



SPACE FOR ANSWERING QUESTION NO.-1

Q.1.

## SECTION-A

8.2

- 1 (a) (ii)  ~~$S = A m^2$~~   $\{M' = \frac{M}{2}$ , length only decreases to  $\frac{1}{2}$
- (b) (iv)  ~~$M'^2 T^{-2} A^{-1}$~~   $\{$  for construction  $M'$   $\propto$   $\frac{1}{T^2}$   $\}$
- (c) (iii)  ~~$800A 8\text{ }\text{\AA}$~~   $\{ r_n \propto \frac{n^2}{z} \}$
- (d) (ii)  ~~$J = AT^2 e^{-h/T}$~~   $\{$  Richardson equation  $\}$
- (e) (iii)  ~~$\sin^{-1}\left(\frac{8}{9}\right)$~~   $\{ \sin C = \frac{h}{n}, C$  is critical angle  $\}$
- (f) (iv) ~~67W~~
- (g) (i) ~~0.6UF<sup>3</sup>~~  $\{$  all are in parallel  $\}$
- (h) (ii) ~~charge dependence~~
- (i) (i) ~~1:1~~  $\{$  We know  $i = \left(\frac{\partial n}{\partial t}\right)_V$  but value  $\Delta n \propto \frac{1}{R}$ . And  $R \propto \frac{1}{C}$  series  $\}$
- (j) (iii)  ~~$\frac{6\pi i^2}{2\pi d}$~~   $\{$  is equal in all resistors  $\}$   
 $\{$  using Ohm's law, Stewart's law  $\}$

Q.1 = 10

Lear

Q. 3.

A-1101732

2.

- (a) ~~No~~, the solid is not an insulator.
- (b) Self inductance of a conducting coil is defined as the emf induced in the coil for unit rate of change of current through it.

$$L = \frac{-\epsilon}{\left(\frac{di}{dt}\right)}$$

where  $L$  = self inductance $\epsilon$  = emf induced $\frac{di}{dt}$  = rate of change of current.

- (c) Holes are major charge carriers in p-type semiconductor. Electrons are minor charge carriers in p-type semiconductor.
- (d) A glass rod rubbed with silk cloth ~~loses~~ some electrons.
- (e) Yes, X-ray waves are electromagnetic waves.
- (f)  $^{14}_6\text{C}$ ,  $^{16}_8\text{O}$  are isotones.

Ans



(g) Drift velocity  $v_d = \left(\frac{-eE}{m}\right)l$

or  $v_d = \left(\frac{-eV}{ml}\right)$

where  $e$  = charge  $m$  = mass of  $e^-$

$V$  = potential difference

$l$  = length of conductor

$\Rightarrow v_d \propto V$

$v_d = 0.5 \text{ mm/s}$  when  $V = 1.5 \text{ V}$

when  $V = 3 \text{ V}$ ,  $v_d = 1 \text{ mm/s}$  using proportionality

$$\frac{v_{d_1}}{V_1} = \frac{v_{d_2}}{V_2}$$

Thus drift velocity is 1 mm/s.

(h) Unit of electric permittivity in SI unit is  $C^2 N^{-1} m^{-2}$

(i) Instantaneous power in the inductor will have a frequency of 100 Hz.

(j) We know,  $\mu = \frac{\sin(A + D_m)}{\sin(A/2)}$

$$\Rightarrow \mu = \frac{\sin\left(\frac{60^\circ + D_m}{2}\right)}{\sin\left(\frac{60^\circ}{2}\right)} \quad A = \text{angle of prism} = 60^\circ$$

$$\Rightarrow \sin\left(30^\circ + \frac{D_m}{2}\right) = \frac{1}{\sqrt{2}} \quad \text{or} \quad 30^\circ + \frac{D_m}{2} = 45^\circ$$



or  $D_m = 30^\circ$  (23°) = 6° ~~minimum deviation~~

Required minimum deviation is  $30^\circ$ .

→ Minimum spread = 10°  
 Minimum Hologram = 10°  
 Minimum point = 10°

### Group-B

Q. 3.

3.(a) Given, current through conductor(I) = 3.08 A  
 cross section of copper wire(A) =  $1.54 \times 10^{-6} \text{ m}^2$   
 resistivity of copper is( $\rho$ )  $1.724 \times 10^{-8} \Omega \cdot \text{m}$ .

magnitude of electric current density of copper wire( $J$ ) =  $\frac{I}{A}$

$$= \frac{3.08}{1.54 \times 10^{-6}} \text{ A/m}^2$$

$$= 2 \times 10^6 \text{ A/m}^2$$

We know,  $E = J \rho$  { $E$  is magnitude of electric field}

$$\Rightarrow E = 1.724 \times 10^{-8} \times 2 \times 10^6$$

$$= 3.448 \times 10^{-2} \text{ N/C}$$

∴ Electric field inside the conductor is  $3.448 \times 10^{-2} \text{ N/C}$

Ans

$$= \left( \frac{m^2}{s^2} + 0 \right) \text{ Ans} \rightarrow$$



- (\*) Light waves consist of small packets of photons.
- (b) The given situation is shown by the following figure.

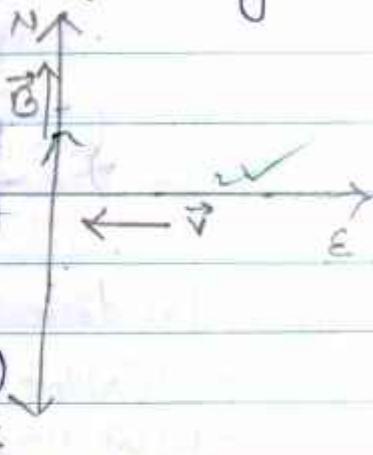
Let us denote S-N direction

as Y-axis and W-E direction

as X-axis,

Given magnetic field  $\vec{B} = 10^{-4} \hat{j}$  T : ( $\vec{B}$ )

and velocity of electron  $= 10^8$  (-i) m/s : ( $\vec{v}$ )



We know,  $\vec{F}_B = q(\vec{v} \times \vec{B})$  where  $\vec{F}_B$  = magnetic force on electron.

$q$  = charge on electron

$$\text{Q) } \vec{F}_B =$$

$$\vec{F}_B = 1.6 \times 10^{-19} c \left\{ 10^8 (-i) \times 10^{-4} \hat{j} \right\}$$

$$= 1.6 \times 10^{-19} \times 10^4 (-\hat{i}) = 1.6 \times 10^{-15} N (-\hat{i})$$

Thus, magnetic force is  $1.6 \times 10^{-15} N$  into the paper.

(d) We know,  $R = \rho \frac{l}{A}$  where  $\rho$  = resistivity

$\rho$  = resistivity

$l$  = length of conductor

$A$  = area of cross section of conductor

Lets



Given,  $\frac{r_{Cu}}{r_{Al}} = \frac{5}{9}$   $\frac{l_{Cu}}{l_{Al}} = \frac{1}{2}$  { it stands for }  
 and  $\frac{D_{Cu}}{D_{Al}} = \frac{1}{1}$  { ! D stands for diameter }  
 ... suffix Cu stands for copper and Al stands for aluminum

practical note  $\Rightarrow \frac{A_{Cu}}{A_{Al}} = \frac{(\pi D_{Cu}^2)}{(\pi D_{Al}^2)} \cdot \frac{1}{1}$

$$\Rightarrow \frac{R_{Cu}}{R_{Al}} = \left( \frac{r_{Cu} \cdot l_{Cu}}{A_{Cu}} \right) / \left( \frac{r_{Al} \cdot l_{Al}}{A_{Al}} \right)$$

$$= \left( \frac{r_{Cu}}{r_{Al}} \right) \cdot \left( \frac{l_{Cu}}{l_{Al}} \right) \cdot \left( \frac{A_{Al}}{A_{Cu}} \right)$$

$$= \frac{5}{9} \times \frac{1}{2} \times \frac{1}{1} \quad \{ \text{from above} \}$$

$$= \frac{5}{18}$$

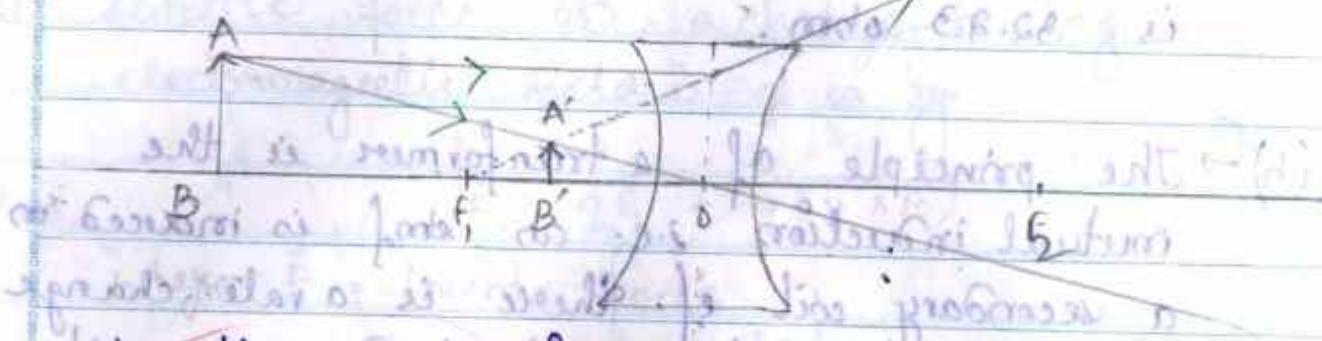
$\therefore$  Resistance of copper and aluminum wires is

(d) In ~~ratio~~ for the ratio  $5:18$

(e) Given the image of an extended image kept in front of a lens is found to be virtual, erect and diminished. The lens is a concave lens.

To obtain  $f > u > -v$   
 :  $v < 0$

Lens



~~2 In the given figure, AB is object, A'B' is virtual, erect and diminished image.~~

~~Q F<sub>1</sub> and F<sub>2</sub> are the foci of the concave lens.~~

(g) We know, power (P) dissipated in a circuit resistance

$$P = VI \quad \text{where } V \text{ is voltage P.D.}$$

~~- (1) across the circuit resistance~~

~~various factors are also current I = current in the circuit~~

~~current drawn from source~~

$$\text{given } P = 1.5 \text{ kW}, V = 220 \text{ V}$$

$$\therefore 1.5 \times 10^3 \text{ W} = 220 \text{ V} \times I \text{ Amp.}$$

$$\therefore I = \frac{1.5 \times 10^3}{220} \text{ Amp} = \frac{75}{11} \text{ Amp} \approx 6.82 \text{ Amp}$$

~~2 Resistance (R) of the heater is given by~~

$$R = \frac{V}{I}.$$

$$\text{or } R = \frac{220}{(75/11)} \Omega \approx 32.22 \Omega$$

~~∴ Current drawn by heater is 6.82 Amp and its resistance~~



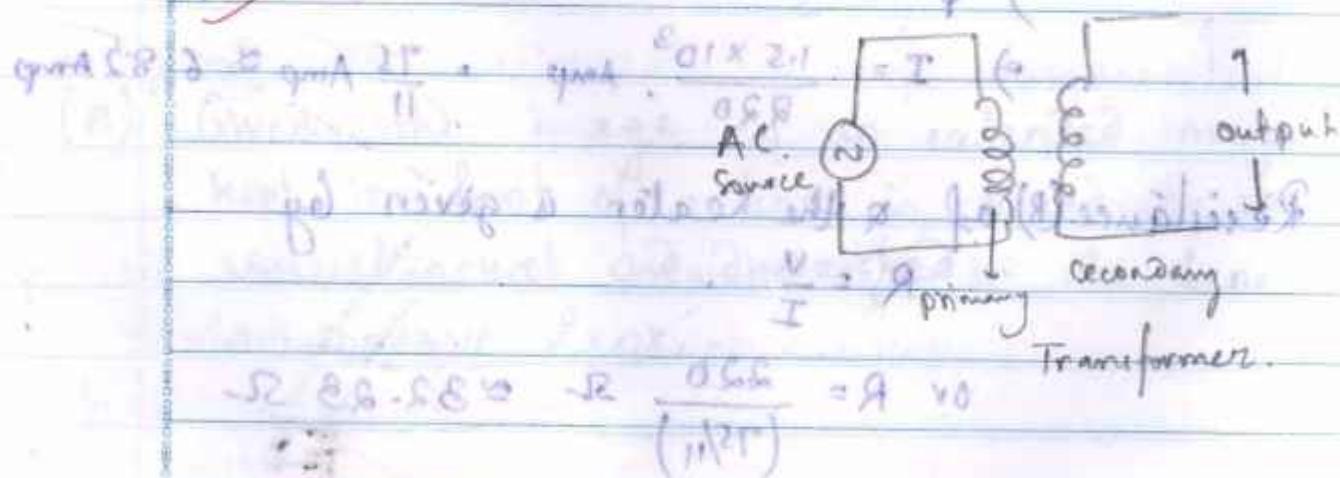
is 32.23 ohm.

(h) → The principle of a transformer is the mutual induction i.e. an emf is induced in a secondary coil if there is a rate of change of current in the neighbourhood primary coil.

→ An AC source is connected across primary coil as the current through the coil varies continuously owing to periodically varying voltage which induces an emf in the secondary coil.

→ But a DC source would mean constant current through primary coil which won't induce emf in the secondary coil.

~~That's why transformer works on AC not DC.~~



$$-52 \times 0.28 = -52 \frac{0.60}{(121)} = 9 \text{ V}$$

~~so this is the question is related to current transformer.~~



(i) Lorentz force on a charge moving in an electromagnetic field is given by

$$\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B})$$

where  $\vec{F}$  = Lorentz force

$q$  = charge of particle

$\vec{E}$  = electric field

$\vec{v}$  = velocity of particle

$\vec{B}$  = magnetic field.

Ratio at which Lorentz force does

Work done  $\frac{dW}{dS}$  by Lorentz force to move the particle through  $dS$  =  $\vec{F} \cdot d\vec{s}$

$$(q\vec{E} + q(\vec{v} \times \vec{B})) \cdot d\vec{s}$$

We know,

$$d\vec{s} = \vec{v} dt$$

$$\Rightarrow dW = q(\vec{E} + q(\vec{v} \times \vec{B})) \cdot \vec{v} dt$$

$$\therefore \frac{dW}{dt} = (q\vec{E} + q(\vec{v} \times \vec{B})) \cdot \vec{v}$$

~~2. unit of Lorentz force =  $q\vec{E} + q(\vec{v} \times \vec{B})$~~

~~∴ Rate at which Lorentz force does work =  $\vec{F}_e \cdot \vec{v}$~~

~~unit of Lorentz force =  $Coulomb \cdot m/s$~~

~~unit of Lorentz force =  $N/C$~~

Lore



(j) If a spherical surface <sup>(conductor)</sup> is given a charge  $Q$ , then the charge  $Q$  resides on its surface and potential ( $V$ ) of surface becomes  $\frac{kQ}{R}$ . where  $R$  = radius.  $k = \frac{1}{4\pi\epsilon_0}$ ,  $\epsilon_0 = \text{permittivity of free space}$

We know capacitance of the system =  $\frac{Q}{V}$

{ capacitance consists of spherical conductor and infinity }  
as potential at infinity

is taken as zero  
then potential diff. can be taken as  $V$

$\checkmark$   $C = \frac{Q}{V} = \frac{Q}{\left(\frac{kQ}{R}\right)} = \frac{R}{k}$   $\therefore C = \frac{R}{k} = \frac{R}{4\pi\epsilon_0 R} = \frac{1}{4\pi\epsilon_0}$

$\therefore C = \frac{1}{4\pi\epsilon_0 R}$  where  $\epsilon_0$  = absolute permittivity of free space.

∴ Capacitance of an isolated spherical conductor of radius  $R$  =  $\frac{1}{4\pi\epsilon_0 R}$ .

(k) Faraday's law of magnetic induction states that

- (i) an emf is induced in a circuit if the magnetic flux linked with it changes
- (ii) emf is induced till the flux linked with it changes with time.
- (iii) emf induced in the circuit is equal to negative



rate of change of magnetic flux through

Mathematically,  $\epsilon = - \left( \frac{\partial \Phi_B}{\partial t} \right)$

where  $\epsilon$  = emf induced in the circuit

$\left( \frac{d\Phi_B}{dt} \right)$  = rate of change of magnetic flux  
through it.

(Demiductum is converted into A (s))  
(Demiductum is converted into G, G is a pure (s))

G is a pure (s) with of charge of  
magnetic field. Gopt, Gash, etc?

- (1) Threshold frequency is the frequency of incident light above which photoelectric emission is observed from the substance.

Mathematically  $v_0 = h\nu_0$

where  $h$  = work function  
of substance (in eV)

$v_0$  = threshold frequency  
 $v_0 = \frac{h}{e}$  where  $e$  = Planck's constant  
 $v_0$  = threshold frequency

$$\checkmark \rightarrow v_0 = \frac{h}{e} = \frac{1.83 \text{ eV}}{6.63 \times 10^{-34} \text{ Js}} \quad \therefore h = 6.63 \times 10^{-34} \text{ Js}$$

$$\text{Ans} \Rightarrow v_0 = \frac{1.83 \times 1.6 \times 10^{-19} \text{ J}}{6.63 \times 10^{-34} \text{ Js}} \approx 0.43 \times 10^{15} \text{ Hz}$$



Q. 10. Threshold frequency of sodium is  $0.43 \times 10^{15} \text{ Hz}$ .

$$\frac{63}{2} = 20$$

metals

4.(a) → A diamagnetic substance is weakly repelled by magnetic field. Its intensity of magnetization is opposite to the applied magnetic field.  
Ex. lead, gold.

A paramagnetic substance is attracted by magnetic field. It is magnetized in the direction of magnetic field.

Ex. chromium, manganese

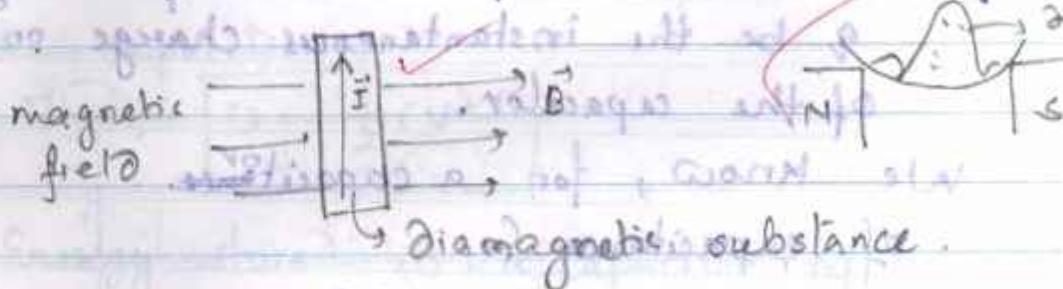
→ Susceptibility ( $k$ ) of diamagnetic substance is small and negative and its relative permeability ( $\mu$ ) is less than one.

$$k < 0 \quad \text{and} \quad \mu = 1 + k < 1$$

Susceptibility ( $k$ ) of paramagnetic substance is small and positive and its relative permeability ( $\mu$ ) is greater than 1, i.e.  $k > 0$  and  $\mu = 1 + k > 1$ .

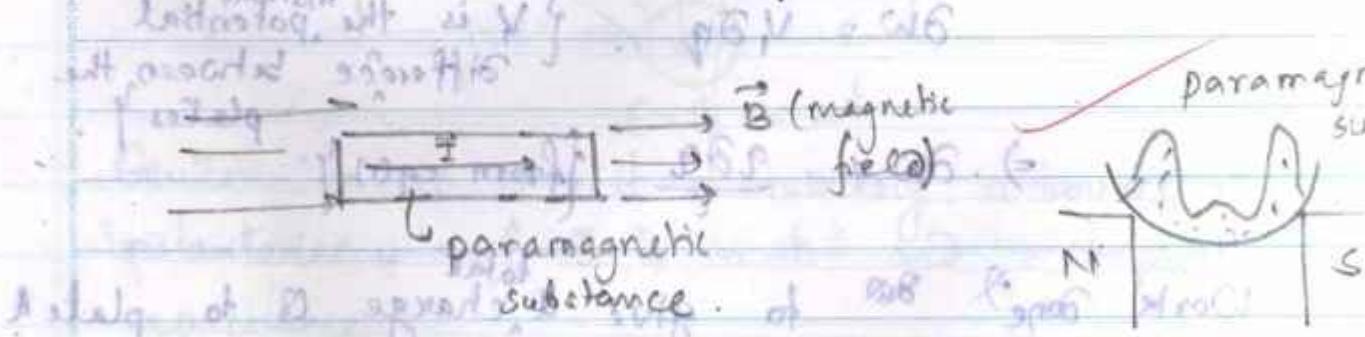


→ Diamagnetic substances set themselves perpendicular to magnetic field lines, if free to do so.  
 If they are taken in powdered form and placed in a dish that has two poles placed at the extremes then it appears as a heap in the middle of the dish.



Paramagnetic substance set themselves in the direction of magnetic field, if free to do so.

If they are taken in powdered form and placed in a dish that has two poles placed at extremes, it appears as two heaps near the poles.



paramagnetic substance.

$$\text{Force} = \frac{\mu_0}{4\pi} \cdot \frac{I_1 I_2}{r^2} \cdot \frac{1}{2} \cdot \frac{1}{3} = W$$

Ques



(b) Work has to be done in charging a capacitor against the electric field. Let the 2 plates do a desired charge. This work done is stored as potential energy of the capacitor.

Let  $Q$  be the desired amount of charge.

$q$  be the instantaneous charge on each plate of the capacitor.

We know, for a capacitor of capacitance  $C$ ,

$$q = CV \quad (1)$$

where  $V$  = potential difference

of the plates.

$q$  = instantaneous charge on each plate.

Work done to add  $\Delta q$  amount of charge to plate A against the persistent electric field is

$$\Delta W = V_i \Delta q \quad \{ V_i \text{ is the instant potential difference between the plates}\}$$

$$\Rightarrow \Delta W = \frac{q \Delta q}{C} \quad \{ \text{from eq(1)} \}$$

Work done to give a total charge  $Q$  to plate A is

$$\int_0^W \Delta W = \frac{1}{C} \int_0^Q q \Delta q$$

$$\Rightarrow W = \frac{1}{C} \cdot \left[ \frac{q^2}{2} \right]_0^Q = \frac{Q^2}{2C}$$

Lec



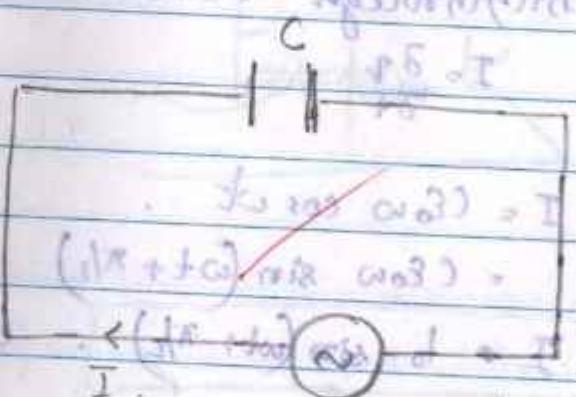
on.  $W = \frac{1}{2} CV^2$  In this case where  $V$  is the final potential difference between the plates.

This work done is stored as potential difference of the capacitor.

$$\text{Thus } V = \frac{1}{2} CV^2$$

$\therefore$  Potential Energy stored in a capacitor of capacitance charged to a potential difference  $V$  is  $E = \frac{1}{2} CV^2$

(c)



$$E = E_0 \sin \omega t$$

Given an AC circuit containing a source of instantaneous emf  $E = E_0 \sin \omega t$  and a capacitor of capacitance  $C$ .

Potential difference across the capacitor  $C$  is equal to the instantaneous emf [applying Kirchhoff's Law of potential voltage]

$$\Rightarrow V_C = E_0 \sin \omega t \quad \{ V_C = \text{potential diff. across capacitor}\}$$



We know, potential difference ( $V$ ) is related to instantaneous charge ( $q$ ) on capacitor and its capacitance ( $C$ ) as

$$q = CV.$$

(V) - ~~AC voltage~~  $\Rightarrow V = \frac{q}{C}$

$$\Rightarrow E_0 \sin \omega t = \frac{q}{C} \quad \left\{ \text{from eqn (1)} \right\}$$

$$\Rightarrow q = C E_0 \sin \omega t$$

$$\Rightarrow \frac{dq}{dt} = C E_0 \omega \cos \omega t$$

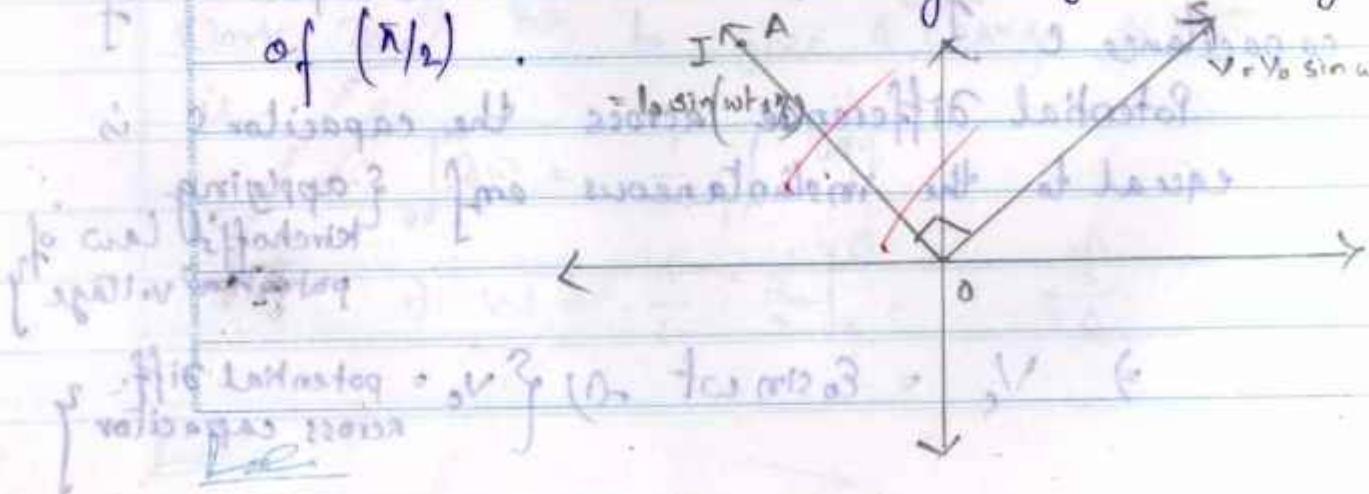
As current ( $I$ ) through a circuit is

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

So  $I = C E_0 \omega \cos \omega t$   
 $= C E_0 \omega \sin (\omega t + \pi/2)$

$$I = I_0 \sin (\omega t + \pi/2) \quad \text{where } I_0 = C E_0 \omega$$

This shows in a pure capacitance AC circuit, current leads voltage by a phase angle of  $(\pi/2)$ .





In the given phasor diagram of pure capacitance AC circuit,  $\vec{OA}$  represents current and  $\vec{OS}$  represents voltage.

Q42 (9)

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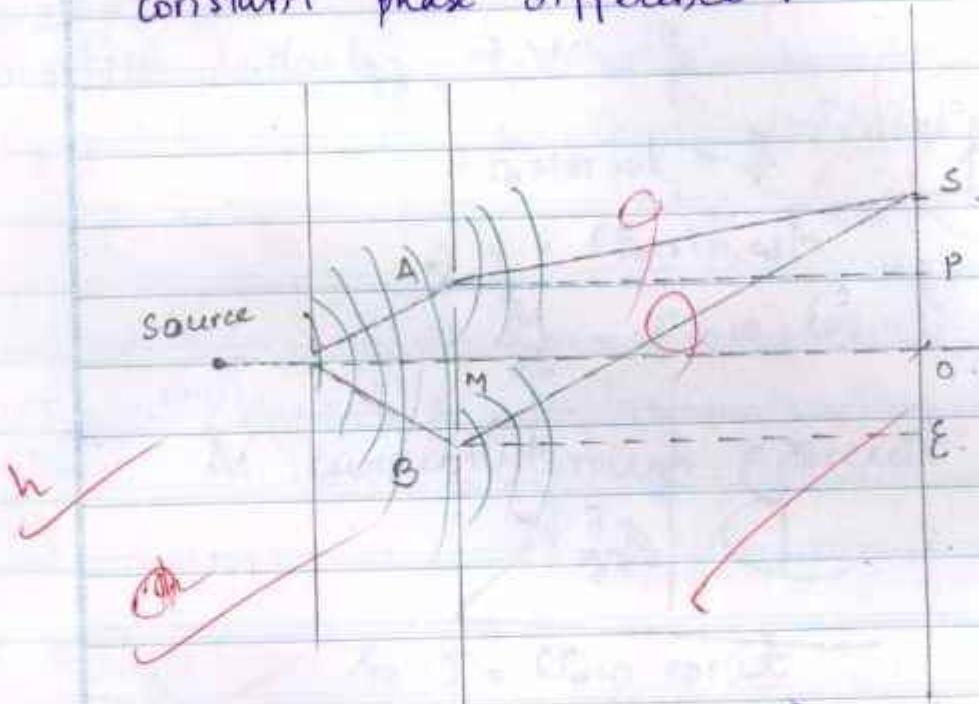
which graph best represents current passing through coil connected in series with bulb of filament lamp and ring of iron core? Ans: A coil with bulb connected in series with a coil with iron core will show lagging current with respect to voltage.

Ans: In case of capacitor, current lags behind voltage by  $90^\circ$ . In case of inductor, current leads voltage by  $90^\circ$ .

Lec

Q.5

5. Interference refers to the superposition of two waves of equal wavelength, frequency and are coherent i.e. no phase difference or constant phase difference.



The given apparatus is of a young's double slit experiment. Source light after passing through a pin hole was allowed to fall on two <sup>new</sup> slits A and B. A screen was placed at a distance from the slits. Let S be the point on the screen where we want to know the intensity.

Principle: <sup>coherent</sup> When two light waves of same frequency and wavelength interfere on screen they produce consecutive maxima and minima.



regions of high intensity or low intensity in consecutive manner.

Let O be the central point of on the screen and M be the central point in the between A and B

Let A and B are separated by distance  $\Delta$

and the screen is separated from the slits by D

$$\Rightarrow AB = \Delta \text{ and } MA = MB = \frac{\Delta}{2}$$

$$\text{and } MO = D$$

Let S be situated at a distance y from O

$$\Rightarrow SO = y$$

S and E are 2 points on the screen directly opposite A and B

From the figure,

$$AS^2 = AP^2 + PS^2 \quad \left. \begin{array}{l} \text{pythagoras} \\ \text{theorem} \end{array} \right.$$

$$\text{and } BS^2 = BE^2 + ES^2$$

$$\Rightarrow BS^2 - AS^2 = (BE^2 + ES^2) - (AP^2 + PS^2)$$

$$= -SP^2 + SE^2 \quad (1) \quad \left. \begin{array}{l} \text{from figure, it is clear} \\ \text{that } BE = AP = MO \end{array} \right.$$

$$\text{From the figure, } SE = SO + OE$$

$$= SO + MB = y + \frac{\Delta}{2}$$

$$\text{and } SP = SO - OP$$

$$= SO - MA = y - \frac{\Delta}{2}$$

$$\Rightarrow SE^2 - SP^2 = (SE - SP)(SE + SP)$$

Ans



$$\text{Path difference} = BS^2 - AS^2 = \left( \left(y + \frac{d}{2}\right) - \left(y - \frac{d}{2}\right) \right) \left( \left(y + \frac{d}{2}\right) + \left(y - \frac{d}{2}\right) \right)$$

$$= 2yd \quad \text{--- (ii)}$$

Equating (i) and (ii), we get 0

$$(BS - AS)(BS + AS) = 2yd \quad \text{--- (iii)}$$

It can be assumed that S is very close to 0

$$\text{and } AS \approx BS \approx MD = D$$

Let  $BS - AS = \Delta x$  path difference

$$\Rightarrow (\Delta x) \cdot (2D) = 2yd \quad (\text{from eq(iii)})$$

$$\Rightarrow \Delta x = \frac{2yd}{2D} = \frac{yd}{D} \quad \text{--- (iv)}$$

We know, the point will be a maxima if  
the optical path difference  $(\Delta x) = n\lambda$  where  $\lambda$  is wavelength

from (iv)  $\frac{yd}{D} = n\lambda$  or  $y = \frac{n\lambda D}{d}$ . ( $n = 0, \pm 1, \pm 2, \dots$ )

Points of maxima are at  $y = 0, \pm \frac{\lambda D}{d}, \pm \frac{2\lambda D}{d}, \dots$

Similarly, if path difference  $(\Delta x) = (2n+1) \frac{\lambda}{2}$ ,

then the point will be a minima ( $n = 0, \pm 1, \pm 2, \dots$ )

Lec



$$\Rightarrow y = \frac{(2n+1)}{2} \frac{\lambda D}{d} \quad (n = 0, \pm 1, \pm 2, \dots)$$

Fringe width : Distance between any two consecutive maxima or any two consecutive minima is known as fringe width. It is denoted by  $\beta$ .

$\Rightarrow \beta$  Let for any two consecutive maxima

$$n = k \text{ and } k+1$$

$$y_{k+1} - y_k = (k+1) \frac{\lambda D}{d} - k \frac{\lambda D}{d} \quad \left\{ \begin{array}{l} y_{k+1} \text{ and } y_k \text{ are} \\ \text{distances of} \\ \text{two consecutive} \\ \text{maxima from } o \end{array} \right.$$

$$\boxed{\beta = \frac{\lambda D}{d}}$$

Similarly  $\beta = \frac{\lambda D}{d}$  if we consider any two consecutive minima into account.

From the derived result, fringe width ( $\beta$ ) can be shown as  $\beta \propto D$ . ( $D$  is the distance between the slits and  $\frac{1}{d}$ . the screen)

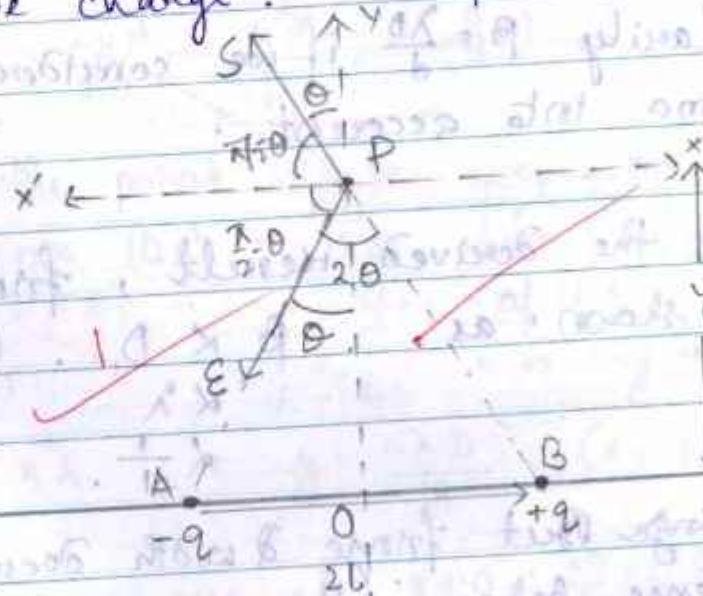
$\therefore$  Fringe width doesn't depend on the distance between the source and the slits as long as the source is placed equidistant from both the slits.

Q. 6.1 Fringe width is independent of distance between the source and the slits. If the source is placed symmetric w.r.t to the slits.



Q.6 Electric dipole stands for a system of two oppositely charged but same magnitude charges placed a few distance apart.

Dipole moment is a vector whose magnitude is equal to the product of magnitude of charge of each particle with the distance between them and has direction pointing from negative charge to positive charge.  $\vec{p} = q\vec{r}$



Lec



Let us place a dipole having charges  $-q$  at A and  $+q$  at B. Let  $AB = 2l$  and we want to find electric field at point P on the equatorial line. Let angle between AP and BP be  $2\theta$ .

Electric field due to charge  $+q$  at P

$$\vec{E}_q = \frac{kq}{(PB)^2} \text{ along } \vec{PS}$$

and electric field due to charge  $-q$  at P

$$\vec{E}_{-q} = \frac{-kq}{(AP)^2} \text{ along } \vec{PC}$$

Breaking the components of  $\vec{E}_q$  along OY and OX and denoting them by  $i$  and  $j$  we get

$$\vec{E}_q = \frac{kq}{(PB)^2} \cos\theta j + \frac{kq}{(PB)^2} \sin\theta (-i) \quad (1)$$

Similarly breaking the components of  $\vec{E}_{-q}$  along OY and OX and representing them as  $i$  and  $j$ , we get

$$\vec{E}_{-q} = \frac{kq \sin\theta}{(AP)^2} (-i) + \frac{kq \cos\theta}{(AP)^2} (-j) \quad (1)$$

from the figure,  $AP^2 = OP^2 + AO^2$  } Pythagorean theorem  
 $BP^2 = OP^2 + OB^2$

$$\Rightarrow AP^2 = y^2 + l^2 \text{ and } BP^2 = y^2 + l^2$$

$$\left. \begin{array}{l} \therefore AO = OB = l \\ OP = y \end{array} \right\}$$



From  $\Delta POA$  and  $\Delta OPB$ ,  
 $\angle APO = \angle BPO = 0$  {  
 P is symmetrical  
 w.r.t to the charges}

In  $\Delta POA$ ,  $\cos 0 = \frac{OP}{AP} = \frac{y}{\sqrt{y^2 + l^2}}$  {  
 AP =  $\sqrt{y^2 + l^2}$  from (ii)  
 OP = y}

$\sin 0 = \frac{OA}{AP} = \frac{l}{\sqrt{l^2 + y^2}}$  {  
 OA = l }.

Net electric field at P =  $\vec{E}_q + \vec{E}_{Eq}$

$$= \left\{ \frac{kq \sin 0}{(PB)^2} (-i) + \frac{kq \cos 0}{(PB)^2} (j) \right\}$$

~~$$+ \left\{ \frac{kq \sin 0}{(AP)^2} (-i) + \frac{kq \cos 0}{(AP)^2} (-j) \right\}$$~~

~~$$= \left( \frac{kq \sin 0}{y^2 + l^2} + \frac{kq \sin 0}{y^2 + l^2} \right) (-i)$$~~

~~{  
 AP = PB =  $\sqrt{y^2 + l^2}$  from (ii)}~~

~~$$\therefore \frac{2kq \sin 0}{y^2 + l^2} (-i) \frac{2kq}{y^2 + l^2} \left( \frac{l}{\sqrt{y^2 + l^2}} \right) (-i) \{ \text{from eq (i)}$$~~

~~$$\frac{2kql}{(y^2 + l^2)^{3/2}} (-i)$$~~

But  $|\vec{p}| = 2ql$  {from dipole moment definition}.

$\therefore \vec{E} = - \frac{k_p}{(y^2 + l^2)^{5/2}} \hat{i}$



P.D.

Given, that the dipole has negligible length  
 (a)  $\epsilon_0 \ll \rho$  or  $\rho \gg l$

so, 
$$\vec{E} = -\frac{k_p}{y^3} \hat{i}$$

So, from the derived result,  
 electric field at any point on the  
 equatorial line has magnitude  $\frac{k_p}{y^3}$  and is  
 directed in a direction opposite to that of  
 electric dipole.

~~forwards~~  
05

01

fb

forwards  $\rightarrow$  05  
 backwards  $\leftarrow$  01

$A/m^2$  - unit

and answer told in is not

$(7.36) \times 10^{-3}$ , then value of

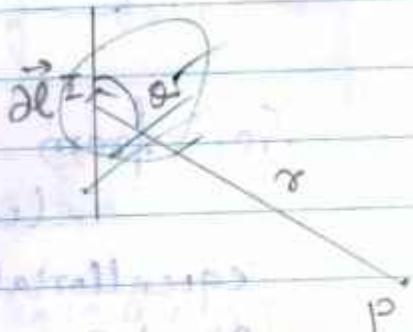
$8.99 \times 10^9$

Ans



Q.7

- (7) If we consider a current carrying element  $d\ell$  carrying a current  $I$  and find magnetic field ( $B$ ) at a distance  $r$  such that the position vector makes an angle  $\theta$  with current direction, then we find



$$B \propto I$$

$$B \propto d\ell$$

$$B \propto \sin\theta$$

$$B \propto \frac{1}{r^2}$$

where  $I$  = current flowing through conductor  
 $d\ell$  = length of current carrying element  
 $r$  = distance between the point and centre of current carrying element.  
 $\theta$  = angle between  $d\ell$  and  $r$ .

$$\Rightarrow B \propto \frac{I d\ell \sin\theta}{r^2}$$

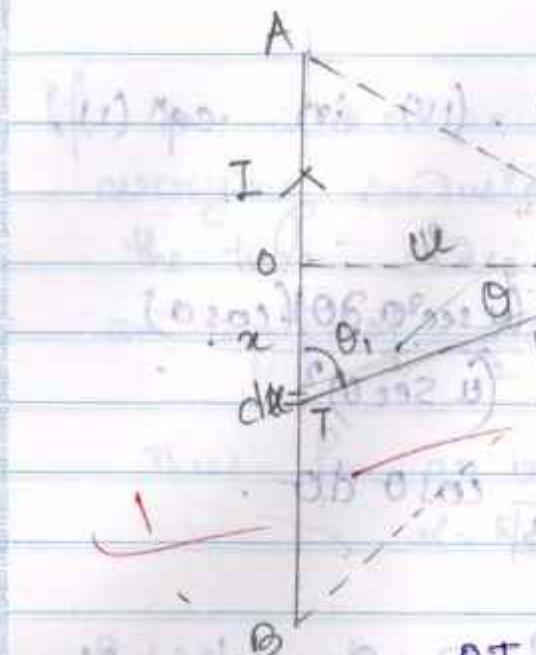
$$\text{or } B = \left( \frac{\mu_0}{4\pi} \right) \frac{I d\ell \sin\theta}{r^2} \quad \text{where } \frac{\mu_0}{4\pi} = \text{constant of proportionality}$$

$$\mu_0 = 4\pi \times 10^{-7} \cdot \text{Tm/A}$$

This is biot savart's law.

In vector form, 
$$\vec{B} = \frac{\mu_0}{4\pi} \frac{I (\vec{d\ell} \times \vec{r})}{|\vec{r}|^3}$$

Laws



Let us consider a wire AB carrying current I such that AO subtends angle  $\alpha$  at P and OB subtends an angle  $\beta$  at P.

Let us consider a small wire element  $dL$  at a distance  $x$  from O such that current element

$OT$  makes an angle  $\theta$  at P.

Let  $OT$  makes an angle  $\theta$ , with  $TP$ .

Let  $OP = r$ .

Then magnetic field due to element  $dL$  at P is given by Biot Savart's law

$$\delta B = \frac{\mu_0}{4\pi} \frac{I dL \sin \theta}{(PT)^2} \quad \text{and is directed into the page} \quad (i)$$

From figure,  $\frac{OP}{TP} = \cos \theta$

$$\Rightarrow \frac{OP}{TP} \sec \theta = TP \quad (ii)$$

$$\theta = \frac{OP}{TP} \tan \theta$$

$$\theta = \frac{OP}{TP} \sec^2 \theta \quad (iii)$$

$$\text{In } \triangle TOP, \theta + \theta_1 = 90^\circ$$

$$\Rightarrow \theta_1 = 90^\circ - \theta \Rightarrow \sin \theta_1 = \cos \theta \quad (iv)$$

and  $\theta_1$  is acute angle  
and  $\theta_1 < 90^\circ$



Putting eqn (i), (iii), (iv) in eqn (i), we get

$$dB = \frac{\mu_0}{4\pi} \cdot I (\sec \theta \cos \phi) \frac{(\cos \alpha)}{(\sec \theta)^2}$$

$$dB = \frac{\mu_0}{4\pi} \frac{I}{a} \cos \theta d\theta$$

Since the magnetic field due to all small area current carrying elements at P is into the paper, so the result can be integrated from  $\alpha$  to  $\beta$  taking sign convention into account.

$$B = \int_{-\beta}^{\alpha} dB = \int_{-\beta}^{\alpha} \frac{\mu_0}{4\pi} \frac{I}{a} \cos \theta d\theta$$

$$= \frac{\mu_0}{4\pi} \frac{I}{a} \left[ \sin \theta \right]_{-\beta}^{\alpha}$$

$$B = \frac{\mu_0}{4\pi} \frac{I}{a} (\sin \alpha + \sin \beta)$$

Net magnetic field is directed into the plane.

(v) thus  $B = \frac{\mu_0}{4\pi} \frac{I}{a} (\sin \alpha + \sin \beta) (-\hat{u})$ . — (v)

Assuming z-axis  $\hat{z}$  and coming out of this plane.



If we take an infinite straight current carrying conductor into account, then the two ends of the conductor will subtend an angle of  $\frac{\pi}{2}$  and  $-\frac{\pi}{2}$  at P.

Thus for an infinite straight conductor,  
 $\alpha = \frac{\pi}{2}$     $\beta = -\frac{\pi}{2}$

Putting this in result (iv), we get

$$\vec{B} = \frac{\mu_0}{4\pi} \frac{I}{u} (\sin(\theta_b) + \sin(\theta_a))$$

$$\vec{B} = \frac{\mu_0 I}{2\pi u} .$$

or 
$$\vec{B} = \frac{\mu_0 I}{2\pi u} (-\hat{u})$$
 { direction taken in this case }

here  $I$  = current flowing in the conductor.

$u$  = distance of P from the straight current carrying conductor.

(ans).

Lec