Section A

1) ~~(B) spherical surface.~~ ~~(A) Plane.~~ (B) spherical surface

2) (B) 1.6×10^{-18} J

3) (C) $-0.24\, nT\, \hat{k}$

4) (D) remain stationary

5) (B) 0.3 mB

6) (C) 15 V

7) (B) L is decreased and A is increased

8) ~~(B)~~ ~~(A)~~ (B) Gamma rays

9) (B) 2

$\angle 45$

$U_1 = -mB$

$U_2 = -mB\frac{1}{\sqrt{2}}$

$U_2 - U_1 = mB(1 - \frac{1}{\sqrt{2}})$

$mB(1 - 0.7)$

$mB(0.3)$

$15 \times 10^{-3} \times 4$

0.004×10^{-3}

$\mu_0 n^2 L A$

$\mu_0 \frac{N^2}{L^2} . L A$

$\mu_0 \frac{N^2}{L} . A$

$\frac{1}{2} mv^2 = \frac{kq}{r}$ $\frac{2k}{v^2}$

$r = \frac{2kq}{mv^2} \propto \frac{q}{m}$

$\frac{r_p}{r_\alpha} = \frac{1 \times 4}{1 \times 2} = 2$

-5 $+5$ P_1 P_2

$V = 10V$

3 4 5 θ

$\sin\theta = \frac{3}{5}$

$\frac{10^{-7}\, i dl \sin\theta}{r^2}$

$\frac{10^{-7}(5)(2 \times 10^{-2})}{25} \times \frac{3}{5}$

$10^{-9} \times \frac{6}{25}$

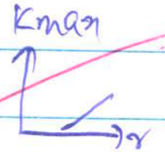
$\frac{2k2^1}{r_2^2} 10^{-9} \times \frac{60}{25} \times 10^{-1}$

$\frac{k}{r^2}$

$0.24\, nT$

3

10) (c)



11) (B) decreases by 87.5 %.

12) (B) 0.05 eV.

13) (D) A is false, R is also false

14) (C) A is true, R is false.

15) (A) Both A and R are correct and R is the correct explanation of A.

16) (A) Both A and R are correct and R is the correct explanation of A.

(P.T.O)

(RW)

$\frac{mv^2}{r} = qvB$

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

$r = \frac{p}{qB}$.

Period: $\frac{2\pi R}{v}$

$= \frac{2\pi a_0 n^2}{v_0 \frac{1}{n}}$

$\frac{2\pi a_0}{v_0} n^3$.

$\therefore P_2 = 8 \cdot \frac{(2\pi a_0)}{v_0}$

$P_1 = \frac{2\pi a_0}{v_0}$.

decrease: $7 \frac{(2\pi a_0)}{v_0}$.

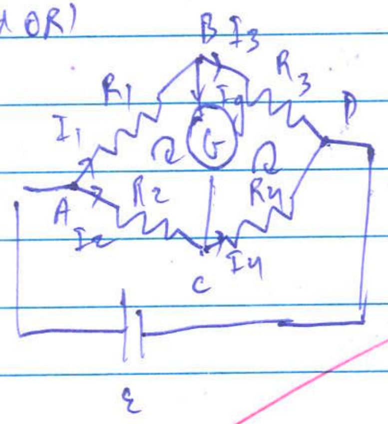
$\% = \frac{7}{8} \times 100$

$= \frac{700}{8}$ 87.5

Section B

(2nd OR)

17(b)



Given, $I_g = 0$.

Applying Kirchhoff's loop rule at

- Junction B

$$I_1 = I_3 + I_g$$

$$\Rightarrow I_1 = I_3 \quad (\because I_g = 0) \quad \ldots (i)$$

- Junction C

$$I_2 + I_g = I_4$$

$$\Rightarrow I_2 = I_4 \quad (\because I_g = 0) \quad \ldots (ii)$$

Applying Kirchhoff's loop rule on loop ABCA

$$-I_1 R_1 + I_2 R_2 + 0 = 0$$

$$\Rightarrow \cancel{I_1 R_1 = I_2 R_2} \quad I_2 R_2 = I_1 R_1$$

$$\Rightarrow \cancel{\frac{I_1}{I_2} =} \quad \Rightarrow \frac{I_2}{I_1} = \frac{R_1}{R_2} \quad \ldots (iii)$$

Applying Kirchhoff's loop rule to BDCB

$$-I_3 R_3 + I_4 R_4 + 0 = 0$$

$$\Rightarrow \quad I_4 R_4 = I_3 R_3$$

$$\Rightarrow \quad \frac{I_4}{I_3} = \frac{R_3}{R_4}$$

Since, $I_2 = I_4$

$I_1 = I_3$

$$\therefore \quad \frac{I_2}{I_1} = \frac{I_4}{I_3}$$

Or, $$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

which is the balanced wheatstone bridge condition

Thus, when resistances in a wheatstone bridge are in proportion $\left(\frac{R_1}{R_2} = \frac{R_3}{R_4}\right)$ no current flows through the central galvanometer.

(P.T.O)

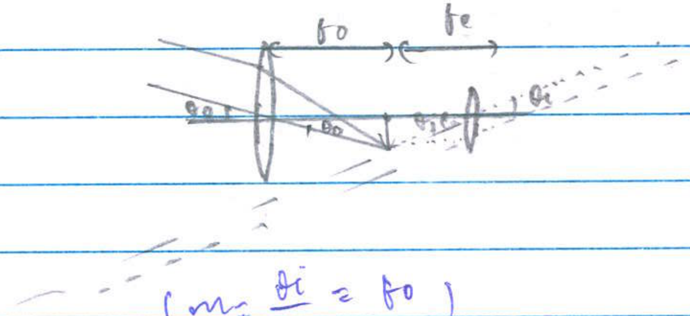
18 In normal adjustment,

magnification of a telescope,

$$m = \frac{f_o}{f_e}$$

$f_o \rightarrow$ focal length of objective

$f_e \rightarrow$ focal length of eye piece



$\left(m = \frac{\theta_i}{\theta_o} = \frac{f_o}{f_e} \right)$

Clearly, separation between lenses, $L = f_o + f_e$.

Given,

$m = 24$

$L = 150$ cm

$mf_e = f_o$

$\Rightarrow 24 f_e = f_o$.

Also,

$f_o + f_e = 150$

$\Rightarrow 24 f_e + f_e = 150$

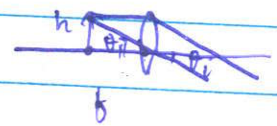
$\Rightarrow 25 f_e = 150$

$\Rightarrow f_e = 6$ cm

$\therefore f_o = 24 f_e = 24 \times 6 = 144$ cm.

Ans → Objective focal length = 144 cm.

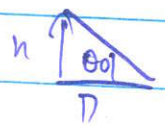
(19)(a) A simple microscope allows, in essence, an object to be brought closer to the eye than the near-point. Thus, it offers magnification.



In normal adjustment,

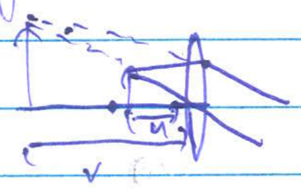
$\theta_o \rightarrow$ max^m angle subtended by the object.

$\rightarrow \frac{h}{D}$.



$\theta_i = \frac{h}{f}$ $\quad \therefore m = \frac{\theta_i}{\theta_o} = \frac{D}{f}$.

When image is formed at near point:



$m = \frac{v}{u}$, $v \to -D$ $(D = 25 cm)$.

Now,

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

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

$\therefore m = v\left(\frac{1}{v} - \frac{1}{f}\right)$

$= -D\left(\frac{1}{-D} - \frac{1}{f}\right)$

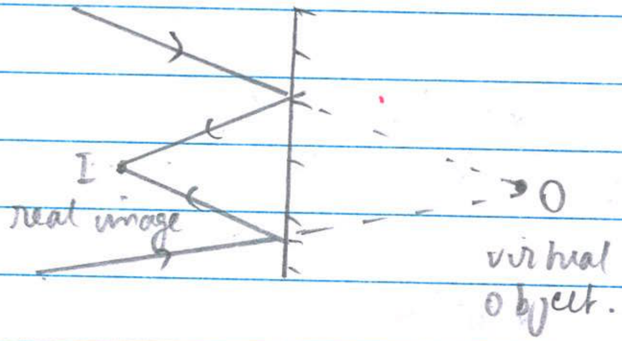
$= 1 + \frac{D}{f}$.

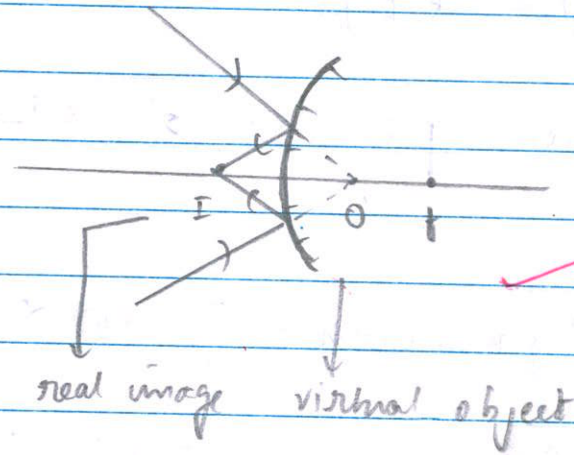
Thus, in near point adjustment, the microscope offers linear magnification also, so image is magnified even if angular sizes are same

19 (b) Plane and convex mirrors can form real images of virtual objects

(19a)

as shown.





For convex lens, f is +ve.

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

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

$$= \frac{u-f}{fu}$$

$$\Rightarrow v = \frac{fu}{u-f}$$

$\therefore$ v is ~~+ve~~ −ve when $u > 0$ and $u < f$.

(Real image is formed of virtual object.

20 Intensity of light $I = 0.1 \ nW \ m^{-2}$.
Area of pupil $A = 0.4 \ cm^2$.

Power, $P = I A = \cancel{0.1 \times 0.4 \times} \ 0.1 \times 10^{-9} \times 0.4 \times 10^{-4}$
$= 4 \times 10^{-15} \ W$.

Avg wavelength, $\lambda = 500 \times 10^{-9} \ m = 5 \times 10^{-7} m$.

Energy per photon $= \frac{hc}{\lambda}$ $(h\nu)$.

$\therefore$ No. of photons entering pupil per second:

$$n \frac{hc}{\lambda} = 4 \times 10^{-15}$$

$$\Rightarrow n = \frac{4 \times 10^{-15} \times \lambda}{c \times h}$$

$\therefore n = \dfrac{\cancel{4}^{2} \times 10^{-15} \times 5 \times 10^{-7}}{3 \times 10^{8} \times \cancel{6.6}^{3.3} \times 10^{-34}}$

$= \dfrac{10}{9.9} \times 10^{-\cancel{30}+34}$

$= \dfrac{10}{9.9} \times 10^{4}$

~~1×10^{4}~~

$= 1.01 \times 10^{4}$

$\therefore$ 1.01×10^{4} photons enter a pupil per second (for minim intensity)

$\frac{1.01}{99)100}$
$\underline{99}$
100

21) $n_e \to$ ~~no.~~ concentration of electrons.
$n_h \to$ ~~no.~~ concentration of holes.

Initially, $n_e = n_h = n_i = 1.5 \times 10^{16}$.

No. of Si atoms $\to 5 \times 10^{28}\ m^{-3}$

Conc. of boron $\to 1$ ppm

$\therefore$ No. of boron atoms $\to 5 \times 10^{28} \times 10^{-6} = 5 \times 10^{22}\ m^{-3}$

We assume ~~No.~~ conc. of free ~~electrons~~ holes are due to dopant atoms only.

$n_h = 5 \times 10^{22}$

For a doped crystal,

$n_e n_h = n_i^2$

$\Rightarrow n_e(5 \times 10^{22}) = 1.5 \times 1.5 \times 10^{32}$

$\Rightarrow n_e = \dfrac{\overset{0.3}{\cancel{1.5}} \times 1.5 \times 10^{10}}{\cancel{5}_1}$

$= 0.45 \times 10^{10}$

$\therefore$ conc^n of holes $= 5 \times 10^{22}\ m^{-3}$

conc^n of electrons $= 0.45 \times 10^{10}\ m^{-3}$

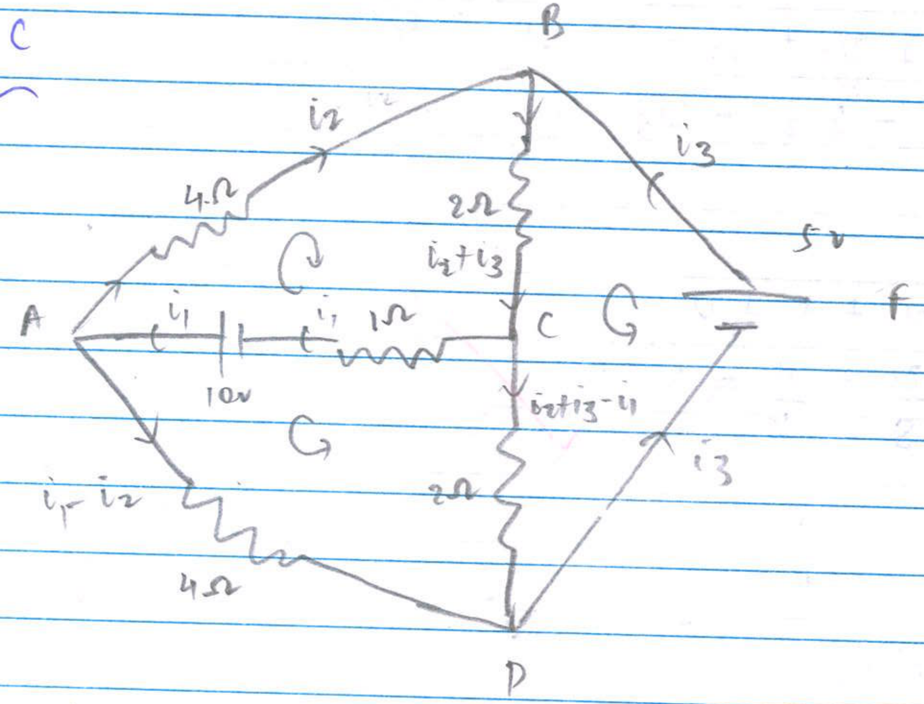
Doping with trivalent boron creates ~~an~~ a p-type crystal

$(n_h >> n_e)$

(P-T-O)

Section C

(22)



The currents are labelled as shown according to Kirchhoff's junction rule.

Applying loop rule to ABCA:

$$10 - 4i_2 - 2i_2 - 2i_3 - i_1 = 0.$$

$$\Rightarrow 10 - 6i_2 - 2i_3 - i_1 = 0$$

$$\Rightarrow 10 = i_1 + 6i_2 + 2i_3 \quad \cdots (i)$$

Applying Kirchhoff's loop rule to ADCA:

$$\cancel{10 - 4i_1 + 4i_2}$$

$$10 - 4(i_1 - i_2) + 2(i_2 + i_3 - i_1) - i_1 = 0$$

$$10 - 4i_1 + 4i_2 + 2i_2 + 2i_3 - 2i_1 - i_1 = 0$$

$$10 = 7i_1 - 6i_2 - 2i_3 \quad \cdots (ii).$$

Adding (i) and (ii)

$$20 = 8i_1 + 0 + 0$$

$$\Rightarrow \quad i_1 = \frac{20}{8} = \frac{10}{4} = 2.5A.$$

Applying loop rule to BDFB :

$$5 - 2(i_2 + i_3) - 2(i_2 + i_3 - i_1) = 0$$

$$5 - 2i_2 - 2i_3 - 2i_2 - 2i_3 + 2i_1 = 0.$$

$$\Rightarrow \quad 5 = 4i_2 + 4i_3 \cancel{+2i} - 2i_1$$

$$\Rightarrow \quad 5 + 2i_1 = 4i_2 + \cancel{4i} \, 4i_3.$$

Since $i_1 = 2.5$

$$\Rightarrow \quad 5 + 5 = 4i_2 + 4i_3$$

$$\Rightarrow \quad 10 = 4i_2 + 4i_3$$

$$\Rightarrow \quad i_2 + i_3 = 2.5$$

$$\Rightarrow \quad i_2 = 2.5 - i_3 \quad \cdots (iii)$$

From (i):

$$10 = i_1 + 6i_2 + 4i_3$$

Putting $i_1 = 2.5$, $i_2 = 2.5 - i_3$

$$10 = 2.5 + 6(2.5 - i_3) + 4i_3$$

$$\Rightarrow 10 = 2.5 + 15 - 4i_3.$$

$$\Rightarrow 4i_3 = 7.5$$

$$\Rightarrow 8i_3 = 15$$

$$\Rightarrow i_3 = \frac{15}{8} A.$$

$$\therefore i_2 = 2.5 - \frac{15}{8} A.$$

$$= \frac{20-15}{8} A.$$

$$= \frac{5}{8} A.$$

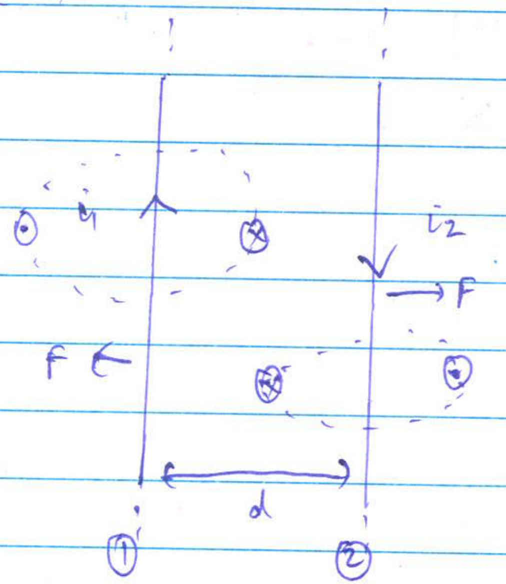
current in AB $\rightarrow i_2 = \frac{5}{8} A = 0.625 A.$

current in AC $\rightarrow i_1 = 2.5 A$

current in BC $= i_2 + i_3 = \frac{5}{8} + \frac{15}{8} = \frac{20}{8} = 2.5 A.$

(Ans)

(23) Due to current flow in one wire, a magnetic field exists. Due to this field, another current carrying wire experiences magnetic force (IBl).



$d \rightarrow$ separation between wires.

$i_1, i_2 \rightarrow$ currents in the wire

Clearly, the magnetic field due to each wire is perpendicular to the plane containing the two wires.

(P-T-O)

Field due to (1) at (2):

By Ampere's circuital law:

$$\oint \vec{B_1} \cdot \vec{dl} = \mu_0 i_1$$

Amperean loop (circle) of radius d is constructed (with wire (1) as axis)
current enclosed, i_1.

Clearly, magnetic field $\vec{B_1}$ is tangential to the loop at every point &

$$\therefore \oint \vec{B_1} \cdot \vec{dl} = B_1 2\pi d.$$

-(i) So, $B_1 2\pi d = \mu_0 i_1$

$$\Rightarrow B_1 = \frac{\mu_0 i_1}{2\pi d}$$

B_1 is normal to wire (2). $(\theta = 90^\circ)$

$\therefore$ magnetic Force on wire (2) due to (1): (on length l)

$$F_{21} = i_2 l B_1 \sin\theta = i_2 l B_1 \quad (\theta = 90^\circ)$$

$$\Rightarrow F_{21} = \frac{\mu_0 i_1 i_2}{2\pi d} \cdot l$$

If $l = 1$, force per unit length, $f_{21} = \frac{\mu_0}{2\pi d} \cdot i_1 i_2$

By cross-product rule, the force on wire ② is AWAY from wire ①.

Similarly, magnetic field $\vec{B_2}$ due to ② at ①:

$$B_2 = \frac{\mu_0 i_2}{2\pi d}$$

Force on length l of wire ①:

$$F_{12} = i_1 l B_2 \sin\theta$$

$$= i_1 l B_2 \quad (\because \theta = 90^\circ)$$

$$= \frac{\mu_0}{2\pi d} \cdot i_1 i_2 \cdot l.$$

If $l = 1$, force per unit length,

$$f_{12} = \frac{\mu_0}{2\pi d} \cdot i_1 i_2$$

This force is directed away from wire ②.

$$f_{21} = -f_{12}.$$

$\therefore$ Force per unit length on each wire,

$$|f| = \frac{\mu_0}{2\pi d} \cdot i_1 i_2$$

Currents in wires (1) and (2) are antiparallel. Thus, the force is repulsive since force on one wire is directed away from the other.

(24) (a) ~~Since~~ current leads voltage by $\frac{\pi}{2}$ in a purely capacitive circuit,

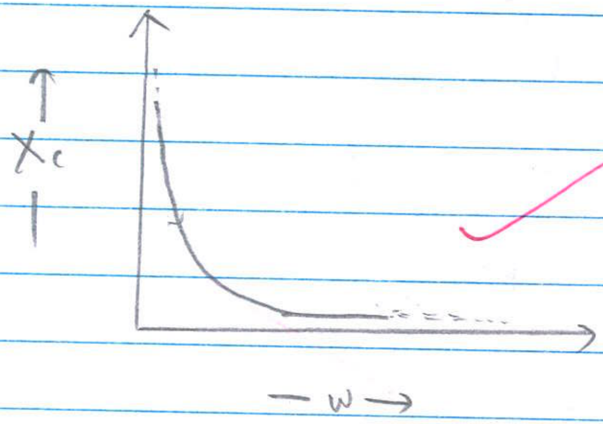
$\therefore X \rightarrow$ capacitor.

(b) Capacitive reactance, $X_C = \frac{1}{\omega C}$

where $C \rightarrow$ its capacitance

$\omega \rightarrow$ angular frequency of ac input.

(c)



Since $X_C = \frac{1}{\omega C}$.

Graph is rectangular hyperbola.

(24) (d) (i) In ac circuit, capacitor is a non-dissipative element.

$\therefore$ Avg Power dissipation across a capacitor is zero over one cycle.

Now, $X_c = \frac{1}{\omega C}$

$\therefore$ For very high frequency ac input, capacitor offers negligible reactance to ac signal.

Also, $i = \frac{V_m}{X_c} \sin(\omega t + \frac{\pi}{2})$ in purely capacitive circuit.

(ii) In dc circuit, capacitor is used to store electrical energy $(\frac{1}{2}CV^2)$. On applying voltage, a capacitor draws charge from dc source. On complete charging, i.e, in steady state, no current flows in the capacitor arm. Thus, it offers infinite resistance to dc current in steady state.

(25) $\vec{E} = 6.3 \cos(1.5y + 4.5 \times 10^8 t)$ NC^{-1} $\hat{i}$

(a) $k = 1.5$ rad m^{-1}, $\omega = 4.5 \times 10^8$ rad s^{-1}

Wavelength, $\lambda = \frac{2\pi}{k} = \frac{2\pi}{1.5} = \frac{2\pi \times 2}{3} = \frac{4 \times 3.14}{3}$ $\frac{4 \times 3.14}{3} =$ $\frac{12.56}{3} = 4.1866$

$= 4.187\ m$

$\therefore \lambda = 4.187\ m.$

Frequency, $\nu = \frac{\omega}{2\pi} = \frac{4.5 \times 10^8 \times 7}{2 \times 22}$

$= \frac{45 \times 7}{44} \times 10^7$

$= 7.16 \times 10^7\ Hz.$

(b) $E_0 = 6.3\ NC^{-1}.$

We have,

$E_0 = cB_0$ (c → speed of light in vacuum)

$\Rightarrow B_0 = \frac{E_0}{c} = \frac{6.3}{3 \times 10^8} = 2.1 \times 10^{-8}\ T$

$3.14 \times 4 = 12.56$

345
$\times 7$
315

$315 \div 44 = 7.16$

308
070
44
260
244
7
308
44

(c) $\vec{E}$ is along $\hat{i}$, ~~vel~~ velocity of wave is along $-\hat{j}$.

Since $\vec{E} \times \vec{B} \parallel \vec{v}$,

$\vec{B}$ must be along $\hat{k}$.

$$\therefore \vec{B} = (2.1 \times 10^{-8}\, T) \cos(1.5y + 4.5 \times 10^{8} t)\, \hat{k}$$

or

$$\vec{B} = (2.1 \times 10^{-8}\, T)\left[\cos(1.5\, rad\, m^{-1})y + (4.5 \times 10^{8}\, rad\, s^{-1})t\right] \hat{k}$$

(26) Bohr's first postulate: an electron in an atom ~~can~~ can revolve around ~~as~~ the nucleus in certain stable orbits without the emission of radiant energy.

These energy-states of an atom are called stationary states and have definite energies.

Bohr's second postulate: an electron can revolve around the nucleus only in those orbits for which the angular momentum (L) is an integral multiple of $\frac{h}{2\pi}$. Thus, the angular momentum of the revolving electron is quantized.

$$L = \frac{nh}{2\pi}$$

$$\Rightarrow mvr = \frac{nh}{2\pi}.$$

$$\therefore v = \frac{nh}{2\pi mr} \quad \text{--- (i)}$$

$m \rightarrow$ mass of electron,

~~v → radius → a~~.

$r \rightarrow$ radius of n^{th} orbit

$v \rightarrow$ orbital speed of e^- in n^{th} orbit.

Now, the electrostatic interaction with nucleus of hydron provides the necessary centripetal force to the electron.

Thus,

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r^2}.$$

$$\Rightarrow mv^2 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r}.$$

$$\Rightarrow r = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{mv^2}$$

from (i)

$$\Rightarrow r = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2 (2\pi)^2 \cdot m^2 r^2}{m\, n^2 h^2}$$

$$\Rightarrow \frac{1}{r} = \frac{1}{4\pi\varepsilon_0} \cdot me^2 \cdot \left(\frac{2\pi}{h}\right)^2 \cdot \frac{1}{n^2}$$

$$\Rightarrow r = \frac{4\pi\varepsilon_0}{me^2} \cdot \left(\frac{h}{2\pi}\right)^2 \cdot n^2$$

$$r = \frac{4\pi\varepsilon_0}{me^2} \cdot \frac{h^2}{4\pi^2} \cdot n^2$$

$$\Rightarrow r = \frac{\varepsilon_0 h^2}{\pi me^2} \cdot n^2.$$

$\therefore$ Radius of n^{th} orbit:

$$r_n = \frac{\varepsilon_0 h^2}{\pi me^2} \cdot n^2$$

$$\Rightarrow r_n = a_0 n^2$$

where $a_0 = \dfrac{\varepsilon_0 h^2}{\pi me^2}$ is radius of first orbit ($n=1$)

$$\therefore \quad r_n = \frac{h^2\varepsilon_0}{\pi me^2} \cdot n^2 \quad \text{(Ans)}$$

(P.T.O)

27 (a) One atomic mass unit (u) is defined as one-twelfth the mass of one $^{12}_{6}C$ atom

mass of one carbon-12 atom = 1.99×10^{-26} kg.

$\therefore$ $1u = \frac{1.99}{12} \times 10^{-26}$ kg $\approx \frac{1}{6} \times 10^{-26}$ kg $= 0.167 \times 10^{-26}$ kg

$= 1.67 \times 10^{-27}$ kg.

(b) Deuteron $\rightarrow$ $^{2}_{1}H$.

(i)

Total mass of protons (m_p) = 1×1.007825 u = 1.007825 u

Mass of 1 neutron (m_n) = 1×1.008665 u = 1.008665 u

Total mass ($m_p + m_n$) = m = 2.016490 u

mass of deuteron, m(D) = 2.014102 u.

$\therefore$ mass defect = m − m(D)

Δm = 2.016490

$-\ 2.014102$

0.002388

Rw

1.007825
1.008665
2.016490

931.5 mev.
0.002
931.5
0.2388
17 4520
74520 x
27945 x x
18630 x x x
2.2244220

Energy equivalent of 1 u = 1u $\times c^2$

$$= \frac{1.67 \times 10^{-27} \times 9 \times 10^{16}}{1.6 \times 10^{-19}} \text{ eV}$$

$= 931.5 \times 10^{6}$ eV.

$= 931.5$ MeV.

∴ Energy required to separate a deuteron into free nucleons $= \Delta m c^2$ (Binding energy)

$= \Delta m \times 931.5$ MeV

$= 0.002388 \times 931.5$

$= 2.224$ MeV

$= 2.224 \times 10^{6} \times 1.6 \times 10^{-19}$

$= 3.558 \times 10^{-13}$ J

$\simeq 3.56 \times 10^{-13}$ J

Ans → Required energy = 2.224 MeV

or 3.56×10^{-13} J

2.224
1.6
13344
2224×
3.5584

$\frac{2.4 \times 10^{-3}}{6}$ $\times 10^{-28} \times 9 \times 10^{16}$

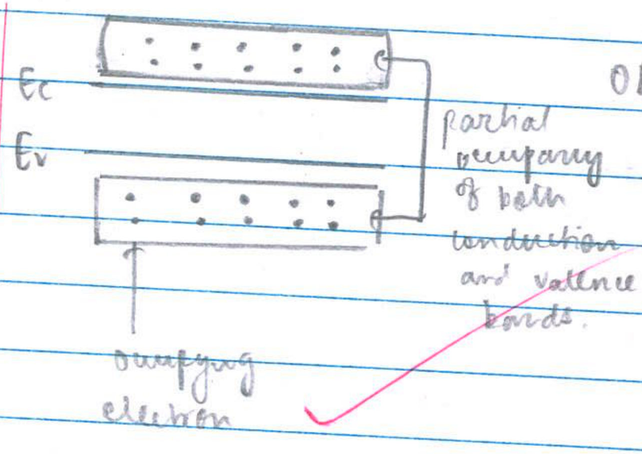
$= 3.6 \times 10^{-13}$ J.

(28) (b) Energy band diagrams:

Here, ~~$E_c \rightarrow$ valence~~ $E_c \rightarrow$ conduction band, $E_v \rightarrow$ valence band

$E_g \rightarrow$ Energy gap (forbidden gap)

For metals



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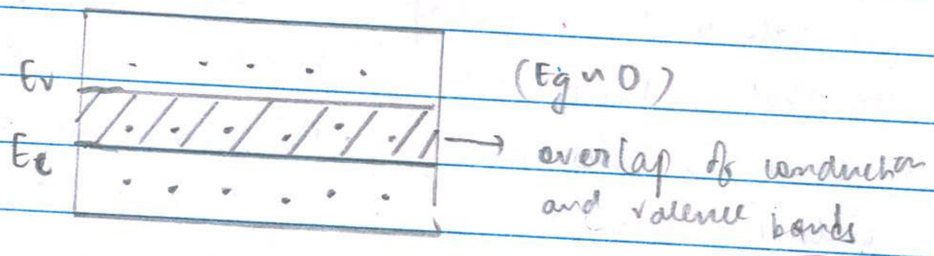
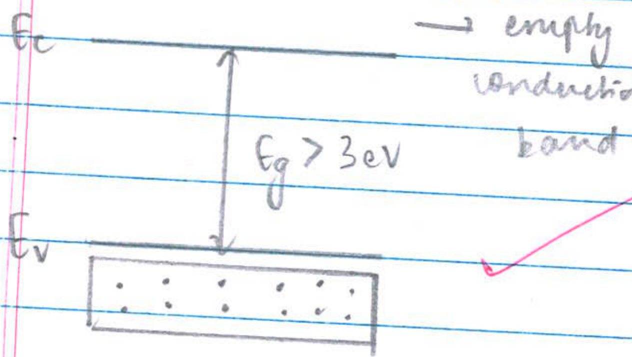
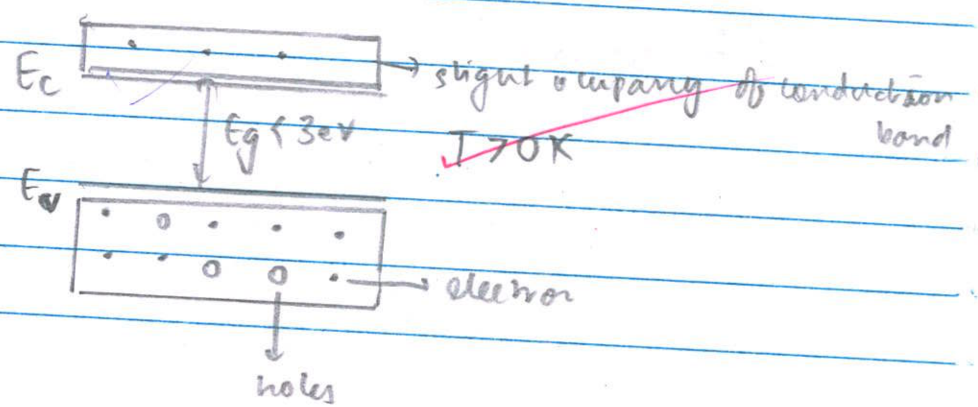


For insulators:



For semiconductors



Metals	Insulators	Semiconductors,
• Either both conduction and valence bands are partially filled, or conduction and valence bands overlap, so that band gap, $E_g = 0$ • Metals are thus good conductors of electricity, with partial occupancy of conduction band at 0K ~~even for~~ when $E_g \sim 0$. ~~At low~~ • Low resistivity, high conductivity. Eg. copper.	• Here, band gap $E_g > 3eV$. Electrons cannot be thermally excited from valence band to conduction band by raising temperatures. • No electrons in conduction band, hence these do not conduct. • High resistivity, low conductivity. Eg. air	• Band gap, $E_g < 3eV$. At adequate temperatures electrons excite to conduction band, leaving vacancies in the valence band. • At 0K, semiconductors are insulators since conduction band is empty. At ~~0~~ $T > 0$~~B~~, these conduct due to flow of electron in conduction band and holes ~~at~~ in valence band. • Intermediate resistivity between metals and insulators. Eg. silicon.

Section D

(29) (i) (D) IV

(ii) (D) accelerate along $-\hat{i}$

(iii) (A) $V = V_0 + \alpha x$

(iv) (a) (C) $E_4 > E_3 > E_2 > E_1$

(30) (i) (D) 6

(ii) (C) 3

(iii) (C) 6

(iv) (D) 10

$a = 2$ mm

$d = 6$ mm.

$W = \frac{2\lambda}{a}$

$w = \frac{\lambda}{d}$

$\frac{2\lambda}{a} = \frac{n\lambda}{d}$

$\frac{2d}{a} = n$

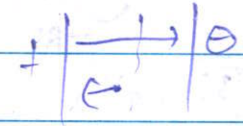
$\Rightarrow n = \frac{2 \times 6}{2}$

$\frac{2\lambda}{a} = \frac{n\lambda}{d}$ $n = \frac{2d}{a}$

$\Rightarrow \frac{2d}{a} = n$ $= \frac{2d}{2a}$

$\Rightarrow \frac{2 \times 6}{2}$ $= \frac{1}{2} \cdot \frac{2d}{a}$

$n = 6$. $= \frac{1}{2} \times 2 \frac{\cancel{6}^{3}}{\cancel{2}_{1}}$



$V = Ed$.

$V - V_0 = Ed$.

$V = V_0 + Ed$.

$= V_0 + \frac{\sigma}{A\epsilon_0} d$.

$V_0 + \frac{Q}{AA\epsilon_0} d$.

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

$E_1 = 20$

$E_2 = 200$

$E_3 = 220$

$E_4 = 300$

$E_4 > E_3$

Section E

(OR)

(31) (b)(i)

(i) $R \to$ radius of spherical shell

$Q \to$ charge

let $\sigma = \frac{Q}{A} = \frac{Q}{4\pi R^2}$ (surface charge density).

We consider a spherical gaussian surface of radius $r < R$.

Charge enclosed by sphere $= 0$.

By Gauss' law

Electric flux, $\Phi_E = \frac{q_{enclosed}}{\varepsilon_0} = 0$.

$\Phi_E = \vec{E} \cdot \vec{A}$

$0 = \vec{E} \cdot \vec{A}$

$\therefore E = 0$ (since $\vec{A} \neq 0$, and $\cos\theta = 1$)

$\therefore$ Electric field, E inside the shell $= 0$

$n = \frac{\cancel{Q} n \lambda D}{d}$

$\frac{0.5 \times d}{D \times \lambda} = n$

$\frac{1}{2} \times \frac{\cancel{6}^{2} \times 10^{-6}}{\cancel{450}\ \cancel{150}\ 50 \times 10^{-9}} \cdot \frac{\cancel{3}^{1}}{4} = n$

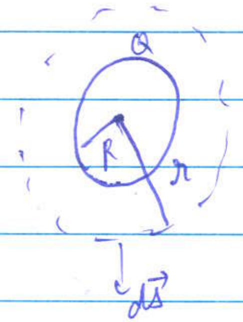
$\frac{10^3}{200}$

$= \frac{1}{100} \times 10^3$

$= 10$

$\therefore E = \frac{\sigma}{2\varepsilon_0}$

(iii) Case (ii) We consider a Gaussian surface with radius $r > R$.



Then electric flux, ϕ_E through the surface,

$$\phi_E = \oint \vec{E} \cdot \vec{ds}$$
$$= E \cdot 4\pi r^2$$

Since the electric field is normal to the ~~area~~ surface ~~Gaussian~~ (or along the area vector) at every point
$(\because \theta = 0, \; EA\cos\theta = EA)$.

(B) Total charge enclosed = ~~Charge~~ Q.

$\therefore$ Electric field at r from centre:

~~E(r)~~

By Gauss' Law,

$$E \, 4\pi r^2 = \frac{Q}{\varepsilon_0}$$

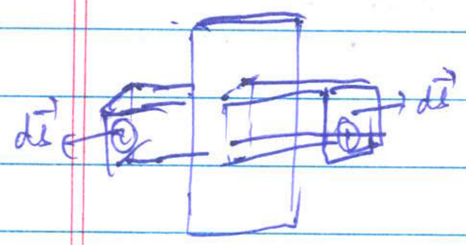
$$\Rightarrow E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

(radially outward).

$\therefore$ Electric field, $E_{inside} = 0$, $(r < R)$, $E_{out} = \frac{Q}{4\pi\varepsilon_0 r^2}$ $(r > R)$

31 (b) (a) For a non-conducting infinite sheet:

Surface charge density $= \sigma$.



We consider a Gaussian parallelopiped.

Clearly electric field $\vec{E}$ is along the lateral surfaces.

$\therefore$ Electric flux, ϕ_E through lateral surfaces $= 0$.

Now, $\vec{E}$ is normal to the cross-sections of the parallelopiped. Let A be cross sectional area.

Flux through surface (1) $\phi_1 \rightarrow EA$ (outward)

And $\phi_2 \rightarrow EA$. (outward)

Total flux, $\phi = \phi_1 + \phi_2$

$= 2EA$.

By Gauss' Law,

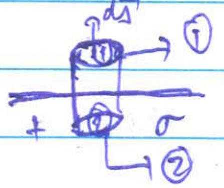
$$\phi = \frac{q_{enclosed}}{\epsilon_0}$$

$$2EA = \frac{\sigma A}{\epsilon_0}$$

$$\therefore E = \frac{\sigma}{2\epsilon_0}$$

[redacted]

Next, we consider a conducting surface, with same surface charge density σ.



We consider an elemental gaussian cylinder.

Field is along the curved surface, $\therefore$ Flux through curved surface = 0

Flux through surface 1 $\rightarrow EA$ $(\because \vec{E}$ is along $\vec{ds})$

Φ_1 where $A \rightarrow$ area of cross section.

~~Net charge~~ $\vec{E}$ is zero inside a conductor.

$\therefore \Phi_2 = 0$.

$\therefore$ Total flux, $\Phi = EA$. (Φ_1)

By Gauss' Law,

$$\Phi = \frac{q_{enclosed}}{\varepsilon_0}$$

$$\Rightarrow EA = \frac{\sigma A}{\varepsilon_0}$$

$$\Rightarrow E = \frac{\sigma}{\varepsilon_0}$$

31

Electric field

outside conductor (charged) → $\frac{\sigma}{\varepsilon_0}$

outside charged non-conducting plate → $\frac{\sigma}{2\varepsilon_0}$

Clearly, the magnitude of electric field is double for the conducting plate

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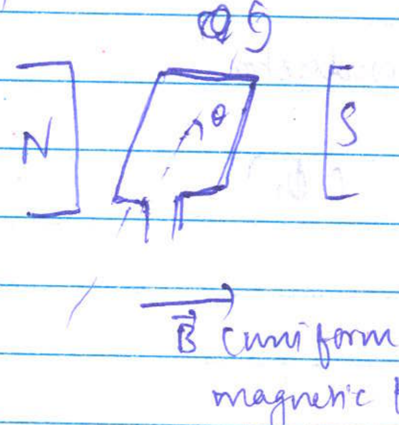
(OR)

32 (b) (i)



Let A be the area of coil.

ω → angular speed.

Let θ = ωt so that θ = 0 at t = 0.

By Faraday's Law of electromagnetic induction,

Induced emf, $\varepsilon = -N\frac{d\phi_B}{dt}$

magnetic Flux ~~B~~ Φ_B through coil $= \vec{B}\cdot\vec{A} = BA\cos\theta$

$= BA\cos\omega t$

$\therefore \quad \varepsilon = -N \frac{d}{dt} BA\cos\omega t$

$= -NBA \frac{d\cos\omega t}{dt}$

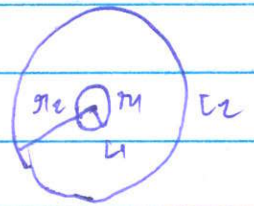
$= NBA\omega \sin\omega t.$

$\therefore$ (Induced emf) $\varepsilon = NBA\omega\sin\omega t$

$\Rightarrow \varepsilon = \varepsilon_0 \sin\omega t$

where $\varepsilon_0 = NBA\omega$

(constant in the given case)

(ii) 

$r_1 = 1\,cm, \quad r_2 = 100\,cm$

Clearly, $r_2 >> r_1$

~~Electr~~ magnetic field due to current carrying loop

$$B = \frac{\mu_0 i R^2}{2(R^2+x^2)}$$

Q Let current i flow through L_2

$\therefore B$ at centre of $L_2 = \frac{\mu_0 i}{2r_2}$

Since $r_2 >> r_1$, the magnetic field can be assumed to be constant through L_1.

$\vec{B}$ is normal to the plane containing the loops.

$\therefore$ magnetic flux through L_1:

$$\phi_{B_1} = BA_1 \qquad (\because \theta = 0° \text{ as } \vec{B} \text{ is along } \vec{A})$$

$$\Rightarrow \phi_{B_1} = \frac{\mu_0 i \pi r_1^2}{2r_2}$$

$$\therefore \phi_{B_1} = \frac{\mu_0 \pi r_1^2}{2r_2} \cdot i$$

But flux linked to L_1 is

$$\phi_1 = M_{12} i_2$$

where $M_{12} \rightarrow$ mutual inductance of L_1 wrt L_2

$$\therefore M_{12} = \frac{\mu_0 \pi r_1^2}{2r_2}$$

We know,

$M_{12} = M_{21} = M.$

$\therefore M = \dfrac{\mu_0 \pi r_1^2}{2r_2}.$

$\frac{\mu_0}{4\pi}$ $M = \dfrac{4\pi^2 \times 10^{-7} \cdot 1\times 10^{-4}}{2\times 1}.$

$= 2\pi^2 \times 10^{-11}$

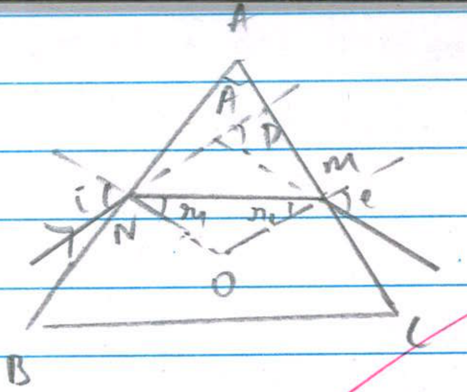
$= 20 \times 10^{-11}$

$= 2 \times 10^{-10}.$

$\therefore$ Mutual inductance $= 2\times 10^{-10}$ H.

(PT-0)

33 (a) i)



A → angle of ~~incidence~~ prism
i → angle of incidence
r_1 → angle of refraction at 1st interface
r_2 → angle of incidence at second interface
e → angle of emergence
D → angle of deviation
N, M → normals to the interface

By geometry,

$D = \angle DNM + \angle DMN$ (exterior angle)

$D = i - r_1 + e - r_2$

$D = i + e - (r_1 + r_2)$

In quadrilateral ANOM

$\angle A + \angle ANO + \angle AMO + \angle NOM = 360°$

$\Rightarrow \angle A + 180 + \angle NOM = 360$

$\Rightarrow \angle A = 180 - \angle NOM$

In Δ NOM,

$r_1 + r_2 + \angle NOM = 180$

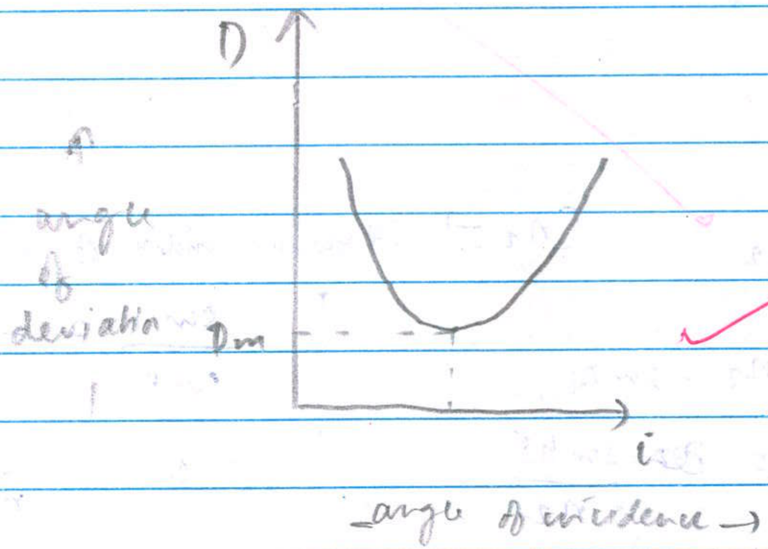
$r_1 + r_2 = 180 - \angle NOM$

$\therefore \quad A = r_1 + r_2.$

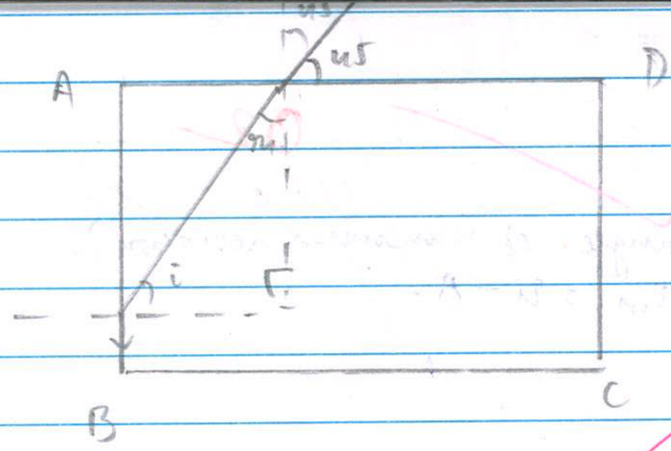
e) $D = i + e - A$

when $D = D_m$ (angle of minimum deviation)

$i = e$ and $D_m = 2i - A$.



(ii)



$e = 90°$ (given)

By snell's law,

$$\frac{\sin 45}{\sin r_1} = n_2$$

($n_2 \to$ refractive index of liquid wrt air)

$\therefore \sin 45 = n_2 \cdot \sin r_1$

$\Rightarrow \sin r_1 = \frac{\sin 45}{n_2}$

$= \frac{1}{\sqrt{2} n_2}$

By geometry,

$i + r_1 = 90°$

$\Rightarrow i = 90 - r_1$

$\Rightarrow \sin i = \sin(90 - r_1)$

$= \cos r_1$

$\frac{\sin i}{\sin e} = \frac{1}{n_2}$

$\Rightarrow \sin i = \frac{1}{n_2}$

$\Rightarrow \cos r_1 = \frac{1}{n_2}$

$\Rightarrow \sqrt{1 - \sin^2 r_1} = \frac{1}{n_2}$

$\Rightarrow \sqrt{1 - \frac{1}{2n_2^2}} = \frac{1}{n_2}$

$\Rightarrow 1 - \frac{1}{2n_2^2} = \frac{1}{n_2^2}$

$\Rightarrow 1 = \frac{3}{2n_2^2}$

$\Rightarrow n_2^2 = \frac{3}{2}$

$\Rightarrow n_2 = \sqrt{\frac{3}{2}}$

$\therefore$ Refractive index of liquid $= \sqrt{\frac{3}{2}}$