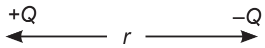
Answers to RPH/Set-1

1. (*b*) In short dipole, $E \propto \frac{1}{r^3} \quad \Rightarrow E \to \frac{E}{8}$

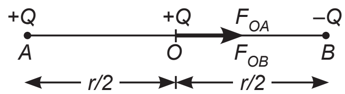
2. (*c*)



Force between two charges

$$F = \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{r^2}$$

When a third charge +Q is placed between the two charges as shown below



Then, force on this charge,

$$F' = F_{OA} + F_{OB} \qquad \text{[towards – Q]}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{(r/2)^2} + \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{(r/2)^2}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{2Q^2}{(r/2)^2} = 8\left[\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{r^2}\right]$$

$$= 8F$$

3. (*d*)

4. (*b*) Half angular width of the central maximum is given by:

$$\sin\theta = \frac{\lambda}{d}$$

Here, $\lambda = 1000 \times 10^{-9}$ m, $d = 2 \times 10^{-6}$ m

$\therefore \qquad \sin\theta = \frac{1000 \times 10^{-9}}{2 \times 10^{-6}}$

$$= 500 \times 10^{-3}$$

$$= 0.5$$

or $\qquad \theta = 30°$

5. (*a*) Given: Initially, $C_1 = 2\,C$ and $C_2 = C$

$$q_1 = 2\,CV \text{ and } q_2 = CV$$

When the capacitor of capacity 'C' is filled with dielectric of constant '*K*', then $C'_2 = KC$

$\therefore$ New charge on C_1

$Q_1 = 2C\,V'$ and new charge on C_2, $Q_2 = C'_2V'$

As charge is conserved,

$\therefore \quad q_1 + q_2 = Q_1 + Q_2$

or $\quad 2CV + CV = 2CV' + C'_2V'$

or $\quad 3CV = 2CV' + 2KCV'$

or $\quad V' = \dfrac{3V}{K+2}$

6. (*d*)

7. (*a*)

8. (*d*) We know, that

$$E_n = \frac{-13.6\,Z^2}{n^2}\ \text{eV}$$

For $n = 1$ and $Z = 4$

$$En = -\frac{-13.6}{(1)^2}(4)^2 = 217.6\ \text{eV}$$

9. (*a*) By Snell's law,

$$\mu = \frac{\sin i}{\sin r}$$

$$\sqrt{3} = \frac{\sin 60°}{\sin r}$$

or $$\sin r = \frac{\sin 60°}{\sqrt{3}} = \frac{\sqrt{3}/2}{\sqrt{3}}$$

or $$\sin r = \frac{1}{2}$$

or $$\sin r = \sin 30°$$

or $$r = 30°$$

10. (*b*)

11. (*c*)

12. (*a*)

13. (*d*)

14. (*d*)

15. (*b*)

16. (*c*)

17. Using, $$E = \frac{hc}{\lambda}$$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{330 \times 10^{-9}} = 6.0 \times 10^{-19}\ \text{J}$$

In eV, $E = \dfrac{6.0 \times 10^{-19}}{1.6 \times 10^{-19}} = 3.76$ eV

$\because$ 3.7 eV < 4.2 eV i.e., less than work function so, no photoelectric emission will take place.

18. We know that

$$I = 4\, I_0 \cos^2 \frac{\phi}{2}$$

Given: Path difference, $\Delta x = \dfrac{\lambda}{4}$

$\because$ $$\Delta\phi = \frac{2\pi}{\lambda} \times \Delta x$$

$$= \frac{2\pi}{\lambda} \times \frac{\lambda}{4} = \frac{\pi}{2}$$

$\therefore$ $$I = 4I_0 \cos^2 \frac{\Delta\phi}{2}$$

$$= 4I_0 \cos^2 \frac{\pi}{4} = 2I_0$$

Or

For minima, $d \sin \theta_1 = n\lambda_1$

For first minimum, $d \sin \theta_1 = (1)\lambda_1$

or $$\sin \theta_1 = \frac{\lambda_1}{d}$$

For first maximum,

$$d \sin \theta_2 = \frac{3}{2}\, \lambda_2$$

or $$\sin \theta_2 = \frac{3d_2}{2d}$$

These above two will coincide if

$$\theta_1 = \theta_2$$

or $$\sin\theta_1 = \sin\theta_2$$

or $$\frac{\lambda_1}{d} = \frac{3\lambda_2}{2d}$$

or $$\lambda_2 = \frac{2}{3}\lambda_1 = \frac{2}{3} \times 660 \text{ nm}$$

$$= 440 \text{ nm}$$

19. Given: $I = 18$ A

$R = 1$ cm $= 10^{-2}$ m

$B_1 = 8 \times 10^{-3}$ T

$r = 0.6$ mm $= 0.6 \times 10^{-3}$ m

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

∴ Magnetic field due to current carrying wire

$$B_2 = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 18}{2\pi \times 0.6 \times 10^{-3}}$$

$$= 60 \times 10^{-4} = 6 \times 10^{-3} \text{ T}$$

Now, Magnitude of resultant magnetic field

$$B = \sqrt{B_1^2 + B_2^2}$$

$$= \sqrt{(8 \times 10^{-3})^2 + (6 \times 10^{-3})^2}$$

$$= 10 \times 10^{-3}$$

$$= 10^{-2} \text{ T}$$

20. Given fusion reaction:

$${}_1H^2 + {}_1H^2 \longrightarrow {}_2He^3 + n$$

∴ Energy released = Final Binding Energy – Initial Binding Energy

$$= 7.73 - 2 \times 2.23$$

$$= 7.73 - 4.46$$

$$= 3.27 \text{ MeV}$$

21. Kinetic energy in the first excited state of hydrogen atom

$$E_K = 3.4 \text{ eV}$$

$$= 3.4 \times 1.6 \times 10^{-19} \text{ J}$$

de Broglie wavelength,

$$\lambda = \frac{h}{\sqrt{2\,m\,E_K}}$$

$$= \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 3.4 \times 1.6 \times 10^{-19}}}$$

$$= 0.67 \times 10^{-9}\text{ m}$$

$$= 0.67\text{ nm}$$

22. For forward biasing

$$\Delta V = 2.4 - 2.0 = 0.4\text{ V}$$

and

$$\Delta I = 80 - 60 = 20\text{ mA} = 20 \times 10^{-3}\text{ A}$$

∴ Forward bias resistance,

$$r_f = \frac{\Delta V}{\Delta I}$$

$$= \frac{0.4}{20 \times 10^{-3}} = 20\ \Omega$$

For reverse biasing,

$$\Delta V = -2 - 0 = -2\text{ V}$$

and

$$\Delta I = -0.25 - 0 = -0.25\ \mu\text{A}$$

∴ Reverse bias resistance,

$$r_r = \frac{\Delta V}{\Delta I}$$

$$= \frac{-2}{-0.25 \times 10^{-6}}$$

$$= 8 \times 10^{6}\ \Omega$$

23. Let after connecting in parallel with an uncharged capacitor

Charge on first capacitor = Q_1

and charge on second capacitor = Q_2

then total charge, $Q = Q_1 + Q_2$ ...(*i*)

and the common potential attained = $V = V_1 = V_2$

∴ $$\frac{Q_1}{C_1} = \frac{Q_2}{C_2}$$ ...(*ii*)

or $$Q = \left(\frac{C_1}{C_2} + 1\right)Q_2$$ [Using (*i*) and (*ii*)]

∴ $$Q_2 = \frac{QC_2}{C_1 + C_2}$$ ...(*iii*) and $$Q_1 = \frac{QC_1}{C_1 + C_2} \qquad \text{...}(iv)$$

Now, $$V_1 = V_2 = \frac{Q}{C_1 + C_2} \qquad \text{...}(v)$$

$$= \frac{Q_2}{C_2} \qquad \text{[From } (iii)\text{]}$$

$$= \frac{Q_1}{C_1} \qquad \text{[From } (iv)\text{]}$$

Final energy,

$$U_f = \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2$$

$$= \frac{1}{2}(C_1 + C_2)V_2^2 \qquad [\because V_1 = V_2]$$

$$= \frac{1}{2}(C_1 + C_2)\frac{Q^2}{(C_1 + C_2)^2} \qquad \text{[Using } (v)\text{]}$$

$$= \frac{Q^2}{2(C_1 + C_2)}$$

Whereas initial energy,

$$U_i = \frac{Q^2}{2C_1}$$

$\therefore$ Loss in energy, $\Delta U = U_i - U_f$

$$= \frac{Q^2}{2C_1} - \frac{Q^2}{2(C_1 + C_2)}$$

$$= \frac{Q^2}{2}\left[\frac{1}{C_1} - \frac{1}{C_1 + C_2}\right]$$

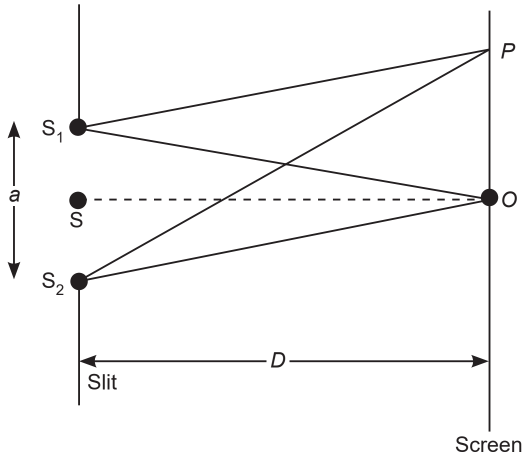
$$= \frac{Q^2}{2}\left[\frac{C_1 + C_2 - C_1}{C_1(C_1 + C_2)}\right]$$

$$= \frac{Q^2C_2}{2C_1(C_1 + C_2)}$$

The lost energy appears in the form of heat.

24. According to Huygen's principle, "the overall effect at any point is the result of the combined contributions of all wavelets taking into account their respective phase differences.

The point 'O' is maxima because contribution from each half of the slit S_1S_2 is in phase. i.e., the path difference is zero.



At point 'P',

(i) If $S_2P - S_1P = n\lambda$

$\Rightarrow$ the point 'P' would be minima

(ii) If $S_2P - S_1P = (2n + 1)\,\dfrac{\lambda}{2}$

$\Rightarrow$ the point would be maxima but with decreasing intensity.

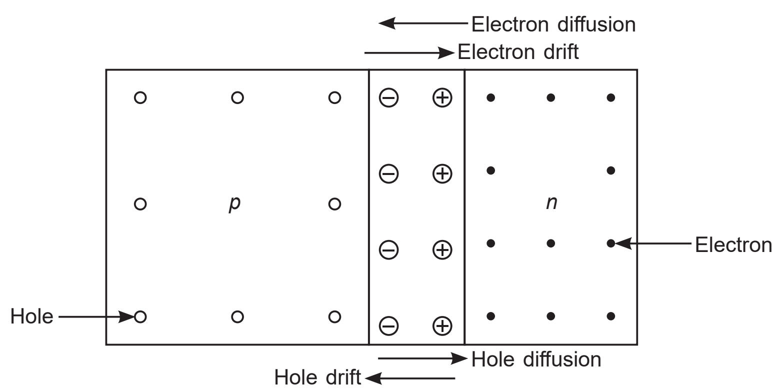
The width of central maxima $= \dfrac{2\lambda D}{a}$

When the width of the slit is doubled the original width, the size of central maxima will be reduced to half and intensity will become four times.

25. Two important processes occuring during the formation of a p-n junction are

(i) diffusion

(ii) drift



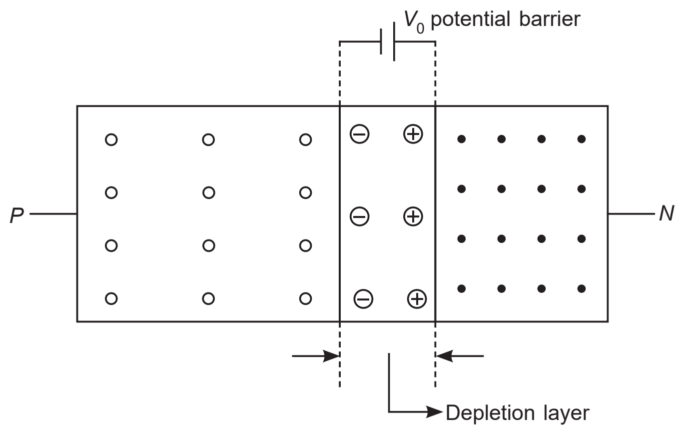
(i) **Diffusion:** In an n-type semiconductor, the concentration of electrons is significantly higher than that of holes, whereas in a p-type semiconductor, the concentration of holes is much higher than that of electrons.

When p-n junction is formed, the concentration gradient causes holes to diffuse from the p-side to the n-side and electrons to diffuse from the n-side to the p-side.

This movement of charge carriers results in a diffusion current across the junction.

(*ii*) **Drift:** The movement of charge carriers due to the electric field is known as drift. Across the junction, a built-in potential barrier creates an electric field directed from the n-region to the p-region. This field causes electrons on the p-side of the junction to move towards n-side, while hole in n-side of the junction to move towards the p-side.

As a result, drift current is generated, which flows in the opposite direction to the diffusion current.



26. (*i*) The condition for a beam of charged particles to pass undeflected through a region of mutually perpendicular electric and magnetic fields is that electric and magnetic forces on the beam must be equal in magnitude and opposite in direction.

i.e., $F_e = F_m$

or $eE = evB$

or $v = \dfrac{E}{B}$

Given that, $E = 50$ kV/m $= 50 \times 10^3$ V/m

$B = 100$ mT $= 100 \times 10^{-3}$ T

$\therefore \quad v = \dfrac{50 \times 10^{+3}}{100 \times 10^{-3}} = 5 \times 10^5$ m/s

(*ii*) The beam of protons strikes the target with constant velocity and hence no force is exerted on the targed.

But if the beam comes to rest, it exerts a force on the target, equal to rate of change of linear momentum of the beam. i.e.,

$$F = \frac{\Delta p}{\Delta t} = \frac{m(0-v)}{q/i} = \frac{-mvi}{q} = \frac{-mvi}{ne}$$

Where n is the number of protons striking the target per second.

Negative sign shows that force is opposite in direction.

27. Given that, $A = 60°$, $\mu = \sqrt{3}$

and $AQ = AR$

$\Rightarrow QR \,||\, BC$

$\Rightarrow \theta$ is angle of minimum deviation

Using, $$\mu = \frac{\sin\left(\frac{A+\theta}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$$\sqrt{3} = \frac{\sin\left(\frac{60+\theta}{2}\right)}{\sin\left(\frac{60}{2}\right)}$$

$$\sqrt{3} = \frac{\sin\left(\frac{60+\theta}{2}\right)}{1/2}$$

or $$\frac{\sqrt{3}}{2} = \sin\left(\frac{60°+\theta}{2}\right)$$

or $$\sin 60° = \sin\left(\frac{60+\theta}{2}\right)$$

or $$60° = \frac{60+\theta}{2}$$

or $$\theta = 60°$$

28. (*a*) We know that,

Electric field due to a long straight charged wire at a distance '*r*' is given by

$$E = \frac{\lambda}{2\pi\varepsilon_0 r} \qquad \ldots(i)$$

The essential centripetal force for circular motion is provided by the electrostatic force.

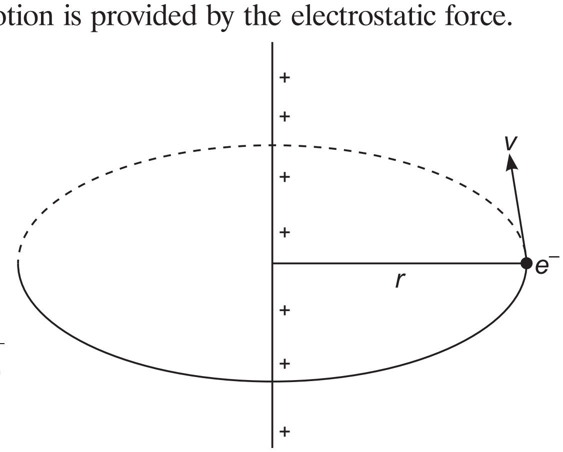
i.e., $$eE = \frac{mv^2}{r}$$

From (*i*), $$e\left(\frac{\lambda}{2\pi\varepsilon_0 r}\right) = \frac{mv^2}{r}$$

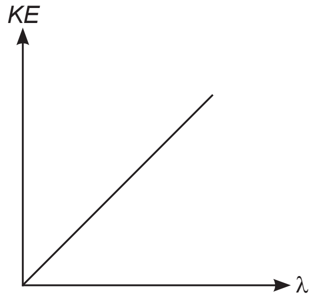
or $$\frac{1}{2}mv^2 = \frac{e\lambda}{4\pi\varepsilon_0}$$

$\therefore$ KE of the electron,

$$K = \frac{1}{2}mv^2 = \frac{e\lambda}{4\pi\varepsilon_0}$$



(*b*)



Graph of KE vs λ

Or

We know that the electric flux through the surface,

$$\phi = \vec{E} \cdot \vec{S}$$

∴ Electric flux through left surface of the cylinder,

$$\begin{aligned} \phi_L &= ES \cos 180° \\ &= -ES \\ &= -(50\,x)\,(s) \\ &= -50\,(1) \times 25 \times 10^{-4} \qquad [\because x = 1 \text{ m}] \\ &= -1250 \times 10^{-4} \\ &= -0.125 \text{ Nm}^2\text{C}^{-1} \end{aligned}$$

Now, flux through the right surface,

$$\begin{aligned} \phi_R &= ES \cos 0° \\ &= ES \\ &= -(50\,x)\,(s) \\ &= (50 \times 2)\,(25 \times 10^{-4}) \qquad [\text{Here, } x = 2 \text{ m}] \\ &= 2500 \times 10^{-4} \\ &= 0.250 \text{ Nm}^2\,\text{C}^{-1} \end{aligned}$$

Net flux through the cylinder,

$$\begin{aligned} \phi &= \phi_L + \phi_R \\ &= -0.125 + 0.250 = 0.125 \text{ Nm}^2\text{C}^{-1} \end{aligned}$$

(*ii*) Charge enclosed by the cylinder

$$\phi = \frac{q}{\varepsilon_0}$$

or

$$\begin{aligned} q &= \phi\varepsilon_0 \\ &= 0.125 \times 8.85 \times 10^{-12} \\ &= 1.107 \times 10^{-12} \text{ C} \end{aligned}$$

29. (*i*) (*c*) (*ii*) (*a*) (*iii*) (*c*) (*iv*) (*d*) ***Or*** (*iv*) (*a*)

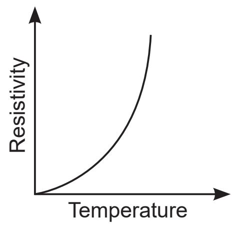
30. (*i*) (*c*) (*ii*) (*b*) (*iii*) (*c*) (*iv*) (*c*) ***Or*** (*iv*) (*b*)

31. Resistivity: It is a fundamental property of a material that quantifies, how strongly it resists the flow of electric current. It is the measure of a material's opposition to the flow of electric current through a unit length of the material for a given cross-sectional area.

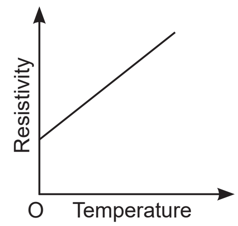
SI unit: Ohm-meter (Ω-m)

Graphs showing the variation of resistivity with temperature.

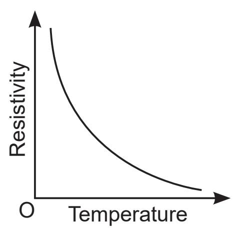
(*i*) For copper



(*ii*) For nichrome



(*iii*) For semiconductor



Variation of Resistivity with temperatue:

The resistivity of materials varies with temperature, which can be expressed as:

For conductor (like copper)

$$\rho(T) = \rho_0 [1 + \alpha (T - T_0)]$$

Where:

- ρ_0 is the resistivity at a reference temperature T_0 (often 20° C)
- α is the temperature coefficient of resistivity (positive for conductors)
- T is the temperature (in °C)

For semiconductors:

$$\rho(T) = \rho_0 e^{-E_g/kT}$$

Where:

- E_g is the energy gap
- k is the Boltzmann's constant
- T is the temperature in Kelvin

Behaviour of Different Materials:

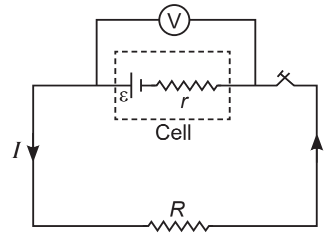
(*i*) **Copper (Conductor):** As temperature increases, resistivity increases due to the increased scattering of conduction electrons by lattice vibrations.

(*ii*) **Nichrome (Alloy):** Alloys like Nichrome exhibit a relatively small change in resistivity with temperature, making them useful in applications requiring stable resistivity across temperature variations.

(*iii*) **Semiconductors:** For semiconductors resistivity decreases as temperature increases. This is because increasing temperature excites more charge carriers across the energy gap, thus reducing resistivity.

Or

(*a*) When the resistor R is connected across the cell, the circuit forms a closed loop. The emf of the cell E, is the total energy supplied per unit charge, while the terminal voltage V is the potential difference across the external resistor, which is less than the EMF due to the internal resistance 'r' of the cell.



According to Ohm's law, the current I flowing in the circuit is given by

$$I = \frac{E}{R+r}$$

The terminal voltage V measured across the external resistor is related to the current I by,

$$V = IR$$

Substitute the expression for I into the equation for V.

$$V = \left(\frac{E}{R+r}\right)R$$

Simplifying, we get

$$V = \frac{ER}{R+r}$$

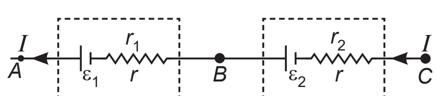
Now, solving in terms of E, V and R for r, we get

$$VR + Vr = ER$$

or $$Vr = (E - V)R$$

or $$r = \left(\frac{E}{V} - 1\right)R$$

(*b*) Let two cells of EMFs ε_1 and ε_2 with their respective internal resistances r_1 and r_2 are connected in series, as shown below:



Terminal potential difference between A and B,

$$V_{AB} = V_A - V_B = \varepsilon_1 - Ir_1 \quad \ldots(i)$$

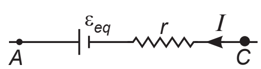
and terminal potential differences between B and C

$$V_{BC} = V_B - V_C = \varepsilon_2 - Ir_2 \quad \ldots(ii)$$

And terminal potential difference between 'A' and 'C'

$$V = V_A - V_C$$
$$= (V_A - V_B) + (V_B - V_C)$$
$$= (\varepsilon_1 - Ir_1) + (\varepsilon_2 - Ir_2) \quad \text{[from equations } (i) \text{ and } (ii)]$$
$$= (\varepsilon_1 + \varepsilon_2) - I(r_1 + r_2) \quad \ldots(iii)$$

If the above combination is replaced by a single cell of equivalent emf 'ε' and internal resistance '*r*', as shown below



Terminal potential difference between 'A' and 'C' is given by

$$V = \varepsilon_{eq} - I_{req} \quad \ldots(iv)$$

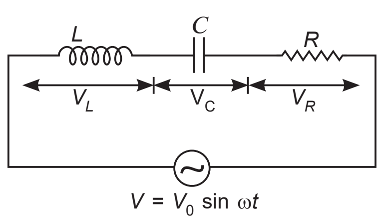
Comparing equations (*iii*) and (*iv*), we get

$$\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$$

and $$r_{eq} = r_1 + r_2$$

32. (*a*) Impedance is the total opposition that an alternating current (AC) circuit presents to the flow of electric current.

(*b*)



Given AC input to the circuit is

$$V = V_0 \sin \omega t$$

Now potential across inductor,

$$V_L = IX_L \quad \ldots(i)$$

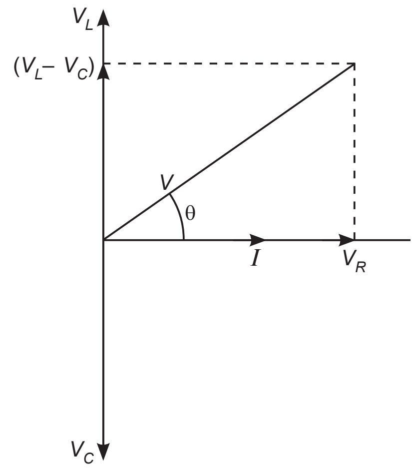
Potential across capacitor,

$$V_C = IX_C \quad \ldots(ii)$$

and potential across resistor

$$V_R = IR \quad \ldots(iii)$$

The phasor diagrams,



From the phasor diagram shown above, it is clear that,

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

Using equations (*i*), (*ii*), and (*iii*), we get

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

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

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

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

Where $Z = \sqrt{(X_L - X_C)^2 + R^2}$, known as impedance of the LCR ac circuit.

Now, from phasor diagram, it is clear that,

$$\tan \phi = \frac{V_L - V_C}{V_R} = \frac{IX_L - IX_C}{IR}$$

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

For resonance,

$$X_L = X_C$$

or $$\omega L = \frac{1}{\omega C}$$

or $$\omega^2 = \frac{1}{LC}$$

or $$\omega = \frac{1}{\sqrt{LC}}$$

or $$2\pi\nu = \frac{1}{\sqrt{LC}}$$

or $$\nu = \frac{1}{2\pi\sqrt{LC}}$$

This is the expression for resonant frequency.

Or

(*a*) Given: $L = 100 \text{ mH} = 100 \times 10^{-3} \text{ H} = 0.1 \text{ H}$

$R = 100\ \Omega$

$X_C = 200\ \Omega$

$V_{rms} = 150\sqrt{2}$

and $$\nu = \frac{500}{\pi} \text{ HZ}$$

$$X_L = \omega L = 2\pi\nu L$$

$$= 2\pi\left(\frac{500}{\pi}\right)\times 0.1 = 100\ \Omega$$

Now, $$Z = \sqrt{(X_L - X_C)^2 + R^2}$$

$$= \sqrt{(100-200)^2 + (100)^2} = \sqrt{100^2 + 100^2} = 100\sqrt{2}\,\Omega$$

$\therefore$ $$I_{rms} = \frac{V_{rms}}{Z}$$

$$= \frac{150\sqrt{2}}{100\sqrt{2}} = 1.5 \text{ A}$$

$\therefore$ Current flowing in the circuit = 1.5 A

Now power dissipated in the resistor,

$$P = I^2_{\text{rms}} \text{ R}$$

$$= (1.5)^2 \times 100$$

$$= 2.25 \times 100$$

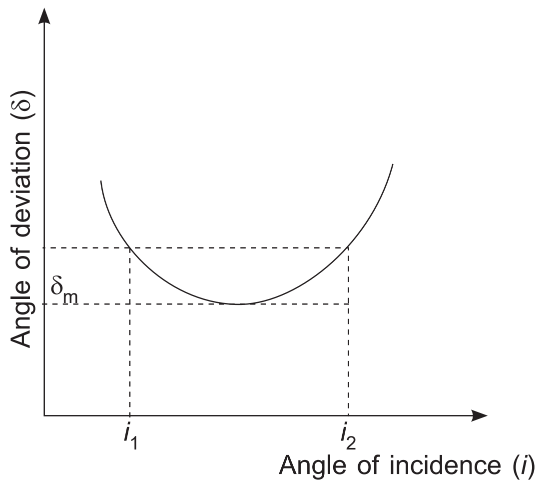
$$= 225 \text{ W}$$

(*b*) The material used for the core of a transformer should possess the following two characteristic properties:

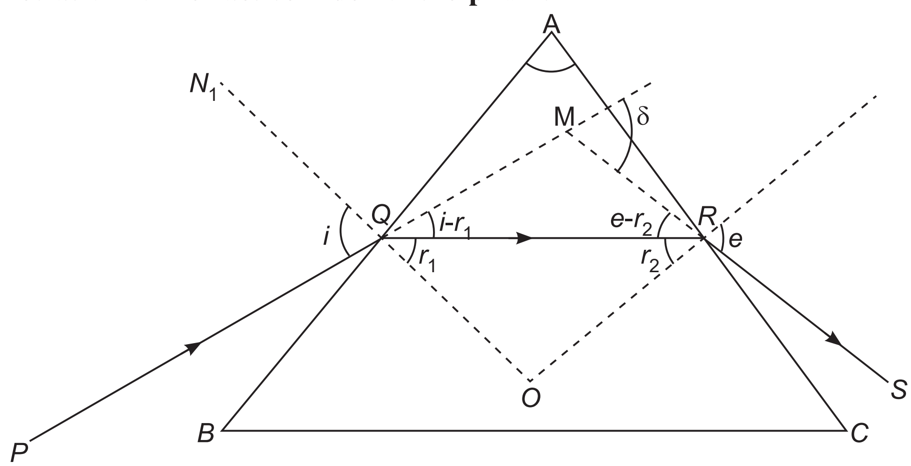
(*i*) High magnetic permeability

(*ii*) Low hysteresis loss and low eddy current loss.

33. Graph between angle of deviation vs angle of incidence:



Deviation for refractive index of the prism:



In ΔMQR, $(i - r_1) + (e - r_2) = \delta$ [exterior angle property of a triangle]

or $(i + e) - (r_1 + r_2) = \delta$ ...(*i*)

In quadrilateral, AQOR,

$$\angle A + \angle Q + \angle O + \angle R = 360°$$

$$\angle A + 90° + \angle O + 90° = 360°$$

or $\angle A + \angle O = 180°$ ...(*ii*)

In ΔQOR,

$$r_1 + r_2 + \angle O = 180° \quad \text{...}(iii)$$

From equations (*ii*) and (*iii*), we get

$$\angle A + \angle O = r_1 + r_2 + \angle O$$

or $\quad r_1 + r_2 = \angle A \quad \ldots(iv)$

Using this in equation (i), we get

$$i + e - A = \delta$$

or $\quad i + e = A + \delta \quad \ldots(v)$

For minimum deviation, $i_1 = e = i$ (say)

and $r_1 = r_2 = r$ (say)

Also refracted ray QR becomes parallel to the base BC of the prism.

$\therefore$ equations (iv) and (v) can be written as

$$2r = \text{A}$$

or $\quad r = \text{A}/2$

and $\quad i + i = A + \delta_m$

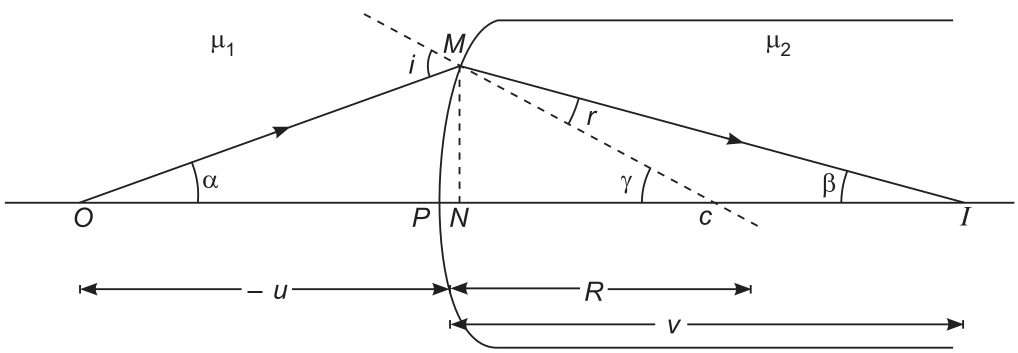
or $\quad i = \dfrac{A + \delta_m}{2}$

Now, Snell's law,

$$\mu = \frac{\sin i}{\sin r}$$

$\therefore \quad \mu = \dfrac{\sin\left(\dfrac{A+\delta_m}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$

Or



By Snell's law,

$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$$

For small angles,

$$\frac{i}{r} = \frac{\mu_2}{\mu_1}$$

or $$\mu_1 i = \mu_2 r \qquad \ldots(i)$$

In ΔMOC,

$$\alpha + \gamma = i \qquad \ldots(ii)$$

and In ΔMCI,

$$\beta + r = \gamma$$

or $$r = \gamma - \beta \qquad \ldots(iii)$$

Using equations (*ii*) and (*iii*) in equatins (*i*), we get

$$\mu_1 (\alpha + \gamma) = \mu_2 (\gamma - \beta) \qquad \ldots(iv)$$

Now in right ΔMNO,

$$\alpha \approx \tan \alpha = \frac{MN}{NO}$$

$$\approx \frac{MN}{PO} = \frac{MN}{-u} \qquad \ldots(v)$$

In right ΔMNI,

$$\beta \approx \tan \beta = \frac{MN}{NI}$$

$$= \frac{MN}{PI} = \frac{MN}{v} \qquad \ldots(vi)$$

In right ΔMNC,

$$\gamma \approx \tan \gamma = \frac{MN}{NC}$$

$$\approx \frac{MN}{PC} = \frac{MN}{R} \qquad \ldots(vii)$$

Using equations, (*v*), (*vi*) and (*vii*) in equation (*iv*), we get

$$\mu_1 \left(\frac{MN}{-u} + \frac{MN}{R}\right) = \mu_2 \left(\frac{MN}{R} - \frac{MN}{v}\right)$$

or $$\frac{\mu_1}{-\mu} + \frac{\mu_1}{R} = \frac{\mu_2}{R} - \frac{\mu_2}{v}$$

or $$\frac{\mu_2}{v} - \frac{\mu_1}{R} = \frac{\mu_2 - \mu_1}{R}$$

The focal length of the convex lens increases when it is immersed in water.