Answers to RPH/Set-1

1. (*a*) spherical with centre at the centre of the dipole.

2. (*c*) We know that, drift velocity,

$$v_d = \frac{I}{neA}$$

$$\Rightarrow \quad v_d \propto \frac{1}{A}$$

$\therefore$ As area increases, drift velocity decreases.

3. (*d*)

4. (*b*)

5. (*a*) Using $P = P_1 + P_2$

6. (*b*)

7. (*d*) They are independent of spin.

8. (*b*)

9. (*a*) $L = \dfrac{\mu_0 N^2 A}{l}$; $L' = \dfrac{\mu_0 (4N^2)(A/4)}{l}$

$\therefore \quad \dfrac{L}{L'} = 1$

10. (*a*) Given: Capacitance of each capacitor = 3 μF

Equivalent capacitance between A and B

$$C_{AB} = \frac{1}{\frac{1}{3}+\frac{1}{3}+\frac{1}{3}} + 3$$

$$= \frac{1}{\frac{3}{3}} + 3$$

$$= 1 + 3 = 4\ \mu F$$

And equivalent capacitance between A and C

$$C_{AC} = \frac{1}{\frac{1}{3}+\frac{1}{3}} + \frac{1}{\frac{1}{3}+\frac{1}{3}}$$

$$= \frac{3}{2} + \frac{3}{2} = \frac{6}{2} = 3\ \mu F$$

Now, $$\frac{C_{AB}}{C_{AC}} = \frac{4}{3}$$

$\therefore$ Ratio = 4 : 3

11. (*b*)

12. (*c*) The magnetic moment M of a straight wire is given by:

$$M = mL$$

where m is the pole strength and L is the length of the wire.

When the wire is bent into a right-angled shape, the effective length between the two poles becomes the diagonal of the right triangle formed by the two halves of the original length L. The new effective length is:

$$L' = \frac{L}{\sqrt{2}}$$

Thus, the new magnetic moment M′ is:

$$M' = mL' = m\left(\frac{L}{\sqrt{2}}\right) = \frac{M}{\sqrt{2}}$$

Therefore, the new magnetic moment is $M' = \frac{M}{\sqrt{2}}$.

13. (*a*) Both Assertion and Reason are true and Reason is the correct explanation of Assertion.

14. (*a*) Both Assertion and Reason are true and Reason is the correct explanation of Assertion.

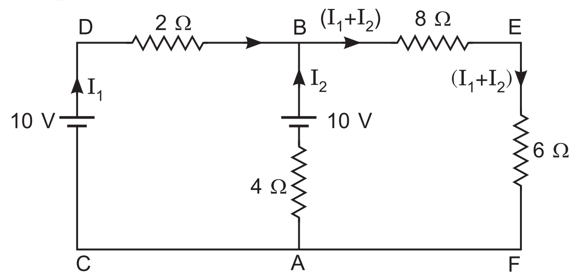
15. (*a*) Both Assertion and Reason are true and Reason is the correct explanation of Assertion.

16. (*d*) Both Assertion and Reason are false.

17. (*i*) Gamma rays are produced by disintegration of atomic nuclei, while radio waves are produced by oscillating electric circuits.

(*ii*) γ-rays are used to provide information about the structure of atomic nuclei, while radio waves are generally used in Radio and TV communication.

18. Applying KVL in the loop CDBAC,



$$10 - 2I_1 - 10 + 4I_2 = 0$$

or $$-2I_1 + 4I_2 = 0$$

or $$I_1 - 2I_2 = 0 \quad ...(i)$$

Applying KVL in the loop ABEFA,

$$-4I_2 + 10 - 8(I_1 + I_2) - 6(I_1 + I_2) = 0$$

or $$-4I_2 + 10 - 14(I_1 + I_2) = 0$$

or $$-4I_2 - 14I_1 - 14I_2 = -10$$

or $$-14I_1 - 18I_2 = -10$$

or $$-7I_1 + 9I_2 = 5 \quad ...(ii)$$

Solving equations (i) and (ii), we get

$$7I_1 - 14I_2 = 0$$

or

$$7I_1 + 9I_2 = 5$$

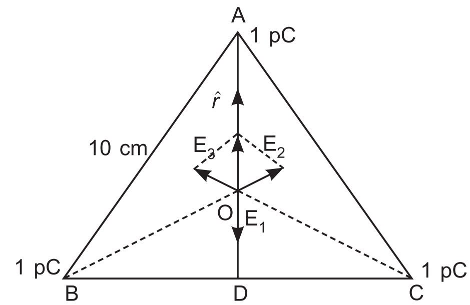
$$- \quad - \quad -$$

$$-23I_2 = -5$$

$$I_2 = \frac{5}{23}\text{ A}$$

$\therefore$ Current in AB branch is $\frac{5}{23}$ A.

19. In the given ΔABC,



$AD = AC \cos 30° = 0.1 \times \frac{\sqrt{3}}{2}$

and so $AO = \frac{2}{3}AD = \frac{2}{3} \times 0.1 \times \frac{\sqrt{3}}{2} = \frac{0.1}{\sqrt{3}}$ m

By symmetry AO = BO = CO

Thus, electric field $\vec{E_1}$ at 'O' due to charge 1 pC at A

$$= \frac{1}{4\pi\varepsilon_0} \frac{1 \times 10^{-12}}{\left(\frac{0.1}{\sqrt{3}}\right)^2} \text{ along AO}$$

Electric field $\vec{E_2}$ at 'O' due to charge 1 pC at 'B'

$$= \frac{1}{4\pi\varepsilon_0} \frac{1 \times 10^{-12}}{\left(\frac{0.1}{\sqrt{3}}\right)^2} \text{ along BO}$$

Electric field $\vec{E_3}$ at 'O' due to charge 1 pC at 'C'

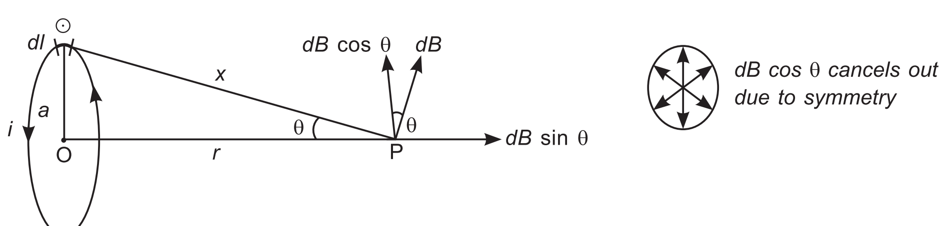
$$= \frac{1}{4\pi\varepsilon_0} \frac{1 \times 10^{-12}}{\left(\frac{0.1}{\sqrt{3}}\right)^2} \text{ along CO}$$

The resultant of $\vec{E_2}$ and $\vec{E_3}$ is $\frac{1}{4\pi\varepsilon_0} \frac{1 \times 10^{-12}}{\left(\frac{0.1}{\sqrt{3}}\right)^2}$ along OA, by the parallelogram law.

Therefore, the total electric field at 'O'

$$= \frac{1}{4\pi\varepsilon_0} \frac{1 \times 10^{-12}}{\left(\frac{0.1}{\sqrt{3}}\right)^2} (\hat{r} - \hat{r}) = 0, \text{ where } \hat{r} \text{ is the unit vector along OA}$$

20. (I)



Magnetic field due to current element dl at P, $dB = \frac{\mu_0}{4\pi} \frac{i\,dl}{x^2}$

As $dB \cos\theta$ cancels out, the effective elementary magnetic field at $P = dB \sin\theta$; $\sin\theta = \frac{a}{x}$

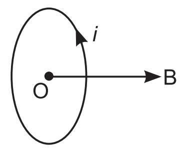
As $B = \oint dB \sin\theta = \frac{\mu_0}{4\pi}\frac{ia}{x^3}\oint dl = \frac{\mu_0}{4\pi}\frac{ia(2\pi a)}{(r^2+a^2)^{3/2}}$ (as $\oint dl = 2\pi a$) ...(i)

The magnetic moment of the coil $M = i\,A = i\,\pi\,a^2$

$$\therefore \quad B = \frac{\mu_0}{4\pi}\frac{2M}{(r^2+a^2)^{3/2}}$$

At the centre of the circular loop $r = 0$, from equation (i), we get

$B = \frac{\mu_0 i}{2a}$;



Or

(II) Nature of magnetic material: Ferromagnetic

Its two properties:

(i) Get strongly magnetised when placed in an external magnetic field.

(ii) Have strong tendency to move from a region of weak magnetic field to strong magnetic field *i.e.* they get strongly attracted to a magnet.

21. (I) Given fusion reaction:

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

$\therefore$ Energy released = Final Binding Energy – Initial Binding Energy

= 7.73 – 2 × 2.23

= 7.73 – 4.46

= 3.27 MeV

Or

(II) 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. (*a*) The new semiconductor has electrons in majority. Therefore, it is a *n*-type semiconductor.

(*b*) As $n_e n_h = n_i^2$

$$\therefore\ n_h = \frac{n_i^2}{n_e} = \frac{(6\times10^8)^2}{8\times10^{12}} = 4.5 \times 10^4 \text{ m}^{-3}$$

(*c*) The energy gap may decrease with doping.

23. (*a*) (*i*) As $\varepsilon = V + iR$

and $i = \frac{\varepsilon - V}{r}$

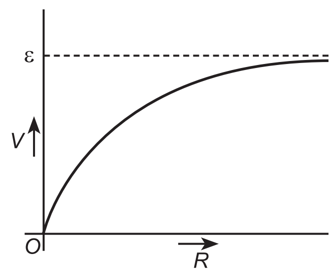
$$V = iR = \left(\frac{\varepsilon - V}{r}\right)R$$

or $V\left(1+\frac{R}{r}\right) = \frac{\varepsilon R}{r}$

$$\therefore\ V = \frac{\varepsilon R}{R\left(1+\frac{r}{R}\right)} = \frac{\varepsilon}{1+\frac{r}{R}}$$

If $R = 0$, $V = 0$

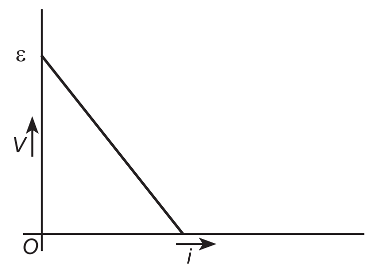
If $R = \infty$, $V = \varepsilon$



(*ii*) $\varepsilon = V + ir$

$\therefore\ V = -ir + \varepsilon$

Hence, V versus i graph has negative slope.



(*b*) Given: $R_1 = 4\ \Omega$, $I_1 = 1$ A;

$R_2 = 9\ \Omega$, $I_2 = 0.5$ A

We know that $E = V + ir = iR + ir$

$E = i(R + r)$

For 1st case $E = 1(4 + r)$ ...(*i*)

For 2nd case $E = 0.5(9 + r)$ ...(*ii*)

From (*i*) and (*ii*), we get

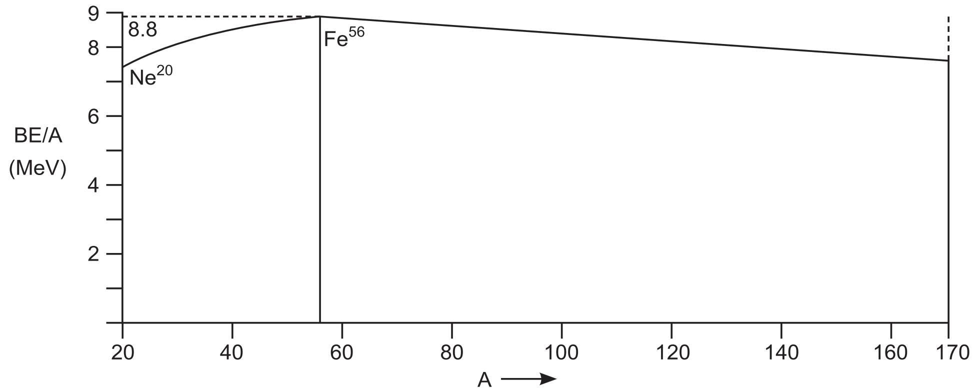
$4 + r = 0.5 \times 9 + 0.5r$

$\Rightarrow\ 0.5\, r = 4.5 - 4 = 0.5$

$\therefore\ r = 1\ \Omega$

and $E = 1 \times (4 + 1) = 5$ V. [From (*i*)]

24. (*a*)



In the beginning of the graph Ne^{20} is stable nucleus. At A = 40, $_{20}Ca^{40}$ is the last nucleus where N/Z ratio is 1. As the value of A increases, to provide stability against proton-proton repulsion more number of neutrons are accommodated in the nuclei and N/Z ratio goes upto 1.6. After Z = 83 (lead) even the higher number of neutron fail to overcome coulombain repulsion and there after the nuclei turn unstable. Fe^{56}, as shown in the graph is most stable nucleus with BE/A = 8.8 MeV (the highest value). From here to A → 170, the ratio BE/A continue to gradually fall till A becomes equal to 207 for Pb. Beyond this value nuclei becomes unstable.

(*b*) B.E. of nucleus $= \dfrac{B.E.}{A} \times A = 7.6 \times 240$ MeV

B.E. of each fragments $= 8.5 \times 120$ MeV

∴ Energy released $= 2 \times 8.5 \times 120 - 7.6 \times 240$

$= 240\,[8.5 - 7.6] = 216.0$ MeV

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

and $AQ = AR$

$\Rightarrow QR \parallel BC$

$\Rightarrow \theta$ is angle of minimum deviation

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

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

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

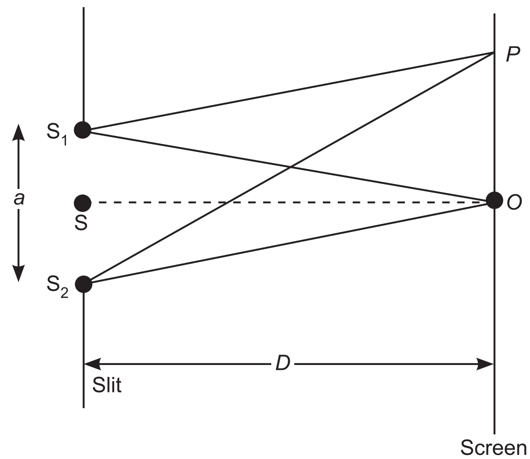
or
$$\frac{\sqrt{3}}{2} = \sin\left(\frac{60° + \theta}{2}\right)$$

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

or $\theta = 60°$

26. 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 $S_2P - S_1P = (2n + 1)\frac{\lambda}{2}$

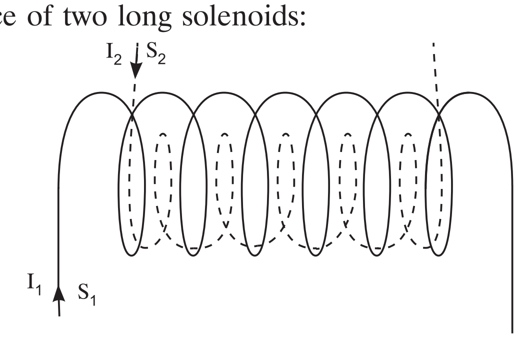
$\Rightarrow$ the point would be maxima but with decreasing intensity.

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

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.

27. (I) **Mutual inductance:** The mutual inductance of two coils may be defined as the induced emf set up in one coil when the current in the neighbouring coil changes at the unit rate.

Mutual Inductance of two long solenoids:



Let first we pass a time varying current I_2 through S_2. The magnetic field set up inside S_2 due to I_2 is

$$B_2 = \mu_0 n_2 I_2$$

where, $$n_2 = \frac{N_2}{l}$$

Total magnetic flux linked with the inner solenoid S_1 is

$$\phi_1 = B_2 A N_1 = \mu_0 n_2 I_2 A N_1$$

∴ Mutual inductance of coil 1 with respect to coil 2 is

$$M_{12} = \frac{\phi_1}{I_2} = \mu_0 n_2 A N_1 = \frac{\mu_0 N_1 N_2 A}{l}$$

Similarly, $$M_{21} = \frac{\mu_0 N_1 N_2 A}{l}$$

Or

(II) (*a*) The SI unit of mutual inductance is Henry (H). The mutual inductance of the coils is said to be One Henry if an induced emf of one volt is set up in one coil when the current in the neighbouring coil changes at the rate of 1 ampere per second.

(*b*) Given: $N_1 = 500, \quad N_2 = 50$

$$r = 2 \text{ cm} = 0.02 \text{ m}$$

$$l = 50 \text{ cm} = 0.50 \text{ m}$$

(*i*) Using,

$$M = \frac{\mu_0 N_1 N_2 \pi r^2}{l} = \frac{4\pi \times 10^{-7} \times 500 \times 50\, \pi\, (0.02)^2}{0.5}$$

$$= 78.96 \times 10^{-6} \text{ H} = 78.96\ \mu\text{H}$$

∴ Mutual inductance of two coils is 78.96 μH.

(*ii*) Using, $$\varepsilon = -M\frac{dI}{dt} = -78.96 \times 10^{-6}\ \frac{(5-0)}{0.02}$$

$$= -19.74 \times 10^{-3} = -19.74 \text{ mV}$$

∴ Induced emf in the second coil is –19.74 mV.

28. (*a*) Torque on the loop, $\tau = MB \sin \theta$

As M and B are parallel,

∴ $\theta = 0$

∴ $\tau = 0$

(*b*) Magnitude of force, $$|\vec{F}| = \frac{\mu_0 I_1 I_2 l}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$= 2 \times 10^{-7} \times 2 \times 1 \times 4 \times 10^{-2}\left[\frac{1}{2\times 10^{-2}} - \frac{1}{4.5\times 10^{-2}}\right]$$

$$= 16 \times 10^{-7}\left[\frac{4.5-2}{2\times 4.5}\right] = \frac{8\times 5\times 10^{-7}}{9} = 4.44 \times 10^{-7} \text{ N}$$

Direction of force is towards conductor, i.e. attractive in nature.

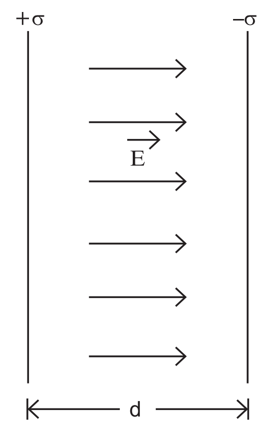
29. (*i*) (*a*) (*ii*) (*b*) (*iii*) (*c*) (*iv*) (*b*)

30. (*i*) In *p*-type semiconductors, the presence of holes increases the number of possible electron transitions. Electrons from neighbouring atoms can easily move to fill holes, making hole-movement equivalent to current flow. This higher mobility of charge carriers compared to pure semiconductors increases conductivity.

(*ii*) Trivalent impurity → Boron; Pentavalent impurity → Phosphorus

(*iii*) This is because the trivalent impurity atoms added are electrically neutral, keeping the overall crystal neutral.

31. **(I)** (*a*) **Working principle of the parallel plate capacitor:** When an uncharged, earthed conductor is brought near to a charged conductor, then the potential of later decreases and its charge holding capacity increases.



Expression for capacitance of parallel plate capacitor: Consider a parallel plate capacitor, where

A = area of each plate

d = distance between the plates

Q = charge on the capacitor

Now, electric field between the plates of the capacitor,

$$E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$$

$$\because \quad E = \frac{V}{d} \quad \text{or} \quad V = Ed$$

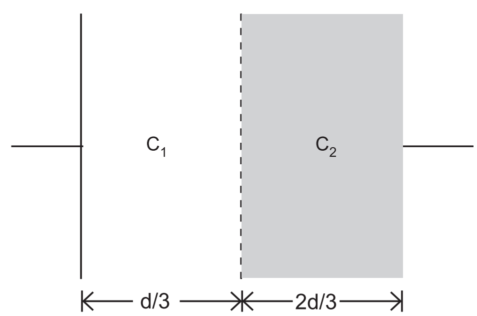
$$\therefore \quad V = \frac{Qd}{AE} \qquad ...(i)$$

If C is the capacitance of the capacitor, then

$$C = \frac{Q}{V} = \frac{Q}{\frac{Qd}{A\varepsilon_0}} \qquad \text{[Using equation } (i)\text{]}$$

$$\boxed{C = \frac{A\varepsilon_0}{d}}$$

(*b*) When there was no dielectric then,



$$C_0 = \frac{\varepsilon_0 A}{d}$$

When dielectric was inserted as shown then equivalent capacitance,

$$\frac{1}{C'} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{\frac{d}{3}}{\varepsilon_0 A} + \frac{\frac{2d}{3}}{K\varepsilon_0 A} = \frac{1}{3C_0} + \frac{2}{3KC_0}$$

$$= \frac{1}{3C_0}\left[1 + \frac{2}{K}\right] = \frac{1}{3C_0}\left[1 + \frac{2}{K}\right] = \frac{K+2}{3KC_0}$$

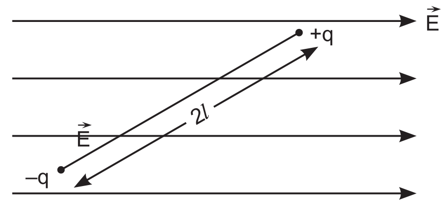
or $$\boxed{C' = \frac{3KC_0}{K+2}}$$

Or

(II) (*a*) A dipole is a system consisting of equal and opposite charges separated by a small distance.

When it is placed in a uniform electric field E, then force experienced by $+q$ charge,

$$F_1 = qE$$



and force experienced by $-q$ charge is

$$F_2 = -qE$$

Net force on the dipole,

$$F = F_1 + F_2$$

$$= qE + (-qE) = 0$$

This shows that net electric force acting on electric dipole is zero, when placed in a uniform electric field.

(*b*) (*i*) Here, work done

$$W = \int_0^{\pi} \tau \, d\theta = \int_0^{\pi} pE \sin\theta \, d\theta \qquad [\because \tau = pE \sin\theta]$$

$$= pE\,[-\cos]_0^{\pi} = -pE[\cos\pi - \cos 0]$$

$$= -pE\,[-1-1] = 2pE$$

(*ii*) Torque acting on the dipole when placed in a uniform electric field is

$$\tau = pE\sin\theta$$

For maximum torque,

$$\sin\theta = 1$$

or $$\theta = \frac{\pi}{2}$$

So, the torque will be maximum on the dipole when it is at an angle of 90° with the electric field.

(*c*) Given: $p = 4 \times 10^{-9}$ Cm, $r = 0.3$ m

(*i*) On axial line

Electric potential, $$V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$$

$$= 9 \times 10^9 \times \frac{4\times10^{-9}}{(0.3)^2}$$

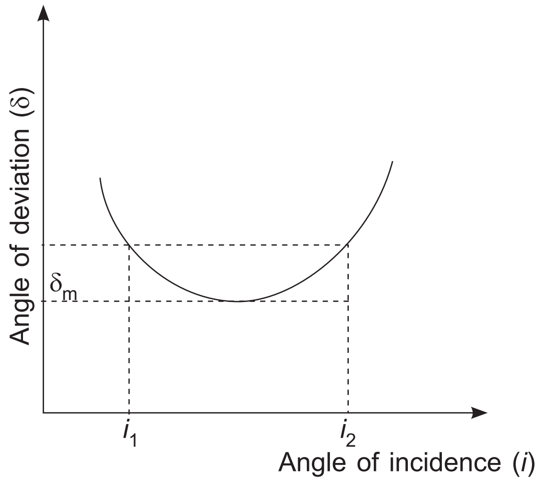
$$= \frac{9\times4}{9\times10^{-2}} = 400 \text{ V}$$

(*ii*) When line makes an angle of 60° with dipole axis

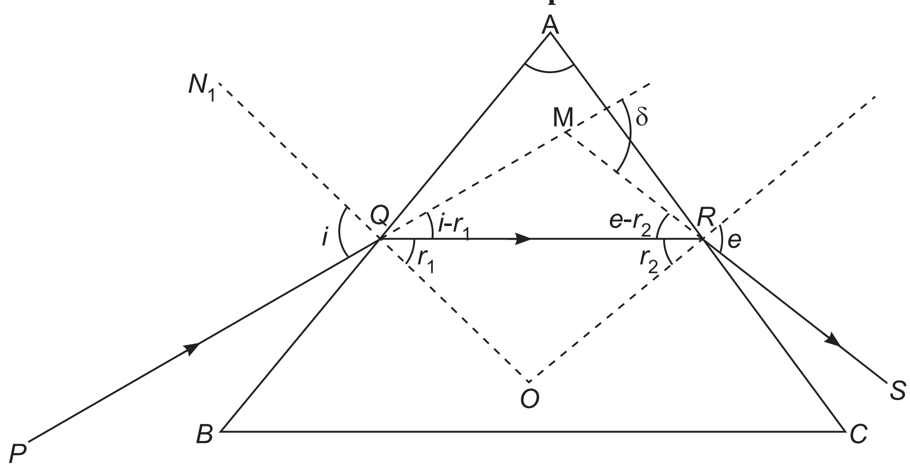
Electric potential, $$V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$$

$$= \frac{9\times10^9\times4\times10^{-9}}{(0.3)^2}\times\frac{1}{2} = 200 \text{ V}$$

32. (I) 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,

$$\angle A + \angle Q + \angle O + \angle R = 360^\circ$$

$$\angle A + 90^\circ + \angle O + 90^\circ = 360^\circ$$

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

In Δ*QOR*,

$$r_1 + r_2 + \angle O = 180^\circ \quad ...(iii)$$

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

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

or $r_1 + r_2 = \angle A$ ...(*iv*)

Using this in equation (*i*), we get

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

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

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

$$2r = A$$

or $$r = A/2$$

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

or $$i = \frac{A + \delta_m}{2}$$

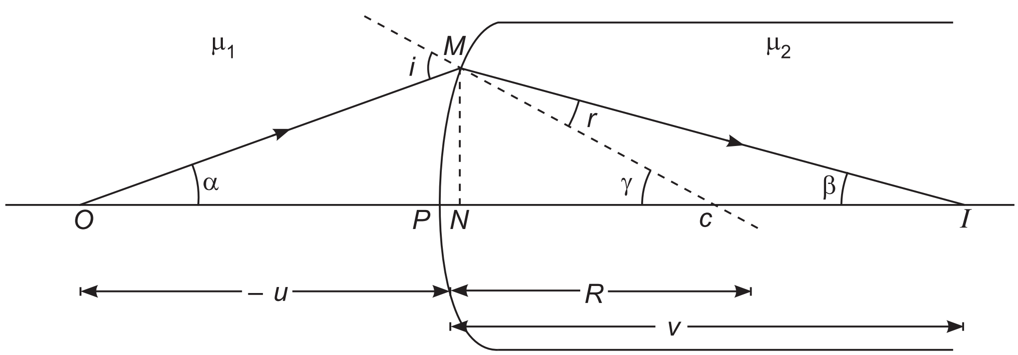
Now, Snell's law,

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

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

Or

(II)



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

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

Now in right ΔMNO,

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

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

In right ΔMNI,

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

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

In right ΔMNC,

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

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

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

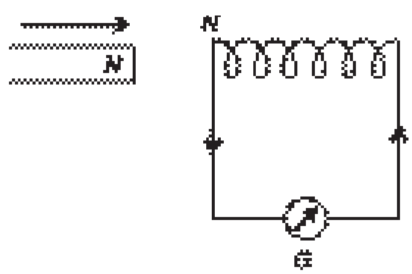
$$\mu_1 \left(\frac{MN}{-u} + \frac{MN}{R}\right) = \mu_2 \left(\frac{MN}{R} - \frac{MN}{v}\right)$$

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

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

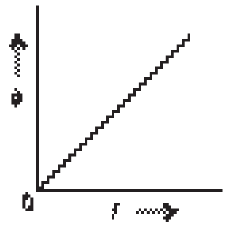
The focal length of the convex lens increases when it is immersed in water.

33. (I) (*a*) When the north pole of a magnet is brought close to a copper coil attached with a galvanometer, an anti-clockwise current flows in the galvanometer showing a deflection towards right.

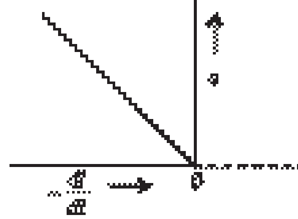


This induced current gives rise to the north pole of the magnet at the left side of the coil. The incoming N-pole of the magnet suffers opposition due to similar polarity of the left end of the coil. External work is being done to overcome this repulsion, which manifests itself as induced emf across the terminals of the coil in accordance with Lenz's law.

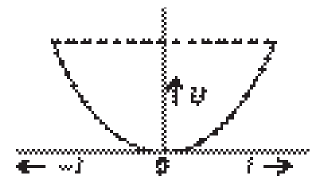
(*b*) (*i*) $\phi = Li$



(*ii*) $e = -L\dfrac{di}{dt}$

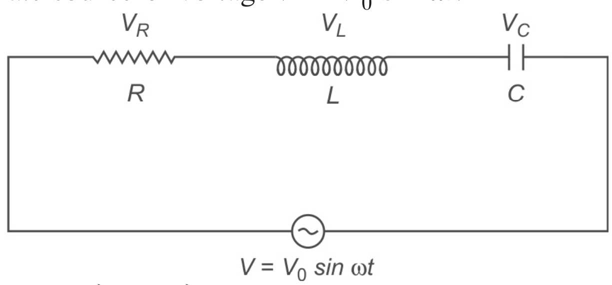


(*iii*) $U = \frac{1}{2}Li^2$



Or

(II) ***LCR* circuit:** Suppose a resistance *R*, on inductance *L* and capacitance *C* are connected in series to an a.c source of voltage $V = V_0 \sin \omega t$.



- Across *R*, phasor $\vec{V_R}$ and $\vec{I}$ are in the same direction.

  So, voltage amplitude is

  $$V_R = I_o R$$

- Across inductor *L*, voltage leads the current in phase by $\pi/2$ radian.

  So, voltage amplitude is

  $$V_L = I_o X_L \quad \text{where} \quad X_L = \text{inductive reactance.}$$

- Across *C*, voltage lags behind the current *I* in phase by $\pi/2$ radian. So voltage amplitude is $V_C = I_o X_C$. Consider $V_L > V_C$.

  So, phasor diagram for LCR circuit is as shown.

  It is assumed that $V_L > V_C$. As $\vec{V_L}$ and $\vec{V_C}$ are in opposite direction, their resultant is $\vec{V_L} - \vec{V_C}$. Using parallelogram law of vector addition

  $$\vec{V} = \vec{V_R} + (\vec{V_L} - \vec{V_C})$$

  Using pythagorean theorem, we get

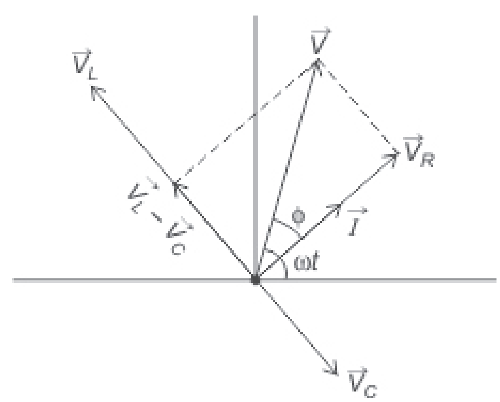
  $$V_o^2 = V_R^2 + (V_L - V_C)^2$$
  $$= I_o^2[R^2 + (X_L - X_C)^2]$$

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

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

  where $\dfrac{V_o}{I_o} = Z$ = effective resistance which opposes the flow of current.

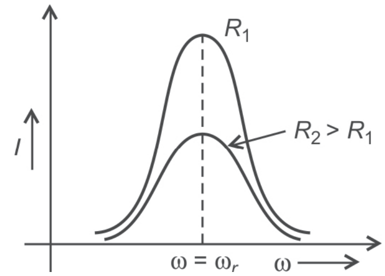
  Z = Impedance of series LCR circuit.



So, instantaneous current in the circuit is

$$I = I_o \sin(\omega t + \phi)$$

The variation of current I as the function of angular frequency 'ω' of the applied AC source for two resistance R_1 and R_2 ($R_2 > R_1$) is shown in the figure.



In a series, LCR circuit, the resonance occurs only when the frequency of the applied a.c. is such that $X_L = X_C$ and the circuit is purely resistive. The current is maximum at $\omega = \omega_r$ such that

$$L\omega_r = \frac{1}{C\omega_r} \quad \text{or} \quad \omega_r^2 = \frac{1}{LC} \quad \text{or} \quad \omega_r = \frac{1}{\sqrt{LC}}$$

At a frequency less than or greater than ω_r, the current falls off. The maximum current is more if the resistance R is less.

A curve with low value of R falls very sharply. Resonance in this case is said to be sharper than the curve with a larger R.

For both LCR circuit, resonant frequency is

$$\omega_r = \frac{1}{\sqrt{L_1C_1}} = \frac{1}{\sqrt{L_2C_2}}$$

$$\Rightarrow \qquad L_1 C_1 = L_2 C_2$$