Section-A

1. Threshold frequency is defined as that minimum frequency that an electromagnetic radiation should have, so that is able to eject electrons (with zero kinetic energy) from the surface of the metal, on which 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.

P.T.O

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, <u>refractive index = 1.73</u>.

3. Signals having frequency greater than 30 MHz are sufficiently energetic that they are able to <u>penetrate the ionosphere</u> of the atmosphere. Hence, 5
these are <u>no longer reflected</u> 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

~~6.~~

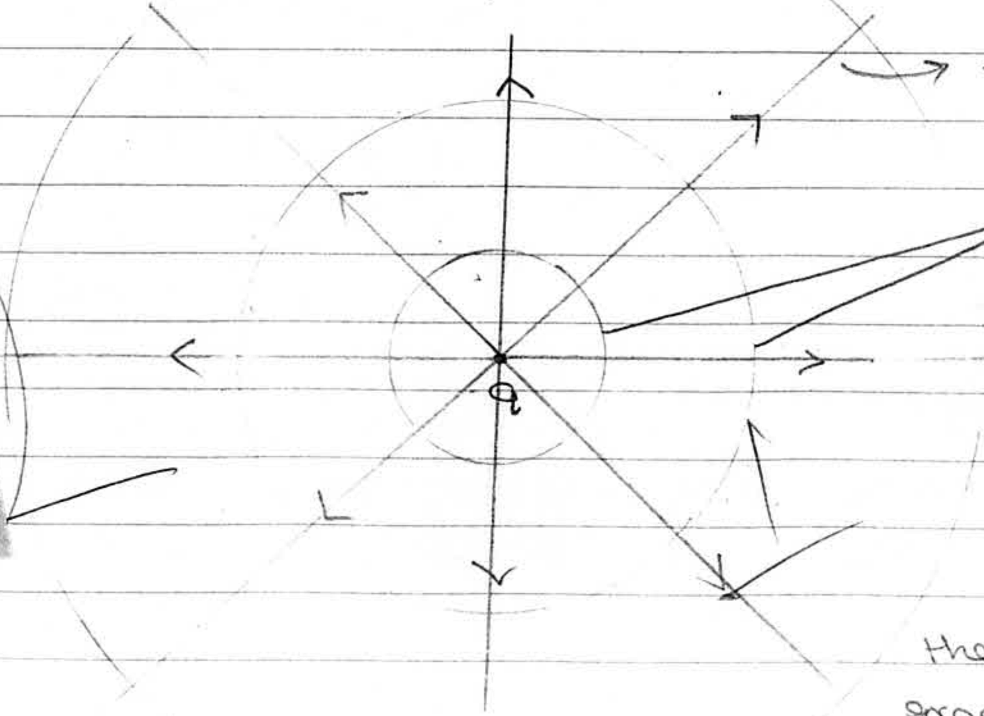
4. Drift velocity of electrons, v_d is given by,

$$\boxed{\vec{v}_d = -\frac{e\vec{E}}{m}\tau}$$

where, $\vec{E}$ 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).

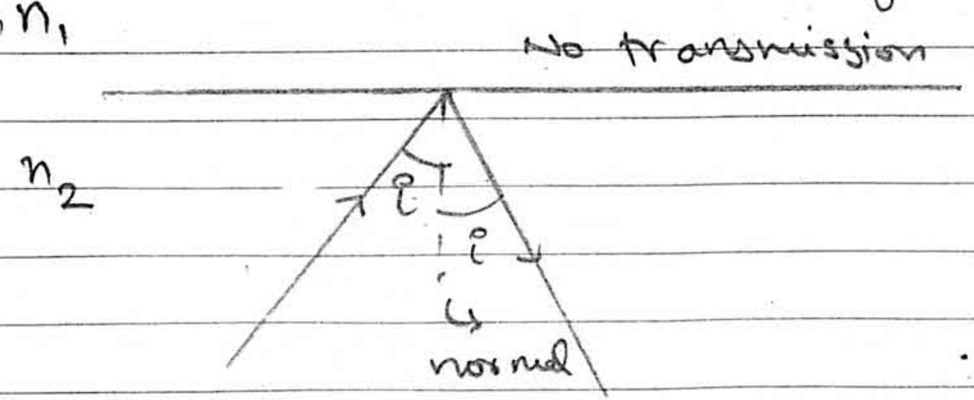
Thus, drift velocity of electrons is related directly to the relaxation time.

5. 

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

Section-D

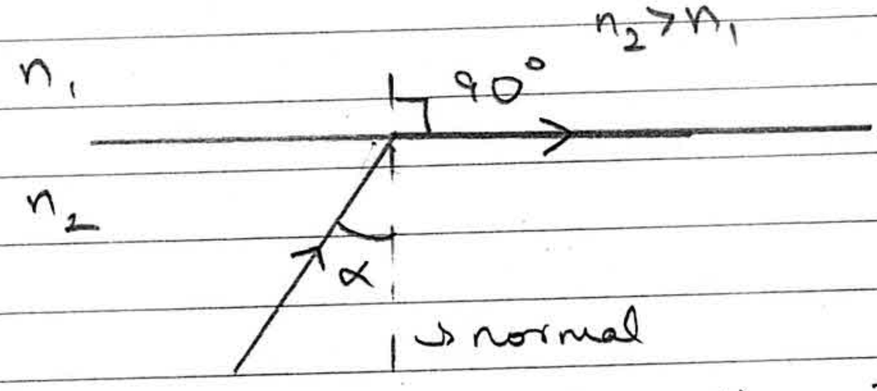
25. (a) When light travels from an optically denser medium towards an optically rarer medium, and is incident on the interface at an angle greater than the critical angle for the given pair of media, we observe total internal reflection of light.



$n_2 > n_1$

and $i > \theta_c$ (critical angle)

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



[n_1 & n_2 are the refractive indices of the medium respectively]

Applying snell's law at the interface,

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

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

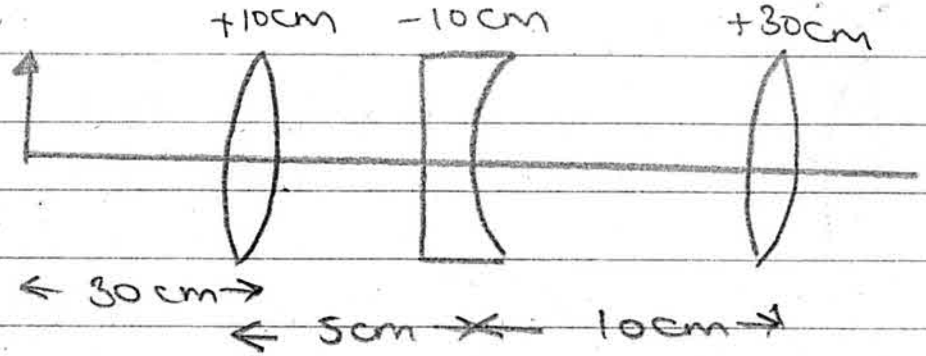
$$\alpha = \sin^{-1}\left(\frac{n_1}{n_2}\right)$$

OR $\alpha = \sin^{-1}\left(\frac{1}{n_{21}}\right)$ [n_{21} is refractive index of denser medium w.r.t rarer medium]

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 medium $= \alpha = \sin^{-1}\left(\frac{1}{n_{21}}\right)$ ($\because \theta_c$ is the minimum angle above which no transmission of light takes place)

Hence, $\boxed{\theta_c = \alpha = \sin^{-1}\left(\frac{1}{n_{21}}\right)}$

(b)



- First, refraction from convex lens of focal length $f_1 = +10$ cm

Object distance, $u_1 = -30$ cm (u)

focal length, $f_1 = +10$ cm (f)

Lens formula,

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

Substituting the values,

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

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

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

$v = +15$ cm

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

So, object distance, $u_2 = (15-5)$ cm $= 10$ cm (u)

focal length, $f_2 = -10$ 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 $v \to \infty$ (image formed at infinity)

Now, these image will act as a virtual object for convex lens of focal length $= +30$ cm

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

focal length, $f_3 = +30$ cm (f)

Lens formula,

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

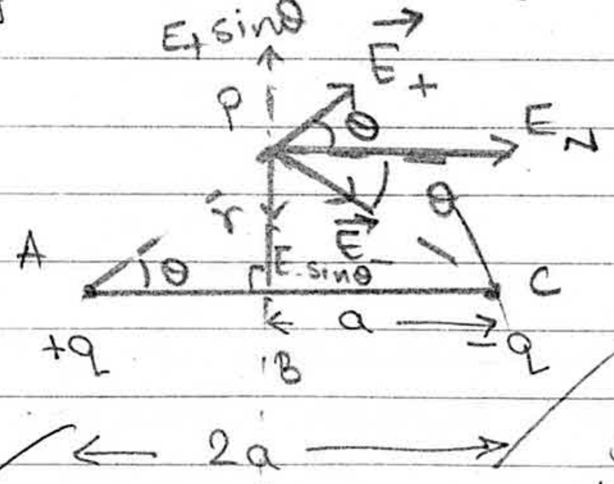
Substituting values,

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

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

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.

26 (a)



Consider the given dipole 'B' is any point on the equitorial line of ~~an~~ the dipole.

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

$$E_+ = \frac{1}{4\pi\varepsilon_0}\frac{q}{(AP)^2} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}$$

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

$$E_- = \frac{1}{4\pi\varepsilon_0}\frac{q}{BP^2} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}$$

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

and vertical components of E_+ and E_- will mutually cancel out. (as $E_+ \sin\theta = E_- \sin\theta$)

$\therefore$ net electric field is only along the horizontal as shown.

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

$$E_N = 2E_+\cos\theta \quad (\text{from } (1))$$

Now in right ΔABP

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

So, $$E_N = 2\frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}\frac{a}{(r^2+a^2)^{1/2}}$$

OR $$E_N = \frac{1}{4\pi\varepsilon_0}\frac{(2qa)}{(r^2+a^2)^{3/2}} = \frac{1}{4\pi\varepsilon_0}\frac{p}{(r^2+a^2)^{3/2}}$$

and vectorially,

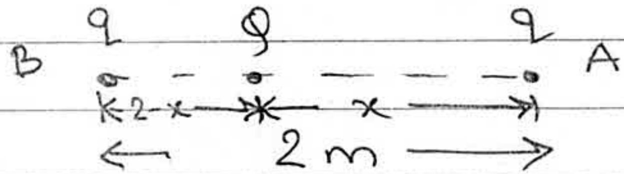
$$\vec{E_N} = \frac{-1}{4\pi\varepsilon_0}\frac{\vec{p}}{(r^2+a^2)^{3/2}},$$

$\vec{p}$ 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 $r >> a$

$$\vec{E_N} = \frac{-1}{4\pi\varepsilon_0} \frac{\vec{p}}{r^3} \quad \text{(ignoring the sum)}$$

(b) 

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 & Q should be in equilibrium.

Now total force on Q

$$F_Q = \frac{-1}{4\pi\varepsilon_0} \frac{qQ}{(2-x)^2} + \frac{1}{4\pi\varepsilon_0} \frac{qQ}{x^2}$$

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

So, $F_Q = 0 \Rightarrow (2-x)^2 = x^2$ 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, F_q (q placed at A)

$$F_q = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{(2)^2} - \frac{1}{4\pi\varepsilon_0}\frac{qQ}{(1)^2}$$

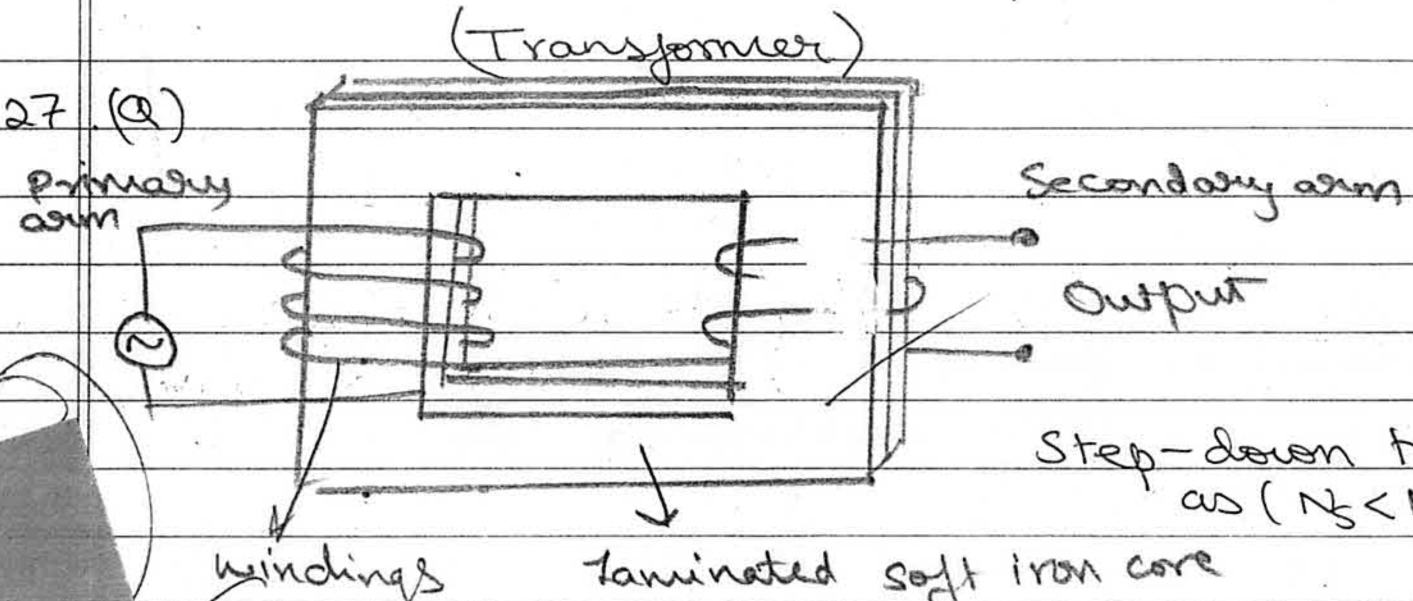
For equilibrium, $F_q = 0$

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

$$\text{OR} \quad |Q| = \frac{q}{4}$$

Hence, for the entire system to be in equilibrium, Q should be placed in between the two charges (at a distance of 1m from either of them) and its value should be $-\frac{q}{4}$.

27. (a)



Step-down transformer as ($N_S < N_P$)

N_S = no. of ~~so~~ 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, $\frac{\varepsilon_P}{\varepsilon_S} = \frac{N_P}{N_S}$ (where ε_P is the emf of primary ~~coil~~ source and ε_S is the ...

Sources of Energy loss

1) Resistive losses - Copper loss - both in wires of primary arm as well as secondary arm (if it is closed), 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) Hysterisis loss - Due to repeated magnetisation and demagnetisation of core, some energy loss takes place which is proportional to the area of the hysteris 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.

P.T.O

(b) No. of wires = 2
Resistance per km = 0.5 ohm km^{-1}
Distance between town and power plant
= 20 km

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

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

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

So, line power loss in the form of heat = $I^2 R$
= $(3 \times 10^2)^2 \times 20$ W
= $9 \times 20 \times 10^4$ W = 1800 kW

Hence, 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 ($\because$ 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.

OR $BINA = J\theta$, where J is the torsional constant of spring and other symbols have their usual meanings.

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, so 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 of a galvanometer is defined as the number of divisions (or degree of angle) by which the needle of galvanometer deflects in order to show a reading of 1V.

Mathematically, voltage sensitivity $= \frac{\theta}{V} = \frac{BNA}{RJ}$

(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 $= \frac{\theta}{I} = \frac{BNA}{J}$

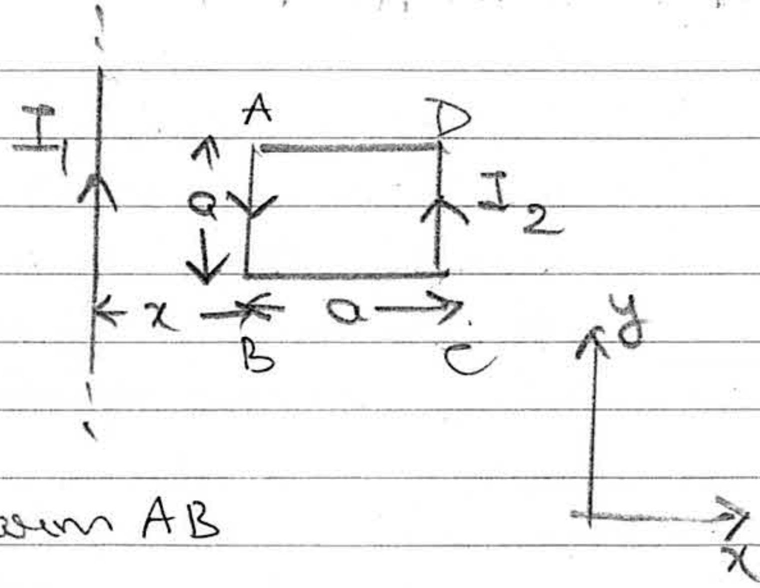
where, R is the resistance of the galvanometer windings. Other symbols have already been defined in part (a).

14. (a) Mutual inductance of a coil (C_1) w.r.t another coil (C_2) is defined as the magnitude of emf induced in coil C_1 when the current through the other coil C_2 changes at the rate of $1 A S^{-1}$.

Mathematically, $\mathcal{E}_1 = -M_{12} \frac{dI_2}{dt}$ (when $\frac{dI_1}{dt} = 1 As^{-1}$, $M_{12} = |\mathcal{E}_1|$)

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

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



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

Force experienced by arm AB

$$\vec{F_{AB}} = \frac{\mu_0 I_1}{2\pi x} I_2 a \hat{i} \quad \text{—(1)} \quad (\text{using } \vec{F} = I\vec{l} \times \vec{B})$$

~~Force experienced by arm BC~~

~~$\vec{F_{DC}} = \mu$~~

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,

$$\vec{F_{BD}} = -\frac{\mu_0 I_1}{2\pi(x+a)} I_2 a \hat{i} \quad \text{—(2)} \quad (\text{using } \vec{F} = I\vec{l} \times \vec{B})$$

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 $\vec{F} = I\vec{l} \times \vec{B}$) — (3)

So, Total force on current carrying loop

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

$$= \frac{\mu_0 I_1 I_2 a}{2\pi x}\hat{i} + (\vec{F}_{BC} + \vec{F}_{DA}) - \frac{\mu_0 I_1 I_2 a \hat{i}}{2\pi(a+x)}$$

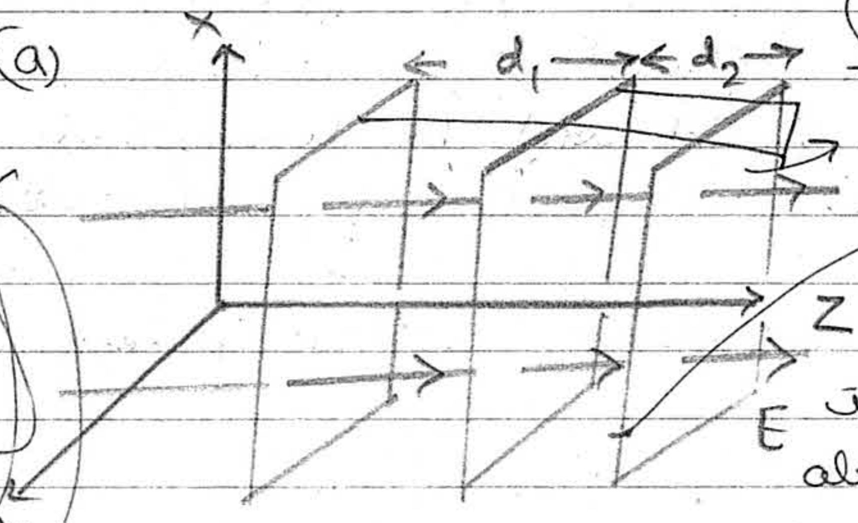
$$\vec{F}_{net} = \frac{\mu_0 I_1 I_2 a \hat{i}}{2\pi}\left[\frac{1}{x} - \frac{1}{a+x}\right] + 0 \quad (\text{from } 1, 2 \ \& \ 3)$$

$$\vec{F}_{net} = \frac{\mu_0 I_1 I_2 a \, a \, \hat{i}}{2\pi x(a+x)}$$

Hence, force acting on square loop is $\boxed{\dfrac{\mu_0 I_1 I_2 a^2}{2\pi x(a+x)}}$

towards right.

5. (a)



(Parallel to ~~Along~~ x-y plane)

Plane surface (equipotential surfaces)

Also, $d_2 < d_1$ as electric field is uniformly increasing along the z-direction (axis)

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

$(0,0,-z)$ $-q\,(0,0,-a)$ $q\,(0,0,a)$ $(0,0,+z)$

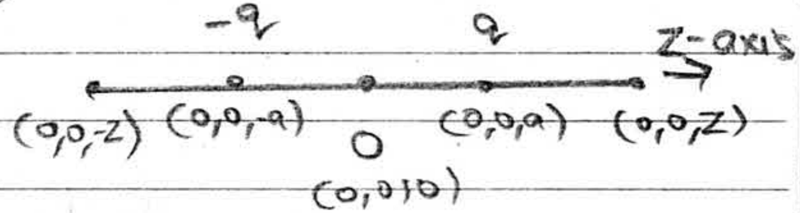
Now, potential at $(0,0,+z)$

$$V_{+z} = V_q + V_{-q} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(z-a)} + \frac{1}{4\pi\varepsilon_0}\frac{(-q)}{(z+a)}$$

$$V_{+z} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{z-a} - \frac{1}{z+a}\right]$$

$$V_{+z} = \frac{q}{4\pi\varepsilon_0}\left[\frac{z+a-z+a}{z^2-a^2}\right]$$

$$V_{+z} = \frac{2qa}{4\pi\varepsilon_0(z^2-a^2)}$$



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

$$= \frac{-q}{4\pi\varepsilon_0(z-a)} + \frac{q}{4\pi\varepsilon_0}\frac{1}{(z+a)}$$

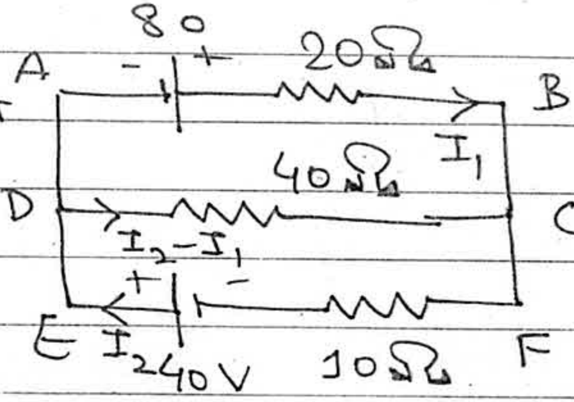
$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{z+a} - \frac{1}{z-a}\right]$$

$$= \frac{q}{4\pi\varepsilon_0(z^2-a^2)}(-2a) = \frac{-2qa}{4\pi\varepsilon_0(z^2-a^2)}$$

Hence, electrostatic potential at point $(0,0,z)$ is $\frac{1}{4\pi\varepsilon_0}\frac{2qa}{z^2-a^2}$

and at $(0,0,-z)$ is $\frac{-1}{4\pi\varepsilon_0}\frac{2qa}{z^2-a^2}$

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 ABCDA

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

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

$$80 = 60I_1 - 40I_2$$

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

Now, applying Kirchhoff's loop rule in the loop DCFED,

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

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

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

Solving (1) & (2),

$\cancel{8 = 6I_1 - 4I_2}$

$16 = 12I_1 - 8I_2$ (from ①)

and $12 = 15I_2 - 12I_1$ (from ②)

(Adding)

$28 = 7I_2$

OR $I_2 = 4\,A$ — ③

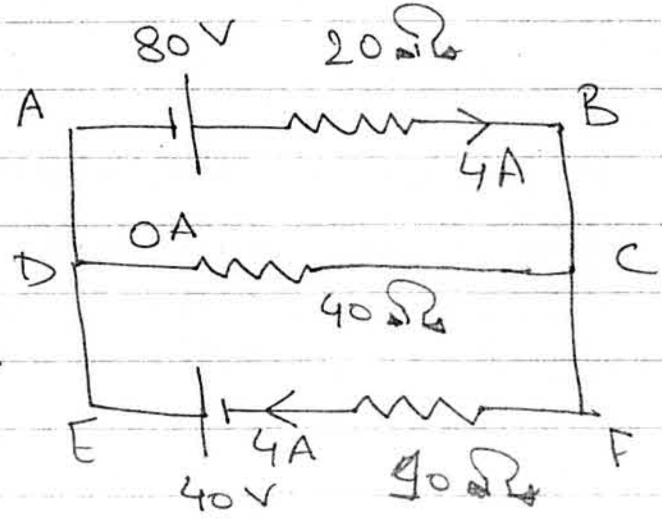
and from ①,

$4 = 3I_1 - 2I_2$

$4 = 3I_1 - 2(4)$

OR $I_1 = 4\,A$

So, the circuit becomes.



Hence, no current flows through inner 40 ohm resistor and 4A ~~goes~~ flows ~~from~~ through rest of the resistors.

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

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

(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 $= 60\text{ yr} = \dfrac{\ln 2}{\lambda_A}$

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

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

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

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

Using law of radioactive decay,

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

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

We want $M_A = 2M_B$ — (3)

So,

$$2M_B = \frac{N_B}{2} e^{-\lambda_A t} \quad \text{— (5) (From (3) & (4))}$$

& $$M_B = N_B e^{-\lambda_B t} \quad \text{— (6)}$$

Dividing (5) by (6)

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

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

Taking log both sides

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

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

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

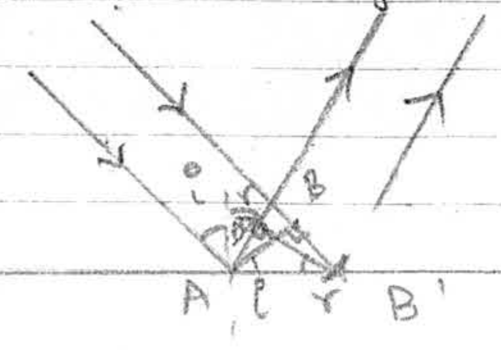
$$OR\ 2 = t\left(\frac{1}{30} - \frac{1}{60}\right)$$

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

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

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)



AB is the wavefront.

$BB' = vt$

In order to find the position of wavefront at some later time t, we use Huygens principle and draw a sphere of radius vt, where v - speed of light such that point B reaches the reflecting surface at B' and A reaches D.

Now, in two right triangles,

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

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

$AB' = AB'$ (hypotenuse)

and $AD = AB$ (using Huygen's Principle)

So, $\Delta ADB' \cong \Delta ABB'$

OR $\angle BAB' = \angle DAB'$

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)

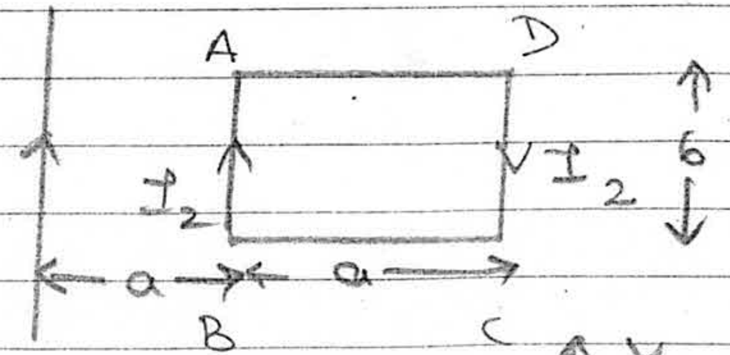
17 (a) Self-inductance of a coil is defined as the magnitude of back emf induced in the coil when the current through it changes at the rate of $1\,A\,s^{-1}$.

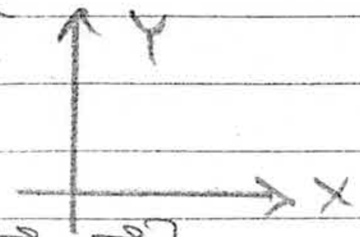
Mathematically, $\mathcal{E}_b = -L\dfrac{dI_1}{dt}$ (if $\dfrac{dI}{dt} = 1\,A\,s^{-1}$, $|\mathcal{E}_b| = L$ = self-inductance)

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

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

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





Force on side AB of the loop

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

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

Force on side

Magnetic field at a distance of 2a from the infinitely long current carrying wire,

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

Force acting on side CD,

$$\vec{F}_{CD} = \frac{\mu_0 I_1 I_2 b}{2\pi(2a)} \hat{i} \quad - (2) \quad \left(\text{using } \vec{F} = I\vec{l} \times \vec{B}\right]$$

Now, the force experienced by sides BC and DA ~~are~~ will be equal in magnitude but opposite in direction as these two sides are placed symmetrically in the external magnetic field.

(For example - Force on BC will act downwards whereas force on DA will act upwards, using $\vec{F} = I\vec{l} \times \vec{B}$, or $\vec{F}_{BC} + \vec{F}_{DA} = 0$ — (3))

Therefore, total force on the loop

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

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

(from ①, ② & ③)

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

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

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

$\therefore m_\alpha > m_p > m_e$ (α = α-particle, p = proton, e = 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 a very high attenuation.
Hence, 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 = radius of earth.

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

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Supplementary Answer-Book(S) No. 2

Section-B

6. Einstein's photo electric equation

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

where $\frac{1}{2} m_e v^2_{max}$ = 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 and hence the stopping potential of electrons ejected is independent of the ~~frequency~~ intensity of light used but only depends on the frequency of light used. Hence, explains the observation.

(ii) Also, since $\frac{1}{2} m_e v^2_{max} > 0 \Rightarrow h\nu > \phi_0$

OR $\nu > \frac{\phi_0}{h} = \nu_0$

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

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. 8.

(rules out)

7. Mass of deuteron = 2u (m_D)
Mass of alpha particle = 4u (m_α)
Charge on deuteron = +e (q_D)
Charge on α particle = +2e (q_α)

$\left(\because \frac{mv^2}{r} = qvB \right)$

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, $r_\alpha = \frac{m_\alpha v_\alpha}{q_\alpha B} = \frac{p_\alpha}{q_\alpha B}$

So, $\frac{r_D}{r_\alpha} = \frac{p_D}{p_\alpha} \frac{q_\alpha}{q_D} = \frac{2e}{e} = 2$

(as both have same momentum)

So, $r_D : r_\alpha = 2 : 1 = \frac{2}{1}$
(deuteron: α-particle)

8. Power of bulb 1 = P_1

Voltage rating = V

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

Power of bulb 2 = P_2

Voltage rating = V

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

(i) ~~when~~ connected in series,

total Resistance, $R_S = R_1 + R_2 = V^2 \left[\frac{P_1 + P_2}{P_1 P_2}\right]$

Total current flowing through the circuit = $\frac{V}{R_S}$ ($\because$ they are connected to a supply of voltage V)

$$I_T = \frac{\cancel{V}}{V^{2}}\left[\frac{P_1 P_2}{P_1 + P_2}\right] = \frac{1}{V}\frac{P_1 P_2}{P_1 + P_2}$$

Total power drawn = $VI_T = V\frac{1}{V}\left[\frac{P_1 P_2}{P_1 + P_2}\right] = \frac{P_1 P_2}{P_1 + P_2}$

(ii) Now, when both the bulbs are connected in parallel to the voltage supply V.

Power drawn by bulb 1 $= \frac{V^2}{R_1}$ ($\because$ in parallel voltage drop across all components is same)

$= \frac{V^2}{V^2/P_1} = P_1$ — (1)

Power drawn by bulb 2 $= \frac{V^2}{R_2} = \frac{V^2}{V^2/P_2}$

$= P_2$ — (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 surrounding medium $= \frac{4\sqrt{2}}{5} = n_2$

Refractive index of prism w.r.t surroundings $= n_{12} = \frac{n_1}{n_2}$

$$\mu = \frac{\cancel{8}^{2}\cancel{5}}{\cancel{5}\cancel{4}\sqrt{2}} = \sqrt{2}$$

So, using the relation,

$$\mu = \frac{\sin\left(\frac{A+\delta_{min}}{2}\right)}{\sin\frac{A}{2}}$$

$A =$ angle of prism $= 60°$, $\delta_{min} =$ angle of minimum deviation

we get,

$$\sqrt{2} = \frac{\sin\left(\frac{60+\delta_{min}}{2}\right)}{\sin 30°}$$

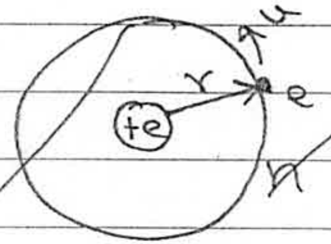
$$\frac{1}{\sqrt{2}} = \sin\left(\frac{60+\delta_{min}}{2}\right)$$

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

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

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

Hence, angle of minimum deviation of prism $= 30^\circ$

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 $\frac{h}{2\pi}$. ~~No other~~ According to him no other orbits were valid for an e to revolve around.

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

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 ∞ OR $n = \infty$.

(maximum energy difference or shortest wavelength)

$$\text{So, } \frac{1}{\lambda} = 109677 \text{ cm}^{-1} \left(\frac{1}{16} - 0 \right)$$

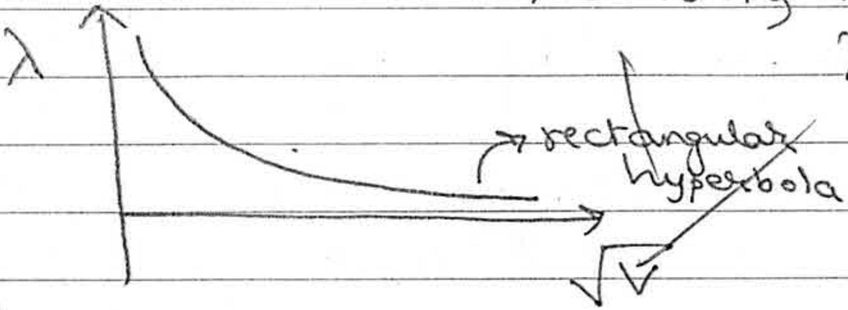
$$\lambda = 16 \times 911.7 \text{ Å}$$

$$= 14587.2 \text{ Å}$$

$$= 1.45872 \times 10^{-6} \text{ m}$$

belongs to infrared radiations of spectrum

11. (a)



According to de-broglie's equation

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

where V is the accelerati[ng] potential

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

$$\left. \text{So, } p = \sqrt{2meV} \right)$$

So, $\lambda \propto \frac{1}{\sqrt{V}}$ for cons[tant] mass and charge [of] particle.

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

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

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-parti[cle] has the shortest wavelength

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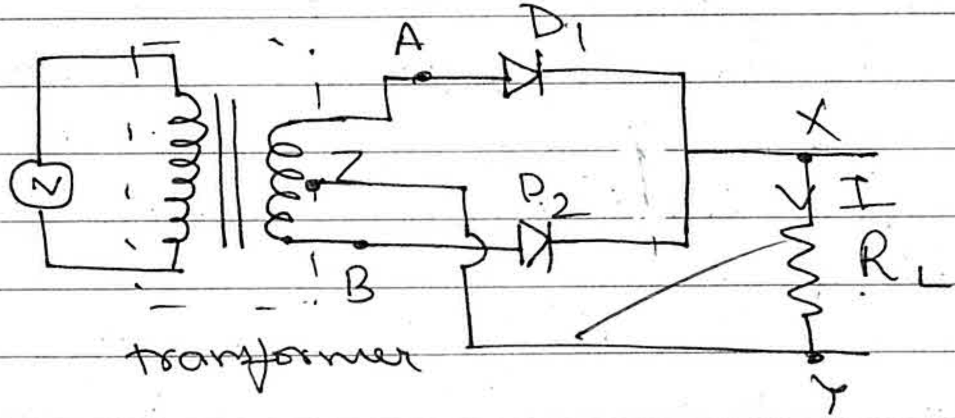
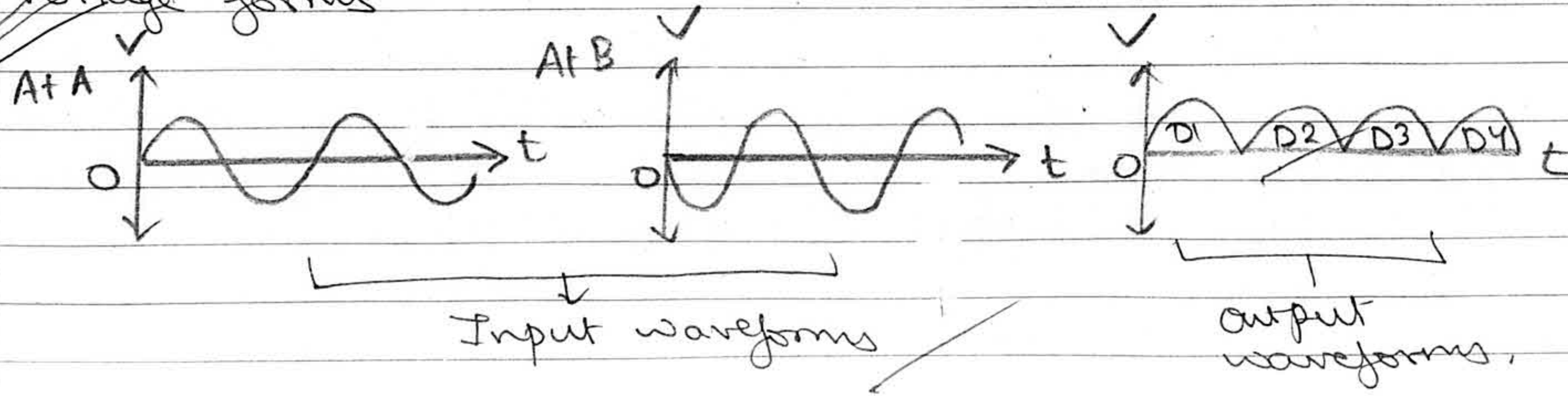
Supplementary Answer-Book(S) No. 1

20. Circuit Diagram of full wave rectifier.



Voltage forms



Rectifier works on the principle that a diode only conducts when it is forward biased and doesn't conduct practically when reverse biased. 21(a)
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. For both cases, voltage drop across R_L is unidirectional and hence, it is able to rectify the AC voltage to produce pulsating DC.

(b)

21(a) Let amplitude of message signal be A_m and that of carrier wave signal be A_c.

Now, 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, $A_c = 15V$

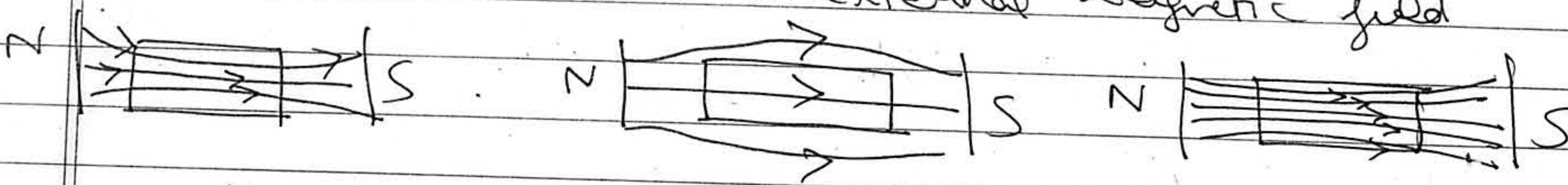
Modulation index, $\mu = \frac{A_m}{A_c} = \frac{10}{15} = \frac{2}{3} = 0.66$

The modulation index is generally kept less than one to avoid any distortion of carrier wave, so that the message signal could be transmitted through the propagating medium effectively. Hence, it is kept less than one, i.e. $A_m < A_c$.

22.

Paramagnetic Substances	Diamagnetic Substances	Ferromagnetic substances.
(i) Are weakly attracted by the external magnetic field.	(i) Are weakly repelled by the external magnetic field	(i) Are strongly attracted by the magnetic field.
(ii) Relative magnetic permeability >1 but not very high.	(ii) Relative magnetic permeability less than 1 but >0.	(ii) Relative magnetic permeability very high >1000
(iii) Gets magnetised in same direction $\chi > 0$ and has unpaired electrons.	(iii) Gets magnetised in opposite directions, $\chi < 0$ and has paired electrons	(iii) Gets strongly magnetised in the same direction $\chi >> 1$. Consists of powerful domains

Behaviours in external magnetic field



e.g. Aluminium   e.g. Bismuth   e.g. Iron

23(a)(i) Microwaves – wavelength – 1mm to 0.1m, 3×10^{9} Hz – 3×10^{12} Hz

(ii) U V radiations – wavelength – 400nm to 1nm, 7.5×10^{14} Hz – 3×10^{17} Hz

(b). Average density of oscillating electric field

$$u_E = \frac{1}{2}\varepsilon_0 E_{rms}^2, \text{ where } E_{rms} = \frac{E_0}{\sqrt{2}}$$

Average density of oscillating magnetic field

$$u_B = \frac{1}{2}\frac{B_{rms}^2}{\mu_0} \text{ where } B_{rms} = \frac{B_0}{\sqrt{2}}$$

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

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

Also $c^2 = \frac{1}{\varepsilon_0 \mu_0}$

So, $u_B = \frac{1}{2}\frac{E_{rms}^2 \varepsilon_0 \mu_0}{\mu_0}$

$u_B = \frac{1}{2}\varepsilon_0 E_{rms}^2 = U_E$

Hence, Proved.

24. (a) Wavelength of light used = 600 nm (λ)

Energy associated with light = $\frac{hc}{\lambda}$

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

$= \frac{12.4}{6} eV$

$= 2.067 eV$

∴ D_1 & D_3 will ~~not~~ be able to detect light as energy associated with the wave 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 ~~barrier~~ bias, because the minority carriers ~~ca~~ lead to current in this case.

For e.g. consider an n-type semiconductor.

Let no. of electrons = n

no. of holes = p

Initially, $n >> p$. (n are majority charge carriers)

Now when light of suitable energy falls on it, no. of holes generated = Δp

no. of electrons generated = Δn

Clearly, $\Delta n = \Delta p$

So, fractional increase in holes $\frac{\Delta p}{p} >> \frac{\Delta n}{n}$

Hence, light waves of different intensities can be easily distinguished in ~~reverse~~ bias voltage, as fractional increase in carriers as well as current is more noticeable.

~~Section-B~~