Answers to RPH/Set-2

1. (*b*) Principle of superposition

2. (*a*) $R = \rho\frac{l}{A}$, $R' = \rho.\frac{nl}{A/n} = n^2R$

3. (*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.

4. (*c*)

5. (*a*)

6. (*a*) Linear width is given by:

$$\beta = \frac{2D\lambda}{d} = \frac{2\times5\times800\times10^{-9}}{5\times10^{-3}}$$
$$= 1600 \times 10^{-6} = 1.6 \times 10^{-3} \text{ m} = 1.6 \text{ mm}$$

7. (*c*)

8. (*d*)

9. (*a*) clockwise

10. (*a*)

11. (*d*) Above A = 55, the value of B.E./Nucleon falls rapidly.

12. (*b*)

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

17. Infrared radiations are emitted by hot bodies. They have the wavelength ranging from 8×10^{-7} m to 5×10^{-3} m and the frequency range of 4×10^{14} Hz to 6×10^{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.

18. 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.

19. We know that
$$\phi' = 4\phi$$
$$\phi = \frac{q_1 + q_2 + q_3}{\varepsilon_0} = \frac{q}{\varepsilon_0}$$
Here $q_1 + q_2 + q_3 = q$

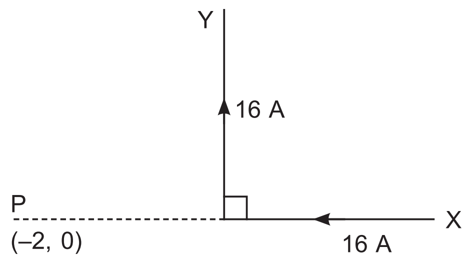
$\therefore$ $$\phi' = \frac{q+Q}{\varepsilon_0}$$

$\therefore$ $$\frac{q+Q}{\varepsilon_0} = 4\left(\frac{q}{\varepsilon_0}\right)$$

$\Rightarrow$ $$Q = 3q$$

20. (I) Given: $I = 16$ A, $r = 2$ mm $= 2 \times 10^{-3}$ m

As the straight wire is bent shown below:



Magnetic field at 'P' due to the wire lying along x-axis is zero.

Using, $$B = \frac{\mu_0 I}{4\pi r}$$
$$= \frac{4\pi \times 10^{-7} \times 16}{4\pi \times 2 \times 10^{-3}}$$
$$= 8 \times 10^{-4} = 0.8 \text{ mT}$$

Or

(II) Given:
$$I = 18 \text{ A}$$
$$R = 1 \text{ cm} = 10^{-2} \text{ m}$$
$$B_1 = 8 \times 10^{-3} \text{ T}$$
$$r = 0.6 \text{ mm} = 0.6 \times 10^{-3} \text{ m}$$
$$\mu_0 = 4\pi \times 10^{-7} \text{ Tm/A}$$

$\therefore$ 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
$$B = \sqrt{B_1^2 + B_2^2}$$
$$= \sqrt{(8 \times 10^{-3})^2 + (6 \times 10^{-3})^2}$$
$$= 10 \times 10^{-3} = 10^{-2} \text{ T}$$

21. (I)

$$B.E. = (2m_P + 2m_n - m_{He})\ u \times 931\ MeV$$
$$= [2(1.007276 + 1.008665) - 4.001508] \times 931$$
$$= [4.031882 - 4.001508] \times 931$$
$$= 0.030374 \times 931 = 28.3\ MeV$$

Or

(II) $\because$ $$\lambda_\alpha = \frac{h}{\sqrt{2m_\alpha q_\alpha V}}$$

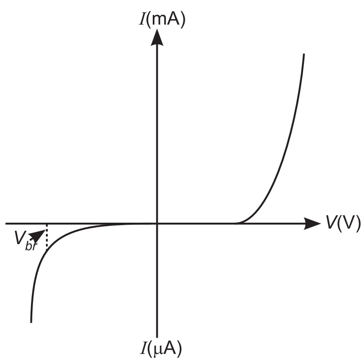
and $$\lambda_p = \frac{h}{\sqrt{2m_p q_p V}}$$

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

$\because$ $$q_p = e$$
$$q_\alpha = 4e$$

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

22. (*a*)



(*b*) When a *p-n* junction is formed, only a limited number of electrons from the n-region flow to the p-region, creating a depletion region. This occurs because, as electrons and holes recombine at the junction, an electric field is generated, which opposes further electron movement, establishing equilibrium and preventing all electrons from flowing across.

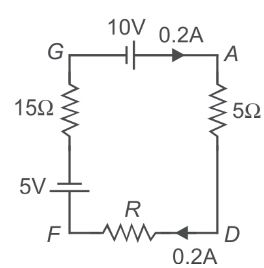
23. Resistance in the arm *BCD* of the circuit.

$$R_1 = 5 + 10 = 15\ \Omega$$

Total resistance across arm *DB*,

$$R_2 = \frac{15 \times 30}{15 + 30} = \frac{15 \times 30}{45} = 10\ \Omega$$

$\therefore$ Total resistance across arm *AD*, $R' = \frac{10 \times 10}{10 + 10} = 5\ \Omega$



Now, circuit reduces to the form shown

From the loop *ADFGA*

$5 \times 0.2 + R \times 0.2 + 15 \times 0.2 = 5$

$$0.2R + 4 = 5$$

$$0.2R = 1$$
$$R = \frac{1}{0.2} = 5\,\Omega$$
$$V_{AD} = 5 \times 0.2 = 1 \text{ volt.}$$

24. (*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 10^7K is required. One such fusion reaction is given below.

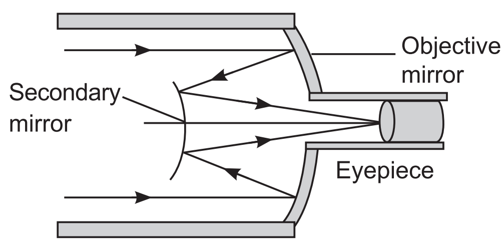
$$^{3}_{2}He + ^{3}_{2}He \longrightarrow ^{4}_{2}He + 2^{1}_{1}H + Q$$

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.

25. A reflecting telescope is generally considered better for observing clearer images. This is because reflecting telescopes use mirrors which eliminate chromatic aberration, a common problem in refracting telescopes caused by different bending of light colours through lenses.

Ray Digram for Gaurav's telescope.



Reflecting telescope

26. (*a*) As the two slits in Young's double slit experiment are illuminated by two different lamps, the sources are not coherent.

Hence, no interference pattern will be observed on the screen.

(*b*) In an interference pattern, the resultant intensity at any point,

$$I' = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

where ϕ is the phase difference at the point between the two waves of intensities I_1 and I_2.

where $\Delta\lambda = 0$, $\phi = 0$ and $\Delta\lambda = \frac{\lambda}{2}$, $\phi = \pi$

Suppose $I_1 = I_2 = I_1$ (say), then

(*i*) when $\Delta\lambda = 0, \phi = 0$

$I' = I_1 + I_1 + 2I_1 \cos\phi = 2I_1(1 + \cos\phi)$

$= 2I_1(1 + 1) = 4I_1$, points is maxima.

(*ii*) when $\Delta\lambda = \lambda/2, \phi = \pi$

$I' = 2I_1(1 - 1)$ $[\because \cos\pi = -1]$

$= 0$, points is minima.

27. (I) Let an alternating current of $I = I_m \sin\omega t$ be passing through a network of L, C and R creating a potential difference of $V = V_m \sin(\omega t \pm \phi)$ where ϕ is the phase difference. Then the power consumed is given by

$$P = VI = V_m I_m \sin(\omega t \pm \phi)\sin\omega t$$

$$\therefore \quad P = V_m I_m (\sin\omega t\cos\phi \pm \cos\omega t\sin\phi)\sin\omega t$$

$$P = V_m I_m \left(\sin^2\omega t\cos\phi \pm \frac{1}{2}\sin 2\omega t\sin\phi\right)$$

$$P_{av} = \frac{\int_0^T P\,dt}{\int_0^T dt} \Rightarrow P_{av} = \frac{V_m I_m}{T}\left[\int_0^T \sin^2\omega t\cos\phi\,dt + \frac{1}{2}\int_0^T \sin\phi\sin 2\omega t\,dt\right]$$

$$P_{av} = \frac{V_m I_m}{T}\left[\frac{T}{2}\cos\phi + 0\right] \qquad \left[\because \int_0^T \sin^2\omega t\,dt = \frac{T}{2} \text{ and } \int_0^T \sin 2\omega t\,dt = 0\right]$$

$$P_{av} = \frac{V_m I_m}{2}\cos\phi = V_{\text{rms}} I_{\text{rms}} \cos\phi$$

(*a*) No power is dissipated if (*i*) resistance in the circuit is zero and (*ii*) phase angle between voltage and current is $\pi/2$.

(*b*) Maximum power is dissipated if (*i*) resistance in the circuit is maximum and (*ii*) phase angle between voltage and current is zero.

Or

(II) (*a*) The circuit element X is a resistor and Y is a capacitor.

(*b*) Here, $R = X_C = \dfrac{V_{rms}}{\sqrt{2}}$

When X and Y are connected in series, the impedance is given by

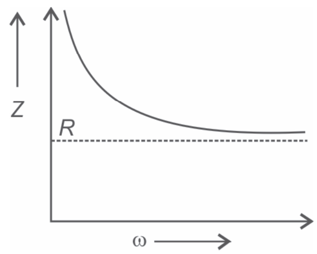
$$Z = \sqrt{R^2 + X_C^2} = \sqrt{2R^2} = \sqrt{2}R$$

$$I_{rms} = \frac{V_{rms}}{\sqrt{2}R} = \frac{\sqrt{2}R}{\sqrt{2}R} = 1 \text{ A}$$

(*c*)

$$Z = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + \frac{1}{\omega^2 C^2}}$$

The Z-ω graph will be of the type as shown in the figure.



28. (*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

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

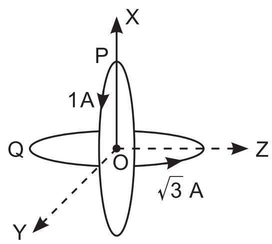
where I is the magnitude of current, dl is the length of element, θ is the angle between the length of element and the line joining the element to the point of observation, and r is the distance of the point from the element.

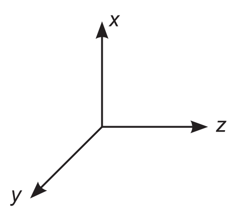
In vector notation, $$\vec{dB} = \frac{\mu_0}{4\pi}\frac{I\,(d\vec{l} \times \vec{r})}{r^3}$$

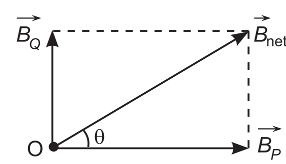
Its SI unit is tesla. Its direction is perpendicular to the plane in which $d\vec{l}$ and $\vec{r}$ lie.

Since, $\vec{dB} \propto I(\vec{dl} \times \hat{r})$, 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*

Magnetic field due to coil, $P = \vec{B_P} = \dfrac{\mu_o I}{2\,r}\hat{k}$

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

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

$$\therefore \quad \vec{B}_{\text{net}} = \vec{B_P} + \vec{B_Q} = \frac{4\pi \times 10^{-7}}{2\,R}[\hat{k} + \sqrt{3}\,\hat{i}]$$

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

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

29. (*i*) (*b*)

(*ii*) (*a*)

(*iii*) (*b*) Given: $V = 100$ V

Using, $$\lambda = \frac{h}{\sqrt{2meV}}$$

$$= \frac{6.6 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 100}}$$

$$= \frac{6.6 \times 10^{-34}}{\sqrt{29.72 \times 10^{-48}}}$$

$$= \frac{6.6 \times 10^{-34}}{5.45 \times 10^{-24}}$$

$$= 1.23 \times 10^{-10} \text{ m} = 1.23 \text{ Å}$$

(*iv*) (*c*) For proton, we know that

$$\lambda_1 = \frac{h}{\sqrt{2mE}}$$

For photon, $$E = \frac{hc}{\lambda_2}$$

or $$\lambda_2 = \frac{hc}{E}$$

Therefore, $$\frac{\lambda_1}{\lambda_2} = \frac{\frac{h}{\sqrt{2mE}}}{\frac{hc}{E}}$$

$$= \frac{c}{\sqrt{2m}}\sqrt{E}$$

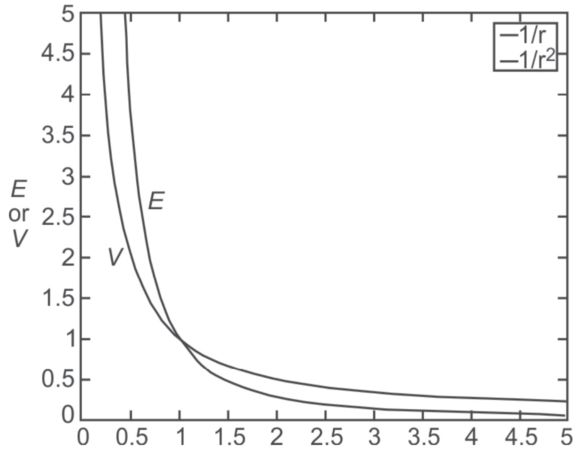
or $$\frac{\lambda_1}{\lambda_2} \propto E^{1/2}$$

30. (*i*) Electrons move freely in the conduction band, whereas holes represent the absence of electrons in the valence band. The effective mass of holes is larger due to stronger interaction with the crystal lattice, making them less mobile than electrons. As a result, although both carriers contribute to conduction, electrons dominate the conductivity of intrinsic semiconductors.

(*ii*) This is because all electrons are bound in covalent bonds and no free charge carriers are available.

(*iii*) This is because holes do not exist outside the semiconductor; only electrons can flow in the metal wire.

31. (I) (*a*) $E \propto \frac{1}{r^2}$ and $V \propto \frac{1}{r}$



(*b*) Let V_1 and V_2 be the potential differences that must be applied across the parallel and the series combinations of two capacitors C_1 and C_2 (given that $C_1 : C_2 :: 1 : 2$). Given that the energy stored in two cases are equal.

If $C_1 = C,\ C_2 = 2C$

In parallel combination, the effective capacity, $C_P = C_1 + C_2$

$$C_P = C + 2C = 3C$$

$$\therefore \quad U_1 = \frac{1}{2}C_pV_1^2 = \frac{1}{2}3CV_1^2 \quad \text{...}(i)$$

In series combination, the effective capacity $C_S = \frac{C_1C_2}{C_1+C_2}$

$$\therefore \quad C_S = \frac{C \times 2C}{3C} = \frac{2C}{3}$$

$$\therefore \quad U_2 = \frac{1}{2}C_SV_2^2 = \frac{1}{2}\left(\frac{2C}{3}\right)V_2^2 = \frac{1}{3}CV_2^2 \quad \text{...}(ii)$$

Given: $U_1 = U_2$

$$\therefore \quad \frac{3}{2}CV_1^2 = \frac{1}{3}CV_2^2$$

$$\Rightarrow \quad \frac{V_1^2}{V_2^2} = \frac{C}{3} \times \frac{2}{3C} = \frac{2}{9}$$

$$\therefore \quad \frac{V_1}{V_2} = \frac{\sqrt{2}}{3}$$

Hence, the ratio of potential differences is $\sqrt{2} : 3$.

Or

(II) (*a*) We know that E for line charge,

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

$\therefore$ Centripital force, $\dfrac{mv^2}{r} = eE$

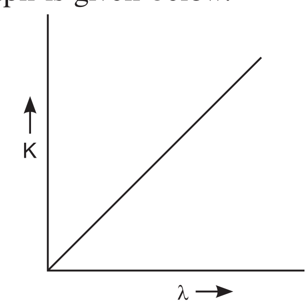
or $\dfrac{mv^2}{r} = \dfrac{e\lambda}{2\pi\varepsilon_0 r}$

$\Rightarrow$ $mv^2 = \dfrac{e\lambda}{2\pi\varepsilon_0}$

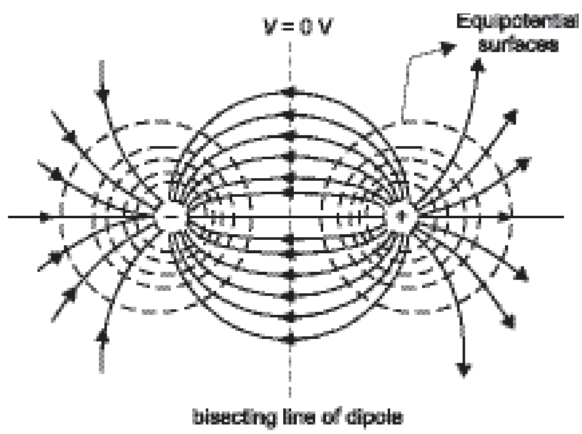
$\therefore$ Kinetic energy, $K = \dfrac{e\lambda}{4\pi\varepsilon_0}$

(*b*) As Kinetic energy, $K \propto \lambda$

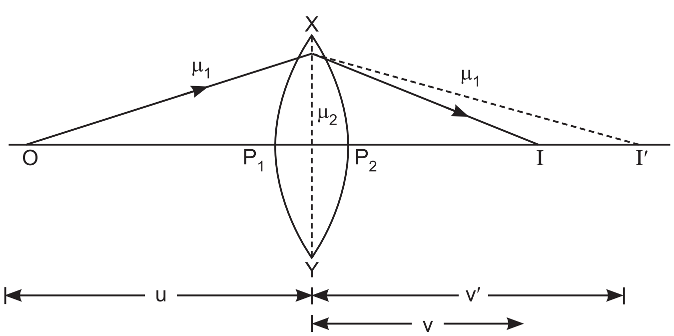
Therefore, *K* v/s λ graph is given below.



(*c*) The equipotential surfaces of a system of two equal and opposite charges, i.e. a dipole are as shown below.



32. (I) (*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 $$\frac{1}{v} - \frac{1}{\text{u}} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

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

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

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 $\mu_g < \mu_l$

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

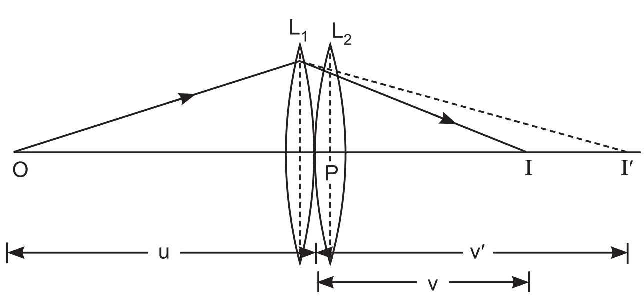
or $\mu_g < \mu_l$

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

Therefore, the lens acts as a concave lens.

Or

(II) (*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

$$m = m_1 \times m_2$$

33. (I) Given: $N_P = 100$, $k = 100$, $E_P = 220$ V, $P_i = 1100$ W

(*a*) Using, $\frac{N_S}{N_P} = k$

$$\frac{N_S}{100} = 100$$

or $N_S = 100 \times 100 = 10^4$

(*b*) Using, $P_i = E_P I_P$

$$1100 = 220 \times I_P$$

or $I_P = \frac{1100}{220} = 5$ A

(*c*) Using, $\frac{E_S}{E_P} = k$

$E_S = kE_P$

$= 100 \times 220 = 22000 = 22$ kV

(*d*) Using, $\frac{E_S}{E_P} = \frac{I_P}{I_S}$

$\frac{22000}{220} = \frac{5}{I_S}$

or $I_S = \frac{5}{100}$

$= 0.05$ A

(*e*) If the transformer is ideal then the output power is same as that of input power

$\therefore\ P_0 = 1100$ W

Or

(II) (*a*) **Principle of an AC generator:** An AC generator works on the principle of electromagnetic induction.

Operation of an AC generator:

♦ **Construction**

(*i*) Armature: A rectangular coil of wire wound on a soft iron core that rotates between two poles of a magnet.

(*ii*) Provided by a permanent magnet or electromagnets.

(*iii*) Slip rings: Two rings connected to the ends of the armature coil that rotate with it.

(*iv*) Brushes: Carbon or metal brushes that are in contact with the slip rings to transfer the generated current to the external circuit.

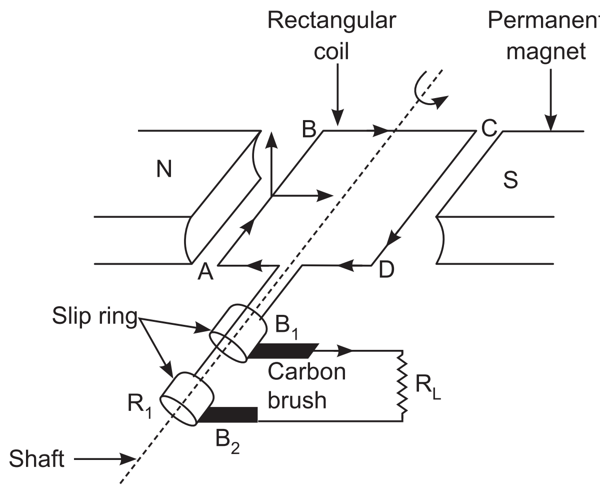
♦ **Working of AC generator:**

(*i*) Rotation of coil: When the armature coil is rotated in the magnetic field, it cuts through the magnetic lines of force, inducing an emf in the coil due to electromagnetic induction.

(*ii*) **Alternating current generator:**

- When the coil rotates through 0° to 180° (in the first half of the rotation) the induced current flows in one direction.
- From 180° to 360° (in the second half of the rotation), the direction of the induced current reverses due to the change in the direction of motion of the coil relative to the magnetic field.
- This results in an alternating current.

♦ **Diagram**



(*b*) **Expression for induced emf:** Let the armature rotates with angular velocity ω then at any time '*t*' angular displacement $\theta = \omega t$

∴ Change in magnetic flux

$$\frac{d\phi_B}{dt} = \frac{d}{dt}(BA\cos\theta)$$

$$= \frac{d}{dt}(BA\cos\omega t)$$

$$= -BA\omega\sin\omega t$$

By Faraday's law, $\varepsilon = \frac{-d\phi_B}{dt}$

∴ $\varepsilon = BA\omega\sin\omega t$

For '*N*' number of turns of the coil, total induced emf

$$\varepsilon_n = NBA\omega\sin\omega t$$