# MODEL PAPER-1 (SOLUTIONS) 2020-21
## (PHYSICS)
## SECTION – A

**1.** The field lines start (or diverge) from the positive charge and terminate (or converge) on negative charge. If electric field lines form closed loops, then these lines must originate and terminate on the same charge which is not possible So, electric field lines can't form closed loop .

[Also accept, if students write, electric field is conservative nature.] **[1]**

**2.** Microwave is used in RADAR with frequency range b/w $3 \times 10^{10}$ Hz – $10^{12}$ Hz **[1]**

**OR**

An accelerated charge produces an oscillating electric field in space which produces an oscillating magnetic field, which is again a source of oscillating electric field and so on. As a result electro magnetic wave is produced.

**3.** $\vec{F} = q(\vec{v} \times \vec{B})$ **[1]**

**4.** The quality factor (Q) factor of series LCR resonant circuit is defined as the ratio of the voltage developed across the inductor or capacitor at resonance to the applied voltage, which is the voltage across R. **[1]**

$$Q = \frac{IX_L}{IR} = \frac{\omega_0 L}{R}$$

It is dimensionless hence, it has no units.

**OR**

Quality factor represents sharpness of resonance and is given as $Q = \frac{\omega_r}{\omega_2 - \omega_1}$

it is unitless.

**5.** Moving coil galvanometer works on the principle that when a current carrying coil placed in a magnetic field, it experiences a torque so, it get deflected and by measuring deflection we can measure current. **[1]**

**6.** $r_n \propto n^2 \Rightarrow r_2 / r_1 = 4/1$ **[1]**

**7.** The radius of a nucleus of mass number A is related as if $R = R_0 A^{1/3}$, where $R_0$ is a constant. **[1]**

**OR**

${}_{11}Na^{23}$, ${}_{10}Ne^{23}$.

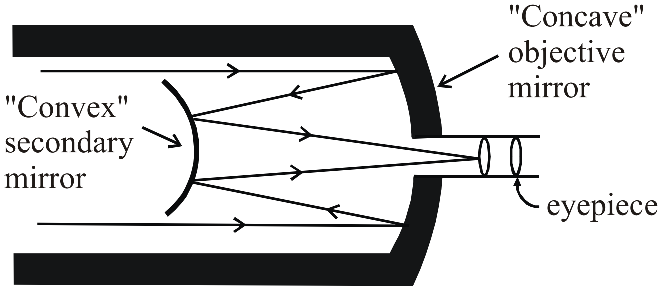
**8.** (i) As (Pentavalent impurity) (ii) Al (Trivalent impurity) **[1]**

**OR**

GaAs are preferred material because –

(a) Band gap (~ 1.0 to 1.8 eV)
(b) High optical absorption (~ $10^4$ cm$^{-1}$)
(c) Electrical conductivity
(d) Availability of raw material
(e) Low cost.

**9.**



**[1]**

(Reflecting telescope)

**10.** Two sources are perfectly coherent if their frequency is same and their phase difference is constant. **[1]**

**11.** **(b)** **[1]**

**12.** **(a)** **[1]**

**13.** **(a)** **[1]**

**14.** **(c)** **[1]**

## SECTION – B

**15.** **(i) d, (ii) c, (iii) c, (iv) b, (v) a** **[4 × 1 = 4]**

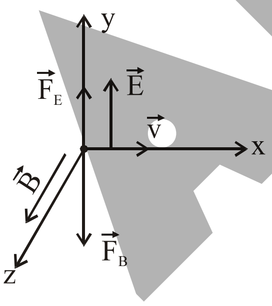
**16.** **(i) b, (ii) a, (iii) c, (iv) d, (v) d** **[4 × 1 = 4]**

## SECTION–C

**17.** Consider a charge 'q' moving with velocity $\vec{v}$ in the presence of both electric field $(\vec{E})$ & magnetic field $(\vec{B})$ experiences a force given as- **[2]**

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

Assume, $\vec{E}$ & $\vec{B}$ are ⊥ to each other & also ⊥ to the velocity of the particle.



Directions of electric force ( $\vec{F}_E$ ) & magnetic force ( $\vec{F}_B$ ) are just opposite.

$\therefore\ \vec{F} = q(E - vB)\hat{j}$

if magnitudes of electric and magnetic force are equal then, net force on the particle is zero & it will move undeflected in the fields.

qE =qvB or $\boxed{v = E/B}$

The above condition is used to select charged particles of a particular velocity.

**18.** (1) In Young's experiment, all the bright fringes formed are of same intensity, whereas in single slit diffraction experiment, the bright fringes are of varying intensity. **[2]**

(2) In Young's experiment, fringes of minimum intensity are perfectly dark, whereas in single slit diffraction experiment, fringes of minimum intensity are not perfectly dark.

**OR**

According to Huygens's principle

(1) Each source of light spreads waves in all directions.

(2) Each point on the wavefront give rise to new disturbance which produces secondary wavelets which travels with the speed of light.

(3) Only forward envelope which encloses the tangent gives the new position of wave front.

(4) Rays are always perpendicular is the wavefront.

**19.** **(i) Charge is quantized :** Charge on any body always exists in integral multiples of a fundamental unit of electric charge. This unit is equal to the magnitude of charge on electron ($1e = 1.6 \times 10^{-19}$ coulomb). So charge on anybody is $Q = \pm ne$, where n is an integer and e is the charge of the electron. Millikan's oil drop experiment proved the quantization of charge or atomicity of charge

**(ii) Charge is conserved :** In an isolated system, total charge (sum of positive and negative) remains constant whatever change takes place in that system. **[2]**

**20.** Change in current $dI = 0 - (5) = -5A$ **[2]**

Change in time $dt = 0.1$ s

average emf $\varepsilon = 200$ V

$$\Rightarrow \varepsilon = -L\frac{dI}{dt}$$

$$200 = L\left(\frac{5}{0.1}\right) \Rightarrow L = \frac{20}{5} = 4H$$

**21.** (i) Induced emf in arm PQ **[2]**

$e = -Blv$

$e = -0.1 \times 10 \times 10^{-2} \times 20$

$e = -0.2$ V

(ii) Current induced in loop

$$I = \frac{|e|}{R} = \frac{0.2}{2} = 0.1A$$

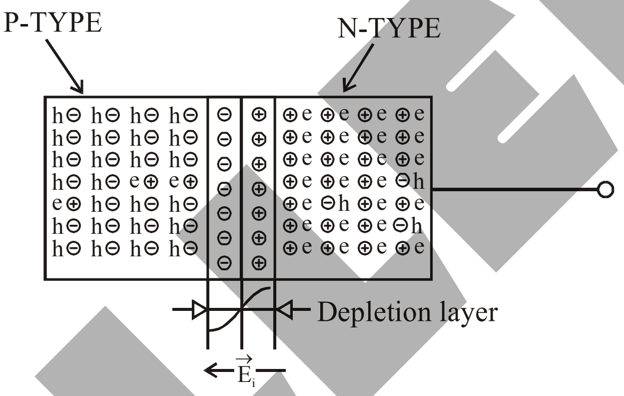
**22.** From $\frac{1}{f}=(\mu_{21}-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$ **[2]**

$$\frac{1}{f}=(1.55-1)\left[\frac{1}{R}-\left(-\frac{1}{R}\right)\right] \qquad \boxed{\because R_1=R_2=R}$$

$$\frac{1}{f}=(.55)\left[\frac{2}{R}\right]=\frac{1.1}{R}$$

$$\frac{1}{20}=\frac{1.1}{R}\Rightarrow R=1.1\times 20=22\text{cm}$$

**23.** It is clear that, N-type semiconductor has an excess of free electrons and P-type has an excess of holes therefore when both are placed together to form a junction, electrons move towards the P-side and holes move towards N-side due to concentration gradient. Departure of an electron from the N-side to the P-side leaves a positive donor ion on N-side and likewise hole leaves a negative acceptor ion on the P-side resulting in the formation of depletion layer having width $\simeq 10^{-7}$m. **[2]**



**Depletion layer :** It is the layer near the junction in which electrons are absent on n side and holes are absent on p side.

**Potential barrier :** Due to the accumulation of immobile ions near the junction an electric potential difference ($V_b$) developes b/w n side & p side which acts as a barrier for further diffusion of electrons and holes.

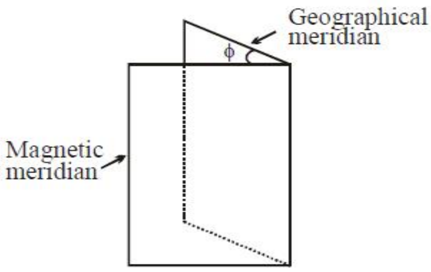
$$V_b = E_i \times d \quad \text{(volt)}$$

**24.** Earth's magnetic components :- **[2]**

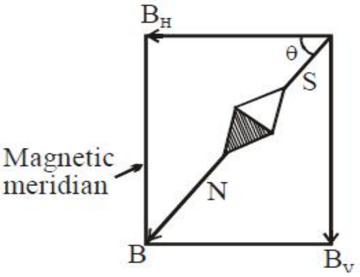
(1) Declination Angle (2) Dip Angle or Angle of inclination

(3) Horizontal Component of earth's magnentic field

**(1) Angle of declination (ϕ) :-** It is the acute angle between magnetic meridian and geographical meridian at a given place.



**(2) Dip Angle(θ) :-** It is direction horizontal resultant magnetic field of earth in magnetic meridian. Dip angle at magnetic pole of earth is 90° and at magnetic equator it is 0°.



B ⇒ resultant magnetic field of earth's magnetism
$B_H$ ⇒ Horizontal component
$B_V$ ⇒ Vertical component

**OR**

Given $B_H = 0.26$ G

$$\cos 60° = \frac{B_H}{B}$$

$$B = \frac{B_H}{\cos 60°} = \frac{0.26}{(1/2)} = 0.52\text{G}$$

**25.** (i) The electromagnetic waves are produced by accelerated charge particles and do not require any material medium for their propagation. **[2]**

(ii) The oscillation of the fields E and B are in same phase and their direction are perpendicular to each other.

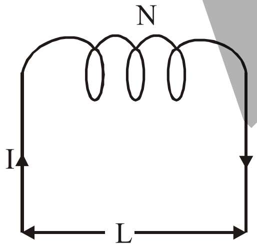
An electromagnetic wave transport linear momentum as it travels through space.

If an electromagnetic wave transfer a total energy U to a surface in time t, then total linear momentum delivered to the surface is P = U/c

If the wave is totally reflected, then the momentum delivered will be 2U/c because the momentum of the wave will change from P to –P

## SECTION -D

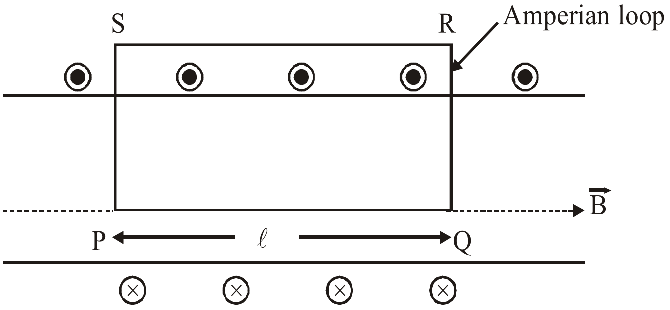
**26.** (a) **[3]**



Here, we consider a current-carrying solenoid having total no of turns N.

∴ no of turns per unit length, $n = \frac{N}{L}$

On applying ACL for the cross-sectional view of this solenoid.



$$\oint \vec{B}.\vec{d\ell} = \int_P^Q \vec{B}.\vec{d\ell} + \int_Q^R \vec{B}.\vec{d\ell} + \int_R^S \vec{B}.\vec{d\ell} + \int_S^P \vec{B}.\vec{d\ell}$$

$$\int_P^Q B\,d\ell\cos 0^\circ + \int_Q^R B d\ell \cos 90^\circ + \int_R^S (0) + \int_S^P B d\ell \cos 90^\circ = \int_P^Q B\,dl$$

From ACL,

$$B\oint d\ell = \mu_0(\Sigma I)$$

$$\therefore \quad B\ell = \mu_0\,(n\ell I)$$

$$\boxed{B = \mu_0 nI}$$

(b) A solenoid has N-S poles whereas toroid doesn't have separate poles.

**27.** Current in the following circuit : **[3]**

$$I = \frac{E}{R + R_w} \qquad R_w = \text{Resistance of potentiometer wire AB}$$

$$I = \frac{2}{15+10} = 0.08\text{A}$$

So potential difference across wire

AB = current × Resistance of wire = 0.08 × 10 = 0.8V

$$\text{So potential gradient along AB} = \frac{\text{Potential difference along AB}}{\text{length of AB}} = \frac{0.8}{1} = 0.8 \text{ V/m}$$

Terminal potential of test cell (secondary ckt)

$$V = E - I' \times r \qquad \left[ I' = \frac{1.5}{1.2+0.3} = 1\text{A} \right]$$

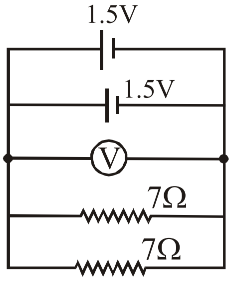
$$V = 1.5 - 1 \times 1.2 = 0.3 \text{ V}$$

Since drop on balancing length of potentiometer wire balance the terminal potential difference of the test cell.

$$\text{So length of AO} = V_{AO}/\text{Potenial gradient along} = \frac{0.3}{0.8} = \frac{3}{8}\text{m}$$

**OR**

A high resistance voltmeter means that no current flow through the voltmeter (practically very less current). When two batteries are connected in parallel, then



$$E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$$

Here $r_1 = r_2 = r$

$E_1 = E_2 = 1.5V$ (given)

$$E_{eq} = \frac{1.5 \times r + 1.5 \times r}{2r}$$

$E_{eq} = 1.5\ V$

Now $\left.\begin{matrix} R_1 = 7\Omega \\ R_2 = 7\Omega \end{matrix}\right]$ given

So $\frac{1}{R_{eq}} = \left(\frac{1}{7} + \frac{1}{7}\right)\Omega$

$$R_{eq} = \frac{7}{2} = 3.5\,\Omega$$

$\because$ $I = \frac{\text{terminal voltage}}{\text{equivalent resistance}}$

V = terminal voltage = 1.4 (given) = voltmeter reading

So $I = \frac{1.4}{3.5} = 0.4\ A$

Now $V = E_{eq} - I \times r_{eq}$

$1.4 = 1.5 - 0.4 \times r_{eq}$

$0.4 \times r_{eq} = 0.1$

$r_{eq} = 0.25\ \Omega$

As $r_{eq} = r/2$ $\left(\because \frac{1}{r_{eq}} = \frac{1}{r} + \frac{1}{r}\right)$

So r of each cell = 0.5Ω

**28.** (a) $E = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2E}{m}}$ **[3]**

But $v = \frac{h}{m\lambda}$ $\therefore$ $\frac{h}{m\lambda} = \sqrt{\frac{2E}{m}}$

$\Rightarrow$ $\lambda = \frac{h}{\sqrt{2mE}}$

(b) $\lambda = \dfrac{h}{\sqrt{2mE_k}} = \dfrac{h}{\sqrt{2m\left(\dfrac{3}{2}kT\right)}}$

$\Rightarrow \lambda = \dfrac{h}{\sqrt{3mkT}}$

$\lambda \propto \dfrac{1}{\sqrt{T}}$

**OR**

$K.E_{max} = \dfrac{1}{2}mv_{max}^2 = h\nu - \phi_0$

(i) Number of photoelectrons emitted per second from a metal surface depends on the number of photons incident on that surface in one second. If intensity of the incident radiations in increased therefore the number of photoelectrons emitted increases.

Therefore $KE_{max}$ is independent of the incident lights intensity.

(ii) If $\nu < \nu_0$, $KE_{max}$ is negative which is impossible.

**29.** The number of atoms in 1kg of ${}_{94}Pu^{239}$ **[3]**

$$= \frac{6.023 \times 10^{23} \times 1000}{239}$$

Energy released per fission = 180 MeV

Energy released by 1kg of ${}_{94}Pu^{239}$

$$= \frac{6.023 \times 10^{23} \times 1000}{239} \times 180\text{MeV}$$

$= 4.53 \times 10^{26}$ MeV

**30.** $H_\alpha$ is a specific deep-red visible spectral line in the Balmer series with a wavelength of 656.28 nm, it occurs when a hydrogen electron transits from its 3rd to 2nd lowest energy level. This transition produces H-alpha photon & the 1st line of Balmer series. **[3]**

$$\frac{1}{\lambda} = R\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right] = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$$

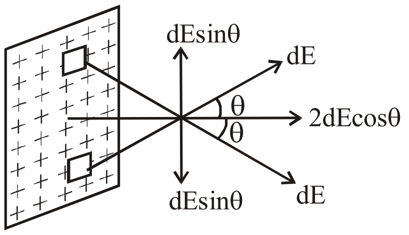
$$\frac{1}{\lambda} = 1.097 \times 10^7 \left[\frac{5}{36}\right]$$

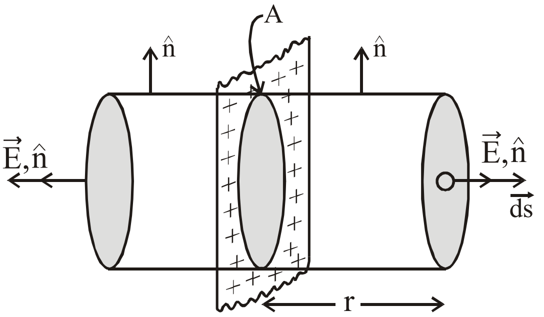
$$\nu = \frac{c}{\lambda} = \frac{3 \times 10^8 \times 1.097 \times 10^7 \times 5}{36}$$

$$\upsilon = 4.57 \times 10^{14}\,\text{Hz}$$

## SECTION – E

**31.** **[5]**





As shown in figure, considering a cylindrical gaussian surface of cross section A

(i) **Flux through curved surface :**

$$\phi = \vec{E}\cdot\vec{dS} = EdS\cos 90^\circ = 0$$

At the points on the curved surface, the field vector $\vec{E}$ and area vector $\vec{dS}$ make an angle 90° with each other. Therefore, curved surface does not contribute to the flux.

**Flux through end caps :**

$$\phi = \oint \vec{E}.\vec{dS} = \oint EdS\cos 0^\circ = EA$$

**Hence, the total flux through the closed surface is :**

$\phi$ = Flux through both end caps + flux through curved surface

or $\phi = EA + EA + 0 = 2EA$ (1)

Now according to Gauss' law for electrostatics

$\phi = q/\varepsilon_0$ (2)

Comparing equations (1) and (2), we get

$2EA = q/\varepsilon_0$

$E = q/2\varepsilon_0 A$ (3)

The area of sheet enclosed in the Gaussian cylinder is also A. Therefore, the charge contained in the cylinder, $q = \sigma A$ as $\sigma$ (surface charge density) $= q/A$

Substituiting this value of q in equation (3), we get

$E = \sigma A/2\varepsilon_0 A$

or $E = \sigma/2\varepsilon_0$

This is the relation for electric field due to an infinite plane sheet of charge. The field is uniform and does not depend on the distance from the plane sheet of charge. Direction of field for positive charge density will be outwards from sheet and the same will be inward for negative charge density.

(ii) Let $C_1 = x$ and $C_2 = 2x$

equivalent capacitance in series combination

$$C_S = \frac{C_1C_2}{C_1+C_2} = \frac{x\times 2x}{x+2x} = \frac{2x}{3} \qquad \therefore C_S = \frac{2x}{3}$$

equivalent capacitance in parallel combination

$C_P = C_1 + C_2 = x + 2x = 3x$

Now given that energy stored in series combination = Energy stored in parallel combination

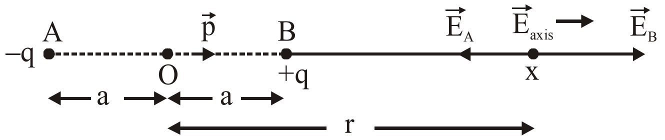
$$\frac{1}{2}C_sV_1^2 = \frac{1}{2}C_PV_2^2$$

$$\frac{1}{2}\times\left(\frac{2x}{3}\right)V_1^2 = \frac{1}{2}\times 3x\times V_2^2$$

$$\Rightarrow \boxed{\frac{V_1}{V_2} = \frac{3}{\sqrt{2}}}$$

**OR**

(a) Let consider a dipole system,



Here, AO = OB = a

OX = r

BX = r – a

AX = r + a

Elec. field $\left(\vec{E}_B\right)$, due to charge at point 'B' is towards $\vec{p}$

Elec. field $\left(\vec{E}_A\right)$, due to charge at point 'A' is opposite to $\vec{p}$

Now, according to the superposition principle,

$$\vec{E}_{axial} = \vec{E}_A + \vec{E}_B$$

$$E_{axial} = \frac{-Kq}{(r+a)^2} + \frac{Kq}{(r-a)^2}$$

$$= Kq\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]$$

$$= Kq\left[\frac{(r+a+r-a)(r+a-r+a)}{(r-a)^2(r+a)^2}\right]$$

$$= \frac{Kq(2r)(2a)}{\left(r^2-a^2\right)^2}$$

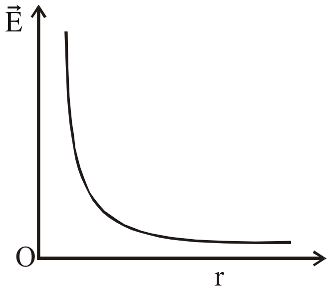
$$\vec{E}_{axial} = \frac{2rk(2a)(q)}{\left(r^2-a^2\right)^2}\hat{r} \qquad \boxed{\because\left|\vec{P}\right| = 2a\times q}$$

$$= \frac{2K P\vec{r}}{r^4} \qquad \boxed{\text{if } 2a << r}$$

then $\vec{E}_{axial} = \dfrac{2K\vec{P}}{r^3}\hat{r}$

Direction lies in the direction of electrin dipole moment, $\vec{P}$

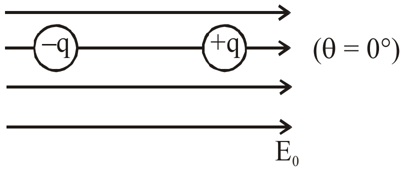
(b)



for (r >> a)

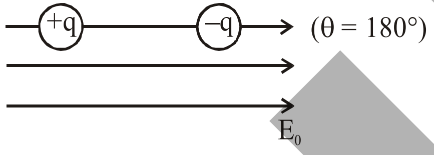
(c)

(i) Stable equilibrium -



$$\text{Torque}(\tau) = PE\sin\theta$$
$$= PE \times \sin 0°$$
$$= 0 \qquad (\because \sin 0° = 0)$$

(ii) Unstable equilibrium



$$\text{Torque}(\tau) = PE\sin\theta$$
$$= PE\sin 180°$$
$$= PE \times 0 = 0 \qquad (\because \sin 180° = 0)$$

**32.** (i) Source frequency, when current is maximum is given by **[5]**

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{8\times 2\times 10^{-6}}} \qquad \{L = 8H \text{ and } C = 2\mu F$$

$$f = \frac{1}{2\pi\times 4\times 10^{-3}}$$

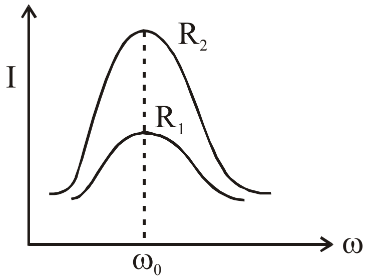
$f = 39.80$ Hz

The frequency at which current maximum, is called resonant frequency.

(ii) given $E_0 = 200V$, $R = 100\Omega$

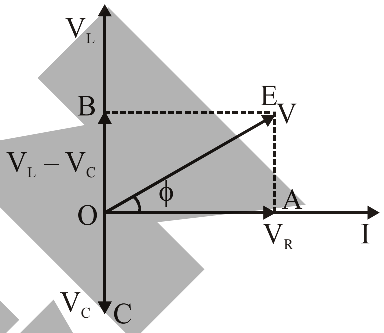
$$I_{max} = \frac{E_0}{R} = \frac{200}{100} = 2A$$

(iii)



**OR**

Suppose OA, OB, OC represents the magnitude of phasor $V_R$, $V_L$ and $V_C$ respectively. In case of $V_L > V_C$, the resultant of ($V_R$) and ($V_L$–$V_C$), represented by OE. Thus from ΔOAE



$$OE = \sqrt{OA^2 + AE^2}$$

$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$

Substituting the value of $V_R$, $V_L$ and $V_C$ we have

$$V = \sqrt{(IR)^2 + (IX_L - IX_C)^2}$$

or $$\boxed{I = \frac{V}{\sqrt{(R)^2 + (X_L - X_C)^2}}}$$

The effective opposition offered by L, C, R to a.c. supply is called impedance of LCR circuit and represented by Z.

$$I = \frac{V}{Z}$$

$$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

Also from ΔOAE

$$\tan\phi = \frac{AE}{OA} = \frac{V_L - V_C}{V_R}$$

or $$\tan\phi = (X_L - X_C)/R$$

or $$\phi = \tan^{-1}\frac{(X_L - X_C)}{R}$$

Power dissipation in LCR circuit :
The instantaneous power supplied by the source is

$$P = VI$$

$$P = (V_m \sin\omega t) \times i_m \sin(\omega t + \phi) = \frac{V_m i_m}{2}[\cos\phi - \cos(2\omega t + \phi)]$$

[2sinAsinB = cos(A–B) – cos(A+B)]

For average power the second term becomes zero in the complete cycle.

So $$P_{av} = \frac{V_m i_m}{2}\cos\phi$$

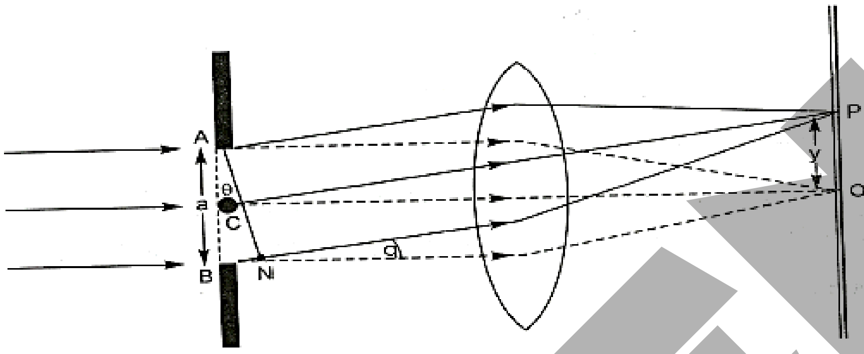
$$P_{av} = \frac{V_m}{\sqrt{2}}\frac{i_m}{\sqrt{2}}\cos\phi = V_{rms}\, i_{rms}\cos\phi$$

$$\boxed{P_{av} = V_{rms} i_{rms} \cos\phi}$$

At resonance condition $\cos\phi = 1$ (because $\phi = 0$), so R becomes effective impedance of a circuit. So power dissipated is maximum at resonance condition.

**33.** The phenomenon of bending of light around the sharp corners and spreading into the regions of the geometrical shadow is called diffraction. **[5]**

**Diffraction from a slit.** A narrow slit of width a is placed at a distance D from the screen. When the slit is illuminated with a monochromatic light of wavelength $\lambda$, then alternate bright and dark bands of light are formed on both the sides of the central maximum.



Path difference between the secondary waves reaches at point P

$BN = AB \sin\theta = a \sin\theta$

If $BN = \lambda$ and $\theta = \theta_1$

$\lambda = a \sin\theta_1$

$\sin\theta_1 = \frac{\lambda}{a}$, $\theta_1$ is the angle up to which the central maxima can extends.

Such angular position on the screen will represent the first secondary minimum. We assume the silt to be divided into two equal halves, the wavelets from the corresponding points of the two halves of the silt will have a path difference of $\frac{\lambda}{2}$, i.e., they reach point P in opposite phase. Hence for second secondary minimum,

$2\lambda = a \sin\theta_2$

$\sin\theta_2 = \frac{2\lambda}{a}$ and $\sin\theta_n = \frac{n\lambda}{a}$ for $n^{th}$ secondary minima

If $y_n$ is the distance of $n^{th}$sec. minimum from the screen, then

$$\tan\theta_n = \frac{OP}{CO} = \frac{y_n}{D}$$

For small n,

$\sin\theta_n = \tan\theta_n$

$$\frac{y_n}{D} = \frac{n\lambda}{a}$$

$$y_n = \frac{n\lambda D}{a}$$

therefore $\beta = y_n - y_{n-1} = \frac{\lambda D}{a}$

For first sec. maxima

$\sin\theta_1' = \frac{3\lambda}{2a}$ {Since the wavelets from each half will reach point P such that out of three equal parts two will cancel out leaving one parts of wavelet to produce the bright fringes.

Similarly, $\sin\theta_2' = \frac{5\lambda}{2a}$

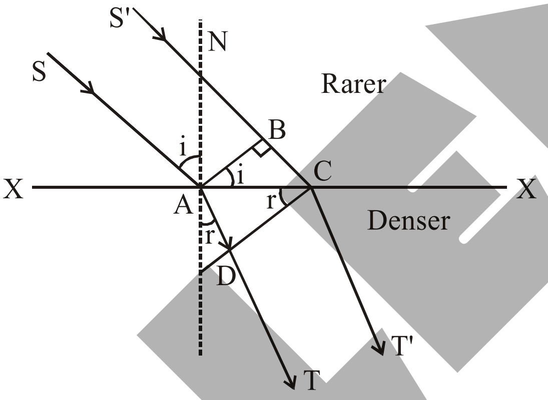
$\sin\theta'_n = \frac{(2n+1)\lambda}{2a}$ force n^th sec. maxima

Therefore $\beta' = y'_n - y'_{n-1} = \frac{\lambda D}{a}$ Both sec. maxima and minima are of same width.

Width of a central maximum : $\beta_0 = \frac{2D\lambda}{a}$

**OR**

(a) Wavefront : It is defined as the locus of all the points vibrating with zero or constant phase difference.



Proof of law of refraction (Snell's Law)

Consider a plane wavefront (AB) incident on the surface XY, separating two media. Let the secondary wavelets from point (B) reach upto point (C) in time (t). So draw an arc of length ($v_2t$) from point A to locate the position of refracted wave front. Now we draw a tangent (CD) on this arc where CD represents refracted wave front.

Clearly incident ray, refracted ray & the normal are respectively ⊥ to incident wave front, refracted wavefront and surface XY.

Also, $\sin i = \frac{BC}{AC} = \frac{v_1 t}{AC}$ ....(i)

& $\sin r = \frac{AD}{AC} = \frac{v_2 t}{AC}$ ....(ii)

From (1) & (2),

$$\frac{v_1}{v_2} = \frac{\sin i}{\sin r}$$

or $\frac{\mu_2}{\mu_1} = \frac{\sin i}{\sin r}$ Snell's Law