

Section-A

1. Threshold frequency is defined as that minimum frequency that an electromagnetic radiation should have, so that it is able to eject electrons from the surface of the metal (with zero kinetic energy) if it is incident. Mathematically, threshold frequency ν_0

$$\nu_0 = \frac{\phi_0}{h}$$

where ϕ_0 is the work function of the corresponding metal.

Or in other words it is the minimum frequency of incident radiation for which photoelectric effect is observed.

2. Brewster angle, $i_B = 60^\circ$

Therefore, from Brewster's law, refractive index of denser medium w.r.t rarer medium, $n = \tan i_B = \tan 60^\circ = 1.73$

Hence, refractive index = 1.73.

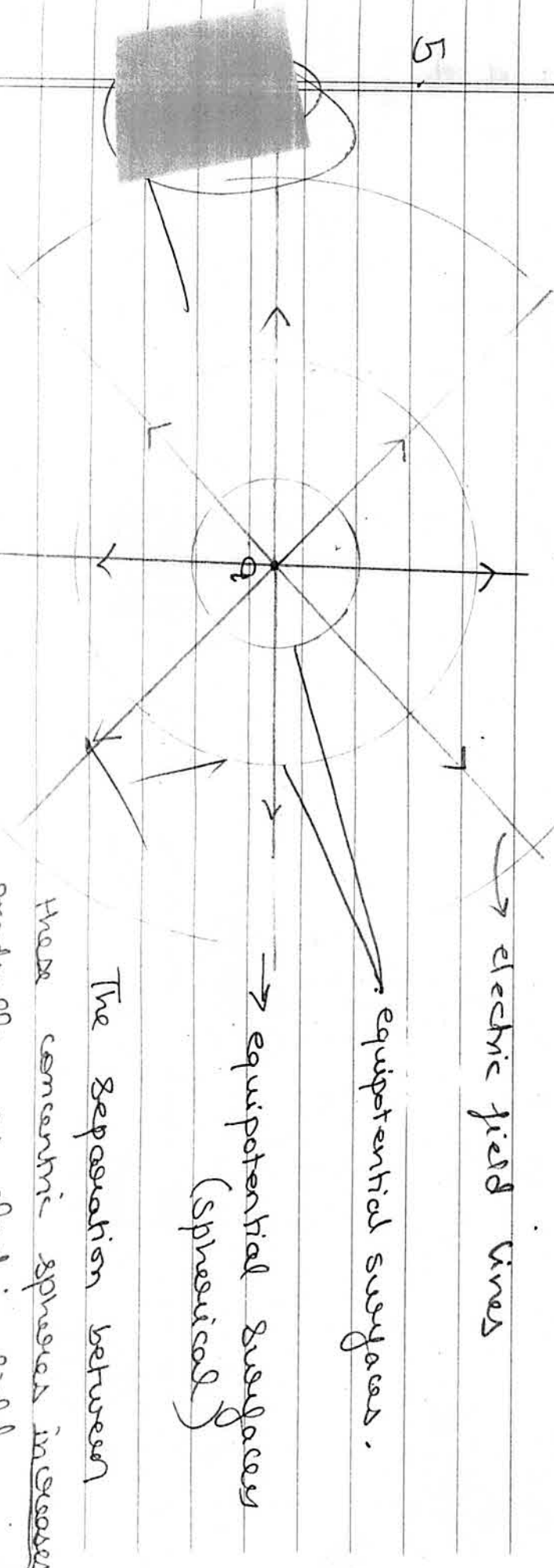
3. Signals having frequency greater than 30 MHz are sufficiently energetic that they are able to penetrate the ionosphere of the atmosphere. Hence, these are no longer reflected by the ionosphere. Thus, these are not used for sky wave propagation (which makes use of ionospheric reflection), hence, frequency is kept less than 30 MHz.

4. Drift velocity of electrons, v_d is given by,

$$\vec{v}_d = -\frac{eE\tau}{m}$$

where, E is the external electric field and τ is the relaxation time.

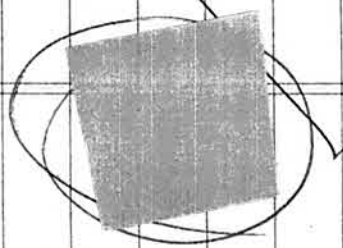
Hence, we can see that magnitude of drift velocity of electron varies linearly with relaxation time for a constant potential difference (and also electric field).
 Thus, drift velocity of electrons is related directly to the relaxation time.



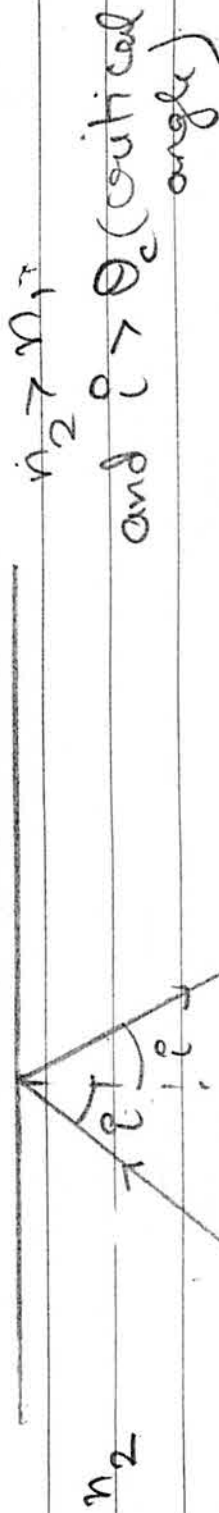
The separation between these concentric spheres increases gradually as electric field decreases as we go away from charge.

Section-D

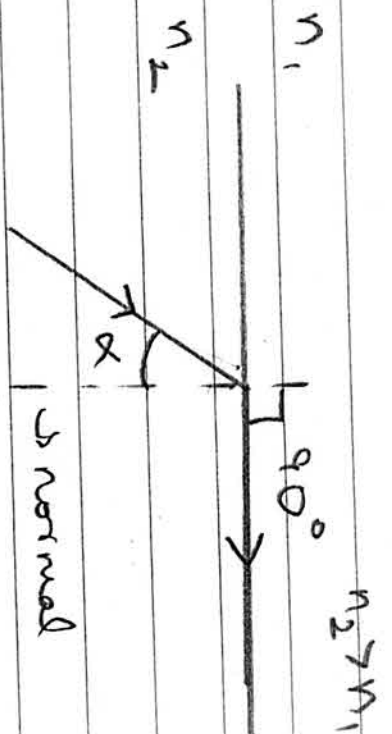
25. (a) When light travels from an optically denser medium towards an optically rarer medium, and is incident on the interface at an angle greater than the critical angle for the given pair of media, we observe total internal reflection of light.



no transmission



Now let us obtain the angle for which the light ray is just transmitted and grazes along the surface.



Applying Snell's law at the interface,

$$n_2 \sin \alpha = n_1 \sin 90^\circ$$

$$\sin \alpha = \frac{n_1}{n_2}$$

[$n_1 \Delta n_2$ are the refractive indices of the medium respectively] $\alpha = \sin^{-1} \left(\frac{n_1}{n_2} \right)$

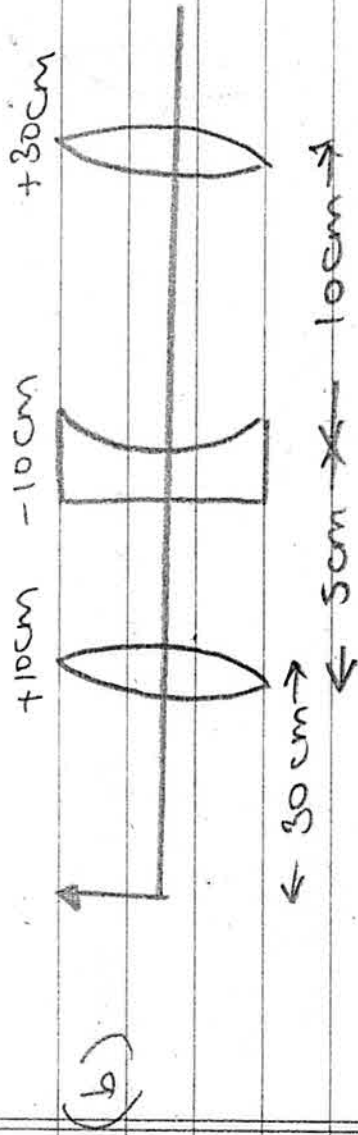
$$\text{OR } \alpha = \sin^{-1} \left(\frac{1}{\frac{n_2}{n_1}} \right) \left[\frac{n_2}{n_1} \text{ is refractive index of denser medium w.r.t rarer medium} \right]$$

Now, it is clear that if we increase the angle of incidence greater than α , no transmission of light will take place and light will be totally internally reflected. Thus, the critical angle for the pair of media $= \alpha = \sin^{-1} \left(\frac{1}{\frac{n_2}{n_1}} \right)$ (90° is the minimum angle above which no transmission of light takes place)

Hence,

$$\theta_c = \alpha = \sin^{-1} \left(\frac{1}{\frac{n_2}{n_1}} \right)$$

(90° is the minimum angle above which no transmission of light takes place)



First, subtraction from convex lens of focal length $f_1 = +10\text{ cm}$

Object distance, $u_1 = -30\text{ cm}$ (u)
 focal length, $f_1 = +10\text{ cm}$ (f)
 lens formula,

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

Substituting the values,

$$\frac{1}{v} + \frac{1}{30} = \frac{1}{10}$$

$$\frac{1}{v} = \frac{1}{10} - \frac{1}{30}$$

$$\frac{1}{v} = \frac{2\cancel{0}}{30\cancel{0}}$$

$$v = +15\text{ cm}$$

Now this image will act as a virtual object for concave lens of focal length = -10 cm.

So, object distance, $u_2 = (15-5) \text{ cm} = 10 \text{ cm}$ (u)
 focal length, $f_2 = -10 \text{ cm}$ (f)
 lens formula

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

~~Substituting~~ values,

$$\frac{1}{v} - \frac{1}{10} = \frac{-1}{10}$$

$$\frac{1}{v} = 0$$

OR $v \rightarrow \infty$ (image formed at infinity)

Now, these image will act as a virtual object

for convex lens of focal length = +30 cm

So, object distance $u_3 = \infty - 30 \text{ cm} = \infty$ (u)

focal length $f_3 = +30 \text{ cm}$ (f)

lens formula?

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

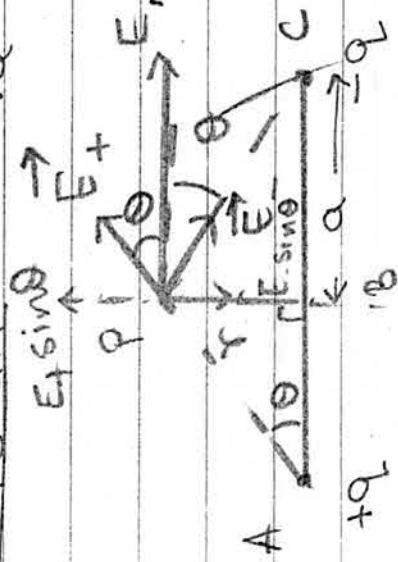
Substituting values,

$$\frac{1}{v} - \frac{1}{\infty} = \frac{1}{30}$$

$$v = +30 \text{ cm}$$

Hence the final image will be formed at 30 cm to the right of convex lens of focal length = 30 cm or at a distance of 75 cm to the right of the object.

at (a)



Consider the given dipole 'B' is any point on the equatorial line of the dipole.

So, electric field at P due to point charge $(+q)$

$$E_+ = \frac{1}{4\pi\epsilon_0} \frac{q}{(AP)^2} = \frac{1}{4\pi\epsilon_0} \frac{q}{(r^2 + a^2)}$$

electric field at P due to negative charge (-q)

$$E_- = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} = \frac{1}{4\pi\epsilon_0} \frac{q}{(r^2+a^2)}$$

Clearly $|\vec{E}_+| = |\vec{E}_-|$ — (1)

and vertical components of E_+ and E_- will ~~mutually~~ cancel out. (as $E_+ \sin\theta = E_- \sin\theta$)
 So, net electric field is only along the horizontal direction.

So, net electric field $E_N = E_+ \cos\theta + E_- \cos\theta$

$E_N = 2E_+ \cos\theta$ (from (1))

Now in right $\triangle ABP$

$$\cos\theta = \frac{AB}{AP} = \frac{a}{\sqrt{r^2+a^2}}$$

So, $E_N = 2 \frac{1}{4\pi\epsilon_0} \frac{q}{(r^2+a^2)} \frac{a}{(r^2+a^2)^{3/2}}$

OR $E_N = \frac{1}{4\pi\epsilon_0} \frac{(2qa)}{(r^2+a^2)^{3/2}} = \frac{1}{4\pi\epsilon_0} \frac{p}{(r^2+a^2)^{3/2}}$

and vertically,

$$\vec{E}_N = -\frac{1}{4\pi\epsilon_0} \frac{p}{(r^2+a^2)^{3/2}} \vec{p}$$

\vec{p} is the dipole moment of the given dipole and is from right to left. ($p = 2qa$)
 The negative sign indicates that \vec{E}_N is opposite to \vec{p} as shown.

for $r \gg a$ ✓

$$\vec{E}_N = -\frac{1}{4\pi\epsilon_0} \frac{\vec{p}}{r^3}$$
 (ignoring the sign)



Let q be placed in between the charges as shown at a distance of x from A as shown.

Now, for system to be in equilibrium, charges q & q should be in equilibrium. Now, for q on q

$$F_q = -\frac{1}{4\pi\epsilon_0} \frac{q^2}{(2-x)^2} + \frac{1}{4\pi\epsilon_0} \frac{q^2}{x^2}$$

(assuming right direction to be positive and q to be negative)

$$So q Fq = 0 \Rightarrow (2-x)^2 = x^2 \text{ OR } x = 1m$$

(condition of equilibrium)

Now for any of the q to be at equilibrium it is necessary for q to be negative to counteract for any repulsion faced by it due to the other positive charge q.

So q Fq (q placed at A)

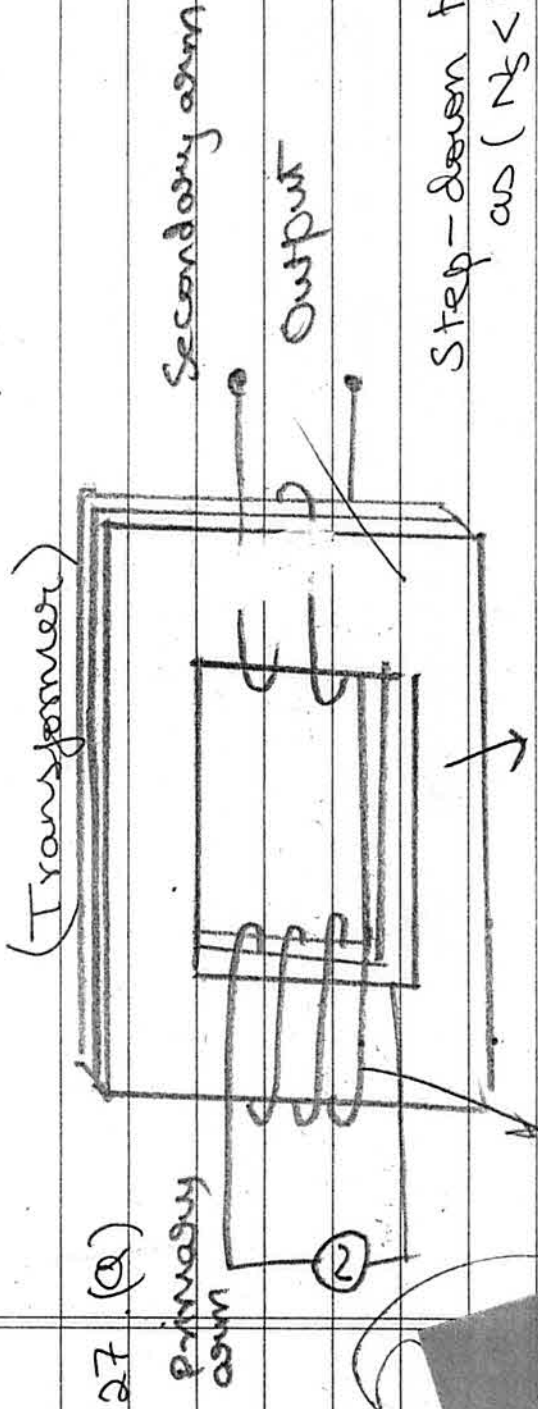
$$Fq = \frac{1}{4\pi\epsilon_0} \frac{q^2}{(2)^2} - \frac{1}{4\pi\epsilon_0} \frac{qQ}{(1)^2}$$

For equilibrium, $Fq = 0$

OR $\frac{q^2}{4} = \frac{qQ}{1}$

OR $1Q1 = \frac{q}{4}$

Hence, for the entire system to be in equilibrium q should be placed in between the two charges and its distance q in from either q then should be $-\frac{q}{4}$.



Step-down transformer
as ($N_s < N_p$)

windings laminated soft iron core

$N_s =$ no. of windings in secondary arm.

$N_p =$ no. of windings in primary arm.

Principle

Transformer works on the principle of mutual induction. The alternating current in primary produces an alternating magnetic flux. This change in magnetic flux gets linked with the windings in secondary arm and induces an emf in it as well which is proportional to N_s .

Namely,
$$\frac{E_p}{E_s} = \frac{N_p}{N_s}$$

(where E_p is the emf of primary and E_s is the emf of secondary)

Sources of Energy loss

- 1) Resistive losses = Copper loss - both in wires of primary ~~and~~ as well as secondary ~~and~~ if it is loaded & as a wire always has finite resistance
- 2) Flux leakage - The entire flux produced in primary coil may not get linked with the secondary coil & and some flux may leak through the core.
- 3) Hysteresis loss - Due to repeated magnetisation and demagnetisation of core & some energy loss takes place which is proportional to the area of the hysteresis loop.
- 4) Eddy current losses - Eddy currents may be induced in the core due to changing magnetic flux through it & leading to large losses of energy in the form of heat.

(b) No. of wires = 2

Resistance per km = 0.5 ohm km^{-1}

Distance between town and power plant
= 20 km

$$\text{Total resistance of path} = 2 \times 0.5 \times 20 \\ = 20 \text{ ohm (R)}$$

Now the town receives a power of 1200 kW from the power plant at voltage of 4000 V (\therefore step down transformer is 4000-220V, and the transformers are considered to be ideal - so no power loss).

$$\text{So, current flowing} = \frac{\text{Power}}{\text{Voltage}} = \frac{1200 \times 10^3 \text{ A}}{4000} \\ = 300 \text{ A (I)}$$

So, line power loss in the form of heat = $I^2 R$

$$= (3 \times 10^2)^2 \times 20 \text{ W} \\ = 9 \times 20 \times 10^4 \text{ W} = 1800 \text{ kW}$$

range, 1800 kW of energy is lost while transmitting electricity.

Section-C

Q No-13

(a) Moving coil galvanometer works on the principle that a current carrying loop experiences a torque in magnetic field (∴ It has a magnetic moment associated with it). This torque produced is then balanced by the ~~counter~~ torque of the spring producing the necessary deflection of the needle.

$$\text{OR } BINA = J\theta, \text{ where } J \text{ is the torsional}$$

constant of spring and other symbols have their usual meanings.

$$\text{So, } \theta = \frac{BINA}{J}$$

OR $\theta \propto I$ (current flowing through the coil)

(b) Galvanometer as such cannot be used to measure the value of current in a given circuit because :-

(i) It is a very sensitive instrument and has a very low maximum deflection current, i.e. it will show maximum deflection most of the time and can get damaged. In such situation it is not of much use.

(ii) Galvanometer has appreciable resistance of its own (due to windings), therefore, will alter the current flowing through the circuit and will not give accurate results (readings).

(c) (i) Voltage sensitivity is defined as the number of divisions (or degree scale) of galvanometer deflection in order to show a reading of 1V.

Mathematically, voltage sensitivity = $\frac{\theta}{V} = \frac{GNA}{RT}$

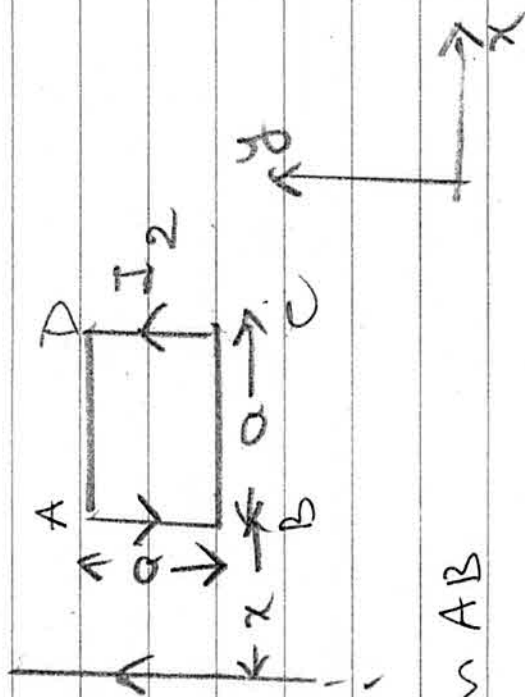
(ii) Current sensitivity of a galvanometer is defined as the number of divisions or the angle by which the galvanometer needle deflects when the current flowing through it is 1 A.
 Mathematically, current sensitivity = $\frac{\theta}{I} = \frac{BNA}{I}$

where, R is the resistance of the galvanometer windings. Other symbols have already been defined in part (a).

4. (a) Mutual inductance of a coil (C1) w.r.t another coil (C2) is defined as the magnitude of emf induced in coil C1 when the current through the other coil C2 changes at the rate of 1 A s⁻¹.
 Mathematically, $\mathcal{E}_1 = -M_{12} \frac{dI_2}{dt}$ (when $\frac{dI_1}{dt} = 1 \text{ A s}^{-1}$)
 $M_{12} = M_{21}$

S.I. unit of mutual inductance is Henry (H)

(b) Magnetic field due to I_1 infinitely long wire at distance x ,



$$B_x = \frac{\mu_0 I_1}{2\pi x} \otimes$$

Force experienced by arm AB

$$\vec{F}_{AB} = \frac{\mu_0 I_1 I_2 a}{2\pi x} \hat{c} \quad \text{--- (1) (using } \vec{F} = I \vec{\ell} \times \vec{B} \text{)}$$

Force experienced by ~~arm~~ DC

$$\vec{F}_{DC} = \mu$$

Magnetic field due to infinitely long wire at a distance of $x+a$,

$$B_{x+a} = \frac{\mu_0 I_1}{2\pi(x+a)} \otimes$$

Force experienced by ~~arm~~ DC,

$$\vec{F}_{BD} = -\frac{\mu_0 I_1 I_2 a}{2\pi(x+a)} \hat{c} \quad \text{--- (2) (using } \vec{F} = I \vec{\ell} \times \vec{B} \text{)}$$

Clearly, force experienced by arms BC and DA will be equal in magnitude and opposite in direction, because these are placed symmetrically.

(for e.g. force on DA will be downwards whereas force on BC will act upwards - using $\vec{F} = I \vec{l} \times \vec{B}$)

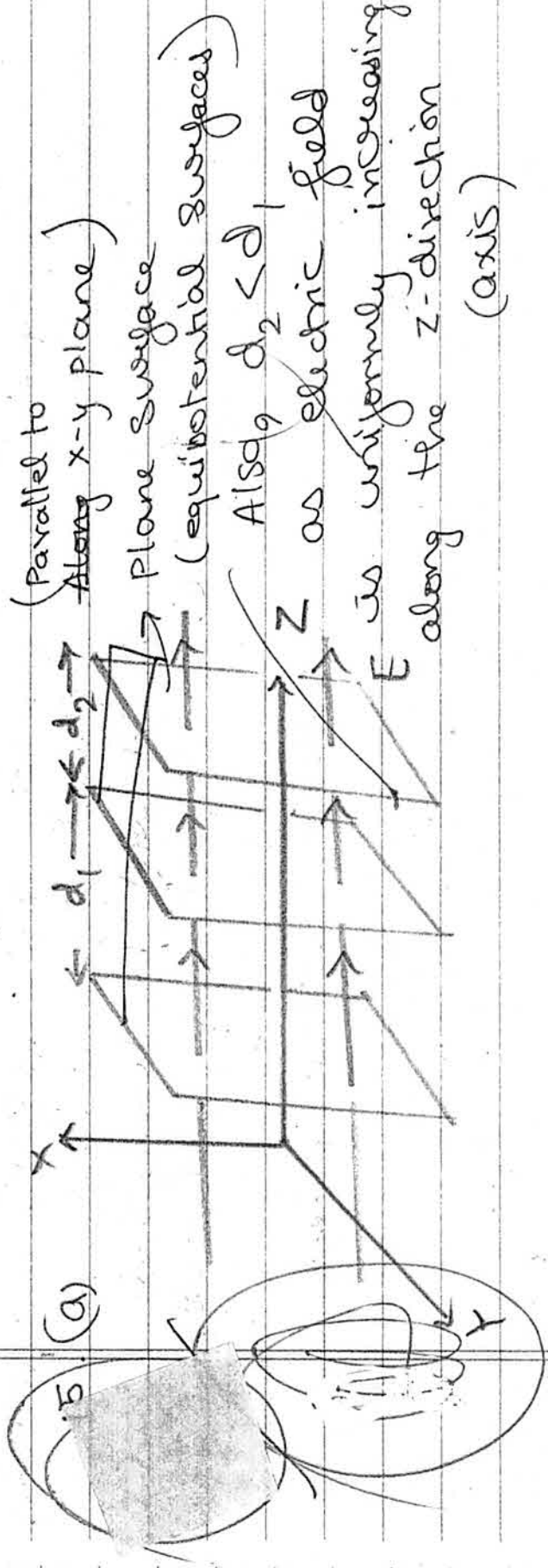
So, Total force on current carrying loop

$$\begin{aligned} \vec{F}_{\text{net}} &= \vec{F}_{AB} + \vec{F}_{BC} + \vec{F}_{CD} + \vec{F}_{DA} \\ &= \frac{\mu_0 I_1 I_2 a}{2\pi x} \hat{i} + (\vec{F}_{BC} + \vec{F}_{DA}) \quad \text{E.g. } \frac{\mu_0 I_1 I_2 a}{2\pi(a+x)} \hat{i} \\ \vec{F}_{\text{net}} &= \frac{\mu_0 I_1 I_2 a}{2\pi} \left[\frac{1}{x} - \frac{1}{a+x} \right] + 0 \quad (\text{from } \textcircled{1}, \textcircled{2}) \\ \vec{F}_{\text{net}} &= \frac{\mu_0 I_1 I_2 a}{2\pi x(a+x)} \hat{i} \end{aligned}$$

Hence a force acting on square loop is

$$\frac{\mu_0 I_1 I_2 a^2}{2\pi x(a+x)}$$

towards right.



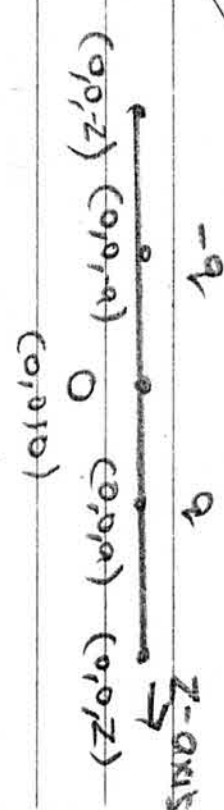
(b) Electrostatic potential at point $(x, y, 0)$ is zero, because it is lying on the equatorial plane of the dipole and is equidistant from both $+q$ and $-q$.
 $(0, 0, z)$ $-q(0, 0, -a)$ $+q(0, 0, a)$ $(0, 0, z)$
 Now, potential at $(0, 0, z)$

$$V_z = V_q + V_{-q} = \frac{1}{4\pi\epsilon_0} \frac{q}{(z-a)} + \frac{1}{4\pi\epsilon_0} \frac{(-q)}{(z+a)}$$

$$V_{+z} = \frac{q}{4\pi\epsilon_0} \left[\frac{1}{z-a} - \frac{1}{z+a} \right]$$

$$V_{+z} = \frac{q}{4\pi\epsilon_0} \left[\frac{z+a - z-a}{z^2-a^2} \right]$$

$$V_{+z} = \frac{2qa}{4\pi\epsilon_0 (z^2-a^2)}$$



and $V_{-z} = V_{-q} + V_q$

$$= \frac{-q}{4\pi\epsilon_0 (z-a)} + \frac{q}{4\pi\epsilon_0 (z+a)}$$

$$= \frac{q}{4\pi\epsilon_0} \left[\frac{1}{z+a} - \frac{1}{z-a} \right]$$

$$= \frac{q}{4\pi\epsilon_0} \frac{(-2a)}{(z^2-a^2)} = \frac{-2qa}{4\pi\epsilon_0 (z^2-a^2)}$$

Hence, electrostatic potential at point $(0,0,z)$ is $\frac{1}{4\pi\epsilon_0} \frac{2qa}{z^2-a^2}$

and at $(0,0,-z)$ is $\frac{-1}{4\pi\epsilon_0} \frac{2qa}{z^2-a^2}$

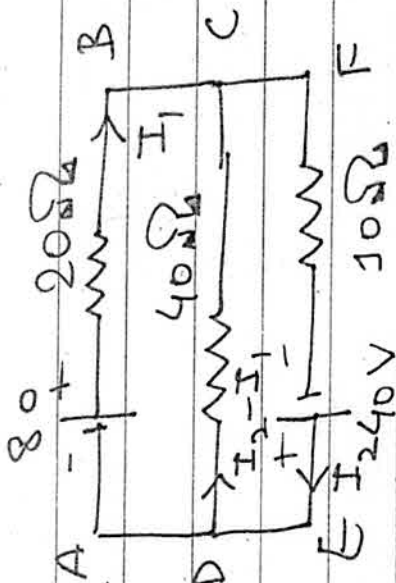
16. Distributing the current

as shown using

Kirchhoff's junction

rule at all the

junctions.



Now applying Kirchhoff's ~~voltage~~ ^{loop} rule in the loop A B C D A

$$80 - 20I_1 + 40(I_2 - I_1) = 0$$

$$80 = 20I_1 + 40I_2 - 40I_1$$

$$80 = 60I_1 - 40I_2$$

$$\text{OR } 4 = 3I_1 - 2I_2 \quad \text{--- (1)}$$

Now, applying Kirchhoff's loop rule in the loop D C F E D,

$$-40(I_2 - I_1) - 10I_2 + 40 = 0$$

$$\text{OR } 40 = 10I_2 + 40I_2 - 40I_1$$

$$\text{OR } 4 = 5I_2 - 4I_1 \quad \text{--- (2)}$$

Solving (1) & (2),

$$8 = 6I_1 - 4I_2$$

$$16 = 12I_1 - 8I_2 \quad (\text{From (1)})$$

$$\text{and } 12 = 15I_2 - 12I_1 \quad (\text{From (2)})$$

(Adding)

$$28 = 7I_2$$

$$\text{OR } I_2 = 4 \text{ A} \quad \text{--- (3)}$$

and from (1)

$$4 = 3I_1 - 2I_2$$

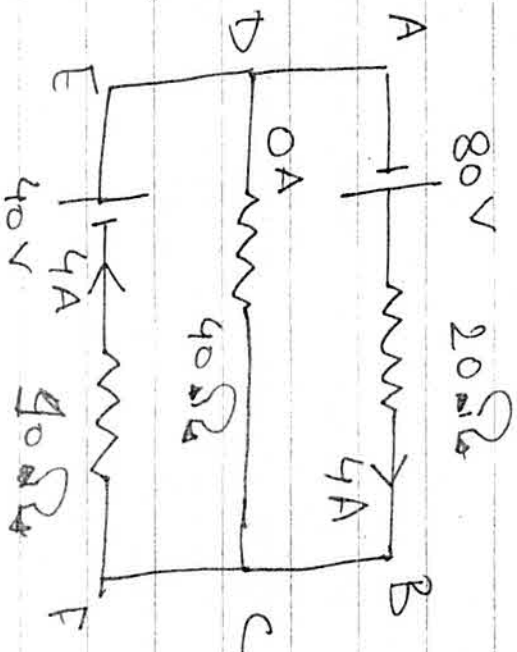
$$4 = 3I_1 - 2(4)$$

$$\text{OR } I_1 = 4 \text{ A}$$

So, the circuit becomes.

Hence, no current flows through inner 40Ω resistor and

4 A flows through each of the resistors.



20

7. (a) Let half life be $T_{1/2}$ and average life of radioactive nucleus be τ

So, $T_{1/2} = \tau \ln 2$

(b) Let initial amount of nucleus of A be $= N_A$

and initial amount of nucleus of B be $= N_B$

According to question, $N_B = 2N_A$ — (4)

Let decay constant be respectively λ_A & λ_B

So, half life of A $= 60 \text{ yr} = \frac{\ln 2}{\lambda_A}$

$$\text{So, } \lambda_A = \frac{\ln 2}{60} \text{ yr}^{-1}$$

and half life of B $= 30 \text{ yr} = \frac{\ln 2}{\lambda_B}$

$$\text{So, } \lambda_B = \frac{\ln 2}{30 \text{ yr}}$$

Now, at some other time t , let number of nuclei of A be M_A & that of B be M_B .

Using laws of radioactive decay

$$M_A = M_A e^{-\lambda_A t} \quad \text{--- (1)}$$

$$\text{and } M_B = N_B e^{-\lambda_B t} \quad \text{--- (2)}$$

$$\text{we want } M_A = 2M_B \quad \text{--- (3)}$$

So,

$$2M_B = \frac{N_B e^{-\lambda_A t}}{2} \quad \text{--- (4) (From (3) & (2))}$$

$$\& M_B = N_B e^{-\lambda_B t} \quad \text{--- (5)}$$

Dividing (4) by (5)

$$2 = \frac{1}{2} \frac{e^{-\lambda_A t}}{e^{-\lambda_B t}}$$

$$4 e^{\lambda_A t} = e^{\lambda_B t}$$

Taking log both sides

$$\ln 4 + \lambda_A t = \lambda_B t$$

$$\frac{2 \ln 2 + \frac{2 \ln 2 t}{60}}{30} = \frac{2 \ln 2 t}{60}$$

$$\text{So } 2 + \frac{t}{60} = \frac{t}{30}$$

$$\text{OR } 2 = t \left(\frac{1}{30} - \frac{1}{60} \right)$$

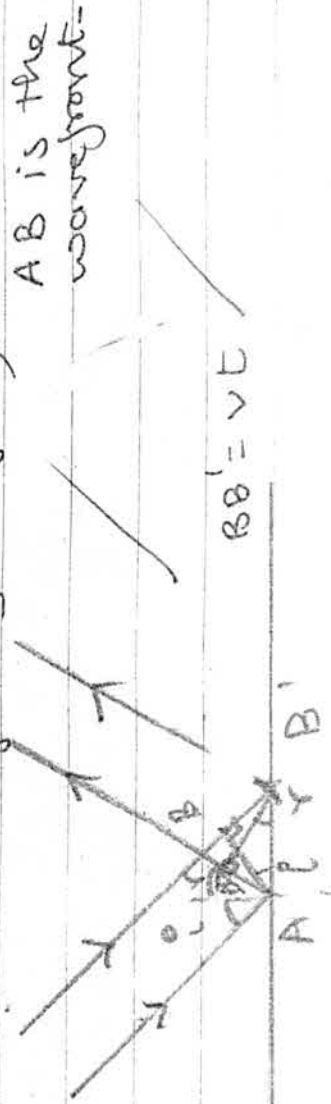
$$2 = \frac{t}{60}$$

$$\text{OR } t = 120 \text{ years.}$$

Hence, after 120 years the required concentration of nuclei A & B will be achieved.

18. Wavefront is defined as the surface of constant phase or the locus of all the points of the medium vibrating/oscillating in the same phase.

Consider a plane wavefront of light as shown. (incident on a reflecting surface)



In order to find the position of wavefront at some later time t we use Huygens principle and draw a sphere of radius $v \cdot t$ where v - speed of light. Such that point B reaches the reflecting surface.

Now, in two right triangles,

$\Delta ADB'$ and $\Delta ABB'$

and A reaches D.

$$\angle ADB' = \angle ACB = 90^\circ$$

$$AB' = AB' \text{ (hypotenuse)}$$

$$\text{and } AD = AB \text{ (using Huygens Principle)}$$

$$\text{So, } \Delta ADB' \cong \Delta ABB'$$

$$\text{OR } \angle BAB' = \angle DAB'$$

$$\text{OR } i = r$$

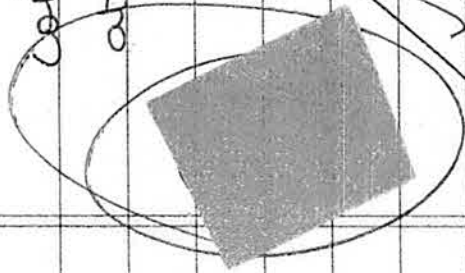
Hence, angle of incidence is equal to angle of reflection. Hence laws of reflection is verified (they obviously lie in the same plane, as wavefronts are planar)

17 (a) Self-inductance of a coil is defined as the magnitude of back emf induced in the coil when the current through it changes at the rate of 1 A s⁻¹.

Mathematically, $\mathcal{E}_b = -L \frac{dI_1}{dt}$ (if $\frac{dI}{dt} = 1 \text{ A s}^{-1}$)

$$|\mathcal{E}_b| = L = \text{self-inductance}$$

S.I. unit of self-inductance is Henry (H).



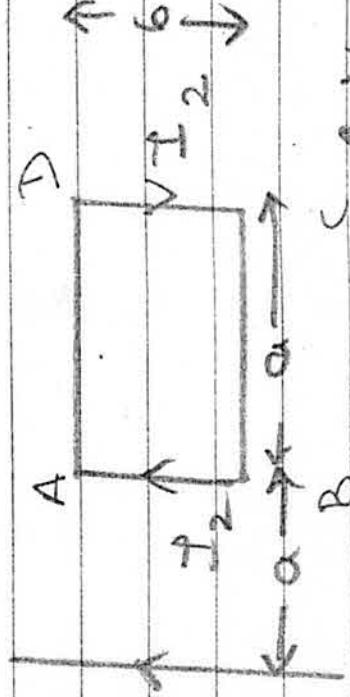
(b) Magnetic field at a distance a due I_1 to the infinitely long wire,

$$B_a = \frac{\mu_0 I_1}{2\pi a} \otimes$$

Force on side AB of the loop

$$\vec{F}_{AB} = \frac{\mu_0 I_1 I_2 b}{2\pi a} (-\hat{i}) \quad \text{--- (1)}$$

[Using $\vec{F} = I \vec{l} \times \vec{B}$]



Therefore, total force on the loop

$$\vec{F}_{\text{net}} = \vec{F}_{AB} + \vec{F}_{BC} + \vec{F}_{CD} + \vec{F}_{DA}$$

$$= -\frac{\mu_0 I_1 I_2 b}{2\pi a} \hat{i} + 0 + \frac{\mu_0 I_1 I_2 b}{2\pi(2a)} \hat{i}$$

(From (1), (2) (3))

$$\vec{F}_{\text{net}} = -\frac{\mu_0 I_1 I_2 b}{2\pi a} \hat{i} \left[1 - \frac{1}{2} \right]$$

$$= -\frac{\mu_0 I_1 I_2 b}{4\pi a} \hat{i}$$

Hence, the loop experiences a resultant force of $\left[\frac{\mu_0 I_1 I_2 b}{4\pi a} \right]$ towards left

अपना अनुक्रमांक इस उत्तर-पुस्तिका

पर न लिखें

Please do not write your

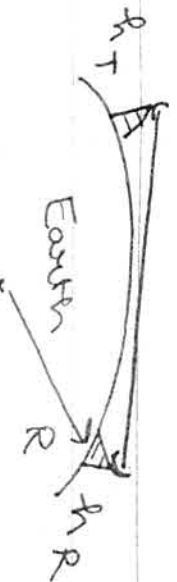
Roll Number on this Answer-Book

अतिरिक्त उत्तर-पुस्तिका(ओं) की संख्या.....

Supplementary Answer-Book(S) No. 3

$$\alpha \approx \frac{7}{m_p} \frac{m_e}{m_e} \quad (\alpha = \alpha\text{-particle}, p = \text{proton}, e = \text{electron})$$

12. Signal transmitted from a TV tower uses space wave method for signal transmission. \therefore the transmitting antenna and the receiving antenna should lie along a straight line for effective communication. However due to curvature of earth the signals are unable to exceed a particular distance and obstructed by the Earth's surface thus leading to ~~or~~ very high attenuation.
- ~~TV signals cannot be received beyond a particular distance.~~
- Considering the transmitting tower to have a height ' h_T ' and receiving tower to have a height ' h_R ' the

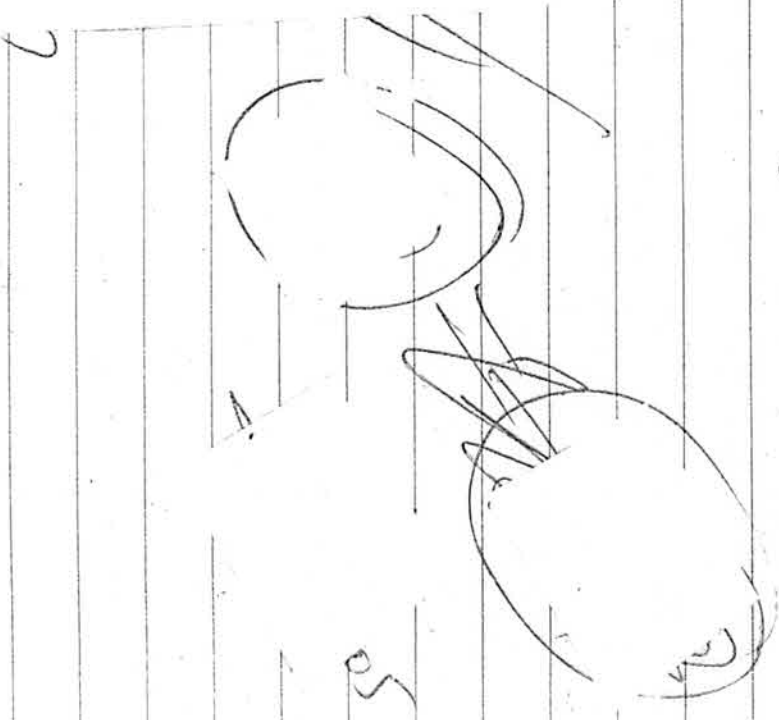
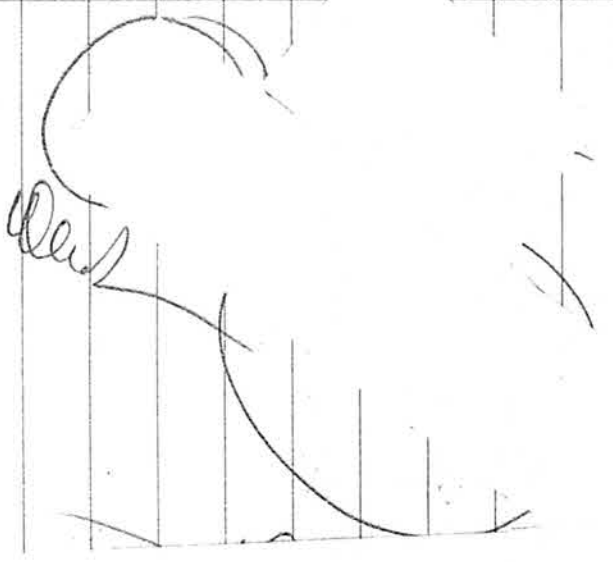


maximum range possible is equal to

$$R_{max} = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$

where $R = \text{radius of earth}$.

So, this must be the optimum separation between the receiving and transmitting antenna.



अपना अनुक्रमांक इस उत्तर-पुस्तिका

पर न लिखें

Please do not write your

Roll Number on this Answer-Book

अतिरिक्त उत्तर-पुस्तिका(ओं) की संख्या.....

Supplementary Answer-Book(S) No. 2

Section-B

6. Einstein's photo electric equation

$$\frac{1}{2} m_e v_{\max}^2 = h\nu - \phi_0$$

where $\frac{1}{2} m_e v_{\max}^2$ = maximum kinetic energy of electron.

and $h\nu$ = energy of ^{incident} wave, ϕ_0 = work function of metal.

It explains that

(i) The ^{maximum} kinetic energy of electrons and hence the stopping potential is independent of the frequency of light used but only depends on the frequency of light used. Hence, explains the observation.

(ii) Also since $\frac{1}{2} m_e v_{\max}^2 > 0 \Rightarrow h\nu > \phi_0$
OR $\nu > \frac{\phi_0}{h} = \nu_0$

where $\nu_0 = \frac{\phi_0}{h}$ = threshold frequency

8. Hence, a minimum frequency of light is required to observe photoelectric effect, characteristic to the metal. Thus, explains the observations and the fact that intensity has got to do anything with ejection of electron.

∴ Mass of deuteron = $2u$ (m_D)

Mass of alpha particle = $4u$ (m_α)

Charge on deuteron = $+e$ (q_D)

Charge on alpha particle = $+2e$ (q_α) ($\frac{1}{2} m v^2 = q v B$)

Radius of path of deuteron $r_D = \frac{m_D v_D}{q_D B} = \frac{p_D}{q_D B}$

Radius of path of α-particle, $r_α = \frac{m_α v_α}{q_α B} = \frac{p_α}{q_α B}$

$$\text{So } \frac{r_D}{r_α} = \frac{p_D}{p_α} \frac{q_α}{q_D} = \frac{2e}{e} = 2$$

(As both have same momentum)

$$\text{So } r_D : r_α = 2 : 1 = \underline{2} \\ \text{(deuteron: } \alpha\text{-particle)}$$

8.

Power of bulb 1 = P_1

Voltage rating = V

$$\text{Resistance} = \frac{V^2}{P_1} = R_1 \quad (\because P_1 = \frac{V^2}{R})$$

Power of bulb 2 = P_2

Voltage rating = V

$$\text{Resistance} = \frac{V^2}{P_2} = R_2$$

(ii) when connected in series of total Resistance $R_S = R_1 + R_2 = \frac{V^2}{\left[\frac{P_1 P_2}{P_1 + P_2}\right]}$

Total current flowing through the circuit = $\frac{V}{R_S}$

(\because they are connected to a supply of voltage V)

$$I_T = \frac{V}{\left[\frac{P_1 P_2}{P_1 + P_2}\right]} = \frac{1}{V} \frac{P_1 P_2}{P_1 + P_2}$$

Total power drawn = $V I_T = V \downarrow \left[\frac{P_1 P_2}{P_1 + P_2}\right] = \frac{P_1 P_2}{P_1 + P_2}$

(ii) Now, when both the bulbs are connected in parallel to the voltage supply V Power drawn by bulb 1 = $\frac{V^2}{R_1}$ (∵ in parallel voltage drop across all components is same)

$$= \frac{V^2}{R_1} P_1 = P_1 \quad \text{--- (1)}$$

$$\text{Power drawn by bulb 2} = \frac{V^2}{R_2} = \frac{V^2}{V^2/P_2} = P_2 \quad \text{--- (2)}$$

Total power drawn from the source = $P_1 + P_2$ (From (1) & (2))

9. Refractive index of prism = $1.6 = \frac{8}{5} = n_1$

Refractive index of a medium = $4\sqrt{2} = n_2$

Refractive index of prism w.r.t surroundings = $n_1 = n_2$

$$\mu = \frac{8^2 - 5^2}{8^2 + 5^2} = \frac{9}{17}$$

So, using the relation,

$$\mu = \frac{\sin(A + \delta_{min})}{\sin A}$$

$$\frac{9}{17} = \frac{\sin A}{2}$$

A = angle of prism & δ_{min} = angle of minimum deviation

we get,

$$\frac{9}{17} = \frac{\sin(60 + \delta_{min})}{\sin 30^\circ}$$

$$\frac{9}{17} = \sin\left(\frac{60 + \delta_{min}}{2}\right)$$

$$\frac{60 + \delta_{\min}}{2} = \sin^{-1} \frac{1}{\sqrt{2}} = 45^\circ$$

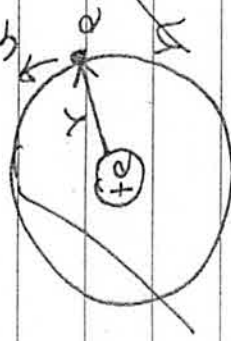
$$60 + \delta_{\min} = 90^\circ$$

$$\delta_{\min} = 30^\circ$$

Hence, angle of minimum deviation of prism = 30°

10.

Let the H atom be as shown where n is the principal quantum number.



Bohr's quantization principle :- The electron can revolve around the nucleus inside a H-atom in only those orbits in which its angular momentum is quantised and is equal to an integral multiple of $\frac{h}{2\pi}$. According to him no other orbits were valid for an e to revolve around.

Mathematically, $L = \frac{nh}{2\pi}$, $n \in \mathbb{Z}$

OR $mvr = \frac{nh}{2\pi}$

For Brackett series,

$$\frac{1}{\lambda} = 109677 \text{ cm}^{-1} \left(\frac{1}{16} - \frac{1}{n^2} \right), \quad n = \text{quantum number.}$$

To obtain shortest wavelength of Brackett series, transition should be made from $n = \infty$ (maximum energy difference or shortest wavelength)

$$\begin{aligned} \text{So } \frac{1}{\lambda} &= 109677 \text{ cm}^{-1} \left(\frac{1}{16} - 0 \right) \\ \lambda &= \frac{16 \times 9113 \text{ \AA}}{109677.2 \text{ \AA}^{-1}} \\ &= 1.45872 \times 10^{-6} \text{ m} \end{aligned}$$

belongs to infrared radiations of spectrum

According to de-Broglie's equation

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mqV}}$$

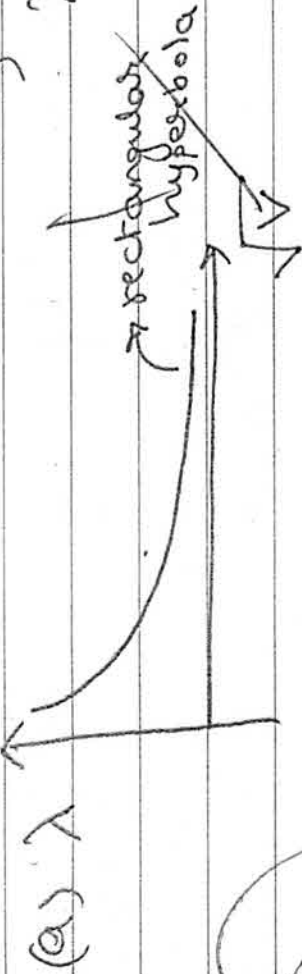
where V is

the acceleratⁿ

potential

So $\lambda \propto \frac{1}{\sqrt{V}}$ for catho

rons and charge^d particle.



$$\left(\frac{p^2}{2m} = K = eV \right)$$

So, $p = \sqrt{2meV}$

(b) According to de-Broglie's equation,

$$\lambda = \frac{h}{p} \quad , \quad p = \text{momentum.}$$

Also, $\frac{p^2}{2m} = K = \text{kinetic energy}$

So, $p = \sqrt{2mK}$

$$\therefore \lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}}$$

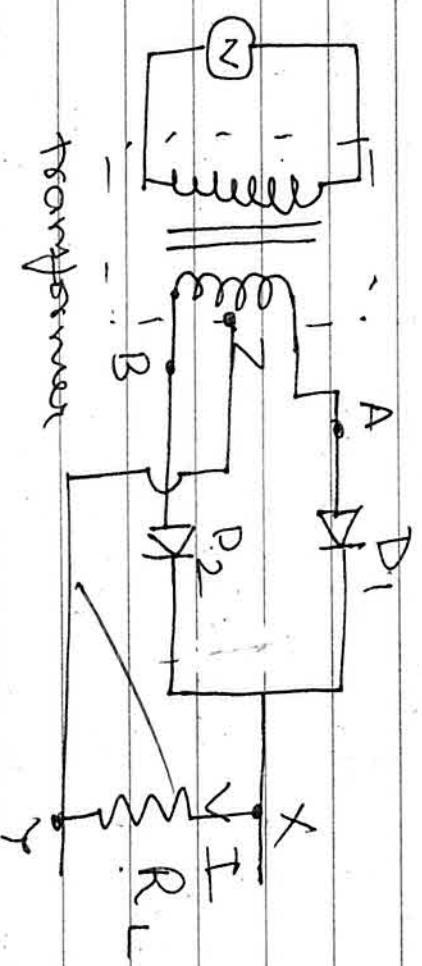
for constant K , $\lambda \propto \frac{1}{\sqrt{m}}$

Hence, α -part has the shortest wavelength.

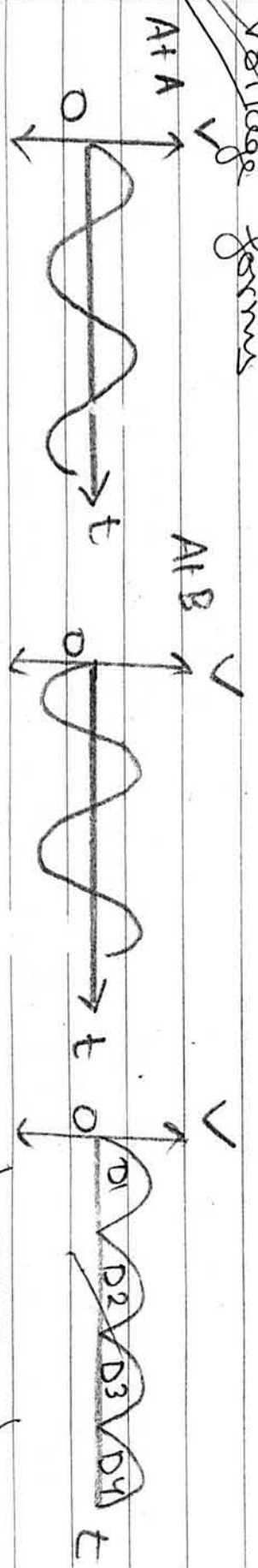
अपना अनुक्रमांक इस उत्तर-पुस्तिका पर न लिखें
Please do not write your Roll Number on this Answer-Book

अतिरिक्त उत्तर-पुस्तिका(ओं) की संख्या.....
Supplementary Answer-Book(S) No. 1

ac.
Circuit Diagram of full wave rectifier.



Voltage forms



Input waveforms

Output waveforms

Rectifier works on the principle that a diode only conducts when it is forward biased and doesn't conduct practically when reverse biased.

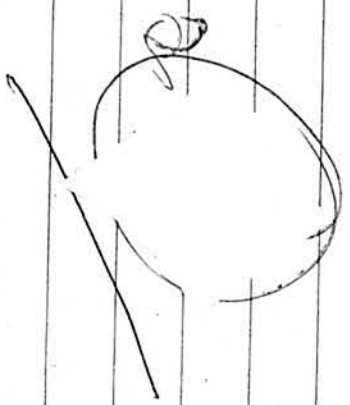
When voltage at A is higher than B, D1 is forward biased whereas D2 is reverse biased, therefore, current flows in the loop AXYZA and voltage appears across R_L .

When B is at a higher voltage than A, D2 is forward biased whereas D1 is reverse biased. Hence, current flows in the loop BXYZB and voltage appears across R_L . In both cases a voltage drop across R_L is in the same direction and hence it is able to rectify the AC voltage to produce pulsating DC.

2(a)

(b)

also let amplitude of message signal be A_m and that of carrier wave signal be A_c according to question.



$A_m + A_c = A$ — maximum amplitude

and $A_c - A_m = B$ — minimum amplitude

So $2A_c = A + B$

OR $A_c = \frac{A+B}{2}$ — (1)

and $A_m = A - A_c = \frac{A-B}{2}$ — (2)

So modulation index of signal = $\frac{A_m}{A_c} = \frac{A-B}{A+B}$

(from (1) & (2))

(b) Peak voltage of message signal, $A_m = 10V$

Peak voltage of carrier signal, $A_c = 15V$

Modulation index $\mu = \frac{A_m}{A_c} = \frac{10}{15} = \frac{2}{3} = 0.66$

The modulation index is generally kept less than one to avoid any distortion at receiver.

wave so that the message signal could be transmitted through the propagating medium effectively. Hence, it is kept less than one, i.e. $\mu < 1$.

22. Paramagnetic Substances

(i) Are weakly attracted by the external magnetic field.
(ii) Relative magnetic permeability $\mu > 1$ but not very high.

(iii) Gets magnetised in same direction $\chi > 0$ and has unpaired electrons.

Diamagnetic Substances

(i) Are weakly repelled by the external magnetic field.
(ii) Relative magnetic permeability less than 1 but > 0 .

(iii) Gets magnetised in opposite directions, $\chi < 0$ and has paired electrons.

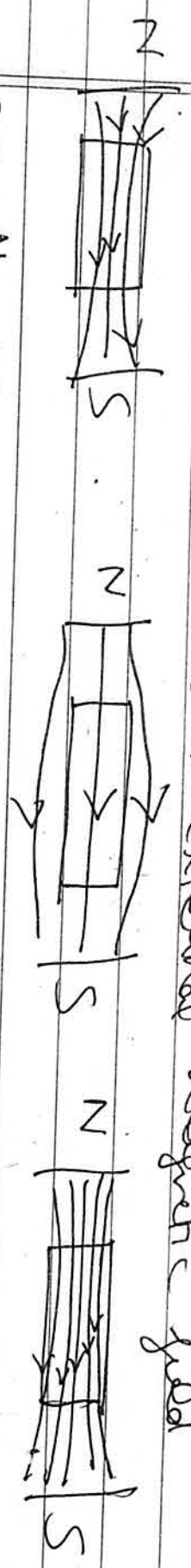
Ferromagnetic Substances.

(i) Are strongly attracted by the magnetic field.

(ii) Relative magnetic permeability μ very high $\mu \gg 1$.

(iii) Gets strongly magnetised in the same direction $\chi \gg 1$. Consists of powerful domains.

Behaviour in external magnetic field



e.g. Aluminium

e.g. Bismuth

e.g. Iron

(a)(i) Microwaves

(ii) UV radiations - wavelength - 1mm to 10m, $3 \times 10^8 \text{ Hz} - 3 \times 10^{12} \text{ Hz}$
~~400nm to 1nm~~, $7.5 \times 10^{14} \text{ Hz} - 3 \times 10^{17} \text{ Hz}$

(b) Average density of oscillating electric field

$$U_E = \frac{1}{2} \epsilon_0 E^2 \text{ where}$$

$$E_{rms} = \frac{E_0}{\sqrt{2}}$$

Average density of oscillating magnetic field

$$U_B = \frac{1}{2} \frac{B_{rms}^2}{\mu_0} \text{ where}$$

$$B_{rms} = \frac{B_0}{\sqrt{2}}$$

$$N_{rms} \frac{E_0}{B_0} = \frac{E_{rms}}{B_{rms}} = c \text{ (speed of light)}$$

So, ① becomes $U_B = \frac{1}{2} \frac{E_{rms}^2}{\mu_0 c^2}$

Also $c^2 = \frac{1}{\epsilon_0 \mu_0}$

So, $U_B = \frac{1}{2} \frac{E_{rms}^2 \epsilon_0 \mu_0}{\mu_0}$

$U_B = \frac{1}{2} \epsilon_0 E_{rms}^2 = U_E$

Hence, Proved.

24. (a) Wavelength of light used = 600 nm (λ)
Energy associated with light = $\frac{hc}{\lambda}$

= $\frac{1240 \text{ eV}}{600}$

600

= $\frac{2.067 \text{ eV}}{83}$

83

= 2.067 eV

E_g P_1 & P_2 will ~~not~~ be able to detect light as energy associated with the source is less than their band gap (2.5 eV & 3 eV respectively)

So, no e-h generation will take place

(b) Photo-diodes are required to operate in reverse ~~bias~~ bias, because the minority carriers ~~is~~ lead to current in this case.

For e.g. Consider an n-type semiconductor,

for n_0 of electrons = n
 p_0 of holes = p

Initially $n \gg p$. (In case majority charge carriers are present)
 Now when light of suitable energy falls on it, n_0 of holes generated = Δp
 p_0 of electrons generated = Δn

Clearly, $\Delta n = \Delta p$
 So a fractional increase in holes $\frac{\Delta p}{p} \gg \frac{\Delta n}{n}$

1. Hence, light of different intensities can be easily distinguished in ~~an increase~~ bias voltage, as fractional increase in ~~currents~~ as well as current is more noticeable.

~~See XIA-2~~

(

|

|

AT