pi}{60\pi} = \dfrac{1}{60}$



So, req. time $= \dfrac{T}{4} = \dfrac{1}{240}$ s

10. **(a)** $2\pi nt = 400\pi t$ $\therefore$ $n = 200$

$I_0 = 50\sqrt{2}$ amp.

r.m.s. current = $I_0/\sqrt{2} = 50$ amp.

11. **(a)** As $i = (2 \sin \omega t + 6 \cos \omega t)$A

$i = \sqrt{2^2 + 6^2}\left[\dfrac{2}{\sqrt{2^2+6^2}}\sin \omega t + \dfrac{2}{\sqrt{2^2+6^2}}\cos \omega t\right]$

$= \sqrt{40}\ [\cos\theta \sin \omega t + \sin\theta \cos \omega t]$,

where $\cos\theta = \dfrac{2}{\sqrt{40}}$ and $\sin\theta = \dfrac{6}{\sqrt{40}}$

$i = \sqrt{40} \sin(\omega t + \theta)$

$\therefore$ $i_{rms} = \dfrac{i_0}{\sqrt{2}} = \dfrac{\sqrt{40}}{\sqrt{2}} = 2\sqrt{5}$A

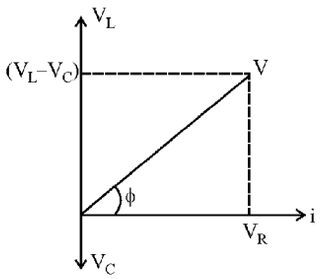
12. **(a)** Peak value, $I_0 = \dfrac{e_o}{R}$

13. **(c)**

14. **(c)** When resistance is connected to A.C source, then current & voltage are in same phase.

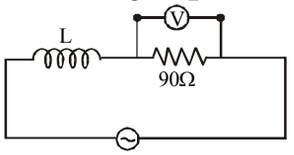
15. **(a)** The phase difference between the current and the voltage in the series LCR circuit is

$\tan\phi = \dfrac{X_L - X_C}{R}$ ... (i)



And from phasor diagram, if the current is leading the voltage, then the phase difference should be negative. so from eq. (i) $X_C > X_L$

16. (a)



Using ohm's law, $V = I_{rms}R$

$36 = I_{rms}R$

$$36 = \frac{120}{\sqrt{X_L^2 + R^2}} \times R \quad \left[\because I_{rms} = \frac{V}{\sqrt{X_L^2 + R^2}}\right]$$

$$36 = \frac{120 \times 90}{\sqrt{X_L^2 + 90^2}}$$

$$\sqrt{X_L^2 + 90^2} = 300$$

$X_L = 286.18 \quad [\because X_L = \omega L]$

$$= \omega L = 286.18 \; L = \frac{286.18}{376.8} \Rightarrow L = 0.76 \text{ H}$$

17. (c) Since resonance frequency is unchanged ω' = ω

$$\frac{1}{\sqrt{L'C'}} = \frac{1}{\sqrt{LC}} \Rightarrow L'C' = LC \Rightarrow L'(4C) = LC \Rightarrow L' = \frac{L}{4}$$

New Inductance should be decreased by

$$L - L' = L - \frac{L}{4} = \frac{3L}{4}$$

18. (b) At resonance reactance, Z = R

$$\therefore \text{ Current } I = \frac{V}{R} = \text{maximum}$$

When resistance, $R' = \frac{R}{2}$

Current, $I' = \frac{V}{R'} = \frac{2V}{R} = 2I$

19. (a) In First case

Current, $I = \frac{V}{R} = \frac{20}{R} \Rightarrow R = \frac{20}{5} = 4\Omega$

In second case

Current, $i = \frac{20}{Z}$

$$\Rightarrow \quad 4 = \frac{20}{\sqrt{R^2 + X_L^2}} \Rightarrow \sqrt{R^2 + X_L^2} = 5$$

$$\Rightarrow \quad R^2 + X_L^2 = 25 \Rightarrow X_L = 3\Omega$$

$$\Rightarrow \quad L = \frac{3}{2\pi f} = \frac{1}{2 \times 50} = \frac{1000}{100} \text{mH} \Rightarrow L = 10 \text{ mH}$$

20. (a) In resonance frequency is given by:

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$f_0 = \frac{1}{2\pi\sqrt{100 \times 10^{-3} \times 2.5 \times 10^{-9}}} = \frac{1}{2\pi\sqrt{25 \times 10^{-11}}}$$

$= 10 \times 10^3$ Hz

21. (b) $(V_{rms})_c = i_{rms}X_c = \frac{V_{rms}}{\sqrt{(X_L - X_c)^2 + R^2}} X_c$

Now, $X_c = \frac{1}{\omega C} = 500\Omega$ & $X_L = \omega L = 100\Omega$

$$\therefore \; (V_{rms})_c = \frac{50}{\sqrt{(500-100)^2 + 300^2}} \times 500 = 50 \text{ V}$$

22. (b) Voltage across inductor, $V_L = IX_L = I\omega L$

$$\therefore I = \frac{V_L}{\omega L} = \frac{V_L}{2\pi f L} = \frac{31.4}{2\pi \times 50 \times 10 \times 10^{-3}} = 10\text{A}$$

23. (c) Phase difference (ϕ) between current and voltage

$$\tan\phi = \frac{X_C - X_L}{R}$$

At resonance, $X_C = X_L$

$\therefore \tan\phi = 0$ or $\phi = \tan^{-1}(0) = 0°$

Thus the current and voltage are in phase.

The current is maximum and the impedance is minimum at resonance in an LCR circuit.

24. (a) In an *LR* circuit phase difference is given by

$$\tan\phi = \frac{X_L}{R} = \frac{\frac{1}{\sqrt{3}}}{1} = \frac{1}{\sqrt{3}} = \phi = \frac{\pi}{6}$$

So, $2\pi\upsilon\Delta t = \frac{\pi}{6}$ (where, Δt is time lag)

$$\Delta t = \frac{\pi}{6 \times 2 \times \pi \times 50} = \frac{1}{600}\text{s}$$

25. (a) Inductive capacitance is given by :

$$X_C = \frac{1}{\omega C} = \frac{1}{100 \times 10^{-5}} = 1000\Omega$$

The rms value of current is :

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{V_0}{\sqrt{2}Z} = \frac{50\sqrt{2}}{\sqrt{2} \times 1000} = 0.05 \text{ A} = 50 \text{ mA}$$

26. (c)

27. (a) Inductive reactance is given by :

$X_L = 2\omega L = 2\pi\upsilon L \quad (\because \omega = 2\pi\upsilon)$

Since $X_L \propto \upsilon$ the graph is a straight line.

28. (a) Inductive reactance, $X_L = \omega L = 1000 \times 0.9 = 900$ H

Capacitive reactance,

$$X_C = \frac{1}{\omega C} = \frac{1}{1000 \times 2 \times 10^{-6}} = 500\,\text{F}$$

$$\therefore \text{ Impedance } Z = \sqrt{(300)^2 + (500 - 900)^2} = 500\ \Omega$$

29. (b) Impedance $Z = \sqrt{R^2 + X_c^2}$

$$X_c = \frac{1}{\omega C} = \frac{1}{2\pi \times 50 \times \frac{25}{\pi} \times 10^{-6}} = 400\Omega$$

$$\therefore \quad Z = \sqrt{300^2 + 400^2} = 500\Omega$$

Current $i = \frac{V}{Z} = \frac{200}{500} = 0.4\text{A}$

30. **(a)** We have

$X_L = \omega L \Rightarrow X_L = 2\pi fL = 2\pi \times \frac{628}{2\pi} \times 5 \times 10^{-3} = 3.14\,\Omega$

31. **(d)** Impedance of the series LCR circuit

$= \sqrt{R^2 + (X_L - X_C)^2}$

32. **(a)** Given,

Capacitive reactance, $X_C = 100\ \Omega$

Inductive reactance, $X_L = 200\ \Omega$

Resistance, $R = 100\ \Omega$

Impedance, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$Z = \sqrt{100^2 + (200-100)^2} = 100\sqrt{2}\ \Omega$

RMS value of current, $i_{rms} = \frac{V_{rms}}{Z} = \frac{200\sqrt{2}}{100\sqrt{2}} = 2A$

33. **(a)**

34. **(c)** Voltage E of the ac source

$E = V_C - V_L = 400\ V - 300\ V = 100\ V$

35. **(b)** In resonance $X_L = X_C$

voltage $V = V_L - V_C = 0$

current $I = \frac{V}{R} = \frac{90}{45} = 2\,A$

36. **(a)** Capacitance of wire,

$C = 0.014 \times 10^{-6} \times 200 = 2.8 \times 10^{-6}\ F = 2.8\ \mu F$

For impedance of the circuit to be minimum, $X_L = X_C$

$\Rightarrow \quad 2\pi vL = \frac{1}{2\pi vC}$

$\Rightarrow \quad L = \frac{1}{4\pi^2 v^2 C} = \frac{1}{4(3.14)^2 \times (5\times10^3)^2 \times 2.8 \times 10^{-6}}$

$= 0.35 \times 10^{-3} H = 0.35\ mH$

37. **(c)** From phasor diagram, it is clear that current is lagging with respect to E_{rms}. This may be happen in LCR or LR circuit.

38. **(d)** $V_{rms}\,(6\Omega) = 3V = 6I_V \quad \therefore I_V = 0.5\ A$

$I_V = \frac{1}{2} = \frac{5}{\sqrt{6^2 + X_L^2}} \Rightarrow X_L = 8\Omega$

Now, $V_L = I_V \cdot X_L = \frac{1}{2} \times 8 = 4V$

39. **(a)** In series L-C-R circuit, supply voltage will be

$V_{rms} = \sqrt{V_R^2 + (V_L - V_C)^2} = \sqrt{(40)^2 + (60-30)^2}$

$= \sqrt{1600 + 900} = \sqrt{2500} = 50\ V$

40. **(d)** For the first circuit, $i = \frac{V}{X_L} = \frac{V}{\omega L} \Rightarrow i \propto \frac{1}{\omega}$

For the second circuit, $i = \frac{V}{X_C} = \frac{V}{\frac{1}{\omega C}} = \omega CB \Rightarrow i \propto \omega$

Hence, if the frequency ω of the emf of AC is increased, the value of current will decrease in the first circuit and increase in the second circuit.

41. **(b)** Given, $V_m = 300\ V$, $\omega = 400\ rads^{-1}$

$R = 3\Omega$, $L = 20\ mH = 20 \times 10^{-3}\ H$

and $C = 625\ \mu F = 625 \times 10^{-6}\ F$.

The impedance of the circuit, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

Here, $X_L = \omega L = 400 \times 20 \times 10^{-3} = 8\Omega$

And $X_C = \frac{1}{\omega C} = \frac{1}{400 \times 625 \times 10^{-6}} = 4\Omega$

$\Rightarrow Z = \sqrt{(3)^2 + (8-4)^2} = 5\Omega$

$\therefore$ Peak current, $i_m = \frac{V_m}{Z} = \frac{300}{5} = 60\ A$

42. **(a)** Given, $R = 300\Omega$, $L = \left(\frac{1}{\pi}\right) H$,

$V = 20\ V$ and $v = 200\ Hz$

If ϕ is the phase difference between V and I for R-L circuit, then

$\tan\phi = \frac{\omega L}{R} = \frac{2\pi vL}{R} = \frac{2\pi \times 200}{300} \times \frac{1}{\pi} = \frac{4}{3}$

$\Rightarrow \phi = \tan^{-1}\left(\frac{4}{3}\right)$

43. **(a)** Given, $L = 8\ mH = 8 \times 10^{-3}\ H$,

$C = 20\ \mu F = 20 \times 10^{-6}\ F$, $R = 44\ \Omega$ and $V_{rms} = 220\ V$

Angular resonant frequency of series L- C-R circuit,

$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8\times10^{-3} \times 20 \times 10^{-6}}} = 2500\ rads^{-1}$

Resonant current $= \frac{V_m}{R} = \frac{V_{rms}\sqrt{2}}{R} = \frac{220\sqrt{2}}{44} = 5\sqrt{2}A$

44. **(b)** Wattless current flow in a circuit only when circuit is resistanceless i.e. circuit is purely capacitive or inductive.

45. **(d)** Since the phase difference between L & C is π

$\therefore$ net voltage difference across LC $= 50 - 50 = 0$

46. **(c)** Impedance at resonant frequency is minimum in series LCR circuit.

So, $Z = \sqrt{R^2 + \left(2\pi fL - \frac{1}{2\pi fC}\right)^2}$

When frequency is increased or decreased, Z increases.

47. **(c)**

48. **(b)** The phase difference ϕ is given by

$\tan\phi = \frac{X_L}{R} = \frac{3}{3} = 1 \Rightarrow \phi = \frac{\pi}{4}.$

49. **(b)**

50. **(d)** $E = E_0 \sin\omega t$

$I = I_0 \sin\left(\omega t + \frac{\pi}{3}\right)$

As i can lead the voltage in RC and LCR circuit, so it can be RC or LCR circuit.

51. **(b)** **52.** **(c)**

53. **(a)** $R = 30\Omega$, $X_L = 25\Omega$, $X_C = 25\Omega$

$\therefore Z = \sqrt{(X_L - X_C)^2 + R^2} = 30\Omega$

$\therefore$ Reading of ammeter,

$I_{rms} = \frac{V_{rms}}{Z} = \frac{240}{30} = 8A$

Reading of voltmeter,

$V = I_{rms}\sqrt{(X_L - X_C)^2} = 8\sqrt{(25-25)^2} = 0\,V$

54. **(a)** In LCR series circuit,

L = 10H, C = 40 μF, R = 60Ω, V = 240v

At resonance, Z = R = 60Ω

$\therefore$ Current, $I = \frac{V}{Z} = \frac{240}{60} = 4A$

55. **(c)** Given, $E = 440 \sin 100\pi t$, $L = \frac{\sqrt{2}}{\pi} H$

As, $X_L = \omega L = 100\pi \frac{\sqrt{2}}{\pi} = 100\sqrt{2}\,\Omega$

So, peak current, $I_0 = \frac{E_0}{X_L} = \frac{440}{100\sqrt{2}} = 2.2\sqrt{2}A$

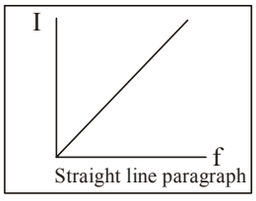
We know AC ammeter reads RMS value therefore reading will be I_{rms}, $I_{rms} = \frac{I_0}{\sqrt{2}} = 2.2A$

56. **(c)** $I = \frac{V}{X_c}$ in Pure Capacitor

$= \frac{V}{\frac{1}{2\pi fc}} = V\,2\pi fc$

$\Rightarrow I \propto f$

other parameters kept constant



57. **(b)**

58. **(c)** Capacitive reactance,

$X_C = \frac{1}{\omega C} = \frac{1}{2\pi \upsilon C} \quad \Rightarrow X_C \propto \frac{1}{\upsilon}$

With increases in frequency, X_C decreases.

Hence, option (c) represents the corrent graph.

59. **(a)** $X_L = \omega L = 3000 \times 10^{-2}\Omega = 30\,\Omega$

$X_C = \frac{1}{\omega c} = \frac{1}{3000 \times 25 \times 10^{-6}} = \frac{1000}{75} = \frac{40}{3}\Omega$

So, $X_L - X_C = \left(30 - \frac{40}{3}\right)\Omega = \frac{50}{3}\Omega$

Given, $R = 100\,\Omega$

As, $\tan\phi = \frac{|X_L - X_C|}{R} = \frac{50}{3 \times 100} = \frac{1}{6}$

$\phi = \tan^{-1}\left(\frac{1}{6}\right) = \tan^{-1}(0.17)$

60. **(c)** The current drawn by inductor and capacitor will be in opposite phase. Hence net current drawn from generator $= I_L - I_C = 0.9 - 0.4 = 0.5$ amp.

61. **(b)** The average power in one cycle is

$P_{avg} = V_{rms}\, I_{rms} \cos(\Delta\phi)$

$= \frac{100}{\sqrt{2}} \times \frac{100 \times 10^{-3}}{\sqrt{2}} \times \cos\left(\frac{\pi}{3}\right) \quad \left[\because V_{rms} = \frac{V_0}{\sqrt{2}}, I_{rms} = \frac{I_0}{\sqrt{2}}\right]$

$= \frac{10^4}{2} \times \frac{1}{2} \times 10^{-3} \quad = \frac{10}{4} = 2.5\ W$

62. **(b)** Using Ohm's law, $R = \frac{V}{I} = \frac{100}{5} = 20\,\Omega$

Impedence is given as:

$Z = \sqrt{X_L^2 + R^2} = \sqrt{3 \times 400 + 400} = 40\,\Omega$

Power dissipated in circuit is,

$P = \left(\frac{V_{rms}}{Z}\right)^2 \times R = \left(\frac{\frac{200}{\sqrt{2}}}{40}\right)^2 \times 20 = 250\ W$

63. **(d)** Average power dissipated

$< P > = I_{rms} V_{rms} \cos\phi$

$= \frac{I_o}{\sqrt{2}} \frac{V_0}{\sqrt{2}} \cos 60^\circ = \frac{20}{\sqrt{2}} \times \frac{10}{\sqrt{2}} \times \cos 60^\circ = 50\ W$

64. **(a)** Given,

Capacitive reactance, $X_c = 4\sqrt{3}\Omega$

Resistance, $R = 4\,\Omega$

Reactance is given by

$Z = \sqrt{R^2 + X_c^2} \Rightarrow Z = \sqrt{4^2 + \left(4\sqrt{3}\right)^2} = 8\Omega$

RMS voltage

$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{8\sqrt{2}}{\sqrt{2}} = 8V$

RMS current

$I_{rms} = \frac{V_{rms}}{Z} = \frac{8}{8} = 1A$

Power dissipated, $P = I^2_{rms} \times R = 1 \times 4 = 4W$

65. **(d)** Power dissipated is given by: $P = VI \cos\phi$

$\therefore P = V \cdot \frac{V}{\sqrt{\omega^2 L^2 + R^2}} \times \frac{R}{\sqrt{\omega^2 L^2 + R^2}}$

$= \frac{V^2 R}{\left(\omega^2 L^2 + R^2\right)} \quad \left[\because \text{as } \phi = \frac{R}{\sqrt{\omega^2 L^2 + R}}\right]$

66. **(b)** Average power dissipated in A.C. circuit is

$P = I^2 Z \cos\phi$

where $\cos\phi$ is the power factor of the circuit.

$\therefore \cos\phi = \frac{P}{I^2 Z} \quad \therefore \cos\phi = \frac{2}{(2)^2 (1)} = 0.5$

67. **(d)**

68. **(c)** $P = \frac{E_v^2 \cos\phi}{Z}$

$P = 3000 = \frac{(240)^2 (0.75)}{Z} \Rightarrow Z = 14.4\Omega$

69. **(d)** The average power in the circuit where $\cos\phi$ = power factory

$< P > = V_{rms} \times I_{rms} \cos\phi$

$\phi = \pi/3$ = phase difference $= \frac{180}{3} = 60$

$V_{rms} = \frac{\frac{1}{\sqrt{2}}}{\sqrt{2}} = \frac{1}{2}\text{volt}\,; I_{rms} = \frac{\frac{1}{\sqrt{2}}}{\sqrt{2}} = \left(\frac{1}{2}\right) A$

$< P > = \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{8} W$

70. **(b)** In LCR series circuit, at resonance, $X_C = X_L = 2R$

Power factor, $\cos\phi = \frac{R}{z} = \frac{R}{R} = 1$

Exercise 2 : ACCELERATOR
Topic-wise MCQs

1. **(a)** $i = i_0 \sin\omega t$

$i = 15\sqrt{2}\sin 2\pi \times 50 \times \frac{1}{600}$

$= 15\sqrt{2}\sin\frac{\pi}{6} = \frac{15\sqrt{2}}{2} = \frac{15}{\sqrt{2}}$ A

2. **(a)** Given, $i = \left[6 + \sqrt{56}\sin(100\pi t + \frac{\pi}{3})\right]$A

$I_{rms} = \sqrt{\frac{\int i^2 dt}{\int dt}}$

$I_{rms} = \sqrt{(6)^2 + \frac{(\sqrt{56})^2}{2}} = \sqrt{36+28} = \sqrt{64}$ $\therefore$ $I_{rms} = 8$A

3. **(c)** $i = 3\sin\omega t + 4\cos\omega t$

$= 5\left[\frac{3}{5}\sin\omega t + \frac{4}{5}\cos\omega t\right] = 5[\sin(\omega t + \delta)]$ ...(1)

$\Rightarrow$ rms value $= \frac{5}{\sqrt{2}}$ $\Rightarrow$ mean value $= \frac{\int_{T_1}^{T_2} i\,dt}{\int_{T_1}^{T_2} dt}$

$\therefore$ initial value is not given hence the mean value will be difference for various time intervals.

If voltage applied is $V = V_m \sin\omega t$ then i given by eq. (1) indicates that it is ahead of V by δ where $0 < \delta < 90°$ which indicates that the circuit contains R and C.

4. **(a)** When $I = I_0$

$I_0 \sin(\omega t_1 + \phi) = I_0 \Rightarrow \sin(\omega t_1 + \phi) = 1$

$\omega t_1 + \phi = \frac{\pi}{2}$ ...(i)

when $I = \frac{I_0}{\sqrt{2}}$ $\Rightarrow I_0 \sin(\omega t_2 + \phi) = \frac{I_0}{\sqrt{2}}$

$\Rightarrow \sin(\omega t_2 + \phi) = \frac{1}{\sqrt{2}}$

$\Rightarrow \omega t_2 + \phi = \frac{\pi}{4}$ ...(ii)

Substracting (ii) from (i), we get

$\omega(t_1 - t_2) = \frac{\pi}{4} \Rightarrow 2\pi f(t_1 - t_2) = \frac{\pi}{4}$

$\Rightarrow t_1 - t_2 = \frac{1}{8f} = \frac{1}{400}$ s = 2.5 ms.

5. **(c)** $I = 20\sin(100\pi t + 0.05\pi)$A

Comparing with standard equation, we get

$I_0 = 20$ A and $\omega = 100\pi$ rad/s

$\Rightarrow I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{20}{\sqrt{2}} = 10\sqrt{2}$A

And, $v = \frac{\omega}{2\pi} = \frac{100\pi}{2\pi} = 50$ Hz

6. **(a)** Since the cpacitor is connected in series to the resistor, current I_C and I_R through the resistor is in phase as represented by choice (a).

7. **(c)** The correct phasor diagram for such circuit is (c), in capacitor, current lead voltage by $\frac{\pi}{2}$.

8. **(d)**

9. **(d)** Element X should be resistance with R

$= \frac{E}{I} = \frac{100}{5} = 20\ \Omega$

Element Y should be inductive with $X_L = 20\ \Omega$

When X and Y are connected in series

$I_0 = \frac{E_0}{Z} = \frac{E_0}{\sqrt{X_L^2 + R^2}} = \frac{100}{20\sqrt{2}} = \frac{5}{\sqrt{2}}$ A

The rms value of the current will be, $I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{5}{2}$ A

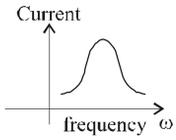
10. **(b)** As $\phi = 0$, we have resonance condition

So, $Z = R$

Thus, $I_{rms} = \frac{V_{rms}}{R} = \frac{220}{20} = 11$**A**

$I_0 = \sqrt{2}\, I_{rms} = 11\sqrt{2} = \sqrt{242}$

11. **(a)** In LCR circuit current first increases then decreases with increase in frequency.



12. **(b)** As voltage and current are in phase so circuit is in resonance.

$\therefore$ $\omega^2 = \frac{1}{LC} \Rightarrow C = \frac{1}{\omega^2 L} = \frac{1}{(2\pi\times 50)^2 \times 80 \times 10^{-3}}$

$\Rightarrow$ $C = 1.27 \times 10^{-4}$ F $= 127$ μF

13. **(d)** The amplitude of the current in the series L-C-R circuit is given by

$i_m = \frac{V_m}{Z} = \frac{V_m}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$ ...(i)

Since, $i_m = \frac{I_{max}}{\sqrt{2}} \Rightarrow I_{max} = i_m\sqrt{2}$

$\Rightarrow \frac{V_m}{R} = i_m\sqrt{2} \Rightarrow i_m = \frac{V_m}{\sqrt{2}R}$ ...(ii)

From Eqs. (i) and (ii), we have

$$\Rightarrow \frac{1}{2}\frac{V_m^2}{R^2} = \frac{V_m^2}{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

$$\Rightarrow 2R^2 = R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2 \Rightarrow R^2 = \left(\frac{\omega L - 1}{\omega C}\right)^2$$

$$\Rightarrow R = \left(\frac{\omega L - 1}{\omega C}\right) \quad ...(iii)$$

If ϕ is the phase difference between V and I, then

$$\Rightarrow \tan\phi = \frac{\omega L - \frac{1}{\omega C}}{R} = \frac{\left(\omega L - \frac{1}{\omega C}\right)}{\left(\omega L - \frac{1}{\omega C}\right)} = 1 \quad \text{[from Eq. (iii)]}$$

$\Rightarrow \tan\phi = 1 = \tan 45^\circ \Rightarrow \phi = 45^\circ$

Power dissipated, $P = i_m^2 Z\cos\phi$

Thus, power dissipated by the circuit becomes half.

14. (c) Capacitive reactance,

$$X_c = \frac{1}{\omega C} = \frac{1}{(2\pi f)C} \qquad \therefore X_c \propto \frac{1}{f}$$

X_C vs f graph is rectangular hyperbola

Inductive reactance

$X_L = \omega L = (2\pi f)L \quad \therefore X_L \propto f$

$\therefore X_L$ vs f graph is straight line.

15. (b) Given,

$V_0 = 283$ volt, $\omega = 320$, $R = 5\ \Omega$, $L = 25$ mH, $C = 1000\ \mu F$

$X_L = \omega L = 320 \times 25 \times 10^{-3} = 8\ \Omega$

$$X_C = \frac{1}{\omega C} = \frac{1}{320 \times 1000 \times 10^{-6}} = 3.1\ \Omega$$

Total impedance of the circuit :

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{25 + (4.9)^2} = 7\ \Omega$$

Phase difference between the voltage and current

$$\tan\phi = \frac{X_L - X_C}{R}$$

$$\tan\phi = \frac{4.9}{5} \approx 1 \Rightarrow \phi = 45^\circ$$

16. (d) $V_{6\Omega} = 3 = 6\ I_v \ \therefore \quad I_v = 0.5$ A

$$I_v = \frac{1}{2} = \frac{5}{\sqrt{6^2 + X_L^2}}, X_L = 8\Omega$$

Now, $V_L = I_v . X_L = \frac{1}{2} \times 8 = 4V$

17. (b) In LCR circuit power will maximum at the condition of resonance .

$X_L = X_C$

$$79.6 = \frac{1}{\omega C} \qquad \therefore\ C = \frac{1}{2\pi \times 50 \times 79.6} = 40\mu F$$

18. (c) For maximum current, $X_L = X_C$

i.e., $\frac{1}{2\pi fC} = 2\pi fL$

$$\Rightarrow \quad C = \frac{1}{4\pi^2 f^2 L} = \frac{1}{4 \times \pi^2 \times 49 \times 10^6 \times 2 \times 10^{-6}}$$

$$\Rightarrow \quad C = \frac{1}{3872} F$$

$x = 3872$

19. (b) Given, $C = 62.5$ nF $= 62.5 \times 10^{-9}$ F

$R = 50\ \Omega$

$f = 2$ kHz $= 2000$ Hz

$$f = \frac{1}{2\pi\sqrt{LC}} \ \Rightarrow\ 2000 = \frac{1}{2\pi\sqrt{L \times 62.5 \times 10^{-9}}}$$

$$L = \frac{1}{4\pi^2 \times 2000^2 \times 62.5 \times 10^{-9}} = 0.1\ H = 100\ mH$$

20. (b) The impedance of the circuit is minimum for a frequency

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{\frac{25}{\pi^2} \times 10^{-3} \times 0.1 \times 10^{-6}}}$$

$2\pi f = \frac{\pi}{5} \times 10^5 \quad \Rightarrow f = 10$ KHz.

21. (a) We have

$$I_0 = \frac{V_0}{Z} = \frac{2500}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{2500}{\sqrt{80^2 + 60^2}} = \frac{2500}{100}$$

$= 25$A

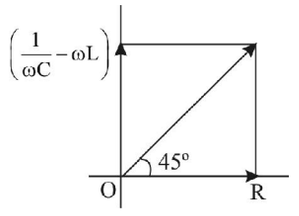
22. (c) $\cos 45° = \frac{R}{X_L}$ ....(i)

$\cos 45° = \frac{R}{X_C}$ ....(ii)

So, from (i) & (ii) we get $X_L = X_C$ i.e. circuit in resonance. LCR circuit is in resonance, behaves as resistive circuit.

$\therefore I_{rms} = \frac{V_{rms}}{R} = \frac{220}{110} = 2$ A

23. (d) From figure,



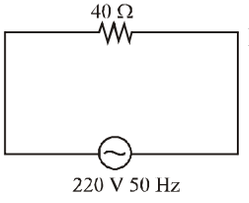
$$\tan 45° = \frac{\frac{1}{\omega C} - \omega L}{R}$$

$$\Rightarrow \frac{1}{\omega C} - \omega L = R$$

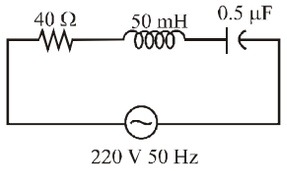
$$\Rightarrow \frac{1}{\omega C} = R + \omega L \quad \left(\because\ \omega = \frac{2\pi}{T} = 2\mu f\right)$$

$$C = \frac{1}{\omega(R + \omega L)} = \frac{1}{2\pi f(R + 2\pi f L)}$$

24. (a)



Here, Z = R



Here, $Z = \sqrt{R^2 + (X_L - X_C)^2}$ and, $X_L \neq X_C$

So, $Z > R$

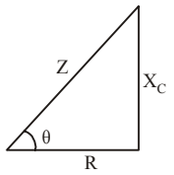
So, rms current in (b) can never be larger than (a).

25. **(c)** In LCR series circuit, at point A,
$X_C > X_L \Rightarrow$ the circuit is capacitive.

26. **(b)** $V_C^2 + V_R^2 = V^2$

$50^2 + V_R^2 = 110^2$

$\Rightarrow V_R = \sqrt{160 \times 60} = 98V$



Then, $I_v = \dfrac{\sqrt{160 \times 60}}{50}$

Also, $I_v = \dfrac{110}{\sqrt{R^2 + X_C^2}} \quad \therefore \dfrac{98}{50} = \dfrac{110}{\sqrt{50^2 + X_C^2}}$

$\Rightarrow X_C = 25.5$

Also, $\omega = 2\pi v = 2 \times 3.14 \times 60 = 376.8$

Now using $X_C = \dfrac{1}{\omega C}$, we get $C = \dfrac{1}{\omega X_C} = 104\ \mu F$

27. **(d)** Reading of voltmeter is zero because the circuit is a resonance circuit.

$$I = \frac{E}{Z} = \frac{E}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{E}{R} = \frac{240}{30} = 8A$$

28. **(d)** Power factor $_{(old)}$
$= \dfrac{R}{\sqrt{R^2 + X_L{}^2}} = \dfrac{R}{\sqrt{R^2 + (2R)^2}} = \dfrac{R}{\sqrt{5}R}$

Power factor$_{(new)}$
$= \dfrac{R}{\sqrt{R^2 + (X_L - X_C)^2}} = \dfrac{R}{\sqrt{R^2 + (2R - R)^2}} = \dfrac{R}{\sqrt{2}R}$

$\therefore \dfrac{\text{New power factor}}{\text{Old power factor}} = \dfrac{\frac{R}{\sqrt{2}R}}{\frac{R}{\sqrt{5}R}} = \sqrt{\frac{5}{2}}$

29. **(b)** Given that power factor of the circuit is P_1, when $X_L = R$

$P_1 = \dfrac{R}{\sqrt{R^2 + (X_L - X_C)^2}} = \dfrac{1}{\sqrt{2}} \quad (\because X_C = 0)$

Power factor of the circuit is P_2, when $X_L = X_C$

$P_2 = \dfrac{R}{\sqrt{R^2 + (X_L - X_C)^2}} = 1$

So, we have $\dfrac{P_1}{P_2} = \dfrac{1}{\sqrt{2}}$

30. **(a)** Power factor of LCR circuit is

$$P_1 = \cos\phi = \frac{R}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{R}{\sqrt{R^2 + (2R - R)^2}}$$

$$= \frac{1}{\sqrt{2}}$$

Power factor of LR circuit is

$$P_2 = \frac{R}{\sqrt{R^2 + X_L^2}} = \frac{R}{\sqrt{R^2 + R^2}} = \frac{1}{\sqrt{2}}$$

Ratio $= \dfrac{P_2}{P_1} = \dfrac{1}{1}$

31. **(b)** As $H = i_{rms}^2 Rt$

$H \propto i_{rms}^2 R$

$$\frac{H_1}{H_2} = \left(\frac{i_{rms_1}}{i_{rms\,2}}\right)^2 \times \frac{R_1}{R_2} = \left(\frac{4}{\frac{4}{\sqrt{2}}}\right)^2 \times \frac{3}{2} = 2 \times \frac{3}{2} = \frac{3}{1}$$

32. **(c)** Given: R = 60Ω, f = 50 Hz, ω = 2 πf = 100 π and v = 24v

C = 120 μf = 120 × 10^{-6}f

$$x_C = \frac{1}{\omega C} = \frac{1}{100\pi \times 120 \times 10^{-6}} = 26.52\Omega$$

$x_L = \omega L = 100\ \pi \times 20 \times 10^{-3} = 2\ \pi\Omega$

$x_C - x_L = 20.24 \approx 20$

$z = \sqrt{R^2 + (x_C - x_L)^2} \Rightarrow z = 20\sqrt{10}\Omega$

$$\cos\phi = \frac{R}{z} = \frac{60}{20\sqrt{10}} = \frac{3}{\sqrt{10}}$$

$P_{avg} = VI\cos\phi, I = \dfrac{v}{z} = \dfrac{v^2}{z}\cos\phi = 8.64$ watt

Energy dissipated (Q) in time t = 60s is
Q = P.t = 8.64 × 60 = 5.17 × 10^2J

33. **(c)** For AC circuit containing inductor only.
$I = I_0 \sin\omega t$

$$V = V_0 \sin\left(\omega t + \frac{\pi}{2}\right) = V_0 \cos\omega t$$

So, power, $P = VI = V_0 \cos\omega t\ I_0 \sin\omega t = \dfrac{V_0 I_0}{2} \sin 2\omega t$

Clearly the frequency becomes 2 times.
f ' = 2f = 2 × 50 = 100Hz

34. **(d)** ω = 100 rad/s
We know that

$$\tan\phi = \frac{X_C}{R} = \frac{1}{\omega CR}$$

$\Rightarrow \tan 45° = \dfrac{1}{\omega CR} \Rightarrow \omega CR = 1$

LHS: ωCR = 10 × 10 × 10^{-6} × 10^3 = 1

35. **(c)** Power factor

$$\cos\phi = \frac{R}{\sqrt{R^2 + \left[\omega L - \frac{1}{\omega(C+C')}\right]^2}} = 1$$

On solving we get,

$$\omega L = \frac{1}{\omega(C+C')} \quad \Rightarrow \quad C' = \frac{1-\omega^2 LC}{\omega^2 L}$$

Hence option (c) is the correct answer.

Exercise 3 : PREVIOUS YEARS MCQs

1. **(b)** $\frac{n_p}{n_s} = \frac{E_p}{E_s} = \frac{1}{25} \therefore E_s = 25\, E_p$

But $E_S I_S = E_p I_p \Rightarrow I_p = \frac{E_S \times I_S}{E_p} \Rightarrow I_p = 50A$

2. **(c)** Inductance, $L = \frac{50}{\pi}$ mH

Resistance, $R = 10\ \Omega$

Capacitance, $C = \frac{10^3}{\pi} \times 10^{-6}$

Inductive reactance, $X_L = \omega L = 2\pi fL$

$= 2\pi \times 50 \times \frac{50}{\pi} \times 10^{-3} = 5\ \Omega$

Capacitive reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$

$= \frac{1 \times \pi}{2\pi \times 50 \times 10^3 \times 10^{-6}} = \frac{10^3}{100} = 10\ \Omega$

Impedance $Z = \sqrt{(X_C - X_L)^2 + R^2}$

$= \sqrt{(10-5)^2 + 10^2}$

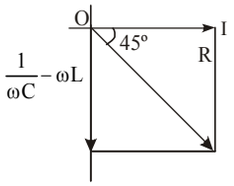
$\Rightarrow \quad Z = \sqrt{125} = 5\sqrt{5}\ \Omega$

3. **(d)** From figure,

$\tan 45° = \frac{\frac{1}{\omega C} - \omega L}{R}$

$\Rightarrow \frac{1}{\omega C} - \omega L = R$

$\Rightarrow \frac{1}{\omega C} = R + \omega L$



$C = \frac{1}{\omega(R+\omega L)} = \frac{1}{2\pi f(R + 2\pi f L)}$

4. **(b)** The average power in one cycle is

$P_{avg} = V_{rms}\, I_{rms} \cos(\Delta\phi)$

$= \frac{100}{\sqrt{2}} \times \frac{100 \times 10^{-3}}{\sqrt{2}} \times \cos\left(\frac{\pi}{3}\right)$

$\left[\because V_{rms} = \frac{V_0}{\sqrt{2}}, I_{rms} = \frac{I_0}{\sqrt{2}}\right]$

$= \frac{10^4}{2} \times \frac{1}{2} \times 10^{-3}$

$= \frac{10}{4} = 2.5\ W$

5. **(c)** Voltage across inductor, $V_L = IX_L = I\omega L$

$\therefore I = \frac{V_L}{\omega L} = \frac{V_L}{2\pi fL} = \frac{31.4}{2\pi \times 50 \times 10 \times 10^{-3}} = 10A$

6. **(c)** Formula for average power:

$\rho_{avg} = V_{rms}\, I_{rms} \cos\phi$

Where ϕ = phase difference $= \frac{\pi}{4}$

$V_{rms} = \frac{V_o}{\sqrt{2}} = \frac{50}{\sqrt{2}}$

$I_{rms} = \frac{I_o}{\sqrt{2}} = \frac{0.05}{\sqrt{2}}$

$\rho_{avg} = \frac{50}{\sqrt{2}} \times \frac{0.05}{\sqrt{2}} \cos\left(\frac{\pi}{4}\right) \approx 0.884W$

7. **(c)** $i = (3 \sin \omega t + 4\cos \omega t)$ A

$\therefore$ Peak current, $I_o = \sqrt{3^2 + 4^2} = 5A$

$\therefore$ RMS current, $I_{rms} = \frac{I_o}{\sqrt{2}} = \frac{5}{\sqrt{2}} A$

8. **(d)** $R = 20\Omega$, $V = 200 \sin(10\pi t)$

$\therefore \quad I = \frac{V}{R} = 10 \sin(10\pi t)$ .....(i)

$\therefore I_o = 10, I_{rms} = \frac{I_o}{\sqrt{2}} = \frac{10}{\sqrt{2}}$

$\therefore$ From equation (i),

$10 = 10\sin(10\pi t_1) \Rightarrow \sin(10\pi t_1) = \sin\frac{\pi}{2}$

$\therefore t_1 = \frac{1}{20}$s

Again, $\frac{10}{\sqrt{2}} = 10\sin(10\pi t_2)$

$\Rightarrow \sin(10\pi t_2) = \sin\frac{\pi}{4}$

$\therefore t_2 = \frac{1}{40}$s

$\therefore \quad \Delta t = t_1 - t_2 = \frac{1}{20} - \frac{1}{40} = \frac{1}{40} = 2.5 \times 10^{-2}$s

9. **(d)** Voltage across the capacitor (c) resistor (R) and inductor (L) are in the ratio $V_e : V_R : V_L = 2 : 3 : 6$ and $V_{circuit} = 240V$, $V_L = ?$

In series LCR circuit, $V_{ac} = \sqrt{V_R^2 + (V_L - V_c)^2}$

$\therefore\ 240 = \sqrt{(3x)^2 + (6x - 2x)^2}$ or $(240)^2 = 3x^2 + 4x^2$

$\therefore\ x = \sqrt{\frac{240 \times 240}{25}} = 48$

$\therefore$ Voltage across the inductor $V_L = 6 \times 48 = 288V$

10. (b) $\tan\phi = \frac{x_L}{R} = \frac{1/\sqrt{3}}{1} = \frac{1}{\sqrt{3}} \Rightarrow \phi = \tan^{-1}\left(\frac{1}{\sqrt{3}}\right)$

$\phi = 30°$

Time lag $= \frac{\phi}{360°} \times T,\ T = \frac{1}{f} = \frac{1}{50}$

Time lag $= \frac{30}{360°} \times \frac{1}{50} = \frac{0.02}{12}$

Time lag $= \frac{1}{600}$s

11. (a) Use relation between flux and inductance:

$\phi = LI,\ L = \frac{\phi}{I} = \frac{32 \times 10^{-6}}{4 \times 10^{-3}} = 8 \times 10^{-3}$H

Use energy stored formula in an inductor.

$U = \frac{1}{2}LI^2 = \frac{1}{2} \times 8 \times 10^{-3} \times \left(4 \times 10^{-3}\right)^2 = 6.4 \times 10^{-8}$J

or 64×10^{-9} J

12. (a) In a series resonant LCR circuit, power dissipated $P \propto I^2$ where I is the current amplitude

Let maximum current = I_0

So, maximum power $P_0 \propto I_0^2$

$P = \frac{1}{2}P_0 \Rightarrow I^2 = \frac{1}{2}I_0^2$

$I = \frac{I_0}{\sqrt{2}}$

13. (d) For LCR series circuit,

$R = 4\Omega,\ X_C = 6\Omega,\ X_L = 9\Omega$

$\therefore$ The impedance of the circuit is

$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(4)^2 + (9-6)^2} = 5\Omega$

14. (b) For series RL circuit, $R = 450\Omega,\ f = \frac{75}{\pi}$Hz

$\cos\phi = 0.6 = \frac{3}{5} \Rightarrow \tan\phi = \frac{4}{3}$

$\therefore \tan\phi = \frac{X_L}{R} = \frac{(2\pi f)L}{R}$

$\Rightarrow \frac{4}{3} = \frac{2\pi \times \frac{75}{\pi} \times L}{450}$

$\therefore\ L = 4H$

15. (b) For better tunning quality factor must be high

$Q = \frac{1}{R}\sqrt{\frac{L}{C}},$

sharpness of resonance is determined by the quality factor L must be high and R and C must be minimum.

16. (a) In LCR series circuit

$V = \sqrt{V_R^2 + (V_L - V_C)^2}$

$= \sqrt{(40)^2 + (60-30)^2} = \sqrt{2500} = 50V$

17. (c) Resonant frequency $f_o = \frac{1}{2\pi\sqrt{L_c}}$

When a dielectric slab of constant K = 16 is inserted completely between the plates of the capacitor then capacitance becomes

$C' = KC = 16C$

$\therefore f_o' = \frac{1}{2\pi\sqrt{L \times 10C}} = \frac{f_o}{4}$

18. (b) $R_S = 10^3\Omega,\ R_L = 10\Omega$

Effective load seen at primary

$R_L' = \left(\frac{N_P}{N_S}\right)^2 \times R_L$

$R_L' = R_S$

$\left(\frac{N_P}{N_S}\right)^2 R_L = R_S$

$\Rightarrow \left(\frac{N_P}{N_S}\right)^2 = \frac{R_S}{R_L} = \frac{1000}{10} = 100$

$\frac{N_P}{N_S} = \sqrt{100} = 10$

$\frac{N_P}{N_S} = 10:1$

19. (b) Alternating voltage equation, $V = V_o \sin\omega t$ or, $V = V_o \sin 2\pi nt$

Given $V = \frac{V_o}{2},\ n = 50,\ t = ?$

$\therefore \frac{V_o}{2} = V_o \sin 2\pi \times 50 \times t$

or, $\sin\left(\frac{\pi}{6}\right) = \sin(100\pi)t \qquad \therefore t = \frac{1}{600}$s

20. (b) Impedance of the circuit

$2 = \sqrt{R^3 + (X_L - X_C)^2}$

If circuit is purely resistive

$X_L - X_C = 0 \ \Rightarrow\ X_L = X_C$

21. **(b)** $\tan\phi = \frac{X_C}{R} = \frac{1}{\omega CR}$

$$C = \frac{1}{\omega R \tan\phi}$$

$$\Rightarrow \quad C = \frac{1}{200 \times 100\sqrt{3} \times \frac{1}{\sqrt{3}}} = \frac{1}{20000}\text{F}$$

$\Rightarrow$ C = 50 μF

22. **(c)** When iron rod is inserted into the interior of the inductor, inductance increases. As a result, inductive reactance $X_L = \omega L$, also increases,

Hence, impedance, $Z = \sqrt{R^2 + X_L^2}$ increases.

Current, $I = \frac{V_o}{Z}$ decreases.

The glow of the bulb decreases.

23. **(a)** Total voltage $(V) = \sqrt{V_R^2 + V_L^2}$

V_R = 240 V, V_L = 180 V

$\therefore \quad V = \sqrt{(240)^2 + (180)^2}$

$\boxed{V = 300\text{V}}$

24. **(c)** Eddy current losses are reduced by using laminated iron cores. Insulation between layers blocks current loops.

25. **(c)** The given AC current is

$$i = 5\sqrt{2} + 10\cos\left(650\pi t + \frac{\pi}{6}\right)$$

$$\Rightarrow i^2 = 50 + 100\cos^2\left(650\pi t + \frac{\pi}{6}\right) + (2)(5\sqrt{2})(10)\cos\left(650\pi t + \frac{\pi}{6}\right)$$

$$\Rightarrow < i^2 > = 50 + \frac{100}{2} + 0 = 100$$

$\therefore$ The r.m.s. value of current is

$$i_{rms} = \sqrt{< i^2 >} = \sqrt{100} = 10 \text{ amp.}$$

26. **(c)** Given ; $i_0 = 100\sqrt{2}$, $\omega = 100\pi$

$$i_{rms} = \frac{i_0}{\sqrt{2}} = 100 \text{ A} \qquad f = \frac{\omega}{2\pi} = \frac{100\pi}{2\pi} = 50 \text{ Hz.}$$

27. **(a)** The power in AC circuit is $P = V_{rms} \cdot I_{rms} \cos\phi$

For purely resistive (bulb) circuit, $\cos\phi = 1$

$\therefore \quad P = v_{rms}\, i_{rms}$

$\therefore \quad \Rightarrow i_{rms} = \frac{100}{220}$

$\therefore$ Peak current, $i_0 = \sqrt{2}\, i_{rms} = 0.64$ A

28. **(a)** Given: $X_L = 100\ \Omega$, $X_C = 50\ \Omega$, $R = 50\ \Omega$, $V_{rms} = 10$ V

$P = V_{rms} I_{rms} \cos\phi$

$\cos\phi = \frac{R}{z}$, $I_{rms} = \frac{V_{rms}}{z}$

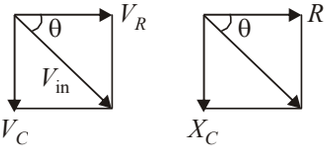
$$\Rightarrow P = V_{rms} \times \frac{V_{rms}}{z} \times \frac{R}{z}$$

$$\Rightarrow P = V_{rms}^2 \times \frac{R}{z^2}$$

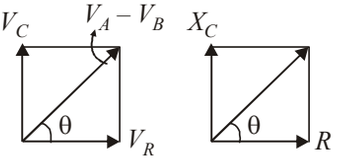
$$\Rightarrow z = \sqrt{R^2 + (X_L - X_C)^2} \Rightarrow z = 50\sqrt{2}\ \Omega$$

$$\therefore P = 100 \times \frac{50}{2500 \times 2} = 1 \text{ W.}$$

29. **(d)** Phasor diagram for V_{in} is



Phasor diagram for $(V_B - V_A)$ is



From above Phasor diagrams,

$\theta + \theta = 90° \Rightarrow \theta = 45°$

$$\therefore \tan\theta = \frac{X_C}{R} \Rightarrow X_C = R \Rightarrow \frac{1}{\omega C} = R$$

$$\therefore \omega = \frac{1}{RC} = \frac{1}{100 \times 10^3 \times 100 \times 10^{-12}} = 10^5 \text{ rad/s}$$

$= 10^x$ rad/s (given)

$\therefore$ x = 5

30. **(a)** Resonance condition in LCR circuit is observed at maximum current.

$$\therefore \text{Angular frequency, } \omega = \frac{1}{\sqrt{LC}}$$

$$= \frac{1}{\sqrt{25 \times 10^{-9} \times 100 \times 10^{-3}}} = 2 \times 10^4 \text{ rad s}^{-1}$$

31. **(a)** Given: rate of change of current, $\frac{dI}{dt} = -8$A/s

R = 12Ω

From Kirchhoff's voltage law,

$$\varepsilon - \frac{L dI}{dt} - IR = 0$$

$12 - 3 \times (-8) - 1 \times 12 = 0$

$\therefore$ I = 3A

32. **(b)** In LCR circuit,

Initially, $I_0 = \frac{E}{R}$

Finally, $I_0' = \frac{E}{2R} = \frac{I_0}{2}$

33. **(b)** Efficiency of transformer $\eta = \frac{V_s I_s}{V_p I_p}$

$\Rightarrow 0.8 = \frac{240 I_s}{4000} \Rightarrow I_s = 13.33A$

34. **(d)** Voltage V = 230 V

$P_i = 2300 \times 5$ watt

Efficienfy, $\eta = \frac{P_0}{P_i}$

$P_0 = 0.9\ P_i$

$P_0 = 2300 \times 5 \times 0.9 = 230 \times I_2 \quad [\because P = IV]$

$I_2 = 45A$

35. **(b)** For LC oscillation,

Maximum current, $I = Q_0.\omega$

$= \frac{CV}{\sqrt{LC}} = V\sqrt{\frac{C}{L}} \quad \left[\because \omega = \frac{1}{\sqrt{LC}} \ \& \ Q_0 = CV\right]$

$= 12\sqrt{\frac{100 \times 10^{-6}}{6.4 \times 10^{-3}}} = 1.5A$

36. **(b)** In AC circuit,

$X_C = 25\Omega,\ X_L = 45\Omega$

$\therefore\ Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{20^2 + (45-25)^2}$

$= 20\sqrt{2}\Omega$

$\therefore I_{rms} = \frac{V_{rms}}{Z} = \frac{220}{20\sqrt{2}} = \frac{11}{\sqrt{2}} = 7.8A$

Also, $\tan\phi = \frac{X_L - X_C}{R} = \frac{45-25}{20} = \frac{20}{20} = 1$

$\therefore\ \phi = 45°$

37. **(b)** Transformer ratio,

$\frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{1}{2} \quad \therefore\ V_S : V_P = 2 : 1$

38. **(b)** Capacitive Reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$

$= \frac{1}{2 \times 3.14 \times 50 \times 10 \times 10^{-6}} = \frac{1000}{3.14}$

Peak current, $i_0 = \sqrt{2} i_{rms} = \sqrt{2}.\frac{V_{rms}}{X_C}$

$= \sqrt{2} \times \frac{210}{1000} \times 3.14 = 0.932 \simeq 0.93A$

39. **(c)** Inductance, $L = \frac{50}{\pi}$ mH

Resistance, $R = 10\ \Omega$

Capacitance, $C = \frac{10^3}{\pi} \times 10^{-6}$

Inductive reactance, $X_L = \omega L = 2\pi fL$

$= 2\pi \times 50 \times \frac{50}{\pi} \times 10^{-3} = 5\ \Omega$

Capacitive reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$

$= \frac{1 \times \pi}{2\pi \times 50 \times 10^3 \times 10^{-6}} = \frac{10^3}{100} = 10\ \Omega$

Impedance $Z = \sqrt{(X_C - X_L)^2 + R^2} = \sqrt{(10-5)^2 + 10^2}$

$\Rightarrow \quad Z = \sqrt{125} = 5\sqrt{5}\ \Omega$

40. **(d)** For resonance frequency $f = \frac{1}{2\pi\sqrt{LC}}$

$\Rightarrow f = \frac{1}{2 \times \pi \times \sqrt{10 \times 10^{-3} \times 1 \times 10^{-6}}} = \frac{10^4}{2\pi}$

$= \frac{10^4}{2 \times 22/7} = 1.591 \times 10^3 \quad \therefore f = 1.591$ kHz

14 Dual Nature of Radiation and Matter

Exercise 1: WARM-UP
Topic-wise MCQs

1. **(a)** Specific charge (e/m) for cathode rays is constant as e and m for cathode rays are fixed.

2. **(c)** As cathode rays are deflected by electric and mangetic fields, it shows that cathode rays carry charged particles (*i.e.*, electrons)

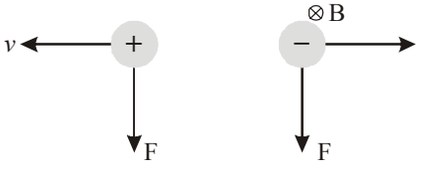
3. **(c)** De-Broglie wavelength,

$$\lambda = \frac{h}{p}\left(\because K.E = \frac{p^2}{2m}\right)$$

$$\lambda = \frac{h}{\sqrt{2mk.E}} = \frac{h}{\sqrt{2mE}}$$

$$\lambda' = \frac{h}{\sqrt{2m\left(\frac{E}{4}\right)}} = \frac{2h}{\sqrt{2mE}} = 2\lambda$$

4. **(a)** In discharge tube cathode rays (a beam of negative particles) and canal rays (positive rays) move opposite to each other. They will experience a magnetic force in the same direction, if a normal magnetic field is applied.



5. **(b)** $K_2 = (1 - 0.36)\, K_1 = 0.64\, K_1$

De-Broglie wavelength of the particle is

$$\lambda = \frac{h}{\sqrt{2mk}} \Rightarrow \lambda \propto \frac{1}{\sqrt{k}}$$

$$\therefore \quad \frac{\lambda_2}{\lambda_1} = \sqrt{\frac{K_1}{K_2}} = \sqrt{\frac{k_1}{0.64k_1}} = 1.25$$

$\therefore \quad \lambda_2 = 1.25\, \lambda_1$

$\therefore$ % increase in de-Broglie wavelength is

$$\% \Delta\lambda = \frac{\Delta\lambda}{\lambda_1} \times 100 = \frac{1.25\lambda_1 - \lambda_1}{\lambda_1} \times 100 = 25\%$$

6. **(a)**

7. **(a)** The de-Broglie wavelength of a particle is

$$\lambda = \frac{h}{\sqrt{2mk}} \Rightarrow \lambda \propto \frac{1}{\sqrt{mk}}$$

$$\therefore \quad \frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha m_\alpha}{m_p k_p}} \Rightarrow \frac{2\lambda_\alpha}{\lambda_p} = \sqrt{\left(\frac{4}{1}\right)\frac{k_\alpha}{k_p}}$$

$$\therefore \quad \frac{k_p}{k_\alpha} = 1:1$$

8. **(a)** de-Broglie wavelength associated with uncharged particle at temperature T is

$$\lambda = \frac{h}{\sqrt{3mKT}} \Rightarrow \lambda \propto \frac{1}{\sqrt{T}}$$

Initial temperature, $T_i = 77 + 273 = 350$ K

Final temperature, $T_f = 1127 + 273 = 1400$ K

$$\therefore \quad \frac{\lambda_i}{\Lambda_f} = \frac{1}{\sqrt{350}} \times \frac{\sqrt{1400}}{1} = \sqrt{4}$$

$$\Rightarrow \quad \frac{\lambda}{\Lambda_f} = 2 \Rightarrow \lambda_f = \frac{\lambda}{2}$$

9. **(c)** $\lambda = \frac{h}{m_p v_p} = \frac{h}{m_e v_e}$; then $m_p v_p = m_e v_e$ or $\frac{v_p}{v_e} = \frac{m_e}{m_p}$

$$\frac{E_p}{E_e} = \frac{\frac{1}{2}m_p v_p^2}{\frac{1}{2}m_e v_e^2} = \frac{m_p}{m_e} \times \left(\frac{m_e}{m_p}\right)^2 = \frac{m_e}{m_p} < 1$$

$\therefore \quad E_p < E_e$

10. **(a)** According to relation, $E = \frac{1}{2}mv^2$

$$\sqrt{\frac{2E}{m}} = v$$

$$\lambda = \frac{h}{\sqrt{2mE}}$$

Because $m_1 < m_3 < m_2$

So for same λ, $E_1 > E_3 > E_2$.

11. **(b)** When electron is accelerated through a potential difference V_1

Kinetic energy, $KE = \frac{P^2}{2m}, \left(\because \text{Momentum, } P = \frac{h}{\lambda}\right)$

$$KE = eV_1 = \frac{\left(\frac{h}{\lambda}\right)^2}{2m}$$

When potential is changed to V_2, then

$$KE = eV_2 = \frac{\left(\frac{h}{1.5\lambda}\right)^2}{2m} \quad \therefore \quad \frac{V_1}{V_2} = (1.5)^2 = \frac{9}{4}$$

12. **(d)** de-Broglie wavelength,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2.m.(K.E)}} \quad \therefore \quad \lambda \propto \frac{1}{\sqrt{K.E}}$$

If K.E is doubled, λ becomes $\frac{\lambda}{\sqrt{2}}$

13. **(b)**

14. **(d)** $qV = \frac{1}{2}mv^2$ or $mv = \sqrt{2qVm}$;

So $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2qVm}}$ *i.e.*, $\lambda \propto \frac{1}{\sqrt{qm}}$;

so $\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{q_\alpha m_\alpha}{q_p m_p}} = \sqrt{2\times 4} = 2\sqrt{2}$

15. **(d)**

16. **(a)** Here, $u = 0$; $a = \frac{eE}{m}$; $v = ?$; $t = t$

$$\therefore \quad v = u + at = 0 + \frac{eE}{m}t$$

de-Broglie wavelength, $\lambda = \frac{h}{mv} = \frac{h}{m(eEt/m)} = \frac{h}{eEt}$

Rate of change of de-Broglie wavelength

$$\frac{d\lambda}{dt} = \frac{h}{eE}\left(-\frac{1}{t^2}\right) = \frac{-h}{eEt^2}$$

17. **(d)** Wavelength, $\lambda = \frac{h}{p} = \frac{h}{mv}$

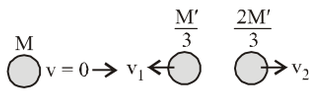
$$\Rightarrow \lambda = \frac{h}{\sqrt{2m(K.E)}} \qquad \therefore h = \frac{h}{\sqrt{2mqV}}$$

Putting the values of m and q and solving we get

$$\lambda = \frac{1.22}{\sqrt{V}}\text{nm}$$

So x stands for $\sqrt{V}$.

18. **(c)**



$|\vec{P}_1| = |\vec{P}_2|$ (from the conservation of momentum)

Here $\vec{P}$ is momentum.

So, $\lambda = \frac{h}{P}$ Here wavelength will be same.

19. **(c)**

20. **(d)** de Broglie wavelength is given as,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$$

Substitute necessary values :

$$\lambda = \frac{6.6\times 10^{-34}}{\sqrt{2\times 9.1\times 10^{-31}\times 1.6\times 10^{-19}\times 400}}$$

$$= \frac{6.6\times 10^{-10}}{\sqrt{2\times 9.1\times 1.6\times 4}} = 0.61 \times 10^{-10}\text{ m} = 0.06\text{ nm}$$

21. **(d)** The de-Broglie wavelength of an electron is

$$\lambda = \frac{h}{\sqrt{2mK}}$$

$$\therefore \lambda = \frac{6.63\times 10^{-34}\text{ Js}}{\sqrt{2\left(9.1\times 10^{-31}\text{kg}\right)\left(120\times 1.6\times 10^{-19}\text{ J}\right)}}$$

$$= 1.12 \times 10^{-10}\text{ m} = 112 \times 10^{-12}\text{ m} = 112\text{ pm}$$

22. **(d)** de Broglie wavelength of the electron is given as

$$\lambda = \frac{12.27}{\sqrt{V}}\text{Å}$$

For V = 100 volt

$$\lambda = \frac{12.27}{\sqrt{100}}\text{Å} = 1.227\text{Å}$$

23. **(c)** As we know that, wavelength of an electron,

$$\lambda = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2m}}.\frac{1}{\sqrt{E}}$$

$$\Rightarrow \quad \log\lambda = \log\left(\frac{h}{\sqrt{2m}}.\frac{1}{\sqrt{E}}\right)$$

$$\Rightarrow \quad \log\lambda = -\frac{1}{2}\log E + \log\frac{h}{\sqrt{2m}}$$

24. **(d)** The force on cathode rays (*i.e.*, charge *e*) moving with velocity $\vec{v}$ due to a perpendicular magnetic field $\vec{B}$ is $-e(\vec{v}\times\vec{B})$, which acts perpendicular to plane of $\vec{v}$ and $\vec{B}$.

25. **(c)** de-Broglie's relation, $\lambda = \frac{h}{p}$

momentum $p = \sqrt{2mE}$

$\Rightarrow \quad \lambda = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2mK}} \quad (\because E = K)$

26. **(a)**

27. **(c)** $E = W_0 + K_{max} \Rightarrow K_{max} = E - W_0 = h\nu - W_0$

$\Rightarrow \quad K_1 = h\nu - W_0$ and $K_1 = 2h\nu - W_0 \Rightarrow K_1 > 2K_1$

28. **(a)** Saturation photoelectric current $\propto$ intensity of incident radiation but it is independent of its frequency. Hence, the saturation photoelectric current becomes doubled, when both intensity and frequency of the incident light are doubled.

29. **(a)** Energy of incident light $E\,(eV) = \frac{12375}{4000} = 3.09$ eV

Stopping potential is – 2V so $K_{max} = 2$ eV

Hence by using $E = W_0 + K_{max} \Rightarrow W_0 = 1.09$ eV ≈ 1.1 eV

30. **(b)**

31. **(a)** $E = h\nu_0 + K_{max} \Rightarrow K_{max} = 3h\nu_0$.

32. **(b)** By using $E = W_0 + \frac{1}{2}mv_{max}^2$: where

$E = \frac{12375}{4558} = 2.71eV$

$\Rightarrow \quad 2.71eV = 2.5\ eV + \frac{1}{2} \times 9.1 \times 10^{-31} \times v_{max}^2$

$\Rightarrow \quad 0.21 \times 1.6 \times 10^{-19} = \frac{1}{2} \times 9.1 \times 10^{-31} \times v_{max}^2$

$\Rightarrow v_{max} = 2.65 \times 10^5$ m/s

33. **(b)** $I_1 > I_2$ (given) $\Rightarrow i_1 > i_2$ ($\because i \propto I$)
and stopping potential does not depend upon intensity. So its value will be same (V_0).

34. **(b)** Stopping potential is that negative potential for which photoelectric current is zero.

35. **(d)** $\because \quad V_0 = \left(\frac{h}{e}\right)\nu - \left(\frac{W_0}{e}\right)$. From the graph $V_2 > V_1$

$\Rightarrow \quad \frac{h\nu_2}{e} - \frac{W_0}{e} > \frac{h\nu_1}{e} - \frac{W_0}{e} \Rightarrow \nu_2 > \nu_2$

$\Rightarrow \quad \lambda_1 > \lambda_2 \left(\text{as } \lambda \propto \frac{1}{\nu}\right)$

36. **(a)** $K_{max} = h\nu - h\nu_0 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$ i.e., graph between K_{max} and $\frac{1}{\lambda}$ will be straight line having slope (hc) and intercept $\frac{hc}{\lambda_0}$ on KE axis.

37. **(a)** Momentum of photon $p = \frac{E}{c}$

$\Rightarrow$ Velocity of photon $c = \frac{E}{p}$

38. **(c)** Energy of photon $E = \frac{hc}{\lambda}(\text{Joules}) = \frac{hc}{e\lambda}(eV)$

$\Rightarrow \quad E(eV) = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19} \times \lambda(Å)} = \frac{12375}{\lambda(Å)}$

$\Rightarrow \quad E(keV) = \frac{12.37}{\lambda(Å)} \approx \frac{12.4}{\lambda}$

39. **(c)** $E = nh\nu \Rightarrow \nu \propto \frac{1}{n} \Rightarrow \frac{n_1}{n_2} = \frac{\gamma_2}{\gamma_1}$.

40. **(d)** K_{max} of photoelectrons doesn't depends upon intensity of incident light.

41. **(d)** Stopping potential depends upon the energy of photon.

42. **(b)** With the increase in intensity of light photoelectric current increases, but kinetic energy of ejected electron, stopping potential and work function remains unchanged.

43. **(c)** Current is directly proportional to the intensity of light.

$\therefore \quad I_1 < I_2$.

44. **(c)** Using Einstein's equation :

$K_{max} = h\upsilon - \phi_0 = eVs$ ...(i)

Since saturation current is same, intensity is also same. But stopping potential is different therefore they have different frequencies.

$\therefore \quad \upsilon_1 < \upsilon_2 < \upsilon_3$

45. **(d)**

46. **(d)** According to Einstein's photoelectric equation

$\therefore \quad \frac{1}{2}mv^2{}_{max} = h\upsilon - \phi_0$

As per question

$\frac{1}{2}mv^2{}_{max_1} = 1\ eV - 0.5\ eV = 0.5\ eV$ ... (i)

and $\frac{1}{2}mv^2_{max_2} = 2.5\text{ eV} - 0.5\text{ eV} = 2\text{ eV}$ ... (ii)

Dividing eqn. (i) by eqn. (ii), we get

$$\frac{v^2_{max_1}}{v^2_{max_2}} = \frac{0.5\text{ eV}}{2\text{ eV}} = \frac{1}{4}$$

$$\text{Ratio} = \frac{v_{max_1}}{v_{max_2}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

47. **(a)** Work function for cesium is 2.14 eV, aluminium is 4.28 eV, silver is 4.70 eV and platinum is 5.65 eV.

$\therefore$ The work function for platinum is highest while it is lowest for cesium.

48. **(a)** **49.** **(b)**

50. **(d)** As the distance of source from the surface increases, intensity of radiation decreases.

$\because$ Intensity (I) $\propto \frac{1}{(\text{distance d})^2}$ and since, photoelectric current (i) $\propto$ intensity (I)

Thus, the variation of i versus d is correctly depicted by the curve d in the given figure.

51. **(d)**

52. **(a)** From the given graph,

The value of stopping potential, $V_0 = -0.54$ V.

53. **(b)** Number of photoelectrons,

$N \propto I$ ...(i)

As, $v \cdot \lambda$ = speed of light c

$$\therefore \quad v \propto \frac{1}{\lambda}$$

Also, $E = hv$

$$\Rightarrow \quad E \propto v$$

$$\Rightarrow \quad E \propto \frac{1}{\lambda} \qquad \text{...(ii)}$$

So, from Eqs. (i) and (ii), we get

$$N \propto I \text{ and } E \propto \frac{1}{\lambda}$$

54. **(b)**

55. **(d)** According to Einstein's photoelectric equation, basic elementary process involved in photoelectric effect is the absorption of a single light quantum (photon) of sufficient energy by a single electron.

Thus, K_{max} depends linearly on the frequency v of incident radiation (photon).

56. **(b)** $K_{max} = hv - \phi_0 = hv - hv_0$ ...(i)

$K_{max} = h(6v) - h(v) = 5\,hv$

57. **(b)**

58. **(a)** By Einstein's equation,

we have $eV_0 = hv - \phi_0$

or $$V_0 = \frac{h}{e}v - \frac{\phi_0}{e}$$

Above is an equation of straight line ($y = mx - c$) with slope $\frac{h}{e}$ and y-intercept = $\frac{\phi_0}{e}$

$\therefore$ Work function, ϕ_0

= e × y-intercept (in eV)

As in the given graph y-intercept = OB

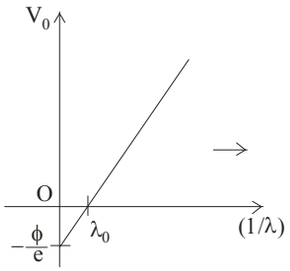
= e × OB (in eV)

59. **(c)**

60. **(c)** $K_{max} = \frac{hc}{\lambda} - \phi_0$

$$\Rightarrow \quad V_0 = \left(\frac{hc}{e}\right)\left(\frac{1}{\lambda}\right) - \frac{\phi_0}{e}$$

The graph between V_0 and $\frac{1}{\lambda}$ is as shown below.



61. **(b)** $K = hv - hv_0$

$$\frac{dK}{dv} = h = \tan\theta$$

$$\Rightarrow \quad \theta = \tan^{-1}(h)$$

62. **(a)**

63. **(b)** $E = \frac{hc}{\lambda} - \phi$

$$\frac{E}{2} = \frac{hc}{\lambda'} - \phi$$

Now $E - \frac{E}{2} = \frac{hc}{\lambda} - \frac{hc}{\lambda'}$

or $$\lambda' = \frac{hc(2hc - E\lambda)}{2\lambda}$$

64. **(b)** The wavelength of violet light is $\lambda = 390\text{ nm} = 390 \times 10^{-9}$ m

$\therefore$ The energy at the violet end is

$$E = \frac{hc}{\lambda}$$

$$= \frac{6.63\times10^{-34}\times3\times10^{8}}{390\times10^{-9}\times1.6\times10^{-19}}\text{eV} = 3.19\text{ eV}$$

65. (d) Energy of each photon in the laser beam = hv

$= 6.63 \times 10^{-34} \times 6 \times 10^{14}$ Unit

Number of photons emitted per second

$$= \frac{2\times10^{-3}}{6.626\times10^{-34}\times6\times10^{14}}$$

$= 5 \times 10^{15}$ photons per second

66. (b) Power of the source

= Number of photons emitted per second × Energy of one photon

$$\therefore \quad n_1\frac{hc}{\lambda_1} = n_2\frac{hc}{\lambda_2}$$

$$\Rightarrow \quad \frac{n_1}{n_2} = \frac{\lambda_1}{\lambda_2} = \frac{2}{400} = \frac{1}{200} = 1:200$$

67. (a)

68. (b) Linear momentum of the photon, $p = \frac{E}{c}$

$$\Rightarrow \quad p = \frac{6\times10^{6}\text{eV}}{3\times10^{8}\text{ms}^{-1}}$$

$= 0.02$ eVs m^{-1}

69. (a) Momentum of photon,

$$p = \frac{E}{c} = \frac{hv}{c} = \frac{h}{\lambda}$$

$$\Rightarrow \quad p = \frac{h}{\lambda} = \frac{h}{1\times10^{-10}} = 10^{10}h$$

70. (d) Energy of n photons,

$$E = \frac{nhc}{\lambda}$$

$\therefore$ The momentum gained by the body is

$$p = \frac{E}{c} = \frac{nh}{\lambda}$$

71. (a)

72. (a) $\lambda = 4500A°$, P = 150W, η = 8%

Efficiency of the lamp,

$$\eta = \frac{\text{Energy of photon}}{\text{Rated energy of lamp}} = \frac{\left(\frac{nhc}{\lambda}\right)}{p.t}$$

$\therefore$ Number of photons emitted per second.

$$\frac{n}{t} = \frac{p.\lambda.\eta}{hc} = \frac{150\times4500\times\frac{8}{100}}{1240\times1.6\times10^{-19}}$$

$= 27.17 \times 10^{18}$

73. (b) For the metal,

$\phi_0 = 2eV$, $k_{max} = 2eV$

By Einstein's photoelectric equation,

$E = \phi_0 + k_{max} = 2 + 2 = 4eV$

$\therefore$ Wavelength of the photon is

$$\lambda = \frac{12400\text{eV}-\text{Å}}{4\text{eV}} = 3100\text{Å}$$

74. (b) λ 4000 Å, $\lambda_0 = 5420$Å

$$\therefore \quad \text{Work function, } \phi_0 = \frac{12400}{\lambda_0(\text{inÅ})}\text{eV} = \frac{12400}{5420} = 2.29\text{ eV}$$

75. (a) $\phi_o = 4.2$ eV, $\lambda = 2000$Å, v_{max} = ?

$$\therefore\ E = \frac{12400}{\lambda(\text{inÅ})}\text{eV} = \frac{12400}{2000} = 6.2\text{ eV}$$

By Einstein's photoelectric equation,

$k_{max} = E - \phi_o = 6.2 - 4.2 = 2eV$

$$\Rightarrow \quad \frac{1}{2}mv_{max}^2 = 2\times1.6\times10^{-19}$$

$\therefore \quad v_{max} = 8.4 \times 10^5$ m/s

76. (a) Wave picture of light has failed to explain photoelectric effect.

77. (c) For photosensitive metal, $\phi_o = 1.1$ eV

By Einstein's photoelectric equation

$$E = \phi_o + \frac{1}{2}mv^2$$

$$\therefore \quad \left(\frac{v_1}{v_2}\right)^2 = \frac{E_1-\phi_o}{E_2-\phi_o} = \frac{1.5-1.1}{2-1.1} = \frac{0.4}{0.9}$$

$$\therefore \quad \frac{v_1}{v_2} = 2:3$$

78. (a) Energy E = hv = ev

So slope of graph drawn between cut-off voltage (V) and frequency of incident light in a photoelectric experiment

$$\frac{v}{v} = \frac{h}{e} = \frac{6.63\times10^{-34}}{1.6\times10^{-19}} = 4.14\times10^{-15}\text{Vs}$$

79. (c) In the given relation E_k stands for maximum K.E. of emitted photoelectron.

80. **(b)** According to Einsten's photoelectric effect, the K.E. of the radiated electrons

$K.E_{max} = E - W$

$\frac{1}{2}mv_1^2 = (1 - 0.5)\text{ eV} = 0.5\text{ eV}$

$\frac{1}{2}mv_2^2 = (2.5 - 0.5)\text{ eV} = 2\text{ eV}$

$\frac{v_1}{v_2} = \sqrt{\frac{0.5}{2}} = \frac{1}{\sqrt{4}} = \frac{1}{2}$

81. **(b)** Given, work function of metal surface, $\phi_0 = 3.13$ eV

Energy of incident photon, $E = 4.13$ eV

According to Einstein's photoelectric equation

$E = \phi_0 + K.E_{max}$

$\Rightarrow 4.13 = 3.13 + K.E_{max}$

$\Rightarrow K.E_{max} = 4.13 - 3.13 = 1\text{ eV}$

82. **(c)** The stopping potential is equal to maximum kinetic energy.

83. **(a)** $K.E. = h\nu - h\nu_{th} = eV_0$ (V_0 = cut off voltage)

$\Rightarrow V_0 = \frac{h}{e}(8.2\times10^{14} - 3.3\times10^{14})$

$= \frac{6.6\times10^{-34}\times4.9\times10^{14}}{1.6\times10^{-19}} \approx 2\text{V}.$

84. **(d)** From Eqn $K.E = h\nu - \phi$

slope of graph of K.E & ν is h,

which is same for all metals.

85. **(b)** For emission of electrons incident energy of each photon must be greater than work function (threshold energy).

86. **(c)**

87. **(d)** $W_0 = h\nu_1 - eV_1 = h\nu_2 - eV_2$

$eV_2 = h(\nu_2 - \nu_1) + eV_1$

$V_2 = \frac{h(n_2 - n_1)}{e} + V_1$

88. **(c)** $h\upsilon = W_{ex}$ + maximum kinetic energy

$h\upsilon_0 = 8\text{ eV} = W_{ex} + 2\text{ eV} \Rightarrow W_{ex} = 6\text{ eV}$

For incoming radiation, energy is

$h \times 1.25\,\upsilon_0 = 10\text{ eV}$, $W_{ex} = 6\text{ eV}$

$\therefore$ Kinetic energy (maximum) = 4 eV.

89. **(a)** $E_k = \frac{hc}{c}\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)(\text{in eV})$

$= \frac{6.6\times10^{-34}\times3\times10^8}{1.6\times10^{-19}}\left(\frac{10^{10}}{1800} - \frac{10^{10}}{2300}\right) = 0.15eV$

90. **(d)** $eV_s = \frac{hc}{\lambda} - W_0$. If λ decreases, V_s increases

91. **(b)** $\frac{1}{2}m\nu_1^2 = 2W_0 - W_0 = W_0$ and

$\frac{1}{2}m\nu_2^2 = 10W_0 - W_0 = 9W_0$

$\therefore \quad \frac{\nu_1}{\nu_2} = \sqrt{\frac{W_0}{9W_0}} = \frac{1}{3}$

92. **(d)** The electron ejected with maximum speed v_{max} are stopped by electric field E =4N/C after travelling a distance d =1m

$\frac{1}{2}mv_{max}^2 = eEd = 4eV$

The energy of incident photon = $\frac{1240}{200} = 6.2$ eV

From equation of photo electric effect

$\frac{1}{2}mv_{max}^2 = h\nu - \phi_0$

$\therefore \quad \phi_0 = 6.2 - 4 = 2.2\text{ eV}$

93. **(c)** $\frac{1}{2}mv^2 = \frac{hc}{\lambda} - \phi \Rightarrow v = \sqrt{\frac{2(hc - \lambda\phi)}{\lambda m}}$

94. **(d)** $K_{max} = \frac{hc}{\lambda} - W = \frac{hc}{\lambda} - 5.01 = \frac{12375}{\lambda(\text{in Å})} - 5.01$

$= \frac{12375}{2000} - 5.01 = 6.1875 - 5.01 = 1.17775 \simeq 1.2\text{ V}$

95. **(b)**

96. **(d)** Momentum of a photon $\propto \frac{E}{c} = \frac{10\times1.6\times10^{-19}}{3\times10^8}$

$= 5.33\times10^{-27}\text{ kg ms}^{-1}$

97. **(a)** Give that, only 25% of 200W converter electrical energy into light of yellow colour

$\left(\frac{hc}{\lambda}\right)\times N = 200\times\frac{25}{100}$

Where N is the No. of photons emitted per second, h = plank's constant, c, speed of light.

$N = \frac{200\times25}{100}\times\frac{\lambda}{hc} = \frac{200\times25\times0.6\times10^{-6}}{100\times6.2\times10^{-34}\times3\times10^8}$

$= 1.5\times10^{20}$

98. **(d)** Higher the frequency, greater is the stopping potential.

99. (a) Energy emitted/sec by $S_1, P_1 = n_1 \frac{hc}{\lambda_1}$

Energy emitted/sec by $S_2, P_2 = n_2 \frac{hc}{\lambda_2}$

$$\therefore \quad \frac{P_2}{P_1} = \frac{n_2}{n_1} \cdot \frac{\lambda_1}{\lambda_2} = \frac{1.02 \times 10^{15}}{10^{15}} \cdot \frac{5000}{5100} = 1.0$$

100. (b) Energy $E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} = \frac{hc}{\phi} = \frac{1242}{\phi}$

$$\lambda_A = \left(\frac{1242}{9}\right) = 138\,\text{nm}$$

$$\lambda_B = \left(\frac{1242}{4.5}\right) = 276\,\text{nm}$$

101. (d)

102. (d) For occurence of photoelectric effect, the incident light should have frequency more than a certain minimum which is called the threshold frequency (v_0).

We have, $\frac{1}{2}mv^2 = hv - hv_0$

For photoelectric effect emission $\nu > \nu_0$

where ν is the frequency of the incident light.

103. (d) For the given frequency of incident light

$K_{max} = eV_0$

where K_{max} is the maximum kinetic energy gained by photoelectron and V_0 is the minimum retarding potential for which the photocurrent stops.

e = charge of electron.

104. (b) Max. K.E. = $h\nu - W_0$; so Max. K.E. $\propto \nu$

105. (b) The photoelectric current $\propto$ Intensity of light.

106. (c) KEmax - $h\nu - \phi_0 = eV_0$

Also, stopping potential depends only on frequency and independent of intensity.

107. (b)

108. (d) For maximum *K.E.*, we will take

higher frequency i.e, $\left(f = \frac{9 \times 10^{15}}{2\pi} Hz\right)$

$$(K.E.)_{max} = hf - \phi = \left(\frac{4.14 \times 10^{-15} \times 9 \times 10^{15}}{2\pi} - 2.50\right) eV$$

$= 5.93 - 2.50 = 3.43eV$, nearest is 3.42 *eV*.

109. (c) A certain minimum amount of energy is required to pull the electron out from the surface of the metal. This minimum energy required by an electron to escape from the metal surface is called the work function of the metal.

110. (a) For the longest wavelength to emit photo electron

$$\frac{hc}{\lambda} = \phi \Rightarrow \lambda = \frac{hc}{\phi}$$

$$\Rightarrow \lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{4 \times 1.6 \times 10^{-19}} = 310\ \text{nm}$$

111. (a) The energy of each photon

$$= \frac{200}{4 \times 10^{20}} = 5 \times 10^{-19}\ \text{J}$$

$$\text{Wavelength} = \lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34}) \times (3 \times 10^8)}{5 \times 10^{-19}}$$

$$\Rightarrow \lambda = 4.0 \times 10^{-7} = 400\ \text{nm}$$

112. (c) $hc/\lambda_0 = W_0$; $\frac{(\lambda_0)_1}{(\lambda_0)_2} = \frac{(W_0)_2}{(W_0)_1} = \frac{4.5}{2.3} = 2:1.$

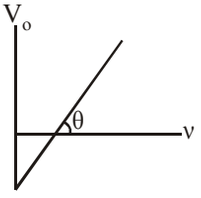
113. (a) For photoelectric effect

$$\frac{h\nu}{e} - \frac{\phi_o}{e} = V_o$$

The slope is

$$\tan\theta = \frac{h}{e} = \text{constant}$$

$\therefore$ The ratio will be 1.



114. (a)

115. (b) Since work function for a metal surface is $W = \frac{hc}{\lambda_0}$

where λ_0 is threshold wavelength or cut-off wavelength for a metal surface.

here W = 4.125 eV = $4.125 \times 1.6 \times 10^{-19}$ Joule

$$\text{so } \lambda_0 = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{4.125 \times 1.6 \times 10^{-19}} = 3000\text{Å}$$

116. (c) By using $E = W_0 + K_{max}$

$$E = \frac{12375}{5000} = 2.475\ \text{eV and } K_{max} = eV_0 = 1.36\ \text{eV}$$

So $2.475 = W_0 + 1.36 \Rightarrow W_0 = 1.1$ eV.

117. (a) Using Einstein' equation, $V_0 = \left(\frac{h}{e}\right)\nu - \frac{W_0}{e}$

Comparing this equation with y = mx + c.

We get intercept on $-V_0$ axis as $-\frac{W_0}{e}$.

$$\Rightarrow \quad OB = \frac{W_0}{e} \Rightarrow W_0 = OB \times e$$

Exercise 2 : ACCELERATOR
Topic-wise MCQs

1. **(c)** Photon & electron will have same energy E

$$E(\text{photon}) = \frac{hc}{\lambda} \text{ and } E(\text{electron}) = \frac{h}{\sqrt{2mE}}$$

$$\frac{\lambda_{photon}}{\lambda_{electron}} = \frac{\frac{hc}{E}}{\frac{h}{\sqrt{2mE}}} = c\sqrt{\frac{2m}{E}}$$

2. **(d)** de-Broglie wavelength $\lambda = \frac{h}{P} = \frac{h}{mv}$

$$= \frac{h}{\sqrt{2mE}} \text{ where } E = \frac{1}{2}mv^2$$

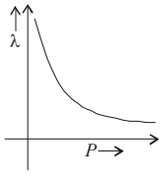
Squaring both sides,

$$\lambda^2 = \frac{h^2}{4m^2E} \Rightarrow \frac{1}{\lambda^2} \propto E$$

Hence $\frac{1}{\lambda^2}$ versus E graph is a straight line passes through the origin.

3. **(c)** Wavelength, $\lambda = \frac{h}{P} \Rightarrow \lambda \propto \frac{1}{P}$

So graph will be rectangular hyperbola as shown below



4. **(d)** From Einstein's photoelectric equation

$$\frac{hc}{\lambda} = \phi_0 + k$$

Where ϕ_0 = work function
k = maximum kinetic energy of photoelectrons

$$\therefore \frac{hc}{\lambda} = k = \frac{P^2}{2m} \Rightarrow P = \sqrt{\frac{2mhc}{\lambda}} \left[\because \phi = \text{negligible}\right]$$

de-Broglie wavelength,

$$\lambda_d = \frac{h}{P} = \frac{h}{\sqrt{2mhc/\lambda}} \Rightarrow \sqrt{\lambda} = \lambda_d\sqrt{\frac{2mc}{h}}$$

$$\therefore \lambda = \left(\frac{2mc}{h}\right)\lambda_d^2$$

5. **(c)** Using, $\lambda = \frac{12.27}{\sqrt{V}}$ Å

$$\Rightarrow \sqrt{V} = \frac{12.27 \times 10^{-10}}{1.227 \times 10^{-11}} = 10^2$$

[Given, $\lambda = 1.227 \times 10^{-11}$ m]

$\therefore V = 10^4$ volt

6. **(b)** de-Broglie wavelength of electron

$$\lambda = \frac{12.27}{\sqrt{V}} \text{Å} = \frac{12.27 \times 10^{-10}}{\sqrt{10000}} = 12.27 \times 10^{-12} \text{m}$$

7. **(a)** We know that,

de-Broglie wavelength $\lambda = \frac{\hbar}{P} = \frac{h}{\sqrt{2m(KE)}}$

K.E. of thermal neutron $= \frac{3}{2}kT$

$$= \frac{h}{\sqrt{2m\left(\frac{3}{2}kT\right)}} = \frac{h}{\sqrt{3mkT}}$$

8. **(a)** For electron De-Broglie wavelength,

$\lambda_e = \frac{h}{\sqrt{2mE}}$; For photon E = pc

$\Rightarrow$ De-Broglie wavelength, $\lambda_{Ph} = \frac{hc}{E}$

$$\therefore \frac{\lambda_e}{\lambda_{Ph}} = \frac{h}{\sqrt{2mE}} \times \frac{E}{hc} = \left(\frac{E}{2m}\right)^{1/2}\frac{1}{c}$$

9. **(b)** Given : work function ϕ of metal = 2.28 eV
Wavelength of light λ = 500 nm = 500 × 10^{-9}m

$$KE_{max} = \frac{hc}{\lambda} - \phi \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{5 \times 10^{-7}} - 2.82$$

KE_{max} = 2.48 – 2.28 = 0.2 eV

$$\lambda_{min} = \frac{h}{p} = \frac{h}{\sqrt{2m(KE)_{max}}}$$

$$= \frac{\frac{20}{3} \times 10^{-34}}{\sqrt{2 \times 9 \times 10^{-31} \times 0.2 \times 1.6 \times 10^{-19}}} = 2.80 \times 10^{-9} \text{ nm}$$

$\therefore \quad \lambda \geq 2.8 \times 10^{-9}$ m

10. (d) As $P = \frac{E}{c}$

$$\lambda_p = \frac{hc}{E} \quad ...(i)$$

$$\lambda_e = \frac{h}{\sqrt{2mE}} \Rightarrow \lambda_e^2 = \frac{h^2}{2mE} \quad ...(ii)$$

From equations (i) and (ii)

$$\lambda_p \propto \lambda_e^2$$

11. (d) **12. (d)**

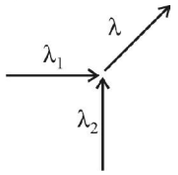
13. (a) $\lambda \propto \frac{1}{\sqrt{k}} \quad \therefore \quad \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{k_2}{k_1}}$

$$\frac{2000\text{Å}}{\lambda_2} = \sqrt{\frac{1\times10^6\text{eV}}{1\text{eV}}} \Rightarrow \lambda_2 = 2\text{Å}$$

14. (a) From the de-Broglie relation,

$$p_1 = \frac{h}{\lambda_1}$$

$$p_2 = \frac{h}{\lambda_2}$$



Momentum of the final particle (p_f) is given by

$$\therefore \; p_f = \sqrt{p_1^2 + p_2^2} \Rightarrow \frac{h}{\lambda} = \sqrt{\frac{h^2}{\lambda_1^2} + \frac{h^2}{\lambda_2^2}} \Rightarrow \frac{1}{\lambda^2} = \frac{1}{\lambda_1^2} + \frac{1}{\lambda_2^2}$$

15. (a) $KE = \frac{P^2}{2m} = \frac{h^2}{2m\lambda^2} \qquad \left(\because P = \frac{h}{\lambda}\right)$

$$\Rightarrow \; KE \propto \frac{1}{m}; \; \frac{KE_p}{KE_\alpha} = \frac{m_\alpha}{m_p} = 4:1 \qquad \left(\because m_\alpha = 4m_p\right)$$

16. (d) Energy = charge × potential diff.

$E_{electron} = q_e V$ and $E_{proton} = q_p\, 4V$

de-Broglie wavelength $\lambda = \frac{h}{P} = \frac{h}{\sqrt{2mE}}$

$$\lambda_e = \frac{h}{\sqrt{2m_e eV}} \text{ and } \lambda_P = \frac{h}{\sqrt{2m_P e4V}} \quad (\because q_e = q_P)$$

$$\therefore \; \frac{\lambda_e}{\lambda_P} = \frac{\frac{h}{\sqrt{2m_e eV}}}{\frac{h}{\sqrt{2m_P e4V}}} = 2\sqrt{\frac{m_P}{m_e}}$$

17. (d) de-Broglie wavelength, $\lambda = \frac{h}{P}$

Here momentum is same for both the particles of mass 3 m and m, so ratio of de-Broglie wavelength,

$$\frac{\lambda_{2m}}{\lambda_m} = \frac{1}{1}$$

18. (a) Energy of incident radiation = 2.20 eV

Work function of Cs, ϕ_{Cs} = 2.14 eV and ϕ_K = 2.30 eV

ϕ_{Na} = 2.75 eV

Since the work function of caesium, $\phi_{Cs} < \phi_{Incident.}$ Hence photons may be emitted from caesium.

19. (None) By Einstein's photoelectric equation,

$hf = \phi + eV_{stopping}$

when f = ν

$$h\nu = h\nu_0 + e\,\frac{V_s}{2} \qquad \text{..... (i)}$$

when f = ν/2

$$h\frac{\nu}{2} = h\nu_0 + eV_s \qquad \text{..... (ii)}$$

$$\Rightarrow \; \frac{1}{2}\left(h\nu_0 + e\frac{V_s}{2}\right) = h\nu_0 + eV_s \quad \text{[From (i)]}$$

$$\Rightarrow \; -\frac{h\nu_0}{2} = \frac{3}{4}eV_s$$

$$\Rightarrow \; \phi = h\nu_0 = +\frac{3}{2}eV_s, \text{ which is –ve.}$$

So data given is incorrect because 'ϕ' can never be negative.

20. (d) Power, $P = \frac{E}{t} = \frac{n}{t}\left(\frac{hc}{\lambda}\right)$

$$\therefore \text{ No. of photons / second}, \frac{n}{t} = \frac{P}{\left(\frac{hc}{\lambda}\right)}$$

$$\Rightarrow \frac{n}{t} = \frac{3.3\times10^{-3}\times6\times10^{-7}}{6.6\times10^{-34}\times3\times10^{8}} = 10^{16}$$

The number of photons emitted per second from a source of monochromatic radiation of wavelength λ and power P and if E = energy of each photon then,

$$\frac{n}{t} = \frac{P}{E} = \frac{P}{h\nu} = \frac{P}{hc/\lambda}$$

21. **(c)** For photoelectric emission, photoelectric current, incident light frequency should be greater than threshold frequency.

Light of frequency 1.5 times the threshold frequency v_0 incident.

$$v = \frac{3}{2}v_0$$

If frequency is halved,

$$\therefore v' = \frac{v}{2} = \frac{3}{4}v_0 \qquad \because v' < v_0$$

$\therefore$ No photoelectric emission will take place.

22. **(a, d)** Given; $\lambda_0 = 3250 \times 10^{-10}$ m

$\lambda = 2536 \times 10^{-10}$ m

$$\phi = \frac{hc}{\lambda_0} = \frac{4.14\times10^{-15}\times3\times10^{8}}{3250\times10^{-10}} = 3.82\text{eV}$$

$$h\nu = \frac{hc}{\lambda} = \frac{4.14\times10^{-15}\times3\times10^{8}}{2536\times10^{-10}} = 4.89\text{eV}$$

According to Einstein's photoelectric equation,

$K_{max} = h\nu - \phi$

$KE_{max} = (4.89–3.82)\text{eV} = 1.077$ eV

$$\frac{1}{2}mv^2 = 1.077 \times 1.6 \times 10^{-19}$$

$$\Rightarrow v = \sqrt{\frac{2\times1.077\times1.6\times10^{-19}}{9.1\times10^{-31}}}$$

or, $v = 0.6 \times 10^6$ m/s or 6×10^5 m/s

23. **(b)** According to Einstein's photoelectric equation,

$h\nu = \phi_0 + K_{max}$

We have $h\nu = \phi_0 + 0.5$ ...(i)

and $1.2h\nu = \phi_0 + 0.8$ ...(ii)

Therefore, from above two equations $\phi_0 = 1.0$ eV.

24. **(b)** From photo-electric equation,

$h\nu' = h\nu + K_{max}$ ...(i)

$$h.2\nu = h\nu + \frac{1}{2}\,mV^2_{max} \quad [\because \nu' = 2\nu]$$

$$\Rightarrow h\nu = \frac{1}{2}\,mV^2_{max} \Rightarrow V_{max} = \sqrt{\frac{2h\nu}{m}}$$

25. **(a)** Power emitted, $P = nhf \Rightarrow n = \frac{P}{hf}$

$$n = \frac{2\times10^{-3}}{6.6\times10^{-34}\times6\times10^{14}} = 5\times10^{15}$$

26. **(c)** According to photoelectric equation,

$$eV_0 = \frac{hc}{\lambda} - \phi$$

$$\Rightarrow eV_0 = \frac{1240}{300}\text{eV} - 2.13\text{ eV} \Rightarrow eV_0 = 4.13\text{ eV} - 2.13\text{ eV}$$

$\Rightarrow$ So, $V_0 = 2$V

27. **(a)**

28. **(a)** $\lambda_1 = 300$nm, $\lambda_2 = 500$nm

Power, $P = \frac{E}{t} \Rightarrow P \propto E$

$$\therefore \frac{P_1}{P_2} = \frac{E_1}{E_2} = \frac{n_1hc/\lambda_1}{n_2hc/\lambda_2}$$

$$\frac{200}{200} = \frac{n_1}{n_2}\cdot\frac{500}{300}$$

$\therefore n_1 : n_2 = 3:5$

29. **(c)** $K_A = \frac{hc}{\lambda_A} - \phi_0$; $K_B = \frac{hc}{\lambda_B} - \phi_0$

But $\lambda_A = 2\lambda_B$, therefore

$$\therefore \quad K_A < \frac{K_B}{2}$$

30. **(c)** Applying Einstein's formula for photo-electricity

$$h\nu = \phi + \frac{1}{2}mv^2; \qquad h\nu = \phi + K\,;\ \phi = h\nu - K$$

If we use 2ν frequency then let the kinetic energy becomes K'

So, $h \cdot 2\nu = \phi + K' \Rightarrow 2h\nu = h\nu - K + K' \Rightarrow K' = h\nu + K$

31. **(a)** $\lambda = 667\times10^{-9}$ m, $P = 9\times10^{-3}$ W

$P = \frac{Nhc}{\lambda}$, N= No. of photons emitted/sec.

$$N = \frac{9\times10^{-3}\times667\times10^{-9}}{6.6\times10^{-34}\times3\times10^{8}} = 3\times10^{16}\text{ / sec}$$

32. **(a)** Given, $\lambda = 660$ nm, Power = 0.5 kW, t = 60 ms

Power $P = \frac{nhc}{\lambda t} \Rightarrow n = \frac{p\lambda t}{hc} = 10^{20}$

33. **(a)** As we know, $h\upsilon = h\upsilon_0 + \text{K.E.}_{max}$

or $$\frac{hc}{\lambda_{incident}} = \frac{hc}{\lambda_0} + eV_s$$

when $\lambda_{incident} = \lambda$, $V_s = 3$V and for $\lambda_{incident} = 2\lambda$, $V_5 = 1$V.

$$\therefore \frac{hc}{\lambda} = \frac{hc}{\lambda_0} + 3\text{eV} \ \text{...(i) and} \ \frac{hc}{2\lambda} = \frac{hc}{\lambda_0} + 1\text{eV} \ \text{...(ii)}$$

On simplifying (i) and (ii) $\frac{2hc}{\lambda_0} = \frac{1}{2}\frac{hc}{\lambda} \Rightarrow \lambda_0 = 4\lambda$.

34. **(c)** As the metal surface is same, work function (ϕ) is same for both the case.

Initially $KE_{max} = nh - \phi$ ..... (i)

After increase

$KE'_{max} = 3\ nh - \phi$ .... (ii)

For work function ϕ can not be negative or zero,

$v' > \sqrt{3}v$

35. **(a)** As $K.E._{max} = e\ V_s = 0.42\ eV$

Now,

$h\nu = h\nu_0 + (K.E)_{max}$

$$\Rightarrow \frac{12400}{6630} = h\nu_0 + 0.42 \Rightarrow 1.87 - 0.42 = h\nu_0$$

$$\Rightarrow \nu_0 = \frac{1.45 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} \Rightarrow \nu_0 = 3.5 \times 10^{14}$$

$\therefore \nu_0 = 35 \times 10^{13}$ Hz

36. **(a)** For one photo cathode $hf_1 - W = \frac{1}{2}mv_1^2$ ....(i)

For another photo cathode $hf_2 - W = \frac{1}{2}mv_2^2$ ....(ii)

Subtracting (ii) from (i) we get

$$(hf_1 - W) - (hf_2 - W) = \frac{1}{2}mv_1^2 - \frac{1}{2}mv_2^2$$

$$h(f_1 - f_2) = \frac{m}{2}(v_1^2 - v_2^2)$$

$$\Rightarrow v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$$

37. **(a)** Graph of V_s and f given at B (5.5, 0)

$h\nu = \phi + eV_s$ at B, $V_s = 0$

So, $h\nu = \phi$

$$\phi = h\nu \text{ joule or } \phi = \frac{h\nu}{e} \text{ eV (for } V = 0)$$

$$\therefore \phi = \frac{6.62 \times 10^{-34} \times 5.5 \times 10^{14}}{1.6 \times 10^{-19}} \text{eV} = 2.27 \text{eV}$$

38. **(d)** Using equation, $= \frac{hc}{\lambda} - \phi$

$$KE_{max} = \frac{hc}{\lambda} - \phi = \frac{hc}{500} - \phi \quad ...(i)$$

Again, $3KE_{max} = \frac{hc}{200} - \phi$ ...(ii)

Dividing equation (ii) by (i),

$$\frac{3KE_{max}}{KE_{max}} = \frac{3}{1} = \frac{\frac{hc}{200} - \phi}{\frac{hc}{500} - \phi}$$

Putting the value of $hc = 1237.5$ and solving we get, work function, $\phi = 0.61$ eV.

39. **(b)**

40. **(c)** According to question,

$$\frac{1}{2}mv_1^2 = 4\phi \quad ...(i)$$

$$\frac{1}{2}mv_2^2 = 9\phi \quad ...(ii)$$

Dividing (i) by (ii), we get

$$\frac{v_1}{v_2} = \frac{2}{3}$$

41. **(b)**

42. **(c)** As $K.E_{max} = \frac{hc}{\lambda} - \phi$

So, $K_1 = \frac{1230}{800} - \phi$ ...(i) $\left[\because \frac{hc}{\lambda} = \frac{1240}{\lambda(nm)}\right]$

$$2K_1 = \frac{1230}{500} - \phi \quad ...(ii)$$

Multiplying (i) by 2 and substracting it from (ii)

$$\left(\frac{1230}{400} - \frac{1230}{500}\right)\text{eV} = \phi$$

$\Rightarrow \phi = 0.615$ eV

43. **(a)** As we know

$$I = \frac{E}{At} = \frac{nhv}{At} \Rightarrow \frac{n}{t} = \frac{IA\lambda}{hC}$$

$$\Rightarrow \frac{n}{t} = \frac{\rho\lambda}{hc} \Rightarrow \frac{n}{t} = \rho\lambda$$

$$\Rightarrow \left(\frac{n}{t}\right)_2 = \left(\frac{n}{t}\right)_1 \times \frac{p_2\lambda_2}{p_1\lambda_1} = 9 \times 10^{20} \times \frac{P}{P} \times \frac{800}{600} = 12 \times 10^{20}$$

44. **(b)**

Exercise 3 : PREVIOUS YEARS MCQs

1. **(a)** IA = P and, $I = \frac{Nhv}{At}$

$$\frac{N}{t} = \frac{IA}{hv} \Rightarrow \frac{N}{t} = \frac{P}{E}$$

$$n = \frac{P}{E} = \frac{P}{h\nu} = \frac{P\lambda}{hc} \qquad (\because E = h\nu \text{ and } \nu = \frac{c}{\lambda})$$

$\Rightarrow$ Clearly $n \propto \lambda$

$$\Rightarrow \frac{n_1}{n_2} = \frac{\lambda_1}{\lambda_2} = \frac{1}{500}$$

2. **(d)** Given : $v_{particle} = 4v_{electron}$ and, $\lambda_{particle} = 2\lambda_{electron}$

Using $\lambda = \frac{h}{p} \Rightarrow \lambda p$ = constant

$$\therefore \quad \lambda_{particle} \times p_{particle} = \lambda_{electron} \times p_{electron}$$

$$\Rightarrow \quad \lambda_{particle} \times m_{particle} \times v_{particle} = \lambda_{electron} \times m_{electron} \times v_{electron}$$

$$\therefore \quad m_{particle}\, v_{particle} = \frac{m_{electron} v_{electron}}{2}$$

$$\Rightarrow \quad m_{particle} = \frac{m_{electron}}{8}$$

3. **(b)** de-Broglie wavelength is given by

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mk}} \qquad \therefore \quad \lambda \alpha = \frac{1}{\sqrt{m}}$$

$\because \quad m_e < mp < m_\alpha$

$\therefore \quad \lambda_a < \lambda_p < \lambda_e$

4. **(c)** Given, de-Broglie wavelength,

$\lambda = 6600$ Å $= 6.6 \times 10^{-7}$ m

$$\Rightarrow \quad \lambda = \frac{h}{\sqrt{2m\,K\sqrt{2}}}$$

$$\Delta KE = \frac{h^2}{2m\lambda^2} = \frac{(6.6\times10^{-34})^2}{2\times9\times10^{-31}\times(6.6\times10^{-7})^2}$$

$$= \frac{10^{-68}}{18\times10^{-31}\times10^{-14}} = 0.055 \times 10^{-23} = 5.5 \times 10^{-25} \text{J}$$

The work done to accelerate the electron from rest is equal to its final KE.

Work done $\approx 5.56 \times 10^{-25}$ J

5. **(a)** The de-Broglie wavelength of a particle is

$$\lambda = \frac{h}{\sqrt{2mk}} \Rightarrow \lambda \propto \frac{1}{\sqrt{mk}}$$

$$\therefore \quad \frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha m_\alpha}{m_p k_p}} \Rightarrow \frac{2\lambda_\alpha}{\lambda_p} = \sqrt{\left(\frac{4}{1}\right)\frac{k_\alpha}{k_p}}$$

$$\therefore \quad \frac{k_p}{k_\alpha} = 1:1$$

6. **(a)** de-Broglie Wavelength associated with uncharged particle at temperature T is

$$\lambda = \frac{h}{\sqrt{3mKT}} \Rightarrow \lambda \propto \frac{1}{\sqrt{T}}$$

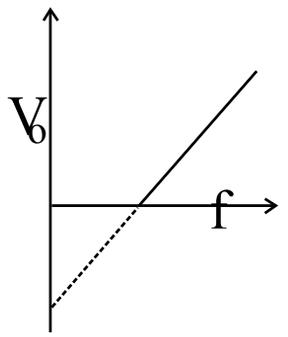
Initial temperature, $T_i = 77 + 273 = 350$ K

Final temperature, $T_f = 1127 + 273 = 1400$ K

$$\therefore \quad \frac{\lambda_i}{\Lambda_f} = \frac{1}{\sqrt{350}} \times \frac{\sqrt{1400}}{1} = \sqrt{4}$$

$$\Rightarrow \quad \frac{\lambda}{\Lambda_f} = 2 \Rightarrow \lambda_f = \frac{\lambda}{2}$$

7. **(c)** In a photoelectric experiment, the slope of the V_0 vs of graph is



$$\text{Slope} = \frac{h}{e} = \frac{6.6\times10^{-34}}{1.6\times10^{-19}} = 4.125 \times 10^{-15} \text{ Js C}^{-1}$$

8. **(c)** From the Einstein's photoelectric equation

$E = \phi + K.E$

Initially, E = 3.1, eV, K.E. = 1.7eV

$\therefore$ 3.1eV = ϕ + 1.7eV ...(i)

Finally, E = 2.5 eV, KE = eV_s

$\therefore$ 2.5 eV = ϕ + eVs ...(ii)

Subtracting (i) from (ii) we get

0.6 eV = 1.7 eV – eV_s

$\Rightarrow$ Vs = 1.7 – 0.6 = 1.1 V

9. **(a)** Using $k_{max} = E(ev) - \phi_o\,(ev) = 4.5 - 3 = 1.5$ ev

or, $k_{max} = 1.5 \times 1.6 \times 10^{-19}$ J

$$\lambda = \frac{h}{\sqrt{2m\,k_{max}}} = \frac{6.64\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times1.5\times1.6\times10^{-19}}}$$

$= 1 \times 10^{-11}$ m = 10Å

10. **(a)** For photosensitive metal surfaces A and B,

$\phi_1 : \phi_2 = 2 : 3$

From Einstein photoelectric equation,

$$V_o = \frac{h}{e}v - \frac{\phi_o}{e} \Rightarrow \text{Slope} = \frac{h}{e} = \text{Constant}$$

$$\therefore \frac{x}{y} = \frac{(\text{Slope of } V_o - v \text{ graph})_A}{(\text{Slope of } V_o - v \text{ graph})_B} = 1:1$$

11. **(a)** Wave picture of light has failed to explain photoelectric effect.

12. **(c)** For photosensitive metal, $\phi_o = 1.1$ eV

By Einstein's photoelectric equation

$$E = \phi_o + \frac{1}{2}mv^2$$

$$\therefore \left(\frac{v_1}{v_2}\right)^2 = \frac{E_1 - \phi_o}{E_2 - \phi_o} = \frac{1.5 - 1.1}{2 - 1.1} = \frac{0.4}{0.9}$$

$$\therefore \frac{v_1}{v_2} = 2:3$$

13. **(a)** Energy $E = hv = ev$

So slope of graph drawn between cut-off voltage (V) and frequency of incident light in a photoelectric experiment

$$\frac{v}{v} = \frac{h}{e} = \frac{6.63\times10^{-34}}{1.6\times10^{-19}} = 4.14\times10^{-15}\text{Vs}$$

14. **(d)** $\lambda(\text{in Å}) = \frac{12.27}{\sqrt{V}} \Rightarrow \frac{12.27}{\sqrt{\frac{200}{3}}}$

$$\lambda = \frac{12.27}{\sqrt{66.67}} \approx \frac{12.27}{8.16} \approx 1.5\text{Å}$$

So, $\boxed{\lambda = 1.5\text{Å}}$

15. **(a)** $K_{max} = \frac{1}{2}mv^2$

$$\Rightarrow K_{max} = \frac{1}{2}\times9.1\times10^{-31}\times(8\times10^5)^2$$

$= 0.5 \times 9.1 \times 64 \times 10^{-21}$

$$K_{max} = \frac{291.2\times10^{-21}}{1.6\times10^{-19}} \approx 1.8\text{eV}$$

$$\therefore \quad V_s = \frac{K_{max}}{e} = 1.8\text{V}$$

16. **(d)** Minimum wavelength of X-ray is given by

$$\lambda_{min} = \frac{h_c}{ev} = \frac{12375}{V_{(\text{in volt})}}\text{Å}$$

$$\Rightarrow \lambda_{min} = \frac{12375}{20\times10^3} = 6187.5\times10^{-4}$$

$= 0.062 \times 10^{-9}$ m $= 0.062$ nm

17. **(d)** de-Broglie wavelength $\lambda = \frac{\lambda}{\sqrt{2mKT}}$ or, $\propto \frac{1}{\sqrt{T}}$

Give $T_1 = 127°C = 127 + 273 = 400$k, $T_2 = 352°C$ $= 352 + 273 = 625$K, $\lambda_1 : \lambda_2 = ?$

$$\therefore \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{625}{400}} = \frac{25}{20} = \frac{5}{4}$$

$\therefore \lambda_1 : \lambda_2 = 5 : 4$

18. **(c)** Use de Broglie relation:

$$\lambda = \frac{h}{p} = \frac{h}{mv} \Rightarrow v = \frac{h}{m\lambda}$$

Kinetic Energy; K.E. $= \frac{1}{2}mv^2 = \frac{1}{2}m = \frac{h^2}{2m\lambda^2}$

Substitute the values.

$$K.E = \frac{\left(6.6\times10^{-34}\right)^2}{2.9\times10^{-31}\times\left(2\times10^{-9}\right)^2} = 6.05\times10^{-20}\text{J}$$

Convert to eV

1 eV $\Rightarrow 1.6 \times 10^{-19}$ J $\Rightarrow$ K.E $= 0.38$ eV

19. **(c)** The de-Broglie wavelength of a particle is

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2m\,qV}} \Rightarrow \lambda \propto \frac{1}{\sqrt{mq}}$$

For proton, $m_p = m$, $q_p = e$

For $\propto$-particle, $m_\propto = 2m$, $q_\propto = 4e$

$$\therefore \frac{\lambda_p}{\lambda\alpha} = \sqrt{\frac{m_\propto\, q_\propto}{m_p\, q_p}} = \sqrt{\frac{(2m)(4e)}{(m)(e)}} = 2\sqrt{2}:1$$

20. **(d)** $r = 0.5$ mm $= 0.5 \times 10^{-3}$ m

$B = 2 \times 10^{-2}$ T

momentum (p) = qBr

$= 2 \times 1.6 \times 10^{-19} \times 2 \times 10^{-2} \times 0.5 \times 10^{-3}$

$= 3.2 \times 10^{-24}$ Kg m/s

$$\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}}{3.2\times10^{-24}} \approx 2.1\times10^{-10}\text{m}$$

$\boxed{\lambda = 2.1\text{Å}}$

21. **(d)** Using conversation of momentum and energy
Final velocity of 8 μg particle

$$V_1' = \frac{m_1 - m_2}{m_1 + m_2} v$$

Final velocity of 4 μg particle

$$V_1' = \frac{2m_1}{m_1 + m_2} v$$

De broglie wavelength $\lambda = \frac{h}{mv}$

$$\lambda_1 : \lambda_2 = \frac{1}{m_1 v_1^1} : \frac{1}{m_2 v_2^2}$$
$$= \frac{1}{8 \times v_2^1} : \frac{1}{4 \times v_2^1} = 2 : 1$$

22. **(c)** De-broglie wavelength

$$\lambda = \frac{h}{p} \text{ or } \lambda \propto \frac{1}{p}$$

λ changes to $\lambda = \frac{0.25}{100}$ i.e., $\lambda_0 = 25 \times 10^{-4} \lambda$

p changes to p_0

$$\frac{\lambda}{\lambda_0} = \frac{p_0}{p} \text{ or } \frac{\lambda}{25 \times 10^{-4} \lambda} = \frac{p_0}{p} \therefore p = 400\, p_0$$

23. **(b)** $K_2 = (1 - 0.36)\, K_1 = 0.64\, K_1$
De-Broglie wavelength of the particle is

$$\lambda = \frac{h}{\sqrt{2mk}} \Rightarrow \lambda \propto \frac{1}{\sqrt{k}}$$

$$\therefore \frac{\lambda_2}{\lambda_1} = \sqrt{\frac{K_1}{K_2}} = \sqrt{\frac{k_1}{0.64 k_1}} = 1.25$$

$\therefore \lambda_2 = 1.25\, \lambda_1$
$\therefore$ % increase in de-Broglie wavelength is

$$\% \Delta\lambda = \frac{\Delta\lambda}{\lambda_1} \times 100 = \frac{1.25\lambda_1 - \lambda_1}{\lambda_1} \times 100 = 25\%$$

24. **(a)** $\vec{v_1} = v_o \hat{i}, \vec{E} = -E_o \hat{i}, \lambda_1 = \lambda$
$\therefore$ Acceleration of electron,

$$\vec{a} = \frac{\vec{F}}{m} = \frac{-e\vec{E}}{m} = \left(\frac{eE_o}{m}\right)\hat{i}$$

$\therefore$ Velocity after time t is

$$\vec{v_2} = \vec{v_1} + \vec{a}\, t = v_o \hat{i} + \left(\frac{eE_o t}{m}\right)\hat{i} = \left(v_o + \frac{eE_o t}{m}\right)\hat{i}$$

$\therefore$ de-Broglie wavelength of electron,

$$\lambda = \frac{h}{mv} \Rightarrow \lambda \propto \frac{1}{v}$$

$$\therefore \frac{\lambda_2}{\lambda_1} = \frac{v_1}{v_2} = \frac{v_o}{v_o + \frac{eE_o t}{m}}$$

$$\therefore \lambda_2 = \frac{\lambda_1}{\left(1 + \frac{eE_o t}{mv_o}\right)} = \frac{\lambda}{\left(1 + \frac{eE_o t}{mv_o}\right)}$$

25. **(d)** $P_{total} = 200W$
$\Rightarrow$ Percentage converted to visible light 11%
$P_{visible}$ = 11% of 200 = 22W
Intensity I is power per unit area
$A = 4\pi r^2 = 4\pi(1)^2 = 4\pi m^{-2}$

$$I = \frac{P_{visible}}{A} = \frac{22}{4\pi} \approx \frac{22}{12.566} \approx 1.75 W/m^2$$

$$\boxed{I = 1.75 W/m^2}$$

26. **(a)** $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mk}} \Rightarrow K.E = \frac{h^2}{2m\lambda^2}$

$$K.E = \frac{(6.63 \times 10^{-34})^2}{2 \times 9.11 \times 10^{-31} \times (10 \times 10^{-10})^2}$$

$$= \frac{4.39 \times 10^{-67}}{2 \times 9.11 \times 10^{-31} \times 10^{-18}} = \frac{4.39 \times 10^{-67}}{1.822 \times 10^{-48}}$$

K.E. $\approx 2.41 \times 10^{-19}$ J
photon energy = work function + K.E.
$8 \times 10^{-19} = \phi + 2.41 \times 10^{-19} \Rightarrow \phi \approx 5.59 \times 10^{-19}$J
Converting it into eV i.e., 3.5 eV

27. **(a)** Minimum wavelength of X-ray

$$\lambda_{min} = \frac{hc}{eV} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19} \times 2 \times 10^4}$$

$$\lambda_{min} = \frac{1.989 \times 10^{-25}}{3.2 \times 10^{-15}} \approx 6.215 \times 10^{-11} m$$

$$\boxed{\lambda_{min} = 0.62 Å}$$

28. **(b)** Energy of one photon
$E = hv = 6.6 \times 10^{-34} \times 5 \times 10^{14} = 3.3 \times 10^{-19}$ J
Number of photons per second

$$n = \frac{\text{Power}}{\text{Energy per photon}} = \frac{33 \times 10^{-3}}{3.3 \times 10^{-19}} = 10^{17}$$

$= 10 \times 10^{16}$

29. **(b)** For photoelectric emission from a metal surface,

$\lambda_o = 6250A°$, $h = 6.6 \times 10^{-34}$ Js

$\therefore$ The work function of the metal is

$$W_o = \frac{h_c}{\lambda_o} = \frac{6.6\times10^{-34}\times3\times10^{8}}{\lambda_o} = \frac{12375\,eV - A°}{\lambda_o(inA°)}$$

$$= \frac{12375\,eV - A°}{6250\,A°} = 1.98eV$$

30. **(a)** $\lambda = 4500A°$, $P = 150W$, $\eta = 8\%$

Efficiency of the lamp,

$$\eta = \frac{\text{Energy of photon}}{\text{Rated energy of lamp}} = \frac{\left(\frac{nhc}{\lambda}\right)}{p.t}$$

$\therefore$ Number of photons emitted per second.

$$\frac{n}{t} = \frac{p.\lambda.\eta}{hc} = \frac{150\times4500\times\frac{8}{100}}{1240\times1.6\times10^{-19}}$$

$= 27.17 \times 10^{18}$

31. **(b)** For the metal,

$\phi_0 = 2eV$, $k_{max} = 2eV$

By Einstein's photoelectric equation,

$E = \phi_0 + k_{max} = 2 + 2 = 4eV$

$\therefore$ Wavelength of the photon is

$$\lambda = \frac{12400eV - Å}{4eV} = 3100Å$$

32. **(b)** λ 4000 Å, $\lambda_0 = 5420Å$

$$\therefore \text{ Work function, } \phi_0 = \frac{12400}{\lambda_0(inÅ)}eV = \frac{12400}{5420} = 2.29 \text{ eV}$$

33. **(d)** $\lambda_1 = 300nm$, $\lambda_2 = 500$ nm, $\frac{v_1}{v_2} = 3$

By Einstein photoelectric equation,

$$E = \phi_0 + \frac{1}{2}mv^2$$

$$\Rightarrow \left(\frac{v_1}{v_2}\right)^2 = \frac{E_1 - \phi_0}{E_2 - \phi_0} = \frac{\left(\frac{1240}{\lambda_1} - \phi_0\right)}{\left(\frac{1240}{\lambda_2} - \phi_0\right)}$$

$$\Rightarrow 9 = \frac{\left(\frac{1240}{300} - \phi_0\right)}{\left(\frac{1240}{500} - \phi_0\right)} \Rightarrow 9\left(\frac{124}{50} - \phi_0\right) = \left(\frac{124}{30} - \phi_0\right)$$

$\therefore \quad \phi_0 \approx 2.28$ eV

34. **(c)** By Einstein's photoelectric equation,

$E = \phi_o + K_{max}$

$$\Rightarrow \frac{hc}{\lambda} = \frac{hc}{\lambda_o} = \frac{1}{2}mv_{max}^2$$

$$\Rightarrow v_{max}^2 = \frac{2mc}{m}\left(\frac{1}{\lambda} - \frac{1}{\lambda_o}\right)$$

$$\Rightarrow \frac{v_{max,1}^2}{v_{max,2}^2} = \frac{\left(\frac{1}{\lambda_0/3} - \frac{1}{\lambda_0}\right)}{\left(\frac{1}{\lambda_0/9} - \frac{1}{\lambda_0}\right)} = \frac{\frac{2}{\lambda_0}}{\frac{8}{\lambda_0}} = \frac{1}{4}$$

$$\therefore \frac{V_{max,1}}{V_{max,2}} = \frac{1}{2}$$

35. **(a)** $\phi_o = 4.2$ eV, $\lambda = 2000Å$, $v_{max} = ?$

$$\therefore E = \frac{12400}{\lambda(inÅ)}eV = \frac{12400}{2000} = 6.2 \text{ eV}$$

By Einstein's photoelectric equation,

$k_{max} = E - \phi_o = 6.2 - 4.2 = 2eV$

$$\Rightarrow \frac{1}{2}mv_{max}^2 = 2\times1.6\times10^{-19}$$

$\therefore \quad v_{max} = 8.4 \times 10^5$ m/s

15 Structure of Atoms and Nuclei

Exercise 1 : WARM-UP
Topic-wise MCQs

1. **(b)**

2. **(a)** The significant result deduced from the Rutherford's scattering is that whole of the positive charge is concentrated at the centre of atom i.e. nucleus.

3. **(d)** α-particle cannot be attracted by the nucleus.

4. **(d)** Rutherford suggested that the electrons revolve around the nucleus in a circular path. But any charged particle in circular motion undergoes acceleration and radiate energy. So, the electron would eventually lose energy and finally fall into the nucleus making the atom highly unstable. Thus, his model could not explain atom's stability.

5. **(c)** $N \propto \frac{1}{\sin^4 \theta/2}$; $\frac{N_2}{N_1} = \frac{\sin^4(\theta_1/2)}{\sin^4(\theta_2/2)}$

or $\frac{N_2}{5\times10^6} = \frac{\sin^4(60°/2)}{\sin^4(120°/2)}$ or $\frac{N_2}{5\times10^6} = \frac{\sin^4 30°}{\sin^4 60°}$

or $N_2 = 5\times10^6 \times \left(\frac{1}{2}\right)^4 \left(\frac{2}{\sqrt{3}}\right)^4 = \frac{5}{9}\times10^6$

6. **(d)**

7. **(a)** The kinetic energy of the projectile is given by

$$\frac{1}{2}mv^2 = \frac{Z_1 e(Z_2 e^2)}{4\pi\varepsilon_0 r_0} = \frac{Z_1 Z_2}{4\pi\varepsilon_0 r_0}$$

Thus energy of the projectile is directly proportional to Z_1, Z_2

8. **(a)** By Bohr' quantization rule

$$L_n = \frac{nh}{2\pi} \Rightarrow mvr = \frac{nh}{2\pi} \Rightarrow mv = \frac{nh}{2\pi r} \Rightarrow p = \frac{nh}{2\pi r}$$

9. **(a)** Frequency of electron in n^{th} orbit is given by

$$\upsilon = \frac{4\pi^2 Z^2 e^4 mK^2}{n^3 h^3} \Rightarrow \upsilon \propto \frac{1}{n^3} \propto \frac{1}{T} \ \because \ T \propto n^3.$$

10. **(c)** Energy in the nth orbit of hydrogen atom is given by,

$$E_n = -\frac{13.6}{n^2}\text{eV}$$

For $n = 2$

$$E_2 = -\frac{13.6}{2^2}\text{eV} = -3.4\text{eV}$$

11. **(c)**

12. **(d)** The period of revolution of hydrogen atom is given by :

$$T_n = \frac{4\varepsilon_0^2 h^3 n^3}{me^4} \Rightarrow T_n \propto n^3$$

For $n = 1$ and for $n = 2$

$$\frac{T_2}{T_1} = \frac{2^3}{1^3} = 8 \Rightarrow T_2 = 8T_1 = 8T$$

13. **(b)** Energy $E_n = -\frac{13.6}{n^2}\text{eV}$

For third orbit, n = 3

$$\therefore \ E_3 = -\frac{13.6}{3^2}\text{eV} = -1.51\text{ eV}$$

14. **(b)** $E = \frac{-13.6Z^2}{n^2}\text{eV}$

If $n = 2, Z = 1$

$$E_2 = \frac{-13.6}{4}\text{eV} \qquad ...(i)$$

If $n = 3, Z = 2$

$$E_3 = -\frac{13.6\times4}{9} \qquad ...(ii)$$

On divide equation (ii) by (i),

$$\frac{E_3}{E_2} = \frac{4\times4}{9\times1} = \frac{16}{9} \Rightarrow E_3 = \frac{16}{9}E_2$$

15. **(c)** Angular momentum of electron is given by:

$$L = \frac{nh}{2\pi}$$

Change in angular momentum is given by

$$= L_4 - L_1 = \frac{4h}{2\pi} - \frac{h}{2\pi} = \frac{3h}{2\pi}.$$

16. **(a)** Energy required to excite an electron from $n = 2$ to $n = 4$ state is given by :

$$E_4 - E_2 = \frac{-13.6}{4^2} - \frac{-13.6}{2^2} = -0.85 + 3.4 = 2.55\text{eV}$$

17. **(d)** Angular momentum is given by :

$$L = \frac{nh}{2\pi} = \frac{3h}{2\pi}$$

On compairing, n = 3

Total energy of electron, in n^{th} orbit is given by :

$$E = \frac{13.6}{n^2}\text{eV} \Rightarrow E = -\frac{13.6}{3^2} = -1.51\text{eV}$$

Kinetic energy of electron in n^{th} orbit is given as

$E_K = |E| \Rightarrow E_K = 1.51$ eV

18. (d) $(E_C - E_A) = (E_C - E_B) + (E_B - E_A)$

$$\Rightarrow \frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} \Rightarrow \frac{1}{\lambda_3} = \frac{\lambda_1 + \lambda_2}{\lambda_1 + \lambda_2}$$

$$\therefore \lambda_3 = \frac{\lambda_1\lambda_2}{(\lambda_1 + \lambda_2)}$$

19. (b) For hydrogen atom, $E_n = -13.6$ eV

$\therefore$ $P.E = 2E_n = 2 \times (-13.6) = -27.2$ eV

20. (b) For hydrogen atom,

$$r_n = \frac{n^2h^2}{4\pi^2 m_e k e^2} \Rightarrow r_1 = \frac{h^2}{4\pi^2 m_e k e^2} \quad ...(i)$$

For μ-meson, $m \to 208m$, $Z = 3$

$$\therefore r_n = \frac{n^2h^2}{4\pi^2 (208m_e) k (3) e^2} \quad ...(ii)$$

From eq(i) and (ii), we get

$$\frac{h^2}{4\pi^2 m_e k e^2} = \frac{n^2h^2}{208 \times 3 \times 4\pi^2 m_e k e^2}$$

$$\Rightarrow n = \sqrt{208 \times 3} \approx 25$$

21. (d) $B.E = 13.6$ eV $= -E_1 \Rightarrow E_1 = -13.6$ eV

For Li^{2+}, $z = 3$, $n_1 = 2$, $n_2 = \infty$

$$\Delta E = E_\infty - E_2 = 0 - \left(-13.6 \times \frac{Z^2}{n_1}\right) = 13.6 \times \frac{(3)^2}{(2)^2} = 30.6 \text{ eV}$$

22. (a) For hydrogen atom,

$$E_1 = -13.6\text{eV}, E_n = \frac{E_1}{n^2} \quad \therefore E_2 = \frac{E_1}{4} = -3.4 \text{ eV}$$

$\therefore$ Potential energy, $U_2 = 2E_2 = 2 \times (-3.4) = -6.8$ eV

23. (c) $K.E. = \frac{kZe^2}{2r}$ and $P.E = -\frac{kZe^2}{r}$; $\therefore \frac{K.E.}{P.E.} = -\frac{1}{2}$

24. (d) Required energy $E_3 = \frac{+13.6}{3^2} = 1.51$ eV

25. (d) According to Bohr's theory, radius of hydrogen atom

in final state, $r_n = r_0 \times \left(\frac{n^2}{Z}\right)$

$$\therefore 2.12 = 0.53 \times \left(\frac{n^2}{1}\right) \text{ or } n^2 = 4 \text{ or } n = 2$$

26. (a) Radius of H-atom is,

$$r = 0.529\frac{n^2}{Z} \Rightarrow 8.48 = 0.529\frac{n^2}{1}$$

$\Rightarrow n^2 = 16 \Rightarrow n = 4$

Energy of orbit is,

$$E = \frac{-13.6Z^2}{n^2} z \Rightarrow E \propto \frac{1}{n^2}$$

$$\Rightarrow E' = \frac{E}{16} \quad \therefore x = 16$$

27. (b) Energy of excited state of hydrogen atom given as

$$E_n = -\frac{13.6}{n^2} = -0.85$$

$$n^2 = \frac{13.6}{0.85} = 16 \Rightarrow n = 4$$

No. of transition $= \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$

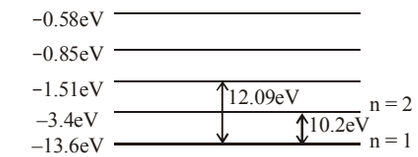
28. (a) Energy of a H-like atom in it's n^{th} state is given by

$$E_n = -Z^2 \times \frac{13.6}{n^2} eV$$

For, first excited state of He^+, $n = 2$, $Z = 2$

$$\therefore E_{He^+} = -\frac{4}{2^2} \times 13.6 = -13.6 eV$$

29. (b) Obviously, difference of 11.1eV is not possible.



30. (b) Energy of excitation, $\Delta E = 13.6\, Z^2 \left(\frac{1}{n_1} - \frac{1}{n_2}\right) eV$

$$\Rightarrow \Delta E = 13.6\,(3)^2 \left(\frac{1}{1^2} - \frac{1}{3^2}\right) = 108.8\, eV$$

31. (c) Ist excited state corresponds to n = 2

2nd excited state corresponds to n = 3

$$\therefore \frac{E_1}{E_2} = \frac{n_2^2}{n_1^2} = \frac{3^2}{2^2} = \frac{9}{4}$$

32. (b) **33. (b)**

34. (a) Radius $r \propto \frac{n^2}{z}$

Where n = no. of orbit and z = atomic number

$$\frac{r_{He^+}}{r_{Be^{3+}}} = \frac{2^2 \times 4}{2 \times 4 \times 4} = \frac{1}{2} \quad \therefore \frac{r_2}{r_1} = \frac{2}{1} \quad \therefore x = 2$$

35. (a) In hydrogen atom,

$$\Delta E = 13.6\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \Rightarrow 12.75 = 13.6\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$$

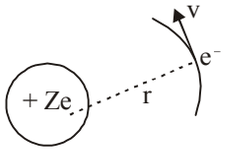
$\therefore \quad n = 4.$

36. (d) According to Bohr, speed of e^- in n^{th} orbit is given by

$$V_n = \frac{2.18 \times 10^6}{n} \times z \quad \therefore V_n \propto z$$

$$\frac{(V_3)_{He^+}}{(V_3)_H} = \frac{Z_{He^+}}{Z_H} = \frac{2}{1}$$

37. (a)



For electron revolution, $F_{centripetal} = \frac{mv^2}{r}$

$$\Rightarrow \frac{KZe^2}{r^2} = \frac{mv^2}{r} \Rightarrow mv^2 = \frac{KZe^2}{r}$$

$$\therefore K = \frac{1}{2}mv^2 = \frac{KZe^2}{2r} \text{ and } U = \frac{-KZe^2}{r}$$

$$\therefore E = K + U = -\frac{KZe^2}{2r} \quad \therefore \frac{E}{U} = \frac{1}{2}$$

38. (a) Centripetal force, $F_C = \frac{mv^2}{r}$

$$\Rightarrow \frac{Kq_1q_2}{r^2} = \frac{mv^2}{r} \Rightarrow mv^2r^2 = Kq_1q_2r$$

$$\Rightarrow \frac{m^2v^2r^2}{m} = Kq_1q_2r \qquad \therefore L \propto \sqrt{r} \qquad [\because L = mvr]$$

39. (c) When the electron drops from any orbit to second orbit, then wavelength of line obtained belongs to Balmer series.

40. (d) $\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{5^2}\right] = R\left[\frac{1}{4} - \frac{1}{25}\right]$

$$\frac{1}{\lambda} = \frac{21R}{100} \quad \therefore \quad \lambda = \frac{100}{21R} = \frac{100}{21 \times 1.1 \times 10^7} = \frac{100}{23.1 \times 10^7}$$

$\lambda = 4329$ Å

This wavelength correspond to Violet.

Hence, the atom will emit violet light.

41. (d) The wavelength of first line of the Lyman series for hydrogen atom is given by

$$\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] \qquad ...(i)$$

The wavelength of second line of Balmer series for hydrogen atom is given by

$$\frac{1}{\lambda'} = Z^2R\left[\frac{1}{2^2} - \frac{1}{4^2}\right] \qquad ...(ii)$$

As given, $\lambda = \lambda'$

From Eqs. (i) and (ii),

$$R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = Z^2R\left[\frac{1}{2^2} - \frac{1}{4^2}\right] \Rightarrow \frac{3}{4} = \frac{3Z^2}{16}$$

$$\Rightarrow \quad Z^2 = 4 \Rightarrow Z = 2$$

42. (d)

43. (a)

44. (c) For hydrogen atom, $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For Balmer series, $n_1 = 2, n_2 = 3, 4, 5, ... \infty$

$$\frac{1}{\lambda_{min}} = R\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) = \frac{R}{4} \Rightarrow \lambda_{min} = \frac{4}{R}$$

For Bracket series, $n_1 = 4, n_2 = 5, 6, 7, ... \infty$

$$\therefore \quad \frac{1}{\lambda_{max}} = R\left(\frac{1}{4^2} - \frac{1}{5^2}\right) = \frac{9R}{16 \times 25}$$

$$\therefore \quad \frac{\lambda_{min}}{\lambda_{max}} = \frac{\frac{4}{R}}{\frac{16 \times 25}{9R}} = 9 : 100$$

45. (b)

46. (c)

47. (b) The smallest frequency and largest wavelength in ultraviolet region will be for transition of electron from orbit 2 to orbit 1.

$$\therefore \quad \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$\Rightarrow \frac{1}{122 \times 10^{-9} m} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = R\left[1 - \frac{1}{4}\right] = \frac{3R}{4}$$

$$\Rightarrow R = \frac{4}{3 \times 122 \times 10^{-9}} m^{-1}$$

The highest frequency and smallest wavelength for infrared region will be for transition of electron from ∞ to 3rd orbit.

$$\therefore \ \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \Rightarrow \frac{1}{\lambda} = \frac{4}{3\times 122\times 10^{-9}}\left(\frac{1}{3^2} - \frac{1}{\infty}\right)$$

$$\therefore \ \lambda = \frac{3\times 122\times 9\times 10^{-9}}{4} = 823.5\text{nm}$$

48. **(a)** $\frac{1}{\lambda_{Balmer}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{5R}{36}, \frac{1}{\lambda_{Lyman}} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3R}{4}$

$$\therefore \ \lambda_{Lyman} = \lambda_{Balmer} \times \frac{5}{27} = 1215.4\text{Å}$$

49. **(d)** $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$. For first wavelength, $n_1 = 2, n_2 = 3$

$\Rightarrow \lambda_1 = 6563$ Å. For second wavelength, $n_1 = 2, n_2 = 4$

$\Rightarrow \lambda_2 = 4861$ Å

50. **(b)** For first member of Lyman series, $n_1 = 1, n_2 = 2$

$$\therefore \quad \frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] \qquad \text{.....(i)}$$

For second member of Lyman series $n_1 = 1, n_2 = 3$

$$\therefore \quad \frac{1}{\lambda'} = R\left[\frac{1}{1^2} - \frac{1}{3^2}\right] \qquad \text{.....(ii)}$$

On dividing (i) and (ii)

$$\lambda' = \frac{27}{32}\lambda$$

51. **(d)** Energy, $\Delta E = 10.2$eV

So, electron is excited to second state.

Hence, number of spectral lines = 1

52. **(a)** Wavelength of H-atom is

$$\frac{1}{\lambda'} = R\left[\frac{1}{1^2} - \frac{1}{3^2}\right]$$

Shortest wavelength for Balmer series:

$$\frac{1}{\lambda'} = R\left[\frac{1}{1^2} - \frac{1}{3^2}\right] \qquad \text{...(i)}$$

Shortest wavelength for Lyman series:

$$\frac{1}{\lambda_L} = Rz^2\left(\frac{1}{1^2} - \frac{1}{\infty}\right) \qquad \text{...(ii)}$$

Dividing eq. (i) and (ii), $\lambda_B : \lambda_L = 4 : 1$

53. **(d)** The wavelength for the least energetic photon

$$\lambda = \frac{hc}{E_2 - E_1}$$

$$E_1 = -\frac{13.6}{1^2}\text{eV} = -13.6\text{ eV} \quad \left(\because E_n = -\frac{13.6}{n^2}\text{eV}\right)$$

$$E_2 = -\frac{13.6}{2^2}\text{eV} = -3.4\text{ eV} \ \therefore \ \lambda = \frac{1240\text{ eV nm}}{-3.4\text{ eV} - (-13.6\text{ eV})}$$

$$= \frac{1240\text{ eV nm}}{-3.4\text{ eV} + 13.6\text{ eV}} = \frac{1240\text{ eV nm}}{10.2\text{ eV}} = 122\text{ nm}$$

54. **(c)** Radius of nucleus $R = R_0 A^{1/3}$ where A is the mass number of nucleus.

$$\therefore \quad \text{Volume of nucleus} = \frac{4}{3}\pi R^3 = \left(\frac{4}{3}\pi R_0^3\right)A$$

$\therefore$ Volume is proportional to A.

55. **(d)** For two nuclei ${}_{52}X^A$ and ${}_{13}A\ell^{27}$,

$R_1 : R_2 = 5 : 3$

Radius of nucleus, $R = R_o A^{1/3}$

$$\therefore \ \frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{A}{27}\right)^{1/3}$$

$$\Rightarrow \ \frac{A}{27} = \left(\frac{5}{3}\right)^3 = \frac{125}{27} \ \therefore \ A = 125$$

$\therefore$ Number of neutrons in nucleus ${}_{52}X^{125}$ is

$n = A - Z = 125 - 52 = 73$

56. **(b)** $R = R_0 A^{1/3} = 1.2 \times 10^{-15} \times (125)^{1/3}$

$$= 1.2 \times 10^{-15} \times (5)^{3\times\frac{1}{3}} = 6 \times 10^{-15}\text{ m}.$$

57. **(c)** We use the formula, $R = R_0 A^{1/3}$

This represents relation between atomic mass and radius of the nucleus.

For berillium, $R_1 = R_0 (9)^{1/3}$

For germanium, $R_2 = R_0 A^{1/3}$

$$\frac{R_1}{R_2} = \frac{(9)^{1/3}}{(A)^{1/3}} \Rightarrow \frac{1}{2} = \frac{(9)^{1/3}}{(A)^{1/3}}$$

$$\Rightarrow \frac{1}{8} = \frac{9}{A} \Rightarrow A = 8\times 9 = 72.$$

58. **(c)** As nuclear density $= \frac{Au}{\frac{4}{3}\pi R^3}$. Also, $R = R_0 A^{\frac{1}{3}}$

$$\Rightarrow R^3 = R_0^3 A \Rightarrow \text{Nuclear density} = \frac{Au}{\frac{4}{3}\pi R_0^3 A} = \frac{3u}{4\pi R_0^3}$$

$\Rightarrow$ Nuclear density is independent of A.

59. **(b)** Protons and neutrons are the constituents of nucleus.

60. **(d)** The nuclear density is independent of the mass number. So, required ratio is 1.

61. **(c)** Nucleus does not contain electron.

62. **(a)**

63. **(b)** Using Einstein's mass–energy relation,
$E = mc^2 = (10^{-3}\text{ kg})(3 \times 10^8\text{ m s}^{-1})^2$
$= 10^{-3} \times 9 \times 10^{16}\text{ J} = 9 \times 10^{13}\text{ J}$

64. **(b)** The moderator is used to decrease the speed of neutrons. Hence option (b) is correct.

65. **(b)** The binding energy per nucleon is given as

$$= \frac{\Delta m \times 931}{4}\text{ MeV} = \frac{0.03 \times 931}{4}\text{MeV} = 6.9825\,\text{MeV}$$

66. **(d)** $m_3 < (m_1 + m_2)$ $(\because m_1 + m_2 = m_3 + E)$
as $E = [m_1 + m_2 - m_3]\,C^2$

67. **(b)** According to mass-energy equivalence relation,
Energy, $E = mc^2$
We have, $E = 2 \times 10^{-3} \times (3 \times 10^8)^2$
$\Rightarrow \quad E = 2 \times 10^{-3} \times 9 \times 10^{16} = 18 \times 10^{13}\text{ J}$

68. **(b)** Using $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T}$ we get $\left(\frac{1}{2}\right)^{t/22} = \frac{10}{100}$

or $10 = 2^{t/22}$ or $\log_{10} 10 = \frac{t}{22}\log_{10} 2$

$\therefore \quad t = \frac{22\ \log_{10} 10}{\log_{10} 2} = \frac{22 \times 1}{0.3010} \approx 73$ years.

69. **(c)** Decay constant, $\lambda = \frac{0.693}{T} = \frac{0.693}{5 \times 3600} = 3.85 \times 10^{-5}$ per sec

70. **(a)** By using $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T}$ or $\frac{1}{64} = \left(\frac{1}{2}\right)^{15/T}$

or $\left(\frac{1}{2}\right)^6 = \left(\frac{1}{2}\right)^{15/T}$ so $\frac{15}{T} = 6$ or $T = 2.5$ hour

71. **(d)** Extremely high temps needed for fusion make K.E. large enough to overcome repulsion between nuclei.

72. **(c)**

73. **(d)** Energy per fission = 200 MeV
$= 200 \times 10^6 \times 1.6 \times 10^{-19}\text{J}$

$$\text{Fission rate} = \frac{128}{200 \times 10^6 \times 1.6 \times 10^{-19}} = 0.4 \times 10^{13}$$
$$= 4 \times 10^{12}$$

74. **(b)** In nuclear reactor

$$\frac{\Delta m}{\Delta t} = 1 \times 10^{-3}\text{g s}^{-1} = 10^{-6}\text{ kg s}^{-1}$$

$$\therefore \quad \text{Power} = \frac{\Delta E}{\Delta t}\left(\frac{\Delta m}{\Delta t}\right)c^2 = 10^{-6} \times \left(3 \times 10^8\right)^2$$

$= 9 \times 10^7\text{ kW}$

75. **(b)** We know, power $P = \frac{\Delta E}{\Delta t} = \frac{\Delta mc^2}{\Delta t}$

$$\therefore \quad \frac{\Delta m}{\Delta t} = \frac{P}{c^2} = \frac{10^9}{\left(3 \times 10^8\right)^2} = \frac{10^{-7}}{9}\text{ kg s}^{-1}$$

$$= \frac{10^{-7}}{9} \times 1000 \times 3600\text{ g h}^{-1} = 4 \times 10^{-2}\text{ g h}^{-1}$$

76. **(a)** Energy released per fission per atom, E = 200 MeV

Number of atoms in 0.1kg of $^{235}_{92}\text{U}$ is

$$N = \frac{0.1 \times 6.023 \times 10^{23}}{235 \times 10^{-3}} = 25.63 \times 10^{22}$$

Energy released per fission of 0.1Kg of $^{235}_{92}\text{U}$ (in kW-h)

$$= \frac{25.63 \times 10^{22} \times 200 \times 10^6 \times 1.6 \times 10^{-19}}{3.6 \times 10^6} = 22.8 \times 10^5\,\text{kwh}$$

77. **(c)** In nuclear reactor,
Neutron multiplication factor, k = 1, then the operation of nuclear reactor is critical.

78. **(b)** Binding energy, $E = \Delta mc^2$

$$\Rightarrow 18 \times 10^8\text{ J} = \Delta m \times (3 \times 10^8)^2 \Rightarrow \Delta m = \frac{18 \times 10^8}{9 \times 10^{16}}$$

$\Rightarrow \Delta m = 2 \times 10^{-8}\text{ kg} = 20\ \mu\text{g}$

79. **(b)**

80. **(a)**

Exercise 2 : ACCELERATOR
Topic-wise MCQs

1. **(a)**

2. **(d)**

3. **(b)**

4. **(a)**

5. **(b)** $v \propto \frac{1}{n}$

Since v is reduced to one - third, therefore
n = 3
Now, $r \propto n^2$
So, $r_2 = 9r$

6. **(a)** Velocity of electron in n^{th} orbit of hydrogen atom is given by :

$$v_n = \frac{2\pi kZe^2}{nh}$$

Substituting the values we get,

$$v_n = \frac{2.2 \times 10^6}{n}\text{m/s} \quad \text{or} \quad v_n \propto \frac{1}{n}$$ Hyperbolic relation.

7. **(d)** Radius of nth orbit $r_n \propto n^2$, graph between r_n and n is a parabola.

Also, $\frac{r_n}{r_1} = \left(\frac{n}{1}\right)^2 \Rightarrow \log_e\left(\frac{r_n}{r_1}\right) = 2\log_e(n)$

Comparing this equation with $y = mx + c$,

Graph between $\log\left(\frac{r_n}{r_1}\right)$ and log (n) will be a straight line, passing from origin.

Similarly it can be proved that graph between $\log\left(\frac{f_n}{f_1}\right)$ and log n is a straight line. But with negative slops.

8. **(a)** $R \propto n^2$; $V \propto \frac{1}{n}$ so VR is $\propto n$; $T \propto n^3 \Rightarrow E \propto \frac{1}{n^2}$

9. **(b)**

10. **(a)** In Bohr's atomic model, only orbital angular momentum is considered. No account is taken for spin or orientation of electron and so Bohr's model gives inaccurate value of angular momentum.

11. **(a)** $\frac{mv^2}{r} = \frac{3q^2}{4\pi\varepsilon_0 r^2} \Rightarrow mvr = \frac{3q^2}{4\pi\varepsilon_0 v}$ ...(i)

and $\frac{nh}{2\pi} = mvr$ ...(ii)

Using (i) and (ii) and putting n = 1

$\frac{h}{2\pi} = \frac{3q^2}{4\pi\varepsilon_0 v} \Rightarrow v = \frac{3q^2}{2\varepsilon_0 h}$

12. **(b)**

13. **(d)** $v_n \propto \frac{Z}{n}$ (for hydrogen atom, z = 1)

$\therefore v_n \propto \frac{1}{n}$ $\therefore \frac{v_3}{v_7} = \frac{7}{3}$

Speed of electron in 3rd orbit will be

$\therefore v_3 = \frac{7}{3}v_7$ ($\because v_7 = 3.6 \times 10^6$ m/s)

$= \frac{7}{3} \times 3.6 \times 10^6$ m/s $= 8.4 \times 10^6$ m/s

14. **(b)** When $F = \frac{k}{r}$ = centripetal force, then $\frac{k}{r} = \frac{mv^2}{r}$

$\Rightarrow mv^2$ = constat $\Rightarrow$ kinetic energy is constant $\Rightarrow T$ is independent of n.

15. **(b)** $E_n = -\frac{13.6}{n^2}$, $P.E_n = 2 \times -\frac{13.6}{n^2}$

and $K.E_n = \frac{13.6}{n^2}$

Clearly, when n increases

'E' increases, *'PE'* increases and *'K.E'* decreases.

16. **(b)** Lyman Series: $n_1 = 1, n_2 = 2, 3 \ldots\ldots \infty$

$\frac{1}{\lambda_{shortest}} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For shortest wavelength, $n_1 = 1, n_2 = \infty$

$\therefore R_H = \frac{1}{915A^\circ}$

Balmer Series : $n_1 = 2, n_2 = 3, 4 \ldots\ldots \infty$
For longest wavelength, $n_1 = 2, n_2 = 3$

$\therefore \frac{1}{\lambda_{longest}} = R_H\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$

$\Rightarrow \lambda_{longest} = \frac{36 \times 915}{5} = 6588A^\circ$

17. **(d)** Frequency is given as:

$f = K\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

For n = 2 to n = 1

$f_1 = K\left(\frac{1}{1} - \frac{1}{4}\right), 3 \times 10^{15} = \frac{3}{4}K$ $\therefore K = 4 \times 10^{15}$

For n = 3 to n = 1

$f_2 = K\left(\frac{1}{1} - \frac{1}{9}\right) \Rightarrow f_2 = 4 \times 10^{15} \times \frac{8}{9} = \frac{32}{9} \times 10^{15}$ Hz

$= \frac{x}{9} \times 10^{15}$ Hz (given) $\therefore x = 32$

18. **(d)** $2E - E = \frac{hc}{\lambda} \Rightarrow E = \frac{hc}{\lambda}$

$\frac{4E}{3} - E = \frac{hc}{\lambda'} \Rightarrow \frac{E}{3} = \frac{hc}{\lambda'}$ $\therefore \frac{\lambda'}{\lambda} = 3 \Rightarrow \lambda' = 3\lambda$

19. **(a)** Series limit of Lyman series is $\infty \rightarrow 1$ ν_1
First line of Lyman series is $2 \rightarrow 1$ ν_2
Series limit for Balmer series $\infty \rightarrow 2$ ν_3
$\therefore \nu_1 - \nu_2 = \nu_3$

20. **(b)** For 2nd line of Balmer series in hydrogen spectrum

$\frac{1}{\lambda} = R\,(1)\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{3}{16}R$

For $Li^{2+}\left[\frac{1}{\lambda}=R\times 9\left(\frac{1}{x^2}-\frac{1}{12^2}\right)=\frac{3R}{16}\right]$

which is satisfied by $n = 12 \rightarrow n = 6$.

21. (d)

22. (b)

23. (b) $\frac{1}{\lambda}=R\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$

$$\frac{1}{\lambda_0}=R\left(\frac{1}{2^2}-\frac{1}{3^2}\right)=R\left(\frac{1}{4}-\frac{1}{9}\right)=\frac{5R}{36}$$

$$\frac{1}{\lambda}=R\left(\frac{1}{2^2}-\frac{1}{4^2}\right)=R\left(\frac{1}{4}-\frac{1}{16}\right)=\frac{3R}{16}$$

$$\frac{\lambda}{\lambda_0}=\frac{5}{36}\times\frac{16}{3}=\frac{20}{27}$$

24. (d) When electron jumps from $M \rightarrow L$ shell

$$\frac{1}{\lambda}=K\left(\frac{1}{2^2}-\frac{1}{3^2}\right)=\frac{K\times 5}{36} \quad \text{..... (i)}$$

When eletron jumps from $N \rightarrow L$ shell

$$\frac{1}{\lambda'}=K\left(\frac{1}{2^2}-\frac{1}{4^2}\right)=\frac{K\times 3}{16} \quad \text{....(ii)}$$

solving equation (i) and (ii) we get $\lambda'=\frac{20}{27}\lambda$

25. (b) We have, $\frac{1}{\lambda}=R_H\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$

So, $\frac{1}{\lambda_1}=R_H\left(\frac{1}{1^2}-\frac{1}{3^2}\right)=R_H\left(\frac{8}{9}\right)\Rightarrow\lambda_1=\frac{9}{8R_H}$

$$\frac{1}{\lambda_2}=R_H\left(\frac{1}{1^2}-\frac{1}{2^2}\right)=R_H\left(\frac{3}{4}\right)\Rightarrow\lambda_2=\frac{4}{3R_H}$$

$$\therefore \frac{\lambda_1}{\lambda_2}=\frac{\frac{9}{8R_H}}{\frac{4}{3R_H}}=\frac{27}{32}$$

26. (d) Energy released $= E_4 - E_2 = -13.6\left(\frac{1}{4^2}-\frac{1}{2^2}\right)\times z^2 eV$

$$=-13.6\left(\frac{1}{16}-\frac{1}{4}\right)\times 16\,eV=-13.6\left(-\frac{12}{64}\right)\times 16\,eV$$

$$=13.6\times\frac{3}{16}\times 16\,eV=40.8\,eV$$

27. (d) As $E(eV)=\frac{1240}{\lambda\,(nm)}=\frac{1240}{124.1}\simeq 10\ eV$

Only in transition (D), the energy gap is 10 eV
So, option (d) is correct

28. (a) We know that $\frac{1}{\lambda}=RZ^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$

The wave length of first spectral line in the Balmer series of hydrogen atom is 6561Å . Here $n_2 = 3$ and $n_1 = 2$

$$\therefore \frac{1}{6561}=R(1)^2\left(\frac{1}{4}-\frac{1}{9}\right)=\frac{5R}{36} \quad \text{...(i)}$$

For the second spectral line in the Balmer series of singly ionised helium ion $n_2 = 4$ and $n_1 = 2$; $Z = 2$

$$\therefore \frac{1}{\lambda}=R(2)^2\left[\frac{1}{4}-\frac{1}{16}\right]=\frac{3R}{4} \quad \text{...(ii)}$$

Dividing equations (i) and (ii), we get

$$\frac{\lambda}{6561}=\frac{5R}{36}\times\frac{4}{3R}=\frac{5}{27} \quad \therefore \quad \lambda = 1215\ Å$$

So, $n_2 = 4$

$n_1 = 2$ is verified.

29. (a) $\frac{R_1}{R_2}=\left(\frac{A_1}{A_2}\right)^{1/3}$

$R_1 = R, R_2 = 2R, A_1 = 27$

$$\Rightarrow \frac{R}{2R}=\left(\frac{27}{A_2}\right)^{1/3} \Rightarrow \frac{1}{8}=\frac{27}{A_2}$$

$A_2 = 216$
It is stable in nature.

30. (d) Density of nucleus, $\rho=\frac{\text{Mass}}{\text{Volume}}=\frac{mA}{\frac{4}{3}\pi R^3}$

$$\Rightarrow \rho=\frac{mA}{\frac{4}{3}\pi(R_0A^{1/3})^3} \quad (\because R = R_0A^{1/3})$$

Here m = mass of a nucleon

$$\therefore \rho=\frac{3\times 1.67\times 10^{-27}}{4\times 3.14\times(1.3\times 10^{-15})^3} \text{ (Given, } R_0 = 1.3\times 10^{-15})$$

$$\Rightarrow \rho = 2.38\times 10^{17}\ kg/m^3$$

31. (a) $V=\frac{4}{3}\pi R^3$

$$\Rightarrow \quad V=\frac{4}{3}\pi R_0^3 A$$

$$\Rightarrow V=\frac{4}{3}\times 3\times 10^{-45}\times 27$$

$\Rightarrow V = 108 \times 10^{-45}$

$\Rightarrow V = 108 \times (10^{-10})^3 \times 10^{-15}$

$\Rightarrow V = 108 \times 10^{-15}\,(Å)^3 = 10^{-13}\,(Å)^3$

32. **(c)** Radius R of a nucleus changes with the nucleon number A of the nucleus as

$R = 1.3 \times 10^{-15} \times A^{1/3}\,m$

Hence, $\frac{R_2}{R_1} = \left(\frac{A_2}{A_1}\right)^{1/3} = \left(\frac{128}{16}\right)^{1/3} = (8)^{1/3} = 2$

$\therefore\ R_2 = 2R_1 = 2\,(3 \times 10^{-15})m = 6 \times 10^{-15}\,m$

33. **(c)**

34. **(b)** $R = R_0 A^{1/3} \Rightarrow \frac{1}{3} R_0 (189)^{1/3} = R_0 A^{1/3}$

$\Rightarrow \frac{1}{3} \times (189)^{1/3} = A^{1/3} \Rightarrow \frac{1}{27} \times 189 = A \Rightarrow A = 7$

35. **(c)** We have, $V \propto A$

$\frac{V_1}{V_2} = \frac{A_1}{A_2} = \frac{1}{3}$

36. **(d)** ${}_{92}U^{235} + {}_0n^1 \rightarrow {}_{92}U^{236}$ and

${}_{92}U^{236} \rightarrow {}_{56}Ba^{144} + {}_{36}Kr^{89} + 3\,{}_0n^1 + Q.$

37. **(a)**

38. **(c)** Given, $m_P = 1.0073u$; $m_N = 1.0087u$; $m_{He} = 4.0015u$

B.E of Helium $= (2m_P + 2m_N - m_{He})\,c^2$

$= (2 \times 1.0073 + 2 \times 1.0087 - 4.0015) \times 931.5 = 28.4\,MeV$

39. **(b)** No. of mole (n) $= \frac{120}{240} = \frac{1}{2}$

No. of molecules (N) $= \frac{1}{2} \times N_A = \frac{1}{2} \times 6 \times 10^{23}$

Energy released $= \frac{1}{2} \times 6 \times 10^{23} \times 200 = 6 \times 10^{25}\,MeV$

40. **(c)** ${}^2_1H$ and ${}^3_1H$ requires *a* and *b* amount of energies for their nucleons to be separated.

${}^4_2He$ releases *c* amount of energy in its formation i.e., in assembling the nucleons as nucleus.

Hence, Energy released $= c - (a + b) = c - a - b$

41. **(a)** Given : Mass of neutron $= M_n$

Mass of proton $= M_p$; Atomic mass of the element $= M$; Number of neutrons in the element $= N$ and number of protons in the element $= Z$. We know that the atomic mass (M) of any stable nucleus is always less than the sum of the masses of the constituent particles.

Therefore, $M < [NM_n + ZM_p]$.

42. **(c)** Rate of decay of Radium = rate of emission of α particles

or $\frac{-dN}{dt} = \lambda N = 3.7 \times 10^{10}$ per second

Number of active atoms $N = \frac{6.023 \times 10^{23} \times 1}{226}$

$\therefore\ \lambda N = \frac{0.693}{T} \times \frac{6.023 \times 10^{23}}{226} = 3.7 \times 10^{10}$

or $T = 1583$ years

Mean life $\tau = 1.44\,T = 1.44 \times 1580 = 2279$ years

43. **(d)** Radioactivity A = 1 milli curie $= 3.7 \times 10^7$ disintegration /sec

$\lambda = \frac{0.693}{T} = \frac{0.693}{1.9 \times 365 \times 24 \times 60 \times 60}$

Number of active atoms $= \frac{6.023 \times 10^{23}}{227}\,m$

(where m is mass)

$\because\ A = \lambda N$

or $3.7 \times 10^7 = \frac{0.693}{1.9 \times 365 \times 24 \times 60 \times 60} \times \frac{6.023 \times 10^{23}}{227}\,m$

or

$m = \frac{3.7 \times 10^7 \times 1.9 \times 365 \times 24 \times 60 \times 60 \times 227}{0.693 \times 6.023 \times 10^{23}} = 1.206\,\mu g$

44. **(b)**

45. **(b)** Binding energy $= 117 \times 8.5 + 117 \times 8.5 - 236 \times 7.6$

$= 234 \times 8.5 - 236 \times 7.6 = 1989 - 1793.6 = 195.4\,MeV$

Thus, in per fission of Uranium nearly 200 MeV energy is liberated.

Exercise 3 : PREVIOUS YEARS MCQs

1. **(b)** $\Delta E = \frac{hc}{\lambda} \Rightarrow \lambda \propto \frac{1}{\Delta E}$

For minimum wavelength, energy gap must be maximum. ΔE is maximum for transition from n = 3 to n = 1.

2. **(b)** $R = R_0 (A)^{1/3}$

$\therefore\ \frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{256}{4}\right)^{1/3} = 4$

$\Rightarrow R_2 = \frac{R_1}{4} = 2$ fermi

3. **(d)** Average BE/nucleon increases first, and then decreases, as is clear from BE curve.

4. **(d)** Longest wavelength in Paschen's series occurs for $n_2 = 4$ to $n_1 = 3$

$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$$\frac{1}{\lambda} = R\left[\frac{1}{(3)^2} - \frac{1}{(4)^2}\right] = R\left[\frac{16-9}{16\times 9}\right]$$

$$\Rightarrow \lambda = \frac{16\times 9}{7R} = \frac{16\times 9}{7\times 1.097\times 10^7} = 1.876\times 10^{-6}\,\text{m}$$

5. **(a)** Nuclear density is independent of atomic number.

6. **(c)** Given, $m_P = 1.0073\text{u}$; $m_N = 1.0087\text{u}$; $m_{He} = 4.0015\text{u}$

$B.E$ of Helium $= (2m_P + 2m_N - m_{He})\,c^2$

$= (2\times 1.0073 + 2\times 1.0087 - 4.0015)\times 931.5$

$= 28.4\,\text{MeV}$

7. **(c)** If the total energy of an electron is positive, the electron is not bound to the nucleus and becomes free or ionized.

8. **(c)** According to Bohr's theory, the wavelength of the radiations emitted from hydrogen atom is given by

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

For second line of Balmer series, $n_2 = 4, n_1 = 2$

$$\frac{1}{\lambda_1} = R\left[\frac{1}{(2)^2} - \frac{1}{(4)^2}\right] = R\left[\frac{3}{16}\right]$$

For first line in Lyman series, $n_2 = 2, n_1 = 1$

$$\frac{1}{\lambda_2} = R\left[\frac{1}{(1)^2} - \frac{1}{(2)^2}\right] = R\left[\frac{3}{4}\right]$$

$$\therefore \frac{\lambda_1}{\lambda_2} = \frac{3R}{4}\times\frac{16}{3R} = 4:1$$

9. **(c)** $E_n = -\frac{13.6}{n^2}\text{eV}$

Kinetic energy is positive and equal to the magnitude of the total energy.

$$K_n = +\frac{13.6}{n^2}\text{eV}$$

3rd excited state $\rightarrow n = 4$

4th excited state $\rightarrow n = 5$

$$K_4 = \frac{13.6}{4^2} = \frac{13.6}{16},\ K_5 = \frac{13.6}{5^2} = \frac{13.6}{25}$$

$$\frac{K_4}{K_5} = \frac{25}{16}$$

10. **(c)** Frequency $v = Rcz^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For Lyman series $n_1 = 1, n_2 = 2, 3, ...$

and for Balmer series $n_1 = 2, n_2 = 3, 4, 5 .....$

Given

$$f = Rcz^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right) - Rcz^2\left(\frac{1}{1^2} - \frac{1}{3^2}\right)$$

$$= Rcz^2\left[\left(\frac{1}{1} - \frac{1}{4} - \frac{1}{1} + \frac{1}{9}\right)\right] = -Rcz^2\left(\frac{5}{36}\right)$$

Therefore for Balmer series

$$f' = Rcz^2\left(\frac{1}{2^2} - \frac{1}{3^2}\right) - Rcz^2\left(\frac{1}{2^2} - \frac{1}{4^2}\right)$$

$$= Rcz^2\left[\left(\frac{1}{4} - \frac{1}{9} - \frac{1}{4} + \frac{1}{16}\right)\right] = -Rcz^2\left(\frac{7}{144}\right)$$

$$= -Rcz^2\left(\frac{7}{4\times 36}\times\frac{5}{5}\right) = -Rcz^2\left(\frac{5}{36}\right)\times\frac{7}{20} = \frac{7}{20}f$$

11. **(a)** For hydrogen atom,

$$E_1 = -13.6\text{eV}, E_n = \frac{E_1}{n^2} \therefore E_2 = \frac{E_1}{4} = -3.4\text{eV}$$

$\therefore$ Potential energy, $U_2 = 2E_2 = 2\times(-3.4) = -6.8\,\text{eV}$

12. **(c)** When transition of electron takes place between two successive orbits, then

Change in angular momentum, $\Delta L = L_n - L_{n-1}$

$$\therefore \Delta L = \frac{nh}{2\pi} - \frac{(n-1)h}{2\pi} = \frac{h}{2\pi}(n - n + 1)$$

$$= \frac{h}{2\pi}$$

13. **(c)** Wavelength of radiation emitted from hydrogen atom is given by

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

In first case

$$\frac{1}{\lambda_1} = R\left[\frac{1}{2^2} - \frac{1}{4^2}\right] = R\left[\frac{1}{4} - \frac{1}{16}\right] = \frac{3R}{16}$$

In second case

$$\frac{1}{\lambda_2} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}$$

$$\therefore \frac{\frac{1}{\lambda_1}}{\frac{1}{\lambda_2}} = \frac{\frac{3R}{16}}{\frac{5R}{36}} = \frac{3R}{16}\times\frac{36}{5R} = \frac{27}{20} \Rightarrow \frac{\lambda_1}{\lambda_2} = \frac{20}{27}$$

14. **(a)** As hydrogen is bombarded with a beam of electrons of E = 13.6 ev energy so n = 1

Hence the series to which the emitted spectral line belongs to Lyman series.

15. **(c)** To find the ratio the shortest wavelengths of Bracket and Balmer series of the hydrogen atom

for Balmer series, $n_1 = 2$ & $n_2 = \infty$

for Bracket series, $n_1 = 4$ & $n_2 = \infty$

$$\frac{1}{\lambda_{Balmer}} = R\left(\frac{1}{2^2}\right) = \frac{R}{4}$$

$$\frac{1}{\lambda_{Bracket}} = R\left(\frac{1}{4^2}\right) = \frac{R}{16}$$

$$\frac{\lambda_{Bracket}}{\lambda_{Balmer}} = \frac{16}{4} \Rightarrow \lambda_{Bracket} : \lambda_{Balmer} = 4:1$$

16. **(b)** Time period $T \propto \frac{n^3}{Z^2}$ where n = no of orbits and

z = atomic number

In 2nd excited state n = 3 and in 3rd excited state

n = 4, Z for hydrogen atom = 1, $T_{2nd} : T_{3rd} = ?$

$$\frac{T_{2nd}}{T_{3rd}} = \frac{(3)^3}{(4)^3} = \frac{27}{64} \quad \therefore \; T_{2nd} : T_{3rd} = 27:64$$

17. **(d)** Use energy level formula:

$$E_n = -\frac{13.6}{n^2}\text{eV}$$

Photon energy $E = E_{higher} - E_{lower}$

Transition $1 : 2 \rightarrow 1$

$$E_{5\rightarrow 1} = -13.6\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = 13.6\left(1 - \frac{1}{4}\right) = 10.2\text{eV}$$

Transition $2 : 5 \rightarrow 2$

$$E_{5\rightarrow 2} = -13.6\left(\frac{1}{2^2} - \frac{1}{5^2}\right) = 13.6\left(\frac{1}{4} - \frac{1}{25}\right) = 2.856\text{ eV}$$

Ratio of energies:

$$\frac{E_{2\rightarrow 1}}{E_{5\rightarrow 2}} = \frac{10.2}{2.856} = \frac{25}{7}$$

18. **(c)** Using Rydberg formula for hydrogen:

$$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

For $\lambda_{32} : \frac{1}{\lambda_{32}} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = R\left(\frac{1}{4} - \frac{1}{9}\right) = R \times \frac{5}{36}$

$$\lambda_{21} : \frac{1}{\lambda_{21}} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = R\left(1 - \frac{1}{4}\right) = R \times \frac{3}{4}$$

$$\frac{\lambda_{32}}{\lambda_{21}} = \frac{27}{5}$$

19. **(d)** Bohr's atomic model is applicable to hydrogen and hydrogen-like atoms.

20. **(b)** The wavelength of spectral series of H-atom is

$$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

For first Lyman line, $n_1 = 1, n_2 = 2$

$$\therefore \frac{1}{\lambda_L} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) \Rightarrow \lambda_L = \frac{4}{3R}$$

For second Balmer line, $n_1 = 2, n_2 = 4$

$$\therefore \frac{1}{\lambda_B} = R\left(\frac{1}{2^2} - \frac{1}{4^2}\right) \Rightarrow \lambda_B = \frac{16}{3R}$$

$$\therefore \frac{\lambda_L}{\lambda_B} = \frac{\frac{4}{3R}}{\frac{16}{3R}} = \frac{1}{4}$$

21. **(c)** $v = RC\left(\frac{1}{n_1^2} - \frac{1}{n^2}\right)$

first line:

$$v_1 = RC\left(\frac{1}{3^2} - \frac{1}{4^2}\right) = RC\left(\frac{1}{9} - \frac{1}{16}\right)$$

$$v_1 = \frac{7RC}{144}$$

second line:

$$v_2 = RC\left(\frac{1}{3^2} - \frac{1}{5^2}\right) = \frac{16RC}{225}$$

difference in frequency is

$$\Delta v = v_2 - v_1 = RC\left(\frac{16}{225} - \frac{7}{144}\right)$$

$$\boxed{\Delta v = \frac{9RC}{400}}$$

22. **(d)** The frequency of Lyman series transition from level n to 1 is given by Rydberg formula:

$$f = R_H\left(1 - \frac{1}{n^2}\right)$$

For the first lyman line $(n = 2 \rightarrow 1)$

$$f_1 = R_H\left(a - \frac{1}{2^2}\right) = \frac{3R_C}{4}$$

For the second Lyman line $(n - 3 \rightarrow 1)$

$$f_2 = R_H\left(1 - \frac{1}{3^2}\right) = \frac{8R_C}{9}$$

The difference between the frequencies is

$$\Delta f = f_2 - f_1 = \frac{8R_C}{9} - \frac{3R_C}{4} = \frac{5R_C}{36}$$

23. **(d)** Energy of emitted photon

$$E = \frac{hc}{\lambda} \text{ or, } \lambda = \frac{hc}{E}$$

Given $E = 5eV = 5 \times 1.6 \times 10^{-19}J$

$$\lambda = \frac{hc}{E} = \frac{6.64 \times 10^{-34} \times 3 \times 10^8}{5 \times 1.6 \times 10^{-19}} \cong 248 \times 10^{-9} m = 248nm$$

24. **(c)** For hydrogen atom,

$$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

For Balmer series, $n_1 = 2, n_2 = 3, 4, 5, ... \infty$

$$\frac{1}{\lambda_{min}} = R\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) = \frac{R}{4} \Rightarrow \lambda_{min} = \frac{4}{R}$$

For Bracket series, $n_1 = 4, n_2 = 5, 6, 7, ... \infty$

$$\therefore \frac{1}{\lambda_{max}} = R\left(\frac{1}{4^2} - \frac{1}{5^2}\right) = \frac{9R}{16 \times 25} \Rightarrow \lambda_{max} = \frac{16 \times 25}{9R}$$

$$\therefore \frac{\lambda_{min}}{\lambda_{max}} = \frac{\frac{4}{R}}{\frac{16 \times 25}{9R}} = 9 : 100$$

25. **(b)** $U = -6.8eV$

$$\therefore \text{ Total energy, } E_n = \frac{U}{2} = \frac{-6.8}{2} = -3.4 \text{ eV}$$

$$\Rightarrow \frac{-13.6}{n^2} = -3.4$$

$$\therefore n = 2$$

$$\therefore \text{ Speed, } v_n = \left(\frac{C}{137}\right).\frac{1}{n}$$

$$\text{for } n = 2, V_2 = \left(\frac{C}{137}\right) \times \frac{1}{2} = \frac{C}{274}$$

26. **(b)** For hydrogen atom, $E_n = -13.6$ eV

$\therefore$ P.E $= 2E_n = 2 \times (-13.6) = -27.2$ eV

27. **(c)** In hydrogen atom, $n = 3$

$$\therefore V_3 = 2.18 \times 10^6 \times \frac{1}{3} = 7.3 \times 10^5 ms^{-1}$$

28. **(a)** In hydrogen atom,

$$\Delta E = 13.6\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$\Rightarrow 12.75 = 13.6\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$$

$$\therefore n = 4.$$

29. **(d)** B.E $= 13.6$ eV $= -E_1 \Rightarrow E_1 = -13.6$ eV

For $Li^{2+}, z = 3, n_1 = 2, n_2 = \infty$

$$\therefore \Delta E = E_\infty - E_2 = 0 - \left(-13.6 \times \frac{Z^2}{n_1^2}\right)$$

$$= 13.6 \times \frac{(3)^2}{(2)^2} = 30.6eV$$

30. **(b)** Nuclear radius is related to the mass number

$R = R_o A^{1/3}$

Ratio or radius is,

$$\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{27}{125}\right)^{1/3} = \frac{3}{5}$$

The surface area of a nucleus is, $S = 4\pi R^2$

The ratio of surface area is

$$\frac{S_1}{S_2} = \frac{4\pi R_1^2}{4\pi R_2^2} = \left(\frac{3}{5}\right)^2 = 9:25$$

31. **(a)** If the relative abundances of the three isotopes A, B and C, (masses m_1, m_2 and m_3) is in the ratio 2 : 3 : 5, the average mass of the element is $0.2m_1 + 0.3m_2 + 0.5\, m_3$

32. **(c)** Given,

Power, P = 64 kW = 64000 W

Number of nuclei,

$$n = \frac{7.2\times10^{18}}{3600} = 2\times10^{15} \text{ per second}$$

Using, $P = nE \Rightarrow E = \frac{P}{n} = \frac{64000}{2\times10^{15}}$

$\Rightarrow E = 32 \times 10^{-12} = 0.32 \times 10^{-10}$ J

33. **(b)** The average energy of a neutron produced in the fission of $^{235}_{92}U$ is 2 MeV = $2 \times 10^6 \times 1.6 \times 10^{-19}$

$= 320 \times 10^{-15}$ J

34. **(c)** In nuclear reactor,

Neutron multiplication factor, k = 1, then the operation of nuclear reactor is critical

35. **(d)** Energy per fission = 200 MeV

$= 200 \times 10^6 \times 1.6 \times 10^{-19}$J

$$\text{Fission rate} = \frac{128}{200\times10^6\times1.6\times10^{-19}} = 0.4\times10^{13}$$

$= 4 \times 10^{12}$

16 Semiconductors Devices

Exercise 1 : WARM-UP
Topic-wise MCQs

1. **(c)** A p-type semiconductor is uncharged or neutral, because during the formation of p-type semiconductor, there is no addition of charged particle into the semiconductor.

2. **(d)** A positive hole is a vacancy created when an electron leaves bond.

3. **(c)** The atom is electrically neutral.

4. **(a)** Thermally generated electrons ($n_i \sim 10^{16}\ m^{-3}$) are negligibly small as compared to those produced by doping.

Therefore, $n_e \approx N_D$

Given, total number of atoms

$= 5 \times 10^{28}\ m^{-3}$

$n_i = 1.5 \times 10^{16}\ m^{-3}$

For every 10^6 atoms, 1 As is doped.

1 As contributely $1e^-$

$n_e = 5 \times 10^{28} / 10^6$

$= 5 \times 10^{22}$

Since, $n_e n_h = n_i^2$

The number of holes

$$n_h = \frac{n_i^2}{n_e} = \frac{(1.5\times10^6)^2}{5\times10^{22}} = \frac{2.25\times10^{32}}{5\times10^{22}}$$

$= 4.5 \times 10^9\ m^{-3}$

5. **(c)** Electric conduction, in a semi conductors occurs due to both electrons & holes.

6. **(a)**

7. **(c)** When small amount of antimony (pentavalent) is added to germanium crystal then crystal becomes n-type semi conductor. Therefore, there will be more free electrons than holes in the semiconductor.

8. **(d)** In extrinsic semi conductor the number of holes are not equal to number of electrons i.e.,

$n_h \neq n_e$

In p - type $n_h > n_e$

In n - type $n_e > n_h$

9. **(b)**

10. **(d)** $n_i^2 = n_e n_h$

$(1.5 \times 10^{16})^2 = n_e\ (4.5 \times 10^{22})$

$\Rightarrow \quad n_e = 0.5 \times 10^{10}$

or $\quad n_e = 5 \times 10^9$

Given $\quad n_h = 4.5 \times 10^{22}$

$\Rightarrow\ n_h >> n_e$

$\therefore$ Semiconductor is p-type and

$n_e = 5 \times 10^9\ m^{-3}$.

11. **(d)** Here, $n_i = 10^{16}\ m^{-3}$, $n_h = 5 \times 10^{22}\ m^{-3}$

As $n_e n_h = n_i^2$

$$\therefore \quad n_e = \frac{n_i^2}{n_h} = \frac{(10^{16}\,m^{-3})^2}{5\times10^{22}\,m^{-3}} = 2\times10^9\,m^{-3}$$

12. **(c)** In semiconductors,

$n_e\, n_h = n_i^2$

$$n_e = \frac{n_i^2}{n_h} = \frac{(1.2\times10^{15})^2}{4\times10^{20}} = \frac{1.44\times10^{30}}{4\times10^{20}}$$

$= 0.36 \times 10^{10} = 3.6 \times 10^9\ m^{-3}$

13. **(b)** Filter circuits are used to get smooth dc. π-filter is the best filter.

14. **(c)** After a large reverse voltage is PN- junction diode, a huge current flows in the reverse direction suddenly. This is called Breakdown of PN-junction diode.

15. **(b)** Note that if PN junction diode is made from germanium or silicon, the energy released due to recombinations of free electrons and holes is in the infrared region. However if the PN junction diode is made from gallium arsenide or indium phosphide, then the energy released due to recombination of free electrons and holes is in the visible region.

16. **(c)** In reverse bias no current flows.

17. **(b)** Depletion layer is more in less doped side.

18. **(b)** In this condition, *P* - *N* junction is reverse biased.

19. **(a)** Since there is no potential difference across *PN* junction, hence no steady current will be there in the circuit.

20. **(b)** Across the *P*-*N* junction, a barrier potential is developed whose direction is from *N* region to *P* region.

21. **(b)** *N* side is at high potential.

22. **(a)** *PN* junction diode conducts when the value of forward bias is more than the potential barrier.

23. **(b)** At a particular reverse voltage in *PN*-junction, a huge current flows in reverse direction known as avalanche current.

24. **(c)** In forward biasing of *PN*-junction diode, current mainly flows due to the diffusion of majority charge carriers.

25. **(a)** Barrier potential offers resistance to both few electrons in *N* region and holes in *P* region.

26. **(b)** Potential across the *PN* junction varies symmetrically and linearly, having *P* side negative and *N* side positive.

27. **(c)** *PN* junction has low resistance in one direction of potential difference +V, so a large current flows (forward biasing). It has a high resistance in the opposite potential difference direction – V, so a very small current flows (Reverse biasing).

28. **(c)** In forward biasing both positive and negative charge carriers move towards the junction.

29. **(b)** In forward biasing *P*-side is connected with positive terminal and *N*-side with negative terminal of the battery.

30. **(a)** In forward biasing, resistance of *PN* junction diode is zero, so whole voltage appears across the resistance.

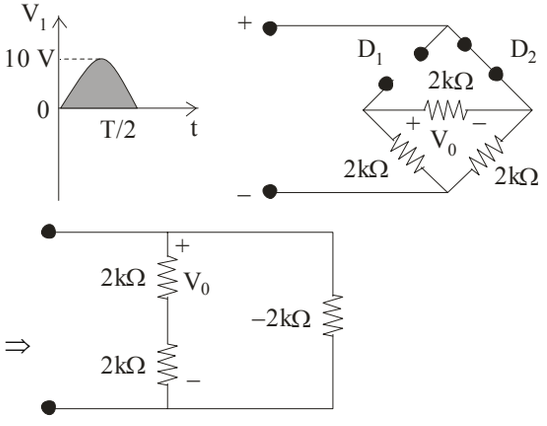
31. **(b)** Half wave rectifier has one diode in series with secondary transformer.

32. **(a)** Option (a) shows correct symbol.

33. **(c)** In photodiode, it is illuminated by light radiations which in turn produces electric current.

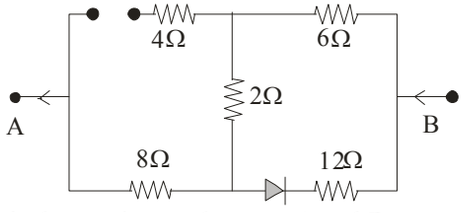
34. **(c)** In full wave rectifier, the output frequency is twice that of input frequency.

35. **(b)** For the positive half cycle of input, the resulting network is shown below:



$$\Rightarrow \left(V_0\right)_{max} = \frac{1}{2}\left(V_i\right)_{max} = \frac{1}{2} \times 10 = 5V$$

36. **(c)** According to the given figure, A is at lower potential w. r. t. B. Hence, both diodes are in reverse biasing, so equivalent circuit can be redrawn as follows:



Equivalent resistance between A and B.

$R = 8 + 2 + 6 = 16\Omega$

37. **(c)**

38. **(b)** When p-n junction is forward biased, the direction of the applied voltage is opposite to the built in potential V_0 (i.e., barrier potential). As a result, the depletion layer width decreases and the barrier height is reduced

$\therefore$ The effective barrier height under forward bias is $V_0 - V$.

39. **(a)** The current under reverse bias is essentially voltage independent upto a critical reverse bias voltage known as breakdown voltage (V_{br}). When $V = V_{br}$, the diode reverse current increases sharply from n to p-side.

Even a slight increase in the bias voltage causes large change in the current. If the reverse current is not limited by an external circuit, the p-n junction will get destroyed due to overheating.

40. **(d)** p-n junction diode primarily allows the flow of current only in one direction, i.e. only in forward bias condition.

Also, the forward bias resistance is low as compared to reverse bias resistance.

So, if an alternating voltage is applied across a diode, the current flows only in that part of the cycle when diode is forward biased. This property is thus used to rectify alternating voltages.

41. **(d)**

42. **(b)** For full wave rectifier, output frequency = 2 × input frequency and for half-wave rectifier, output frequency = input frequency.

Given, input frequency = 50 Hz

$\therefore$ Ratio of output frequency of full wave rectifier to half-wave rectifier

$$= \frac{2 \times 50}{50} = \frac{2}{1}$$

43. **(d)** When the reverse bias voltage $V = V_z$, then the electric field strength is high enough to pull valence electrons from the host atoms on the p-side which are accelerated to n-side. These electrons account for high current observed at the breakdown. Thus, the emission of electrons from the host atoms due to the high electric field is known as internal field emission or field ionisation.

44. **(d)** For voltage regulation operation, increase / decrease in applied voltage should not affect the voltage drop across zener diode.

For this feature to be satisfied, from the graph given for zener diode the part de is best suitable for its operation.

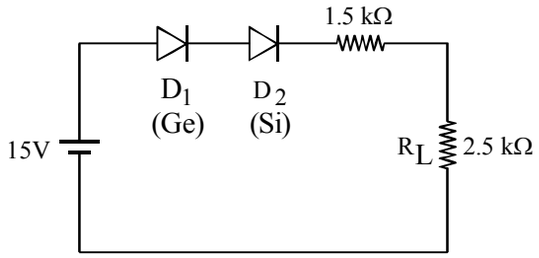
45. **(d)** The magnitude of the photocurrent depends on the intensity of the incident light as the photocurrent is proportional to incident light intensity. So, when intensity is increased, reverse saturation current also increases.

For the given, I–V characteristics of a photodiode for different illumination intensity, the order will be

$I_4 > I_3 > I_2 > I_1$

Thus, maximum illumination of intensity is I_4.

46. (a)



$$i = \frac{15 - 0.7 - 0.3}{2.5 + 1.5} = 3.5\text{mA}$$

$V_L = IR_L = 3.5 \times 2.5$ volt $= 8.75$ volt

47. (b) $V_z = 3V$, $R_1 = 1000\ \Omega$, $R_2 = 2000\ \Omega$

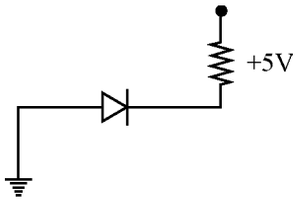
$$i_{battery} = \frac{10-3}{R_1} = \frac{10-3}{1000} = 7\text{ mA}$$

$$i_{2k\Omega} = \frac{V_z}{R_2} = \frac{3}{2000} = 1.5\text{ mA}$$

$i_z = (7 - 1.5)$ mA $= 5.5$ mA

48. (d) P end should be at lower potential and N end at higher potential for reverse biased.

49. (c) For reverse biased of a diode,
Potential of p-side < Potential of n-side i.e.



50. (d) Positive terminal is at lower potential (0V) and negative terminal is at higher potential 5V.

51. (c) When no current flows at the junction plane, then contact potential of junction plane is equal to the forward voltage applied = 0.045 V.

52. (c) In circuit A, both the diodes are in forward bias and in parallel, so $R = 2\ \Omega$

Current, $i = \frac{V}{R} = \frac{8}{2} = 4A.$

In circuit B, only one diode is in forward bias,

so current, $i = \frac{8}{4} = 2$A.

53. (a) The average value of output direct current in a half wave rectifier is = (average value of current over a cycle)/2 $= (2\ I_0/\pi)/2 = I_0/\pi$

54. (d) The average value of output direct current in a full wave rectifier = average value of current over a cycle $= 2\ I_0/\pi$

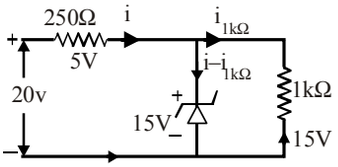
55. (c) $V = \frac{V_o}{\pi} = \frac{10}{\pi}$V

56. (b) In half wave rectifier, we get the output only in one half cycle of input a.c. therefore, the frequency of the ripple of the output is same as that of input a.c. *i.e.*, 50 Hz.

57. (a) $\eta = \frac{0.406}{1 - \frac{R_f}{R_L}}$

$\%\ \eta_{max} = 40.6\%$ $\left(\text{if } \frac{R_f}{R_L} << 1\right)$

58. (d) Voltage across zener diode is constant.



Current in 1kΩ resistor,

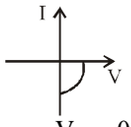
$$(i)_{1k\Omega} = \frac{15\text{volt}}{1k\Omega} = 15\text{ mA}$$

Current in 250Ω resistor,

$$(i)_{250\Omega} = \frac{(20-15)V}{250\Omega} = \frac{5V}{250\Omega} = \frac{20}{1000}\text{A} = 20\text{ mA}$$

$\therefore\ (i)_{\text{zener diode}} = (20 - 15) = 5\text{mA}.$

59. (b) I-V characterstics of solar cell is as shown below.



60. (c) $E = \frac{V}{d} = \frac{0.1}{10^{-6}} = 10^5\ \text{V/m}$

61. (d) "Single input" not acceptable.

62. (d)

(a) $\overline{\overline{A}\cdot\overline{B}} = \overline{\overline{A}} + \overline{\overline{B}} = A + B$

(b) $\overline{\overline{A} + \overline{B}} = \overline{\overline{A}}\cdot\overline{\overline{B}} = A\cdot B$

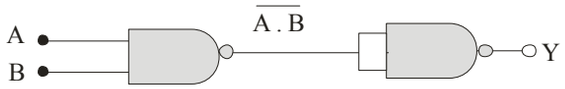
(c) $\overline{(A\cdot B)}\cdot\overline{(A\cdot B)} = A\cdot B + A\cdot B = AB + AB$

(d) $0 + 0 = 0$

Clearly, (d) is incorrect.

63. (b) $\overline{(\overline{A} + \overline{B})}\cdot A = \overline{\overline{(A} + \overline{B)}}\cdot A = (A + B)\cdot A$
$= A\ .\ A + AB = A + AB = A(1 + B) = A$

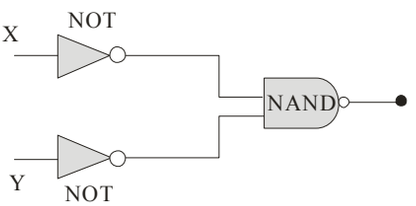
64. (b) Two 'NAND' gates are required as follows



$Y = \overline{A\cdot B}\cdot\overline{A\cdot B} = A\cdot B$

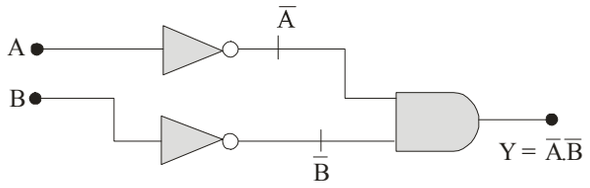
65. (b) Truth table for this digital system of logic gates is as stated below

X	Y	Z
0	0	0
0	1	1
1	0	1
1	1	1

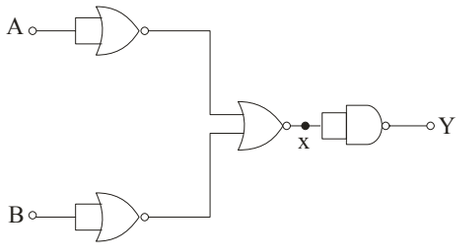


It is obvious from the truth table that this system is equivalent to a single OR gate.

66. **(d)**



67. **(d)**



$Y = \overline{X} = \overline{\overline{A} + \overline{B}} = \overline{\overline{A} \cdot \overline{B}} = \overline{\overline{A}\,\overline{B}}$

68. **(b)** Output, $Y = (A + B) + (B \cdot 1)$

$= A + B + B = A + B$

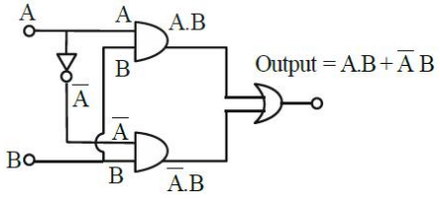
$\therefore Y = 0 \Rightarrow A = 0$ and $B = 0$

69. **(b)** Output $Y = \overline{\overline{A}.\overline{B}} = \overline{\overline{A + B}}$ (By De-Morgan Law)

$\therefore Y = A + B$

This Boolean expression represents OR gate.

70. **(c)** The given circuit is



Output, $Y = A.B + \overline{A}.B = (A + \overline{A}).B$

$Y = 1.B$

$Y = B$

71. **(d)** Truth table of the gate is as follows :

A	B	C	$A+B$	$Y=(A+B).C$	$\overline{Y}$
0	0	0	0	0	1
1	1	0	1	0	1

72. **(a)** The truth table of the output is as follows :

A	B	$\overline{A}$	$\overline{B}$	$\overline{A}+\overline{B}$	$\overline{\overline{A}+B}$
1	1	0	0	0	1
0	0	1	1	1	0
0	1	1	0	1	0
1	0	0	1	1	0
1	1	0	0	0	1
0	1	1	0	1	0

So option (a) is the correct option.

73. **(a)** When $A = 0, B = 0 \Rightarrow Y = 0$

$A = 1, B = 1 \Rightarrow Y = 1$

$A = 0, B = 1 \Rightarrow Y = 0$

$A = 1, B = 0 \Rightarrow Y = 0$

So, this must be AND gate.

74. **(b)** Combination of NAND & NOR gates can produce OR, AND & NOT gates.

75. **(d)**

76. **(d)** Emitter of the transistor is heavily doped, base of the transistor is lightly doped and collector of the transistor is moderately doped.

77. **(a)** Metal oxides with high temperature coefficient of resistivity.

78. **(c)**

79. **(d)**

80. **(c)**

81. **(c)** We know that for common base

$$\alpha = \frac{i_c}{i_e} = \frac{\text{collector current}}{\text{emiter current}} = 0.98$$

and for common emitter

$$\beta = \frac{i_c}{i_b} = \frac{\text{collector current}}{\text{base current}}$$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.98}{1-0.98} = \frac{0.98}{0.02} = 49.$$

82. **(a)** The current gain of transistor in CE and CB configuration is given as,

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.995}{0.005} = 199 \approx 200$$

83. **(c)** Voltage gain = current gain × resistance gain

84. **(b)** The power gain in case of CE amplifier,

$$\text{Power gain} = \beta^2 \times \text{Resistance gain}$$

$$= \beta^2 \times \frac{R_o}{R_i} = (10)^2 \times 5 = 500.$$

85. **(a)**

Exercise 2 : ACCELERATOR
Topic-wise MCQs

1. **(a)** Donor impurity gives extra electron to the atom which is present in its outer shell.
Thus when these type of impurity is added, the concentration of electron increases while that of holes decreases. Thus option (a) is correct answer.

2. **(b)** Majority carriers in an n-type semiconductor are electrons.

3. **(c)** The graph shows reverse baised characteristics, so it should be zener diode which is used as voltage regulator.

4. **(b)**

5. **(d)** In a photo diode, photo current is directly proportional to intensity of incident light.

6. **(b)** The formation of depletion region in p-n junction diode is due to diffusion of both electron and holes.

7. **(b)** Forward bias resistance $= \frac{\Delta V}{\Delta I} = \frac{0.1}{10 \times 10^{-3}} = 10\,\Omega$

Reverse bias resistance $= \frac{10}{10^{-6}} = 10^7\,\Omega$

Ratio of resistances $= \frac{\text{Forward bias resistance}}{\text{Reverse bias resistance}} = 10^{-6}$

8. **(c)** Given,
B and gap of semiconducting material Eg = 1.42 eV
Using, $Eg = \frac{1240}{\lambda}$

$\Rightarrow \quad \lambda = \frac{1240}{1.42} = 875$ nm (Approx)

9. **(d)** Here, $R = 4\ k\Omega = 4 \times 10^3\ \Omega$
$V_i = 60$ V
Zener voltage $V_z = 10$ V
$R_L = 2\ k\Omega = 2 \times 10^3\ \Omega$

Load current, $I_L = \frac{V_Z}{R_L} = \frac{10}{2\times10^3} = 5$ mA

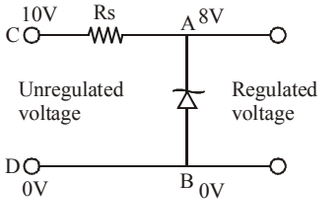
Current through R, $I = \frac{V_i - V_Z}{R}$

$= \frac{60-10}{4\times10^3} = \frac{50}{4\times10^3} = 12.5$ mA

Fom circuit diagram,

$I = I_Z + I_L \Rightarrow 12.5 = I_Z + 5 \Rightarrow I_z = 7.5$ mA

10. **(c)**



Breakdown voltage, $V_b = 8$ volt
$V_A - V_B = 8$ volt
Current through zener diode,

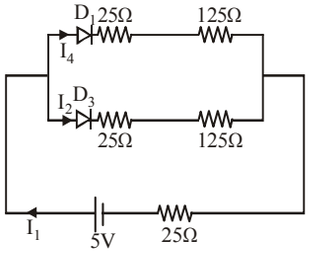
$i = \frac{P}{V} = \frac{1.6W}{8V} = 0.2A$

$V_C - V_A = 10 - 8$ volt
for safe operation of diode,

$\therefore R_S = \frac{V_C - V_A}{i} = \frac{2V}{0.2A} = 10\Omega$

[Note : A zener diode can regulate only if input voltage is ≥ zener breakdown voltage the range of input voltage should be 8 to 10 V so that output voltage remains constant = 8V]

11. **(d)** Diode D_2 is reversed biased.
$\therefore I_3 = 0$



Equivalent resistance of circuit,

$R_{eq} = \frac{150\times150}{300} + 25 = 100\Omega$

$\therefore$ Current, $I_1 = \frac{V}{R} = \frac{5}{100} = 0.05A$ and

$I_2 = I_4 = \frac{0.05}{2} = 0.025A$

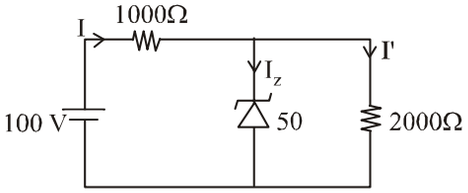
$\therefore \frac{I_1}{I_2} = 2$

12. **(b)** $R = \frac{\Delta V}{\Delta I} = \frac{2.1-2}{(800-400)\times10^{-3}} = \frac{1}{4} = 0.25\ \Omega$

13. **(d)** Here D_1 is in forward bias and D_2 is in reverse bias so, D_1 will conduct and D_2 will not conduct. Thus, no current will flow through DC.

$I = \frac{V}{R} = \frac{5}{10} = \frac{1}{2}$ Amp.

14. **(a)** In the given circuit, the zener diode is used as a voltage regulating device.
Hence, the voltage across 2000Ω is 30V.



Current flowing through 1000Ω, $I = \frac{100-50}{1000} = 50$mA

Current flowing through 2000Ω, $I' = \frac{50}{2000} = 25$mA

Using Kirchoff's current law,
$I = I_z = I' \Rightarrow \quad I_z = I - I = 50 - 25 = 25$mA

15. **(c)** Both the diodes are reverse biased, so, there is no flow of current through 5Ω and 20Ω resistances.
Now, two resistors of 10Ω and two resistors of 5Ω are in series. Hence current I through the network = 0.3 A

16. **(d)** Current in load resistance,

$i_1 = \frac{6}{4\times10^3} = 1.5 \times 10^{-3}$ A = 1.5 mA

For $V = 16$ volt,

$i_s = \frac{(16-6)}{2\times10^3} = 5$ mA

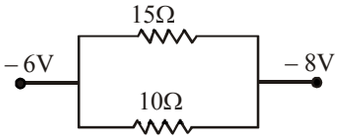
$\therefore \quad i_2 = i_s - i_1 = 5 - 1.5 = 3.5$ mA

17. **(b)** Only in (A) and (C) diodes are forward biased as p-type should be at higher potential and n-type at lower potential.

18. **(c)**

19. **(c)** In p-region of p-n junction
holes concentration > electrons concentration and in n-region of p-n junction.
electrons concentration > holes concentration.

20. **(c)** In the given circuit upper diode is forward biased and lower diode is reverse biased circuit is as shown in figure.



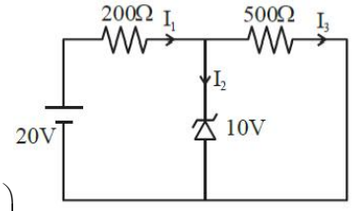
Clearly 15Ω and 10Ω are in parallel

$$\therefore R_{eq} = \frac{15\times10}{15+10} = \frac{15\times10}{25} = 6\Omega$$

21. **(c)** From ohm's law, $I = \frac{V}{R}$

$$I_3 = \frac{10}{500} = \frac{1}{50};$$

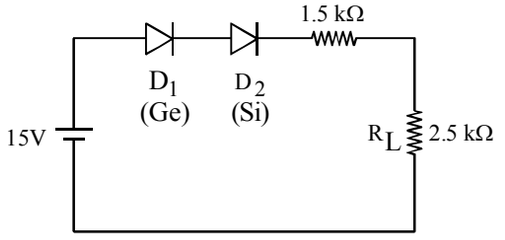
$$I_1 = \frac{10}{200} = \frac{1}{20}$$



$$I_2 = I_1 + I_3 = \left(\frac{1}{20} - \frac{1}{50}\right)$$

$$= \left(\frac{3}{100}\right) = 30 \text{ mA}$$

22. **(a)**



$$i = \frac{15 - 0.7 - 0.3}{2.5 + 1.5} = 3.5\text{mA}$$

$V_L = IR_L = 3.5 \times 2.5$ volt $= 8.75$ volt

23. **(a)** Current in the circuit $I = \frac{8 - 0.5}{2.2\times10^3} A = 3.4$ mA

24. **(b)** Given, zener current, $I = 25$ mA $= 25 \times 10^{-3}$ A

$V_z = 8$ V

Apply K.V.L, we have

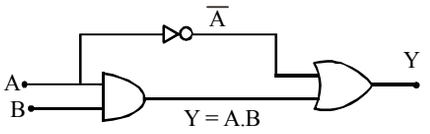
$\varepsilon - IR - V_z = 0$; $20 - IR - 8 = 0$

$IR = 12 \Rightarrow 25 \times 10^{-3} R = 12 \Rightarrow R = \frac{12}{25\times10^{-3}} = 480\ \Omega$

25. **(a)** When
$A = 0, B = 0 \Rightarrow Y = 0$
$A = 1, B = 1 \Rightarrow Y = 1$
$A = 0, B = 1 \Rightarrow Y = 0$
$A = 1, B = 0 \Rightarrow Y = 0$

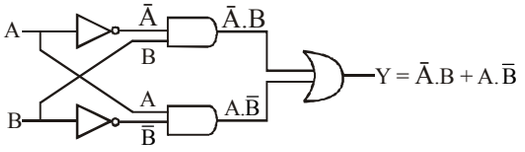
So, this must be AND gate.

26. **(b)**



A	B	$\overline{A}$	Y = A·B	Y
0	0	1	0	1
0	1	1	0	1
1	0	0	0	0
1	1	0	1	1

27. **(a)**

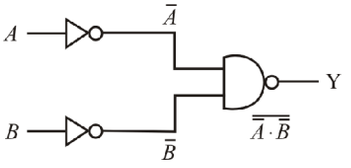


$Y = \overline{A}.B + A.\overline{B}$

The truth table for the given logic circuit is

A	B	$\overline{A}$	$\overline{B}$	$\overline{A}.B$	$A.\overline{B}$	$Y = \overline{A}.B + A.\overline{B}$
0	0	1	1	0	0	0
0	1	1	0	1	0	1
1	0	0	1	0	1	1
1	1	0	0	0	0	0

28. **(b)**



$Y = \overline{\overline{A}\cdot\overline{B}} = \overline{\overline{A+B}} = A + B$

It is OR gate.

A	B	$Y = A + B$
0	0	0
0	1	1
1	0	1
1	1	1

29. **(c)** Truth table of the circuit is as follows

x	y	$\overline{x}$	$a = x.y$	$b = \overline{x}.y$	$z = \overline{a.b}$
0	0	1	0	0	1
0	1	1	0	1	1
1	0	0	0	0	1
1	1	0	1	0	1

30. **(b)** When either of A or B is 1 i.e. closed then lamp will glow.

In this case, Truth table

Input		Output
A	**B**	**Y**
0	0	0
0	1	1
1	0	1
1	1	1

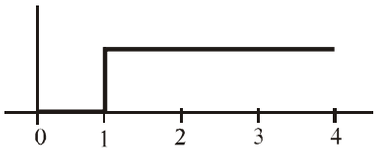
This represents OR gate.

31. **(d)** $Y = \overline{A} . \overline{B} = A + B$

The truth table is given by

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

According to truth table, resultant graph is



32. **(b)** We have truth table as shown

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

Which resembles to NAND gate so, correct option is (b).

33. **(c)** For different values of A & B output y is as follows

A	B	P	Q	Y
0	0	0	0	1
0	1	0	1	1
1	0	0	1	1
1	1	1	1	0

Output $y = \overline{(A \cdot B) \cdot A + B}$ matches with option (c).

34. **(c)**

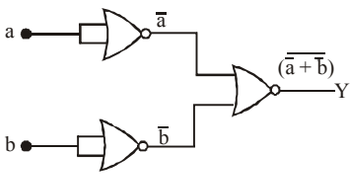
A	B	(A + B)	(A + B). A	$\overline{(A + B).A}$
0	0	0	0	1
0	1	1	0	1
1	0	1	1	0
1	1	1	1	0

35. **(a)** By expanding the final Boolen expression

$$Y = A.\overline{B} + B.\overline{A}$$

Thus the truth table for this expression should be (a).

36. **(a)**



$Y = \overline{\overline{a} + \overline{b}} = (\overline{a.b})\, a.b$

The circuit will follow truth table

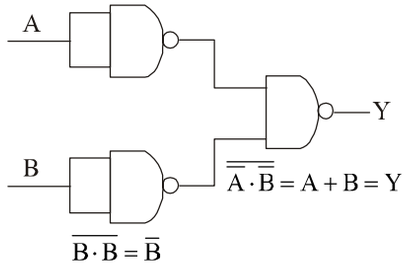
A	B	Output
0	0	0
0	1	0
1	0	0
1	1	1

Hence it is AND gate.

37. **(c)**

$\overline{A \cdot A} = \overline{A}$

38. **(d)**



A	B	Y = A + B
$t_1 \rightarrow 1$	0	1
$t_2 \rightarrow 1$	1	1
$t_3 \rightarrow 1$	1	1
$t_4 \rightarrow 0$	1	1
$t_5 \rightarrow 0$	0	0
$t_6 \rightarrow 0$	1	1

It represent OR gate.

39. **(a)** $I_C = 5.488$ mA, $I_e = 5.6$ mA

$$\alpha = \frac{5.488}{5.6}, \beta = \frac{\alpha}{1-\alpha} = 49$$

40. **(b)** In common emitter configuration for *n-p-n* transistor input and output signals are 180° out of phase *i.e.,* phase difference between output and input voltage is 180°.

41. **(c)** No. of electrons reaching the collector,

$$n_C = \frac{96}{100} \times 10^{10} = 0.96 \times 10^{10}$$

Emitter current, $I_E = \frac{n_E \times e}{t}$

Collector current, $I_C = \frac{n_C \times e}{t}$

$\therefore$ Current transfer ratio,

$$\alpha = \frac{I_C}{I_E} = \frac{n_C}{n_E} = \frac{0.96 \times 10^{10}}{10^{10}} = 0.96$$

42. **(d)**

43. **(c)**

44. **(d)** Given, $R_C = 2\ k\Omega$

$V_C = 2$ V

$R_B = 1\ k\Omega$

$\beta = 100$

$$\frac{V_C}{V_i} = \beta.\frac{R_C}{R_B}$$

$$\Rightarrow \frac{2}{V_i} = 100 \cdot \frac{2}{1}$$

$$\Rightarrow V_i = 10\ \text{mV}$$

45. (b) $\frac{V_o}{V_{in}} = \frac{R_o}{R_{in}} \times \beta = \frac{5\times10^3 \times 62}{500} = 10 \times 62 = 620$

$V_o = 620 \times V_{in} = 620 \times 0.01 = 6.2$ V

$\therefore V_o = 6.2$ volt.

Exercise 3 : PREVIOUS YEARS MCQs

1. (b) When either of *A* or *B* is 1 i.e. closed then lamp will glow.

In this case, Truth table

Input		Output
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

This represents OR gate.

2. (c) Electrons in an unbiased *p-n* junction, diffuse from *n*-region (higher electron concentration) to *p*-region (low electron concentration region).

3. (c) Given,

B and gap of semiconducting material Eg

= 1.42 eV

Using, $Eg = \frac{1240}{\lambda}$

$$\Rightarrow \lambda = \frac{1240}{1.42} = 875\ \text{nm (Approx)}$$

4. (d) Electrons in an unbiased *p-n* junction, diffuse from *n*-region i.e. higher electron concentration to *p*-region i.e. low electron concentration region.

5. (d) At absolute zero temperature, a semiconductor has no free electrons in the conduction bond, so it behaves like on insulator.

6. (c) A transistor is used as an amplifier.

A diode is used as a rectifier.

A zener diode is used as a voltage regulator.

A capacitor is used as a filter circuit.

7. (b) Region I: $V_o \approx V_{CC}$

Input voltage V_i is too law to turn on the transistor

Transistor is OFF $\rightarrow$ No current flows

This is the CUT-OFF region

Region II: Input voltage V_i increases enough to turn on the transistor but not fully.

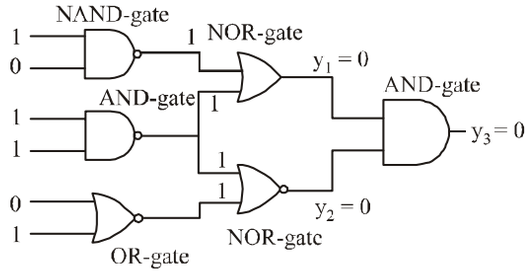
Transistor is partially on, collector current increases

This is the ACTIVE regions (used for application)

Region III: Input voltage is high enough to turn the transistor fully on collector-emitter path behaves like 9 short.

This the SATURATION region.

8. (d)



Therefore, y_1, y_2 and y_3 respectively are (0, 0, 0)

9. (c) A transistor is used as an amplifier.

A diode is used as a rectifier.

A zener diode is used as a voltage regulator.

A capacitor is used as a filter circuit.

10. (a)

11. (c) $\beta = 80$, $R_c = 5\ k\Omega$, $R_B = 1k\Omega$

$V_I = 2mV$

Now, $\frac{V_o}{V_I} = \beta.\frac{R_C}{R_B}$

$$\Rightarrow V_o = 2 \times 10^{-3} \times 80 \times \frac{5}{1} = 0.8\ \text{V}$$

12. (b)

13. (c) For CE configuration of transistor,

$A_v = 150$, $\beta = 50$, $R_B = 850\Omega$

Voltage gain, $A_V = \beta\left(\frac{R_o}{R_I}\right) = \beta\left(\frac{R_C}{R_B}\right)$

$$\Rightarrow 150 = 50 \times \frac{R_c}{850}$$

$\therefore R_c = 3 \times 850 = 2550\Omega$

14. (c) The output of the logic gate circuit is

$$Y = \overline{\overline{(A+B)}.\overline{(A.B)}} = \overline{\overline{A+B}} + \overline{A.B}$$

$$= A + B + \overline{A} + \overline{B} = (A + \overline{A}) + (B + \overline{B}) = 1 + 1 = 1$$

$\therefore$ For any value of input, the output of the circuit is 1.

15. (d) For a common emitter configuration of transistor,

$A_v = 300$, $\beta = 60$, $R_c = 5k\Omega$

Voltage gain, $A_v = \beta.\frac{R_c}{R_B}$

$\Rightarrow 300 = 60 \times \frac{5}{R_B}$

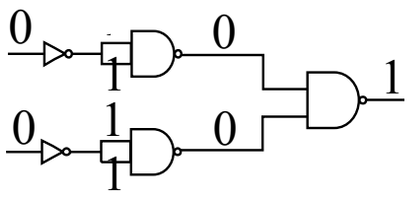
$\therefore R_B = 1\ k\Omega$

16. (d) The voltage gain of a CE configuration transistor is

$$A_V = \frac{V_O}{V_I} = \frac{V_C}{V_B} = \frac{I_C R_C}{I_B R_B} = \left(\frac{I_C}{I_B}\right)\left(\frac{R_C}{R_B}\right)$$

$$= \beta.\frac{R_C}{R_B}$$

17. (a)



In we get Inputs A = 0, B = 0, Final output comes out to be zero. Similarly, follow truth table for NAND table for NAND Gate and verify to get result.

Truth table for NAND Gate

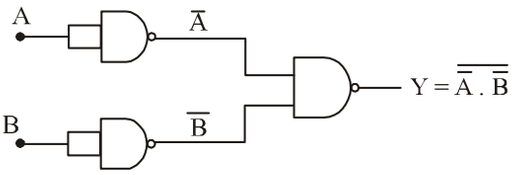
A	B	Y	$\overline{Y}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

18. (d) Given, current amplification factor B = 100,
Rc = 3kΩ Rb = 2kΩ, Power gain P = ?
Power gain = voltage gain

$$(Av) \times B = B \times \frac{R_c}{R_b} \times B = 100 \times \frac{3}{2} \times 100$$

$\therefore P = 15000$

19. (c) The given circuit diagram is



The output Y of the logic circuit is

$Y = \overline{\overline{A} . \overline{B}} = \overline{\overline{A}} + \overline{\overline{B}} = A + B$, which is OR gate.

20. (a) In the given circuit,

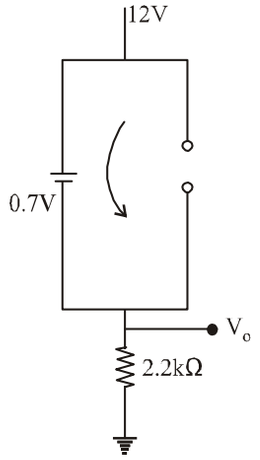
Potential barrier of LED > Potential barrier of diode

So, the equivalent circuit diagram is

$\therefore$ By KVL,

$12 - 0.7 = V_o$

$\therefore V_o = 11.3\ V$



21. (c) At thermal equilibrium,

$$n_i^2 = n_e n_h \Rightarrow n_i = \sqrt{n_e n_h}$$

22. (a)

A	B	$\overline{A}$	$\overline{B}$	$\overline{A} + \overline{B}$	$\overline{\overline{A} + \overline{B}}$	A.B
0	0	1	1	1	0	0
1	0	0	1	1	0	0
0	1	1	0	1	0	0
1	1	0	0	0	1	1

$\left(\overline{\overline{A} + \overline{B}} = A.B\right)$

Hence, it gives AND gate.

23. (d) In n-p-n transistor,

$I_C = 10mA$, $I_C = 95\%$ of $I_E = \frac{95}{100} I_E$

$$\therefore I_E = \frac{100 I_C}{95} = \frac{100 \times 10}{95} = 10.53mA$$

Now, $I_E = I_B + I_C$

$\therefore I_B = I_E - I_C = 10.53 - 10 = 0.53mA$

24. (c) For the given logic gates combination,

$$Y = \overline{\overline{A + A} + \overline{B + B}}$$

$$= \overline{\overline{(A + A)}}.\overline{\overline{(B + B)}} = A.B$$

$\therefore$ The given combination is AND gate.

25. (d) In a common emitter amplifier,

Voltage gain A_v

Current gain complification factor, β

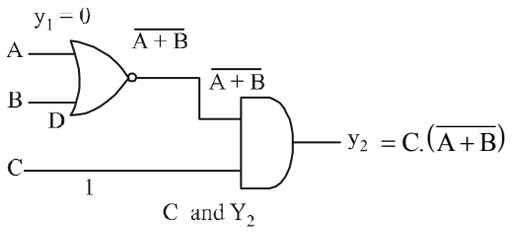
$$\frac{A_v}{\beta} = 4$$

Formula for voltage gain in a CE amplifier:

$$A_v = \beta = \frac{R_c}{r_{in\,(base)}} = \frac{R_c}{V_{in}} = 4$$

The rate of collector to base resistance is 4 :1.

26. (c)



$$y_1 = \overline{A+B}$$

$$y_2 = C.(\overline{A+B})$$

after putting value of A, B and we will get.

$$\boxed{y_1 = 0, y_2 = 0}$$

27. (a) A transistor works as an amplifier when it is in the active region. For this: - Emitter-base junction must be forward biased - collector-base junction must be reverse biased.

28. (a) A = 0, B = C = 1

$$\therefore\ y_1 = \overline{(A.B).B} = \overline{A.B} + \overline{B}$$

$$= \overline{0.1} + \overline{1} = 1 + 0 = 1$$

$$y_2 = \overline{(B+C)+B} = \overline{(B+C).\overline{B}}$$

$$= \overline{(1+1)}.\overline{1} = 0.0 = 0$$

29. (a) The value of Y_1 is

$$Y_1 = \overline{B.C} = \overline{B} + \overline{C} = \overline{1} + \overline{1} = 0 + 0 = 0$$

The value of Y_2 is

$$Y_2 = \overline{\overline{A}.\overline{B.C}} = \overline{\overline{A}} + \overline{\overline{B.C}} = A + B.C$$

$$= 1 + (1.0) = 1 + 0 = 1$$

30. (c) Collector current (I_C) = 98% of I_E

$I_C = 0.98\ I_E$

$I_E = I_B + I_C$

$I_C = 0.98 I_E$

$I_E = I_B + 0.98\ I_E$

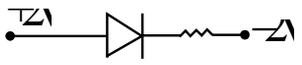
$\Rightarrow I_B = I_E - 0.98 I_E$

$I_B = 0.02 I_E$

$$\frac{I_B}{I_C} = \frac{0.02 I_E}{0.98 I_E} = \frac{0.02}{0.98} = \frac{2}{98} = \frac{1}{49}$$

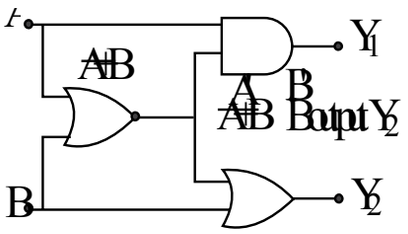
31. (d)

32. (b) Diode is inforward biased if +(ve) end of the diode is at higher potential and –(ve) end of the diode is at lower potential. So (b) is forward biased.



33. (b) From logic circuit, Given A = 1 and B = 1

$$\frac{A'}{A.}\ \frac{B'}{\overline{A+B}}\ \text{Output } Y_1$$



A'	B'	Y_1
A	$\overline{A+B}$	$A.\overline{A+B} = 0$

A'	B'	Y_2
$A+B$	B	$\overline{A+B}+B = 1$

34. (d) $n_e = n_h = 1.5 \times 10^{16}\ m^{-3}$

$\therefore$ Number of intrinsic charge carriers,

$$n_i^2 = n_e n_h = \left(1.5 \times 10^{16}\right)^2$$

Again,

$$\left(1.5 \times 10^{16}\right)^2 = n_e\,(3 \times 10^{22})$$

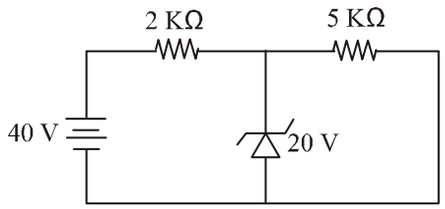
$\therefore\ n_e = 7.5 \times 10^9\ m^{-3}$

35. (c) For semiconductor used for fabrication of visible LEDs,

Band gap $\geq$ 1.8eV

36. (c) For 5kΩ resistance

$$\text{Current } i_{5\Omega} = \frac{20}{5 \times 10^3} = 4\text{mA}$$



For 2kW resistance current

$$i_{2\Omega} = \frac{40-20}{2\times10^3} = 10\text{mA}$$

Therefore current through zener diode $I_2 = 10\text{ mA} - 4\text{mA}$ = 6mA

37. **(c)** using $n_i^2 = n_e n_h$ Given $n_i = 6 \times 10^{15} m^{-3}$, $n_e = 4 \times 10^{22}\ m^{-3}$, n_h = ?

$$(6 \times 10^{15})^2 = 4 \times 10^{22} \times n_h \Rightarrow n_h = \frac{(6\times10^{15})^2}{4\times10^{22}}$$

$= 9 \times 10^8\ m^{-3}$

38. **(c)** The output of the logic circuit is

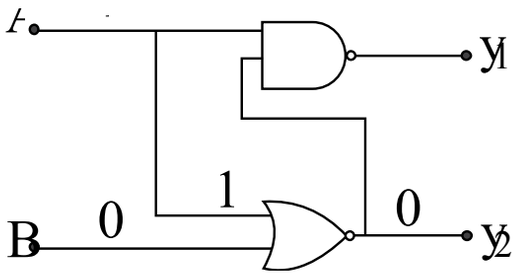
$Y = (A + B) . C = 1$

$\Rightarrow$ A + B = 1 and C = 1

$\Rightarrow$ (A = 0, B = 1, C = 1)

or (A = 1, B = 0, C = 1)

39. **(b)**



$y_2 = \overline{A + B} = \overline{0+1} = 0$

$y_1 = \overline{AB} = \bar{0} = 1$

40. **(c)** Fundamental frequency of output ripple, f_0 = 2 × input frequency

= 2 × 50 = 100 Hz