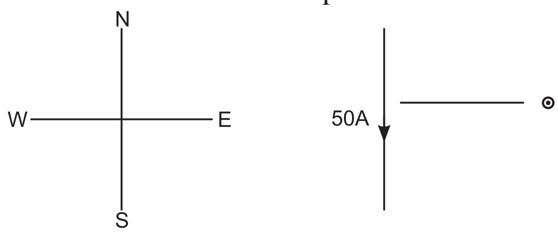
# Answers to RPH–DS1/Set-3

1. (*a*) Excess of electrons will increase the mass of the neutral body, when it is negatively charged.
2. (*d*) $V = kp/r^2$
3. (*d*)
4. (*c*) More intense is the beam, more will be the number of photons in it, hence more will be the number of liberated photoelectrons.
5. (*a*) 


$$B = \frac{\mu_0 i}{2\pi r} = 4 \times 10^{-6}\ T$$

6. (*c*) As $i = ne$; $B = \frac{\mu_0 ne}{2R} \otimes$
7. (*a*)
8. (*a*) The minimum potential required to accelerate a bombarding electron to provoke excitation from the ground state is called the resonance potential.
9. (*b*) The wire AO will be out of the circuit due to balancing Wheatstone bridge.

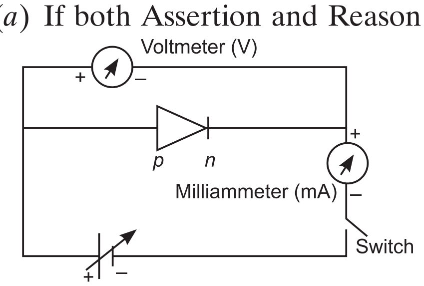
$$\therefore \frac{1}{R_{eff}} = \frac{1}{2R} + \frac{1}{R} = \frac{1+1+2}{2R} \quad \therefore R_{eff} = R/2$$

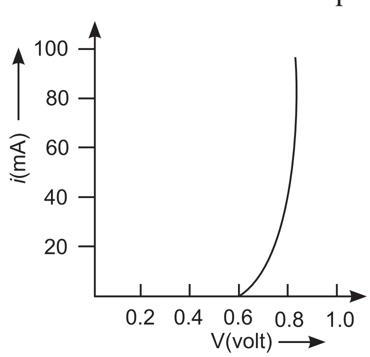
10. (*b*)
11. (*c*) $\phi = 10\,t^2 + 5t + 1$ mWb.

$$|e| = \frac{d\phi}{dt} = 20\text{ t} + 5,$$

At $t = 5$ sec

$|e| = 20 \times 5 + 5 = 105$ milli volt $= 0.105$ V

12. (*c*)
13. (*c*) If Assertion is true but Reason is false.
14. (*b*) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.
15. (*a*) If both Assertion and Reason are true and Reason is correct explanation of Assertion.
16. (*a*) If both Assertion and Reason are true and Reason is correct explanation of Assertion.
17. 



**Forward bias**

**Explanation:** The battery is connected to the silicon diode through a potentiometer (or rheostat), so that the applied voltage can be changed. For different values of voltages, the value of current is noted. In forward bias the current increases at a negligibly slow rate till the voltage, across the diode reaches the threshold voltage. After this the current increases significantly even for a very small voltage (This threshold voltage is –0.2 V for Ge and –0.7 V for Si diode).

**18.** $\because$ $$\lambda_\alpha = \frac{h}{\sqrt{2m_\alpha q_\alpha V}}$$

and $$\lambda_p = \frac{h}{\sqrt{2m_p q_p V}}$$

$\because$ $$m_\alpha = 4m_p$$

$$q_\alpha = 4q_p$$

$\because$ $$q_p = e$$

$$q_\alpha = 4e$$

$\therefore$ $$\frac{\lambda_\alpha}{\lambda_p} = \sqrt{\frac{m_p \,.\, e}{4m_p \,.\, 2e}} = \frac{1}{2\sqrt{2}}$$

**19.** $A = 60°$, R.I. $= n_g = 1.6$; $\delta_m = ?$ , $n_m = \frac{4\sqrt{2}}{5}$

$\because$ $${}_m n_g = \frac{n_g}{n_m} = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}} = \frac{\sin\left(\frac{60°+\delta_m}{2}\right)}{\sin\frac{60°}{2}}$$

$$\frac{1.6}{4\sqrt{2}/5} = \frac{\sin\left(\frac{60°+\delta_m}{2}\right)}{\sin 30°} \qquad \left[\because \sin 30° = \tfrac{1}{2}\right]$$

$\therefore$ $$\sin\left(\frac{60°+\delta_m}{2}\right) = \frac{1.6\times 5}{4\sqrt{2}} \times \frac{1}{2} = \frac{1}{\sqrt{2}} = \sin 45°$$

$\therefore$ $$\frac{60°+\delta_m}{2} = 45° \Rightarrow \delta_m = 30°$$

**20.** In case I, $V = IR$, where $R = \frac{\rho l}{A}$

In case II, $V' = I{\cdot}R'$, where $R' = \frac{\rho\cdot(2l)}{\frac{A}{2}}$

$$R' = 4R$$

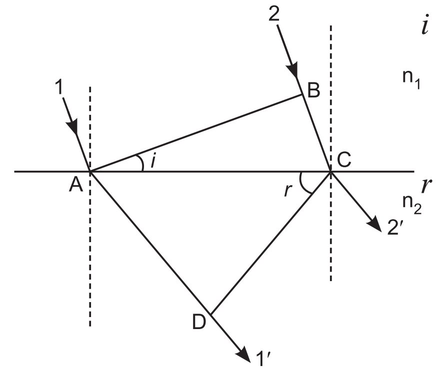
$\therefore$ $$V' = I(4R) = 4V$$

Potential difference should be increased to four times $V$.

**21. Verification of Snell's law of Refraction:**

Let $AB$ is a plane wavefront incident at an angle in denser medium of refractive index $n_2$.

When part of wavefront spreads from $B$ to $C$ with speed $v_2$ in time $t$; then from $A$ it moves to $D$ with speed $v_1$ in rarer medium of refractive index $n_1$. If is the angle by which refracted wavefront bend then




$$= \frac{\sin i}{\sin r} = \frac{BC}{AC} \times \frac{AC}{AD} = \frac{v_2\tau}{v_1\tau}$$

$$= \frac{v_2}{v_1} = \text{constant} = n_{12}$$

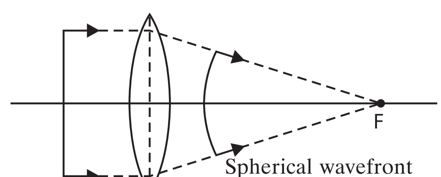
Refractive index of medium 1 w.r.t. 2, $n_{12}$.

$\therefore \quad n_{12} = \frac{v_2}{v_1} = \frac{\sin i}{\sin r}$ [Snell's law]

***Or***

**Wavefront** is a locus of points oscillating in the same phase.

**Huygen's principle:** Each point of a wavefront is the source of a secondary disturbance and the spherical wavelets emanating from these points spread out in all directions with the speed of the wave. The position of wavefront at any later time is given by a common tangential wavefront on the wavelets in forward direction.




Plane wavefront

**22.** (*a*) **Nuclear Fission:** It is a process in which a heavy nucleus splits up into two lighter nuclei of nearly equal masses. It is found that the sum of the masses of the product nuclei and particles is less than the sum of the masses of the reactants, i.e. there is some mass defect. This mass defect appears as energy. One such fission reaction is given below.

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3^{1}_{0}n + Q$$

The $Q$ value of the above reaction is about 200 MeV. The sum of the masses of $^{141}_{56}Ba$, $^{92}_{36}Kr$ and 3 neutrons is less than the sum of the masses of $^{235}_{92}U$ and one neutron.

(*b*) **Nuclear Fusion** : It is the process in which two lighter nuclei combine together to form a heavy nucleus. For fusion, a very high temperature of the order of $10^7$K is required. One such fusion reaction is given below.

$$^{3}_{2}He + ^{3}_{2}He \longrightarrow ^{4}_{2}He + 2^{1}_{1}H + Q$$

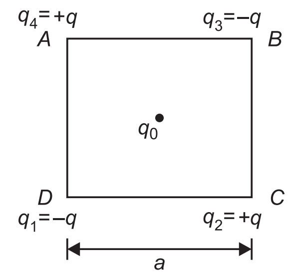
The $Q$ value of this nuclear reaction is 12.9 MeV. It is the energy equivalent of the mass defect in the above reaction.

The energy released per fusion is much less than in fission but the energy released per unit mass is much greater than that released in fission.

**23.** (*a*) We know that work done is equal to change in potential energy of the system.

$W = U - U_\infty = U - 0$

Given: $r = a$, for $AB = BC = CD = AD$




Where $U = \frac{kq_1q_2}{a} + \frac{q_2q_3}{a} + \frac{kq_3q_4}{a} + \frac{kq_4q_1}{a} + \frac{kq_1q_3}{a\sqrt{2}} + \frac{kq_2q_4}{a\sqrt{2}}$

$r = a\sqrt{2}$ for $DB = AC$

$$W = -\frac{4kq^2}{a} + \frac{kq^2}{a\sqrt{2}} + \frac{kq^2}{a\sqrt{2}}$$

$$W = +\frac{kq^2}{a}[\sqrt{2} - 4]$$

$$W = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{a}[\sqrt{2} - 4] = -\frac{1}{4\pi\varepsilon_0}\frac{q^2}{a}(2.59)$$

(*b*) Potential at the centre of the square, is given by

$V = V_A + V_B + V_C + V_D$

$V = 0$ $\quad(\because\ V_A = -V_B = V_C = -V_D)$

$\therefore \quad W = q_0 \times V = 0$

**24.** (*a*) The energy $E$ of a photon of wavelength $\lambda$ is given by

$$E = \frac{hc}{\lambda} \quad \text{where,} \quad h = \text{Planck's constant.}$$

Given: $\lambda = 275\text{ nm} = 275 \times 10^{-9}\text{ m.}$

$$\therefore \quad E = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{275 \times 10^{-9}}\text{ J} = \frac{19.878 \times 10^{-26}}{275 \times 10^{-9} \times 1.6 \times 10^{-19}}\text{ eV} = 4.5\text{ eV.}$$

From the figure, change in energy in transition $B$

$= 0 - (-4.5) = 4.5$ eV.

Therefore, a photon of wavelength 275 nm is emitted in the transition '*B*' only.

(*b*) Again, energy of photon is

$$E = \frac{hc}{\lambda} \quad \text{or} \quad \lambda \propto \frac{1}{E}$$

(*i*) for transition $A$, $\Delta E = 0 - (-2) = 2$ eV,

(*ii*) for transition $D$, $\Delta E = 0 - (-10) = 10$ eV.

Hence, the transition corresponds to the emission of radiation

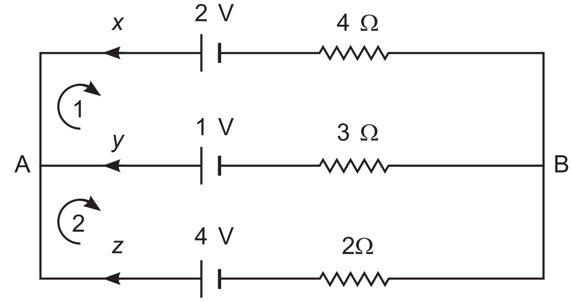
(*i*) for maximum wavelength and minimum energy → transition '*A*'

(*ii*) for minimum wavelength and maximum energy → transition '*D*'

**25.** (*a*) **Kirchhoff's Rules:**

- **Junction rule:** At any junction, the sum of the currents entering the junction is equal to the sum of currents leaving the junction. Junction rule obeys the law of conservation of charge, as at any junction, there is no accumulation of charge.

- **Loop rule:** The algebraic sum of changes in potential around any closed loop involving resistors and cells in the loop is zero. Loop rule obeys the law of conservation of energy. At any instant of time, the total energy supplied by cells is equal to the total energy consumed by resistors.




(*b*) Let us make an alternate circuit.

where $x = -I_1, y = -I_2$ and $z = I_3$

At junction $A$, $x + y + z = 0$

$$\Rightarrow \quad z = -(x+y) \quad ...(i)$$

Taking mesh (1)

$$3y - 4x = -1 \quad ...(ii)$$

Taking mesh (2)

$$2z - 3y = 3 \quad ....(iii)$$

or $\quad -2x - 2y - 3y = 3 \Rightarrow -2x - 5y = 3$

or $\quad 2x + 5y = -3$

or $\quad 4x + 10y = -6 \quad ...(iv)$

Adding (*ii*) and (*iv*)

$$3y - 4x + 4x + 10y = -1 - 6 \Rightarrow 13y = -7 \Rightarrow y = \frac{-7}{13}$$

$$I_2 = -y = \frac{7}{13} \text{ A}$$

From equation (*iii*), we get

$$2z - 3 \times -\frac{7}{13} = 3 \Rightarrow 2z = 3 - \frac{21}{13} \Rightarrow z = \frac{18}{13 \times 2} = \frac{9}{13}$$

$$I_3 = z = \frac{9}{13} \text{ A}$$

From equation (*ii*), we get

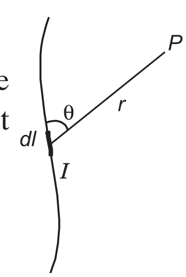
$$3 \times \frac{-7}{13} - 4x = -1 \Rightarrow -21 - 52x = -13 \Rightarrow x = \frac{-8}{52}$$

$$I_1 = -x = \frac{8}{52} \text{ A}$$

Hence, 4 V cell and 1V cell are given out currents while current goes to 2V cell.

**26.** (*a*) Biot-Savart's law states that the magnitude of the magnetic field $dB$ at any point due to a small current element $dl$ is given by

$$dB = \frac{\mu_0}{4\pi} \frac{I\, dl \sin\theta}{r^2}$$



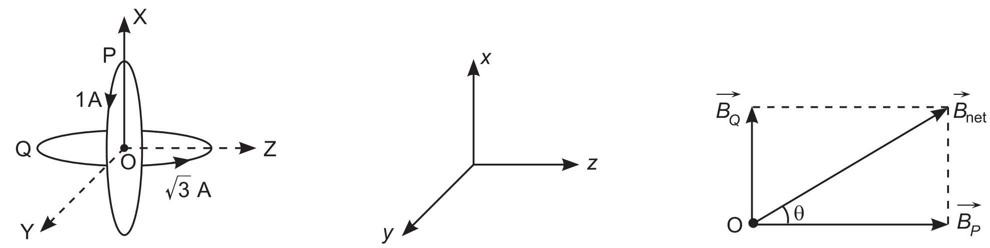

where $I$ is the magnitude of current, $dl$ is the length of element, θ is the angle between the length of element and the line joining the element to the point of observation, and $r$ is the distance of the point from the element.

In vector notation, $\vec{dB} = \dfrac{\mu_0}{4\pi} \dfrac{I(\vec{dl} \times \vec{r})}{r^3}$

Its SI unit is tesla. Its direction is perpendicular to the plane in which $d\vec{l}$ and $\vec{r}$ lie.

Since, $\overrightarrow{dB} \propto I(\overrightarrow{dl} \times \hat{r})$, $dB$ is in the direction given by $(dl\,\hat{k} \times r\hat{j})$, i.e. $-dlr\hat{i}$, i.e. along the negative $x$-axis.

(*b*)




**At centre *O***

$$\text{Magnetic field due to coil, } P = \overrightarrow{B_P} = \frac{\mu_o I}{2r}\hat{k}$$

$$\overrightarrow{B_P} = \frac{4\pi \times 10^{-7} \times 1}{2r}\hat{k}$$

$$\text{Magnetic field due to coil, } Q = \overrightarrow{B_Q} = \frac{4\pi \times 10^{-7} \times \sqrt{3}}{2R}\hat{i}$$

$$\therefore \quad \vec{B}_{\text{net}} = \overrightarrow{B_P} + \overrightarrow{B_Q}$$

$$= \frac{4\pi \times 10^{-7}}{2R}[\hat{k} + \sqrt{3}\,\hat{i}]$$

$$\therefore \quad |\vec{B}_{\text{net}}| = \frac{4\pi \times 10^{-7}}{2R}\sqrt{1+3} = \frac{4\pi \times 10^{-7}}{R}\text{ T}$$

**Direction of $\vec{B}_{\text{net}}$** $\quad \theta = \tan^{-1}\left(\frac{B_Q}{B_P}\right) = \tan^{-1}(\sqrt{3}) = \frac{\pi}{6}$ rad w.r.t. $z$-axis.

**27.** $\gamma$-rays < X-rays < Microwaves < Radio waves.

Infrared radiations are emitted by hot bodies. They have the wavelength ranging from $8 \times 10^{-7}$ m to $5 \times 10^{-3}$ m and the frequency range of $4 \times 10^{14}$ Hz to $6 \times 10^{10}$ Hz. These rays show the properties of reflection, diffraction and penetration through fog. They also have heating effect on thermopiles and bolometers. They are used in greenhouses to keep plants warm and help to improve visibility in haze, fog or mist. The infrared lamps are used in physiotherapy, to provide heat treatment to muscles.

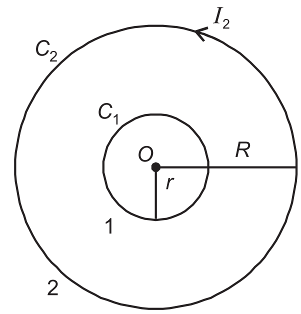
**28.** (*a*) Mutual inductance between two long coaxial solenoids is defined as the magnetic flux linked to the second coil when unit current is flowing in the first coil.

It is the phenomenon by virtue of which a coil resists any change in the strength of current in its neighbouring coil.

(*b*) Let $I_2$ current flow in the second coil of radius $R$. The magnetic field at its centre will be

$$B_2 = \frac{\mu_0 I_2}{2R} \qquad \begin{pmatrix} r_1 = r \\ r_2 = R \end{pmatrix}$$

As $r << R$, the magnetic field $B_2$ is almost constant over the first coil of radius $r$. Hence the magnetic flux linked with the small coil will be




$$\phi_1 = B_2 A_1 = \frac{\mu_o I_2}{2R}.\pi r^2$$

Also by definitions $\phi_1 = MI_2$

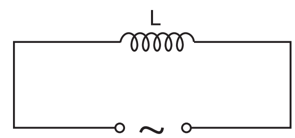
$$\therefore \quad MI_2 = \frac{\mu_o I_2}{2R}\pi r^2$$

$$\therefore \quad M = \frac{\mu_o \pi r^2}{2R}$$

***Or***

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

Due to self induction a back emf is set up in the coil of magnitude $L\frac{di}{dt}$. The net emf thus will be $V_0 \sin \omega t - L\frac{di}{dt}$, which should be equal to zero as there is no resistnace in an ideal inductance.




$$V_0 \sin \omega t - L\frac{di}{dt} = 0$$

$$L\frac{di}{dt} = V_0 \sin \omega t$$

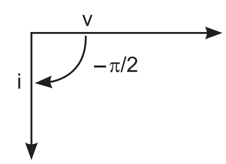
or $$\frac{di}{dt} = \frac{V_0}{L} \sin \omega t$$

or $$di = \frac{V_0}{L} \sin \omega t dt$$

Integrating on both sides

$$i = -\frac{V_0}{\omega L} \cos \omega t$$

or $$i = i_0 \sin(\omega t - \pi/2),$$




where, $i_0 = \frac{V_0}{\omega L}$ is the peak value of current.

We see that in a pure inductor the current lags behind the voltage by $\pi/2$ phase difference. Showing in phasor diagram.

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

***Or***

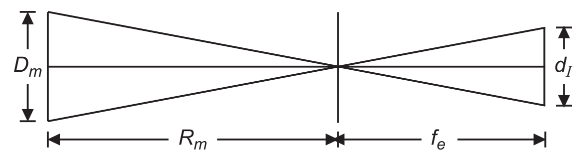
(*iii*) (*d*)
(*iv*) (*a*)

**30.** (*i*) (*c*)
(*ii*) (*d*)
(*iii*) (*c*)

***Or***

(*iii*) (*a*)
(*iv*) (*a*)

**31.** (*a*) Given: $f_o = 15$ m, $f_e = 1$ cm $= 10^{-2}$ m




Angular magnification, $m = \dfrac{f_o}{f_e}$

Substituting the values, $m = \dfrac{15}{10^{-2}} = 1500$

$D_m$ = Diameter of moon's $= 3.48 \times 10^6$ m,

$R_m$ = Radius of moon orbit $= 3.8 \times 10^8$ m

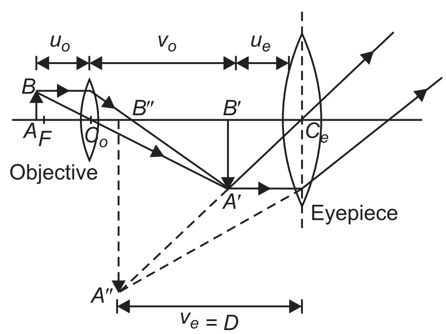
Angular size of the moon $= \dfrac{D_m}{R_m} = \dfrac{3.48 \times 10^6}{3.8 \times 10^8}$ radian

Angular size of the final image = Angular size of the moon × $m$

$$= \frac{3.48}{3.8} \times 10^{-2} \times 1500 = \frac{3.48}{3.8} \times 15$$

$$\therefore \quad \frac{d_I}{f_e} = \frac{3.48}{3.8} \times 15 \Rightarrow d_I = \frac{3.48}{3.8} \times 15 \times 1 \text{ cm} = 13.7 \text{ cm}$$

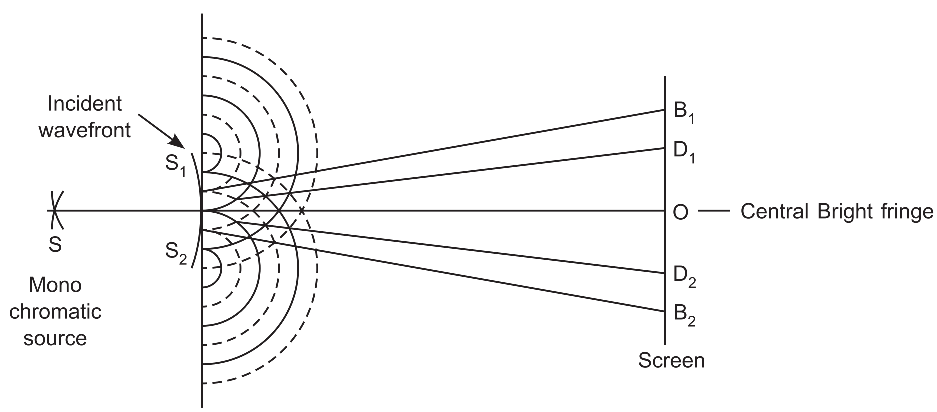
(*b*)




**A compound microscope**

***Or***

(*a*)




Suppose $S_1$ and $S_2$ are two slits on which falls an incident wave front as shown in the diagram originating from monochromatic source $S$. On right side of $S_1$ and $S_2$ are shown crests and troughs of two coherent waveless coming out of $S_1$ and $S_2$. Solid arcs represent crests and dotted ones the troughs. At point $O$ on the screen there will be central bright fringe as crest-crest and trough-troughs meet. Similarly at points $D_1$ and $D_2$ crests and troughs are meeting and dark fringes are obtained. Again at points $B_1$ and $B_2$ the superposition constructive, so they are bright points. This pattern of dark and bright fringes continues on both sides of the central point $O$. The width of these fringes depend on the wavelength of monochromatic light and distance between $S_1$, $S_2$ and screen directly and on the separation of $S_1$ and $S_2$ inversely.

(*b*) (*i*) We know that fringe width, $\beta = \frac{\lambda D}{2d}$

Given that: $\lambda = 6.5 \times 10^{-7}$ m, $D = 1.2$ m, $2d = 4 \times 10^{-3}$ m

$$\therefore \quad \beta = \frac{6.5 \times 10^{-7} \times 1.2}{4 \times 10^{-3}} = 1.95 \times 10^{-4} \text{ m}$$

The distance between third bright fringe from the central maximum = $3B$

$$\therefore \quad 3\beta = 5.85 \times 10^{-4} \text{ m}$$

(*ii*) At a point where the bright fringes of both wavelength concide $n\beta = (n + 1)\beta'$ where $\beta$ is the fringe width of larger wavelength

$$\text{or} \quad n\frac{\lambda D}{2d} = (n+1)\frac{\lambda' D}{2d}$$

or $\quad n\lambda = (n + 1)\lambda'$, Substituting the values

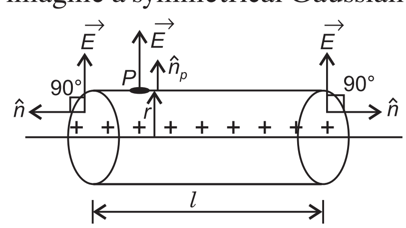
$$n \times 650 = (n + 1)\, 520 = 520n + 520$$

$$\therefore \quad n(130) = 520 \quad \therefore n = 4$$

The least distance from $O$ is $n\beta = 4\beta$

$$= 4 \times 1.95 \times 10^{-4} \text{ m} = 7.8 \times 10^{-4} \text{ m}$$

**32.** Consider a linear charge distribution with charge density $\lambda$. We imagine a symmetrical Gaussian surface around length $l$ of this distribution in such a way that the point $P$ where we have to calculate electric field lies on it.




Electric flux through the circular faces of this Gaussian surface is zero.

$$\phi_s = \int \vec{E} \cdot \vec{ds} = Eds \cos 90° = 0 \qquad (\because \theta = 90°)$$

Electric flux through the curved surface is given by

$$\phi_{cs} = \oint \vec{E} \cdot \vec{ds} = \oint E\, ds$$

$$\phi_{cs} = E\oint ds = E(2\pi rl) \qquad (\because \theta = 0°)$$

Net flux through the Gaussian surface is given by

$$\phi_E = \phi_s + \phi_{cs} = E(2\pi rl) \qquad \ldots(i)$$

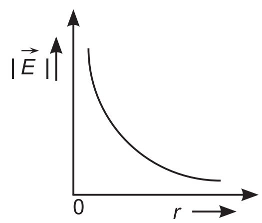
According to the Gauss's theorem

$$\phi_E = \frac{q}{\varepsilon_0} = \frac{\lambda l}{\varepsilon_0} \qquad (\because q = \lambda l) \ldots(ii)$$

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

$$E = \frac{\lambda}{2\pi\varepsilon_0 r} \quad \Rightarrow \quad E \propto \frac{1}{r}$$

$$\vec{E} = \frac{\lambda}{2\pi\varepsilon_0 r} \,.\, \hat{n}$$




**Graph of $|\vec{E}|$ vs r**

Work done in moving a charge '*q*' through a small displacement $\vec{dr}$ is given by

$$dW = \vec{F} \,.\, \vec{dr} = q\vec{E} \,.\, \vec{dr}$$

$$dW = qEdr \cos\theta \; (\theta = 0° \text{ and } \cos 0° = 1)$$

$$dW = q \times \frac{\lambda}{2\pi\varepsilon_0 r} dr$$

$\because$ $$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

Work done in moving the given charge from $r_1$ to $r_2$ ($r_2 > r_1$)

$$W = \int_{r_1}^{r_2} dW = \frac{\lambda q}{2\pi\varepsilon_0} \int_{r_1}^{r_2} \frac{dr}{r}$$

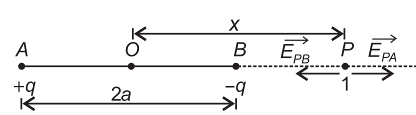
$$W = \frac{\lambda q}{2\pi\varepsilon_0} [\log_e r_2 - \log_e r_1]$$

$$W = \frac{\lambda q}{2\pi\varepsilon_0} \log_e \frac{r_2}{r_1}$$

***Or***

(*a*) **Electric field intensity at a point on the axial line of an electric dipole:** Electric field intensity at a point on the axis of an electric dipole.

Electric field at *P* due to charge at *A*




$$\vec{E}_{PA} = \frac{kq}{(x+a)^2} \hat{i}$$

Electric field at *P* due to charge at *B*

$$\vec{E}_{PB} = -\frac{kq}{(x-a)^2} \hat{i}$$

Net electric field at *P*,

$$\vec{E}_{ar} = \vec{E}_{PA} + \vec{E}_{PB} = kq\left[\frac{1}{(x+a)^2} - \frac{1}{(x-a)^2}\right]$$

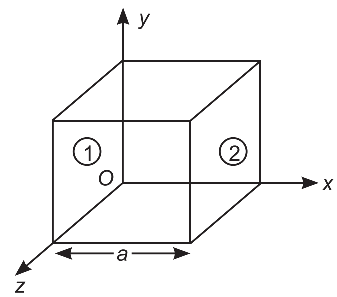
$$\vec{E}_{ar} = kq\left[\frac{x^2 + a^2 - 2xa - x^2 - a^2 - 2xa}{(x^2 - a^2)^2}\right]$$

$$= \frac{2k(q2x)a}{(x^2 - a^2)^2} = \frac{2kpx}{(x^2 - a^2)^2} = \frac{2kx\vec{p}}{(x^2 - a^2)^2}$$

In the limiting case when $x >> a$, $(x^2 - a^2)^2 \simeq x^4$

$$\vec{E}_{ar} = \frac{2\vec{p}}{4\pi\varepsilon_0 x^3}$$

(*b*) As the electric field $\vec{E} = 2x\hat{i}$, it lies only along $x$ axis. Only two faces (1) and(2) of the cube are perpendicular to the direction of $E$, hence contribute to the electric flux.




As $\quad E_1 = 0 \quad (\because x = 0)$

$\therefore \quad \phi_1 = 0$

and $\quad E_2 = 2a$

$$\phi_2 = \int_s 2a\, ds = 2a^3 \quad \left[\because \int_s ds = a^2\right]$$

$\therefore \quad \phi = \phi_1 + \phi_2 = 2a^3$

As $\quad \phi = \dfrac{q}{\varepsilon_0}$

$\therefore \quad q = \varepsilon_0(2a^3)$ will be the charge enclosed by cubical surface.

**33.** (*a*) $\because \quad I_{rms} = \dfrac{V_{rms}}{\sqrt{R^2 + (2\pi\nu L)^2}}$, here $L = \mu_0 n^2 Al$

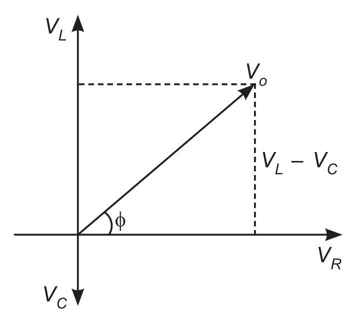
When the iron rod is inserted in a solenoid, the inductance increases according to $L' = \mu_r\mu_0 n^2 Al$, as $\mu_r$ for iron is very large. Therefore, the current in the circuit decreases and bulb will glow dimmer.

(*b*) Given: $V = V_o \sin(1000t + \phi)$, $L = 100$ mH, $C = 2\ \mu$F

$\omega = 1000\ \text{rad s}^{-1}$, $R = 400\ \Omega$

$X_L = \omega L = 1000 \times 100 \times 10^{-3} = 100\ \Omega$

$$X_C = \frac{1}{\omega C} = \frac{1}{1000 \times 2 \times 10^{-6}} = 500\ \Omega$$




(*i*) $V = V_o \sin(1000t + \phi)$

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

or $$\tan\phi = \frac{X_L - X_R}{R} = \frac{100 - 500}{400}$$

$$= \frac{-400}{400} = -1$$

$\therefore \qquad \phi = \dfrac{-\pi}{4}$

$\because X_C > X_L$, $\therefore$ circuit is capacitive in nature and current will lead the voltage by a phase angle of $\pi/4$.

(*ii*) Power factor = 1 when $X_L = X_C'$

$$\therefore \qquad 100 = \frac{1}{\omega(C + C')}$$

$$\Rightarrow \qquad C + C' = \frac{1}{100 \times 1000} = 10\ \mu\text{F}$$

$$\therefore \qquad C' = (10 - 2) = 8\ \mu\text{F}$$

***Or***

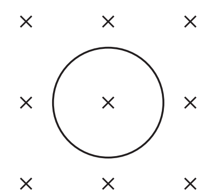
(*a*) **Faraday's law of electromagnetic induction:**

(*i*) Whenever there is a change in the magnetic flux linked with a circuit, an induced emf is set up in it and lasts as long as the magnetic flux linked with it is changing.

(*ii*) The magnitude of the induced emf $\varepsilon$ in a circuit is directly proportional to the rate of change of magnetic flux linked with the circuit.

i.e. $$\varepsilon \propto \frac{-d\phi}{dt}$$

(*b*) Radius $r$ = 12 cm = 0.12 m, Resistance $R$ = 8.5 Ω, $\theta = 0°$



$$A = \pi r^2 = 3.14 \times (0.12)^2 = 0.045\ \text{m}^2$$

Magnetic flux passing through the loop

$$\phi = \text{BA} \cos 0° = \text{BA}$$

$$\therefore \qquad \text{Induced current } i = \frac{-1 d\phi}{R dt} = \frac{-A}{R}\frac{dB}{dt}$$

In time interval, 0 – 2 sec : $\Delta t$ = 2 – 0 = 2 sec

$$\Delta B = 1 - 0 = 1\ \text{T}$$

$$\therefore \qquad i = \frac{-A}{R}\frac{\Delta B}{\Delta t} = \frac{-0.045}{8.5} \times \frac{1}{2}\ \text{A}$$

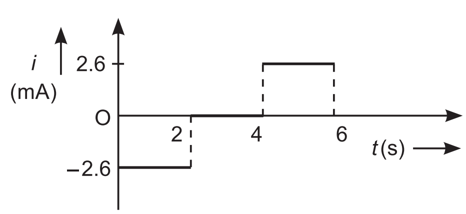
$$i = -2.6 \times 10^{-3}\ \text{A} = -2.6\ \text{mA}$$

From 2 – 4 sec, $\Delta B = 0$;

$\therefore \quad i = 0$

From 4 sec – 6 sec; $\Delta B$ = (0 – 1)T = –1 T; $\Delta t$ = 6 – 4 = 2 s

$$\therefore \qquad i = \frac{-0.045}{8.5} \times \left(\frac{-1}{2}\right) = 2.6 \times 10^{-3}\ \text{A} = 2.6\ \text{mA}$$



(*c*) Lenz's law complies with the principle of conservation of energy. For example, when the N-pole of a bar magnet is pushed into a coil as shown, the direction of induced current in the coil will be such that the end 2 of the coil will act as N-pole. Thus, work has to be done against the magnetic repulsive force to push the magnet into the coil. The electrical energy produced in the coil is at the expense of this work done.