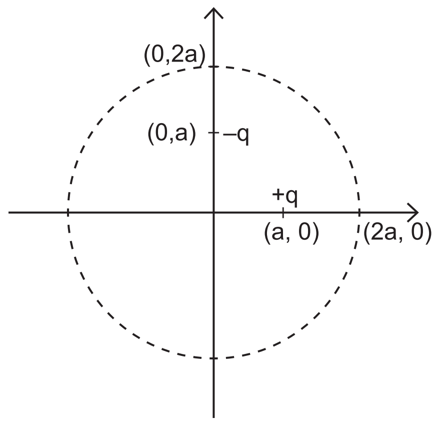
# Answers to RPH–DS2/Set-2

**1.** (*c*) The work done is zero because the force on the unit positive charge is along the radius and the velocity is tangential to the circular path i.e., force and motion are perpendicular to each other.

**2.** (*a*) As the net charge enclosed by the spherical surface is zero, therefore by Gauss's, theorem

$$\phi = \frac{q}{\varepsilon_0} = 0$$




**3.** (*d*) **4.** (*b*) **5.** (*d*) **6.** (*b*) **7.** (*a*)

**8.** (*b*) According to Ampere's circuital law,

$$\oint \vec{B}.d\vec{l} = \mu_0 \Sigma I$$
$$= \mu_0(I_1 + I_2 + I_3 + I_4 + I_5)$$
$$= \mu_0(1 + 2 + 3 - 1 - 4)$$
$$= \mu_0 \text{ Wb/m}$$

**9.** (*a*) When iron rod is inserted, the inductance of the coil increases

Here, $I = \left(\frac{V}{X_L}\right)$

If $X_L$ increases, current decreases and hence bulb will glow less brightly.

**10.** (*c*) The frequency of electromagnetic wave is same as that of oscillating charge particle.

**11.** (*c*)

$$\phi = \frac{1}{2}(16 - t^2)$$

For zero flux, $\frac{1}{2}(16 - t^2) = 0$

or $t = 4s$

New induced emf,

$$\varepsilon = \frac{-d\phi}{dt} = -\frac{1}{2}(-2t) = t$$

At $t = 4$ s, $\varepsilon = 4$ V

**12.** (*b*) Negative sign shows that electron is bound to the nucleus.

**13.** (*d*) If both Assertion and Reason are false.

**14.** (*b*) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

**15.** (*c*) If Assertion is true but Reason is false.

**16.** (*a*) If both Assertion and Reason are true and Reason is the correct explanation of Assertion.

**17.** Given, $V = V_0 \sin \omega t$

It means that given input is AC and diode D will conduct only when it is in forward bias.

$\therefore$ Output across $R_L$, $$V_{av} = \frac{V_0}{\pi} \qquad \ldots(i)$$

and average current, $$I_{av} = \frac{V_{av}}{R}$$

Here $$R = R_s + R_L$$

$\therefore$ $$I_{av} = \frac{V_{av}}{R_S + R_L}$$

$$= \frac{V_0}{\pi(R_S + R_L)} \qquad \text{[From equation } (i)\text{]}$$

$\therefore$ Voltage across $R_L$, $$V_{R_L} = I_{av} R_L$$

$$V_L = \frac{V_0 R_L}{(R_S + R_L)\pi}$$

**18.** From Einstein's photoelectric equation,

$$K_{max} = h\nu - \phi_0$$

For Ist case,

$$E = \frac{hc}{\lambda} - \phi_0 \qquad \ldots(i)$$

Let to double the energy, the wavelength is $\lambda'$.
For 2nd case,

$$2E = \frac{hc}{\lambda'} - \phi_0 \qquad \ldots(ii)$$

Subtracting equation (*i*) from equation (*ii*), we get

$$2E - E = \left[\frac{hc}{\lambda'} - \phi_0\right] - \left[\frac{hc}{\lambda} - \phi_0\right]$$

$$E = \frac{hc}{\lambda'} - \frac{hc}{\lambda}$$

or $$\frac{hc}{\lambda'} = E + \frac{hc}{\lambda}$$

or $$\frac{hc}{\lambda'} = \frac{E\lambda + hc}{\lambda}$$

or $$\boxed{\lambda' = \frac{hc\lambda}{\lambda E + hc}}$$

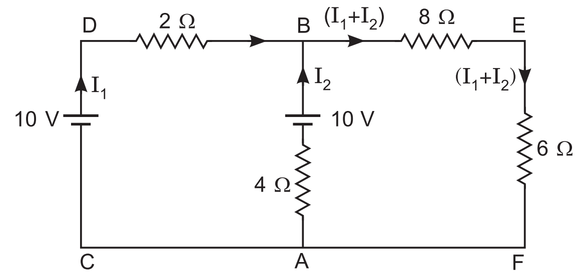
**19.** **Wavefront:** It is defined as the continuous locus of all the particles of the medium which vibrate in the same phase at any instant.

**Huygen's principle:** It states that

(*i*) Each point on a wavefront acts as a fresh source of new disturbance, called secondary waves or wavelets.

(*ii*) The new wavefront at any later time is given by the forward envelope of the secondary wavelets at that time.

**20.** 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 $$7I_1 + 9I_2 = 5$$

$$\underline{- \quad + \quad -}$$

$$-23I_2 = -5$$

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

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

**21.** For convex lens: $f_1 = 10$ cm, u = – 15 cm

Using, $$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\frac{1}{10} = \frac{1}{v} - \frac{1}{-15}$$

or $$\frac{1}{v} = \frac{1}{10} - \frac{1}{15}$$

$$= \frac{3-2}{30} = \frac{1}{30}$$

$$v = 30 \text{ cm}$$

For concave lens: $u = 30 - 5 = 25$ cm, $f_2 = -10$ cm

Using, $$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

or $$\frac{1}{-10} = \frac{1}{v} - \frac{1}{25}$$

or $$\frac{1}{v} = \frac{1}{25} - \frac{1}{10} = \frac{2-5}{50} = \frac{-3}{50}$$

or $$v = \frac{-50}{3} = -16.67 \text{ cm}$$

***Or***

We know that the resultant amplitude,

$$a = \sqrt{a_1^2 + a_2^2 + 2a_1 a_2 \cos\phi}$$

where $\phi$ is the phase difference

$\because$ Intensity $$I \propto a^2$$

or $$I = Ka^2$$

$\therefore$ $$I = K(a_1^2 + a_2^2 + 2a_1 a_2 \cos\phi)$$

For maximum intensity, $$\phi = 0$$

$\therefore$ $$I_{max} = K(a_1 + a_2)^2$$

For minimum intensity, $$\phi = -1$$

$\therefore$ $$I_{min} = K(a_1 - a_2)^2$$

$\therefore$ $$\frac{I_{max}}{I_{min}} = \left(\frac{a_1 + a_2}{a_1 - a_2}\right)^2$$

**22.** (*a*) We know that an $\alpha$–particle contains 2 protons and 2 neutrons.

$\therefore$ Mass of 2 protons = $2 \times 1.007825 = 2.015650$ amu

Mass of 2 neutrons = $2 \times 1.008665 = 2.017330$ amu

Total mass = $2.015650 + 2.017330 = 4.032980$ amu

But Mass of He nucleus = 4.002800 amu

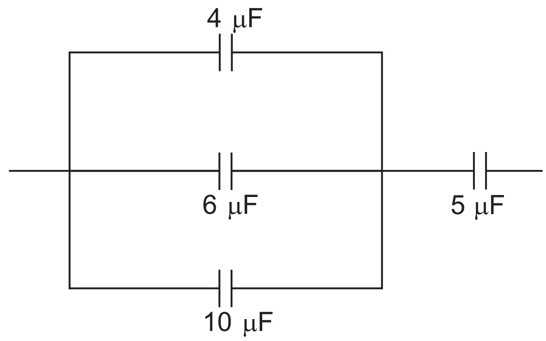
$\therefore$ Mass defect, $\Delta m = 4.032980 - 4.002800 = 0.030180$ amu

$\therefore$ B.E. of $\alpha$-particle = $0.030180 \times 931 = 28.097$ MeV

(*b*) Both the given elements ${}_5^7X$ and ${}_5^9X$ have same atomic number therefore they are both isotopes.

Isotope ${}_5^7X$ has 5 protons and 2 neutrons whereas isotope ${}_5^9Y$ has 5 protons and 4 neutrons. Due to the presence of a greater number of neutrons in ${}_5^9Y$, the strong attractive nuclear force dominates over the electrostatic repulsion between the protons. So, ${}_5^9Y$ is more stable than ${}_5^7X$.

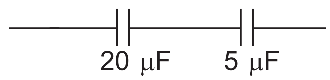
**23.** Equivalent circuit is shown below.




The capacitance of the combination of 4 μF, 6 μF and 10 μF is

$$C' = 4 + 6 + 10 = 20\ \mu F$$

Now,




Equivalent capacitance, $C = \frac{20 \times 5}{20 + 5} = \frac{100}{25} = 4\ \mu F$

Energy stored in the combination is

$$U = \frac{1}{2}\ CV^2$$

$$= \frac{1}{2} \times 4 \times 10^{-6}\ (6)^2$$

$$= 72 \times 10^{-6}\ J$$

**24.** (*a*) (*i*) Such transition will result in Paschen series, when transition takes place from energy orbit, $n_2 = 4, 5, 6$ ..... to $n_1 = 3$.

(*ii*) The transition will result in Brackett series, when transition takes place from energy orbit, $n_2 = 5, 6,....$ to $n_1 = 4$.

(*ii*) For longest wavelength of Paschen series, $n_2 = 4$ and $n_1 = 3$

$$\frac{1}{\lambda_{P_L}} = R\left[\frac{1}{3^2} - \frac{1}{4^2}\right] = \frac{7R}{144}$$

For shortest wavelength of Brackett series, $n_2 = \infty, n_1 = 4$

$$\therefore \qquad \frac{1}{\lambda_{B_S}} = R\left[\frac{1}{4^2} - \frac{1}{\infty^2}\right] = \frac{R}{16}$$

$$\therefore \qquad \frac{\lambda_{P_L}}{\lambda_{B_S}} = \frac{\frac{144}{7R}}{\frac{16}{R}} = \frac{9}{7}$$

$\therefore$ Ratio = 9 : 7

**25.** Given, Length of wire, $l = 1$ m

Current in wire, $I = 1$ A

Cross-sectional area of wire, $A = 2.0\ mm^2 = 2 \times 10^{-6}\ m^2$

Resistivity, $\rho = 1.7 \times 10^{-8}\ \Omega m$

Using, $F = eE$

$\because \quad E = \dfrac{V}{l}$ [$V$ is potential difference]

Also $V = IR$

$$\therefore \quad F = e\left(\frac{IR}{l}\right)$$

$$= e\left[\frac{I}{l}\rho\frac{l}{A}\right] \qquad \left[\because\ R = \rho\frac{l}{A}\right]$$

$$F = \frac{eI\rho}{A}$$

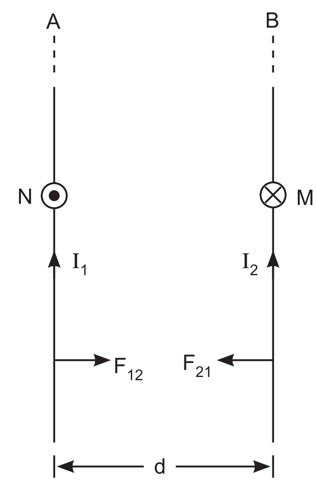
Now putting the values,

$$F = \frac{1.6 \times 10^{-19} \times 1 \times 1.7 \times 10^{-8}}{2 \times 10^{-6}}$$

$$= 8 \times 1.7 \times 10^{-22}$$

$$= 13.6 \times 10^{-22} = 1.36 \times 10^{-21}\ \text{N}$$

**26.** Consider two long current carrying wires carrying current $I_1$ and $I_2$ in the same direction and separated by a distance '$d$'.




Magnetic field at 'M' due to wire 'A',

$$B_1 = \frac{\mu_0 I_1}{2\pi d}$$

Due to this magnetic field, wire 'B' carrying current $I_2$ experiences a force, which is given by

$$F_{21} = I_2 B_1 l$$

[where '$l$' is the length at which force is acting]

$$= \frac{\mu_0 I_1 I_2 l}{2\pi d}$$

Force per unit length, $f = \dfrac{F_{21}}{l} = \dfrac{\mu_0 I_1 I_2}{2\pi d}$

If $I_1 = I_2 = 1$ A and $r = 1$ m, we get

$$f = \frac{\mu_0}{2\pi} = 2 \times 10^{-7}\ \text{Nm}^{-1}$$

Therefore one ampere is defined as that value of steady current, which on flowing in each of the two parallel infinitely long conductors of negligible cross-section placed in vacuum separated by distance of 1 m, produces a force of $2 \times 10^{-7}$ Newton per meter between them.

**27.** (*a*) Microwave is suitable for radar system.

Frequency range : $3 \times 10^{11}$ Hz to $10^{10}$ Hz

(*b*) Infrared radiation is used in muscular treatment.

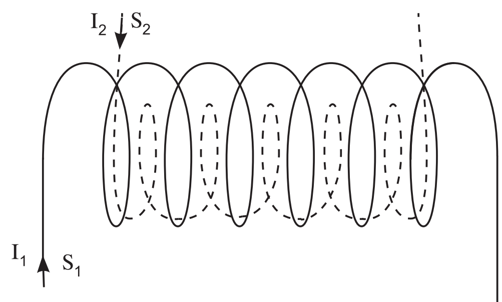
Frequency range: $4 \times 10^{14}$ Hz to $3 \times 10^{11}$ Hz

(*c*) X-rays are used as diagnostic tool in medicine

Frequency range: $3 \times 10^{18}$ Hz to $3 \times 10^{16}$ Hz

**28.** **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

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

$\therefore$ 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***

(*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 mH.

(*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.

**29.** (*i*) (*a*)

(*ii*) (*c*)

(*iii*) (*c*)

(*iv*) (*d*)

***Or***

(*iv*) (*d*)

**30.** (*i*) (*d*)

(*ii*) (*c*)

(*iii*) (*c*)

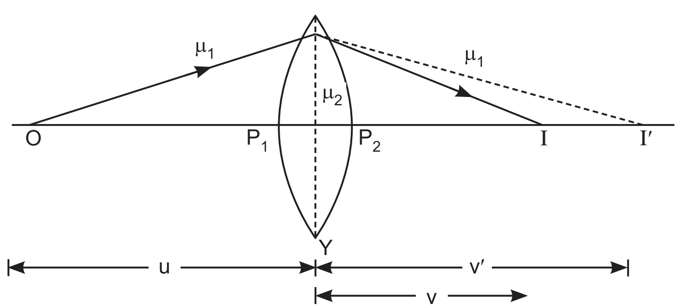
(*iv*) (*d*)

***Or***

(*iv*) (*a*) $\sin\theta = \frac{\lambda}{a} = \frac{500 \times 10^{-9}}{1 \times 10^{-6}} = 500 \times 10^{-3} = 0.5 = \frac{1}{2}$

∴ $\theta = 30°$

**31.** (*a*)




For refraction through $XP_1Y$ surface,

$$\frac{\mu_2}{v'} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R_1} \qquad ...(i)$$

For refraction through $XP_2Y$ surface,

$$\frac{\mu_1}{v} - \frac{\mu_2}{v'} = \frac{\mu_1 - \mu_2}{R_2} \qquad ...(ii)$$

Adding equation (*i*) and (*ii*), we get

$$\frac{\mu_1}{v} - \frac{\mu_1}{u} = (\mu_2 - \mu_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

or $$\frac{1}{v} - \frac{1}{u} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Taking $$\frac{\mu_2}{\mu_1} = \mu$$

$\therefore$ $$\frac{1}{v} - \frac{1}{u} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Had the object been at infinite the image would have formed at focus '*f*'.

*i.e., if* $u = \infty, \quad f = v$

$\therefore$ $$\boxed{\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$$

This is known as lens maker's formula.

(*b*) Using

$$\frac{1}{f_l} = \left(\frac{\mu_g}{\mu_l} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Given that $\mu_g < \mu_l$

$\Rightarrow$ $\frac{\mu_g}{\mu_l} - 1 < 0$

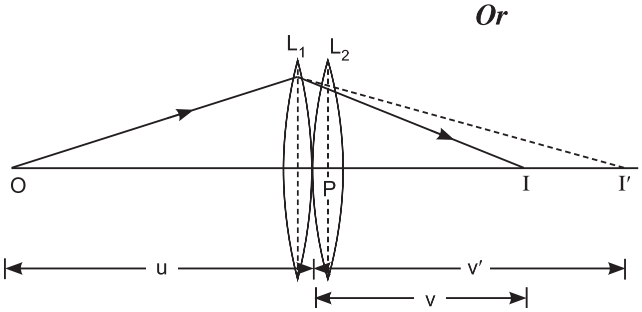
or $\mu_g < \mu_l$

$\Rightarrow$ $\frac{1}{f} = -(\text{ve})$ value

Therefore, the lens acts as a concave lens.

***Or***

(*a*)




For lens $L_1$, we have

$$\frac{1}{v'} - \frac{1}{u} = \frac{1}{f_1} \quad ...(i)$$

For lens $L_2$, we have

$$\frac{1}{v} - \frac{1}{v'} = \frac{1}{f_2} \quad ...(ii)$$

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

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2} \quad ...(iii)$$

If the combination is replaced by a single lens then the focal length is

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad ...(iv)$$

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

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$f = \frac{f_1 f_2}{f_1 + f_2}$$

(*i*) If lens $L_2$ is concave and $f_1 = -f_2$ then $f = \infty$.
Therefore, the combination will act as a plane mirror.

(*ii*) If lens $L_2$ is concave and $f_2 > f_1$, then $f$ is (–ve).
Therefore, the combination will act as a concave lens.

(*iii*) If lens $L_2$ is concave and $f_1 > f_2$, then $f$ is (+ve).
Therefore, the combination will act as a convex lens.

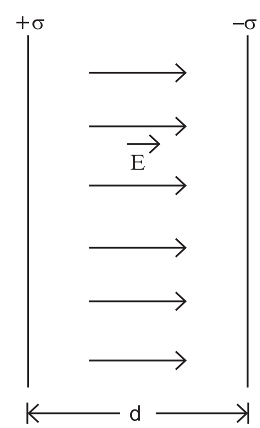
(*b*) The magnifying power of the combination will be

$$m = m_1 \times m_2$$

**32.** (*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,

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

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

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

If C is the capacitance of the capacitor, then

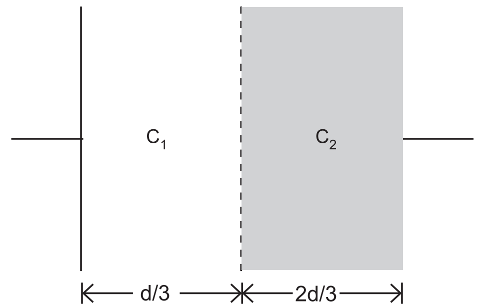
$$C = \frac{Q}{V} = \frac{Q}{\frac{Qd}{A\varepsilon_0}} \quad \text{[Using equation (i)]}$$

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

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

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

When dielectric was inserted as shown then equivalent capacitance,




$$\frac{1}{C'} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$= \frac{\frac{d}{3}}{\varepsilon_0 A} + \frac{\frac{2d}{3}}{K\varepsilon_0 A}$$

$$= \frac{1}{3C_0} + \frac{2}{3KC_0}$$

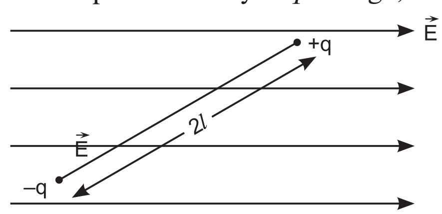
$$= \frac{1}{3C_0}\left[1 + \frac{2}{K}\right] = \frac{1}{3C_0}\left[1 + \frac{2}{K}\right] = \frac{K+2}{3KC_0}$$

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

***Or***

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

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

**33.** (*a*) **Principle:** Transformer works on the principle of mutual induction when a changing current is passed through one of the two inductively coupled coils, an induced emf is set up in the other coil.

(*b*) **Efficiency of a transformer:** It is defined as the ratio of output power to input power consumed by the transformer.

i.e., $$\eta = \frac{\text{Output power}}{\text{Input power}} \times 100\%$$

(*c*) Following are the factors that reduce efficiency of the transformer:

(*i*) Copper loss (*i*) Flux leakage

(*d*) Given: $\varepsilon_1 = 200$ V

$\varepsilon_2 = 20$ V

$R_2 = 20\ \Omega$

$\eta = 80\%$

Here current flowing through secondary,

$$I_2 = \frac{\varepsilon_2}{R_2} = \frac{20}{20} = 1 \text{ A}$$

$$\text{Efficiency} = \frac{\varepsilon_2 I_2}{\varepsilon_1 I_1}$$

or $$\frac{80}{100} = \frac{20\times1}{200\, I_1}$$

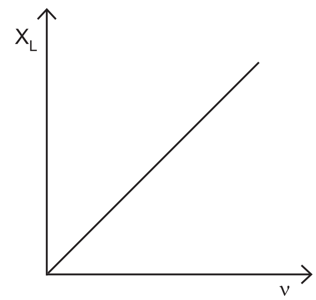
or $$I_1 = \frac{1}{8}$$

$$= 0.125 \text{ A}$$

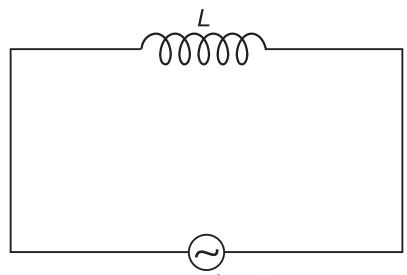
***Or***

**Inductive reactance:** It is defined as the opposition offered by an inductor when an alternating current passes through it.

**Graph for variation of inductive reactance vs frequency:**




AC circuit containing pure inductor




Let in the circuit shown above an a.c. input is given to it.

where $$\varepsilon = \varepsilon_0 \sin \omega t \qquad ...(i)$$

If $I$ is the instantaneous current in circuit then

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

where $L$ is the inductance of the inductor.

Now, by Kirchhoff's 2nd rule,

$$V + \varepsilon = 0$$

or $$V - L\frac{dI}{dt} = 0$$

or $$V = L\frac{dI}{dt}$$

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

Integrating both sides, we get

$$I = \int \frac{V_0}{L}\sin \omega t\, dt$$

$$= \frac{V_0}{L}\left[-\frac{\cos \omega t}{\omega}\right]$$

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

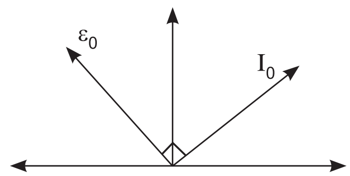
$$= \frac{V_0}{\omega L} \sin\left(\omega t - \frac{\pi}{2}\right) \quad ...(ii)$$

or $$I_0 = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$$

where $$I_0 = -\frac{V_0}{\omega L}, \text{ maximum current in the circuit}$$

On comparing equation (*i*) and (*ii*), we find that the current lags behind the voltage by a phase angle of $\frac{\pi}{2}$.

(*i*) **Phasor diagram**




(*ii*) **Graphs of *V* and *i* vs ω*t***