Answers to RPH/Set-2

1. (*a*) $E = \frac{-dV}{dx} = -\left[\frac{\delta V}{\delta x}\hat{i} + \frac{\delta V}{dy}\hat{j} + \frac{\delta V}{\delta z}\hat{k}\right] = -8x\hat{i}$

At $x = 1$ m

$E = -8(1)\hat{i} = -8\hat{i}$

2. (*a*)

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

$$\beta = \frac{2D\lambda}{d} = \frac{2 \times 5 \times 800 \times 10^{-9}}{5 \times 10^{-3}}$$
$$= 1600 \times 10^{-6} = 1.6 \times 10^{-3} \text{ m} = 1.6 \text{ mm}$$

5. (*c*)

6. (*a*)

7. (*c*)

8. (*a*)

9. (*b*)

10. (*a*)

11. (*b*)

12. (*b*)

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

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

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

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

17. Given, work function, $W = 4.2$ eV

Wavelength, $\lambda = 2000$ Å $= 2 \times 10^{-7}$ m

(*a*)
$$k_{max} = \frac{1}{2}mv_{max}^2 = h\nu - W$$

or
$$\frac{1}{2}mv_{max}^2 = \frac{hc}{\lambda} - W$$

or
$$\frac{1}{2}mv_{max}^2 \text{ (in eV)} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19} \times \lambda} - 4.2 = \left[\frac{1.24 \times 10^{-6}}{\lambda} - 4.2\right] \text{eV}$$
$$= \frac{1.24 \times 10^{-6}}{2 \times 10^{-7}} - 4.2 = 6.2 - 4.2 = 2 \text{ eV}$$

(*b*) The kinetic energy of slowest photoelectron is zero.

18. Given: $\lambda = 600 \times 10^{-9}$ m. $D = 1$ m, $d = 0.5 \times 10^{-3}$ m

Using formula, $\beta = \dfrac{\lambda D}{d}$

Putting the values,
$$\beta = \frac{600 \times 10^{-9} \times 1}{0.5 \times 10^{-3}}$$
$$= 1.2 \times 10^{-3} \text{ m} = 1.2 \text{ mm}$$

Or

Given: $n = 1$, $\lambda = 6 \times 10^{-5}$ cm, $D = 100$ cm

Distance of 1st minimum from central maxima = 0.1 cm

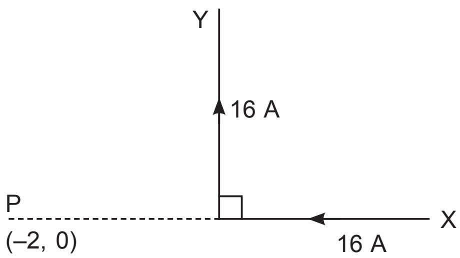
$$\sin\theta = \frac{\text{Distance of 1st minima from the central maxima}}{\text{Distance of the screen from the slit}}$$

or
$$\theta_1 = \frac{0.1}{100} = \frac{1}{1000}$$

Now using,
$$a \sin\theta = n\lambda$$
$$a = \frac{\lambda}{\theta_1} \quad \text{[for small angle]}$$
$$= \frac{6 \times 10^{-5}}{\frac{1}{1000}} = 6 \times 10^{-2} \text{ cm} = 0.06 \text{ cm}$$

19. 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,
$$B = \frac{\mu_0 I}{4\pi r}$$
$$= \frac{4\pi \times 10^{-7} \times 16}{4\pi \times 2 \times 10^{-3}}$$
$$= 8 \times 10^{-4} = 0.8 \text{ mT}$$

20.
$$\text{B.E.} = (2m_p + 2m_n - m_{\text{He}}) \text{ u} \times 931 \text{ MeV}$$
$$= [2(1.007276 + 1.008665) - 4.001508] \times 931$$
$$= [4.031882 - 4.001508] \times 931$$
$$= 0.030374 \times 931 = 28.3 \text{ MeV}$$

21. The angular momentum

$$mvr = \frac{nh}{2\pi}, \text{ which is associated}$$

with planetary motion are incomparably large relative to h.

If we talk about angular momentum of earth in its orbital motion then it is of the order of $10^{70}\,h$.

For such a large value of n, the difference in successive energies and angular momenta of the quantized levels of the Bohr model are so small that it can be predicted as continuous energy level.

22. Given: Voltage drop across diode, $V_d = 0.5$ V

Power rating of diode, $P = 100$ mW $= 0.1$ W

$\therefore$ Resistance of diode, $$R_d = \frac{V_d^2}{P} = \frac{(0.5)^2}{0.1} = \frac{0.25}{0.1} = 2.5\ \Omega$$

$\therefore$ Maximum current through the diode

$$I_{max} = \frac{V_d}{R_d} = \frac{0.5}{2.5} = 0.2 \text{ A}$$

Applied voltage, $V = 1.5$ V

$\therefore$ Total resistance of the circuit,

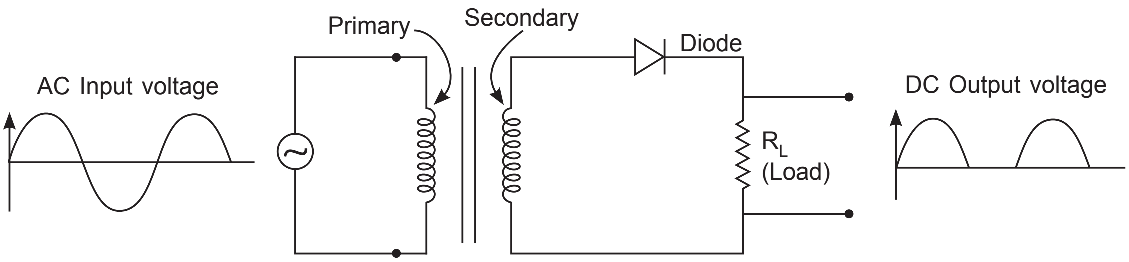
$$R' = \frac{V}{I_{max}} = \frac{1.5}{0.2} = 7.5\ \Omega$$

$\therefore$ $$R = R' - R_d = 7.5–2.5 = 5\ \Omega$$

Or

To assist Riya in converting alternating current to direct current, she can use *p-n* junction diode in a simple rectifier circuit.

The circuit diagram of a half-wave rectifier is shown below:



Working principle of the circuit:

(*a*) **AC input:** The alternating current has a varying voltage that oscillates between positive and negative cycles.

(*b*) ***p-n* junction diode (rectification):** During the positive half cycle of AC, the *p-n* junction diode is forward biased, allowing current to flow through the circuit.

As a result, the load resistor receives current, producing a positive half-cycle at the output.

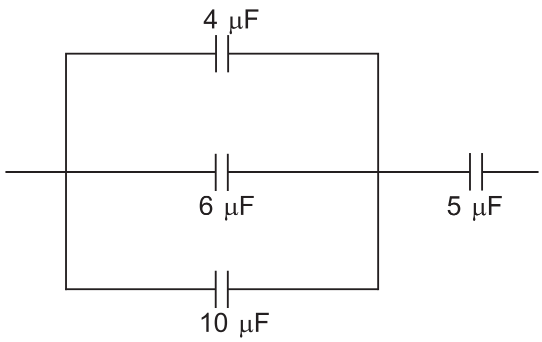
(*c*) **Reverse Bias (No conduction):** During the negative half-cycle of AC, the diode becomes reverse biased, preventing current from flowing through the diode. Hence, no current passes through the load resistor during the negative half-cycle and the output is zero.

(*d*) **Output:** The output across the load resistor is a pulsating direct current with only the positive half-cycles of AC singnal.

To further smooth the output a capacitor can be added in parallel with the load to reduce the ripple and provide a more constant DC voltage.

Thus, Riya can use this *p-n* junction diode-based rectifier circuit to convert AC to DC for her project.

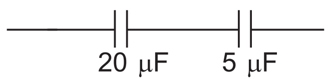
23. Equivalent circuit is shown below.



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

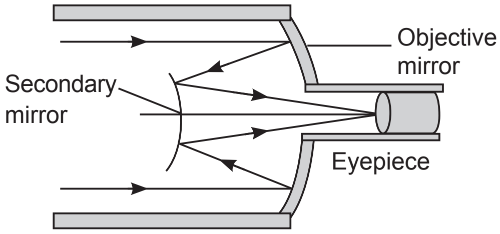
$$U = \frac{1}{2}\ CV^2$$

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

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

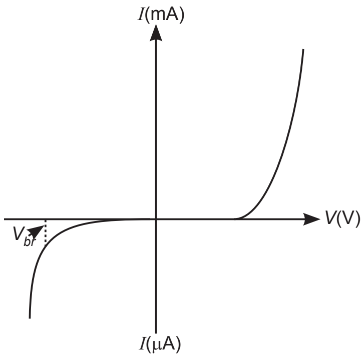
24. A reflecting telescope is generally considered better for observing clearer images. This is because reflecting telescopes use mirrors which eliminate chromatic aberration, a common problem in refracting telescopes caused by different bending of light colours through lenses.

Ray Digram for Gaurav's telescope.



Reflecting telescope

25. (*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.

26. (*a*) Formula used, $$B = \frac{\mu_0 2I}{4\pi r}$$

Magnetic field at 'A' due to wire 2,

$$B_2 = \frac{\mu_0}{4\pi}\frac{2(3I)}{r}, \text{ into the plane of the paper}$$

$$= \frac{\mu_0(6I)}{4\pi r}$$

Magnetic field at 'A' due to wire 3,

$$B_3 = \frac{\mu_0}{4\pi}\frac{2(4I)}{3r} = \frac{\mu_0(8I)}{12\pi r}, \text{ out of the plane of the paper}$$

Net magnetic field at 'A',

$$B_A = B_2 - B_3, \text{ into the plane of the paper}$$

$$= \frac{\mu_0(6I)}{4\pi r} - \frac{\mu_0(8I)}{12\pi r}$$

$$= \frac{2\mu_0 I}{4\pi r}\left[3 - \frac{4}{3}\right] = \frac{2\mu_0 I}{4\pi r}\left[\frac{5}{3}\right]$$

$$= \frac{10\mu_0 I}{4\pi(3r)}, \text{ into the plane of the paper}$$

(*b*) Formula used, $F = IBl$

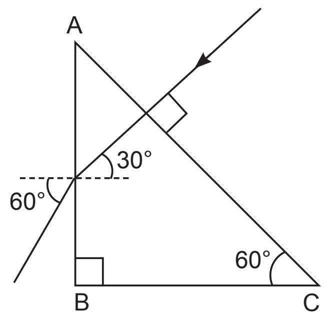
Now Magnetic force per unit length on wire (2),

$$F = F_{21} - F_{23}$$

$$= \frac{\mu_0}{2\pi r}(3I^2) - \frac{\mu_0 (12I^2)}{2\pi (2r)} = \frac{3}{2}\frac{\mu_0 I^2}{\pi r} - \frac{3\mu_0 I^2}{\pi r}$$

$$= -\frac{3}{2}\frac{\mu_0 I^2}{\pi r}, \text{ in the direction of wire 1.}$$

27. Given: $n = \sqrt{3}$



At the interface AC, $i = 0$

$\therefore$ By Snell's law, $\frac{\sin i}{\sin r} = \mu$

or $\frac{\sin 0}{\sin r} = \mu$

$\Rightarrow$ $r = 0$

At interface AB, $i = 30°$

$\therefore$ By Snell's law, $\frac{\sin 30°}{\sin e} = \frac{1}{\mu}$

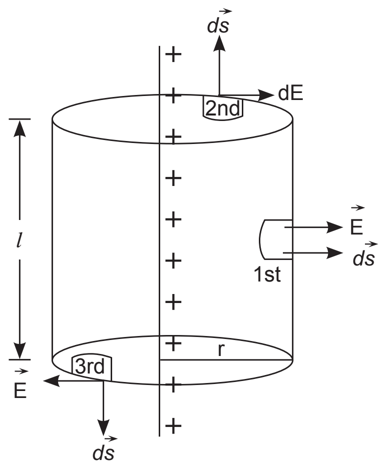
sin $e = \mu \sin 30°$

$$= \sqrt{3}\,(1/2) = \frac{\sqrt{3}}{2}$$

$\Rightarrow$ $e = \sin^{-1}\left(\frac{\sqrt{3}}{2}\right)$

$\Rightarrow$ $e = 60°$

28. Flux passing through the Gaussian surface,



$$\phi_E = \oint \vec{E}.\vec{ds}$$

$$= \int_I \vec{E}.\vec{ds} + \int_{II} \vec{E}.\vec{ds} + \int_{III} \vec{E}.\vec{ds}$$

$$= \int_I Eds \cos 0° + \int_{II} Eds \cos 90° + \int_{III} Eds \cos 90°$$

$$= \int Eds = E(2\pi rl)$$

By Gauss's theorem, $\phi_E = \frac{q}{\varepsilon_0}$

$= \frac{\lambda l}{\varepsilon_0}$ [Where λ is linear change density]

$\therefore$ $\oint \vec{E}.\vec{ds} = \frac{\lambda l}{\varepsilon_0}$

or $E(2\pi rl) = \frac{\lambda l}{\varepsilon_0}$

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

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

30. (*i*) (*c*)

(*ii*) (*b*)

(*iii*) (*b*)

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

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

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

$$= \frac{6.6 \times 10^{-34}}{\sqrt{29.72 \times 10^{-48}}} = \frac{6.6 \times 10^{-34}}{5.45 \times 10^{-24}}$$

$= 1.23 \times 10^{-10}$ m $= 1.23$ Å

Or

(*iv*) (*b*) 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 $$\frac{\lambda_1}{\lambda_2} \propto E^{1/2}$$

31. (*a*) Emf of a cell: It is the potential difference between two electrodes of the cell when no current is flowing through the circuit. It is the maximum voltage the cell can provide and is responsible for driving the electric charge around the circuit.

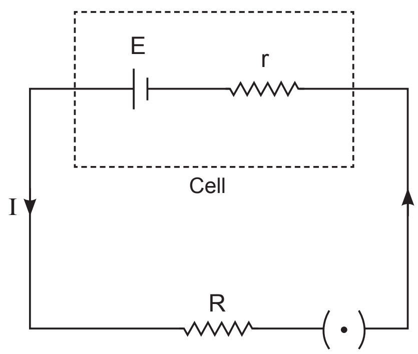
(*b*) Factors affecting the emf of a cell:

(*i*) Nature of electrodes

(*ii*) Nature of electrolyte

(*iii*) Temperature

(*c*) When a current flows through a cell, the terminal potential difference (V) is less than the emf (E) due to the voltage drop across the internal resistance (r) of the cell.



If 'I' is the current flowing through the circuit then

$$E = IR + Ir \quad ...(i)$$

or $$I = \frac{E}{R+r} \quad ...(ii)$$

But, $$V = IR$$

$\therefore$ From equation (*i*)

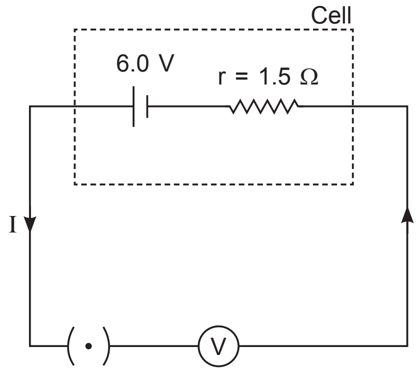
$$E = V + Ir$$

or $$V = E - Ir$$

Using equation (*ii*), $$V = E - \left(\frac{E}{R+r}\right)r$$

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

(*d*) Given: $\varepsilon = 6.0$ V, $r = 1.5\ \Omega$



Resistance of voltmeter, $R = 1000\ \Omega$

$\therefore$ Current in the circuit

$$I = \frac{\varepsilon}{R+r} = \frac{6}{1000+1.5}$$

$$= 5.991 \times 10^{-3} \text{ A}$$

$\therefore$ Potential difference across voltmeter $= (5.991 \times 10^{-3}) \times 1000 = 5.991$ V

Thus, terminal potential difference of the cell

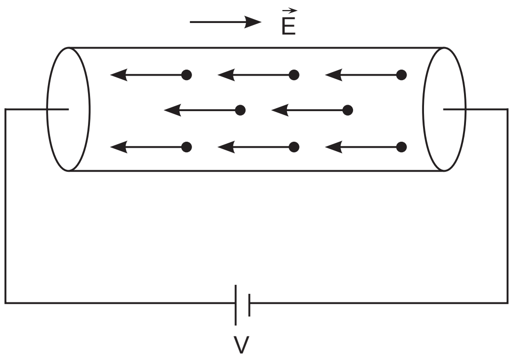
$$V = \text{Potential difference across voltmeter} = 5.991 \text{ V}$$

$$\text{Percentage error} = \frac{\varepsilon - V}{V} \times 100 = \frac{6 - 5.991}{6} \times 100 = 0.15\%$$

Or

(*a*) **Relaxation time:** Relaxation time for free electrons in a conductor is the average time between two successive collisions of an electron with the atoms or ions of the conductor.

(*b*) **Relation between relaxation time and drift velocity:**



Force on each electron

$$\vec{F} = e\vec{E} \qquad \ldots(i)$$

By Newton's 2nd law of motion

$$\vec{F} = m\vec{a} \qquad \ldots(ii)$$

From equations (i) and (ii)

$$e\vec{E} = m\vec{a} \qquad \text{[Where, } m = \text{Mass of an electron]}$$

or

$$\vec{a} = \frac{e\vec{E}}{m} \qquad \ldots(iii)$$

Initially the electrons were in random motion

$$\therefore \qquad \vec{u} = \frac{\vec{u}_1 + \vec{u}_2 + \ldots + \vec{u}_n}{n} = 0 \qquad \ldots(iv)$$

Now if τ is relaxation time, then using 2nd equation of motion,

$$\vec{v}_1 = \vec{u}_1 + \vec{a}\tau_1$$

$$\vec{v}_2 = \vec{u}_2 + \vec{a}\tau_2$$

$$\vec{v}_n = \vec{u}_n + \vec{a}\tau_n$$

$\therefore$ Drift velocity,

$$\vec{v}_d = \frac{\vec{v}_1 + \vec{v}_2 + \ldots + \vec{v}_n}{n}$$

$$= \frac{(\vec{u}_1 + \vec{a}\tau_1) + (\vec{u}_2 + \vec{a}\tau_2) + \ldots + (\vec{u}_n + \vec{a}\tau_n)}{n}$$

$$= \left(\frac{\vec{u}_1 + \vec{u}_2 + \ldots + \vec{u}_n}{n}\right) + \vec{a}\left(\frac{\tau_1 + \tau_2 \ldots + \tau_n}{n}\right)$$

Using equation (iv)

$$\vec{v}_d = \vec{a}\tau$$

Where,

$$\tau = \frac{\tau_1 + \tau_2 + \ldots + \tau_n}{n}$$

Using equation (iii), we get

$$\vec{v}_d = \frac{e\vec{E}}{m}\tau$$

In magnitude form

$$v_d = \frac{-eE}{m}\tau \qquad \ldots(v)$$

Relation for resistivity

We know that,

$$V_d = \frac{-eE\tau}{m}$$

Also we have $E = \frac{-V}{l}$, where V is potential across the length 'l' of the conductor

$$\therefore \qquad v_d = \frac{e\tau}{m}\left(\frac{V}{l}\right) \qquad \ldots(vi)$$

and current flowing $I = neAV_d$

Using equation (vi), we get

$$I = neA\left[\frac{e\tau V}{ml}\right]$$

$$= \frac{ne^2AV\tau}{ml}$$

or $$\frac{I}{V} = \frac{ne^2A\tau}{ml} = \frac{1}{R} \qquad \ldots(vii)$$

$\because$ $$R = \rho\frac{l}{A} \qquad \ldots(viii)$$

$\therefore$ From equations (*vii*) and (*viii*), we get

$$\rho = \frac{m}{ne^2\tau}$$

(*c*) Drift velocity is given by,

$$V_d = \frac{I}{neA} = \frac{V/R}{neA}$$

$$= \frac{1}{neA}\left[\frac{V}{\rho\frac{L}{A}}\right]$$

$$= \frac{V}{n\rho Le}$$

or $$V_d \propto \frac{1}{L}$$

$\therefore$ $$\frac{V'_d}{V_d} = \frac{L}{3L} = \frac{1}{3}$$

$$V'_d = \frac{V_d}{3}$$

32. 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 $$I_P = \frac{1100}{220} = 5 \text{ A}$$

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

$$E_S = kE_P$$

$$= 100 \times 220 = 22000 = 22 \text{ kV}$$

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

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

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

$$= 0.05 \text{ A}$$

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

$\therefore\ P_0 = 1100$ W

Or

Principle of an AC generator: An AC generator works on the principle of electromagnetic induction.

Operation of an AC generator:

(*a*) **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.

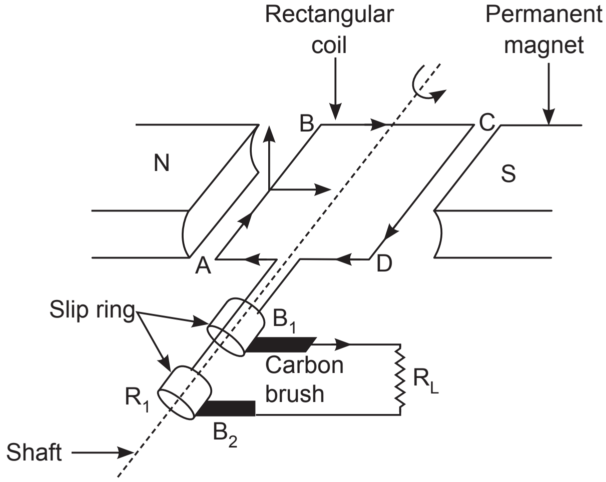
(*b*) **Working of AC generator:**

(*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



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

$\therefore$ 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, $$\varepsilon = \frac{-d\phi_B}{dt}$$

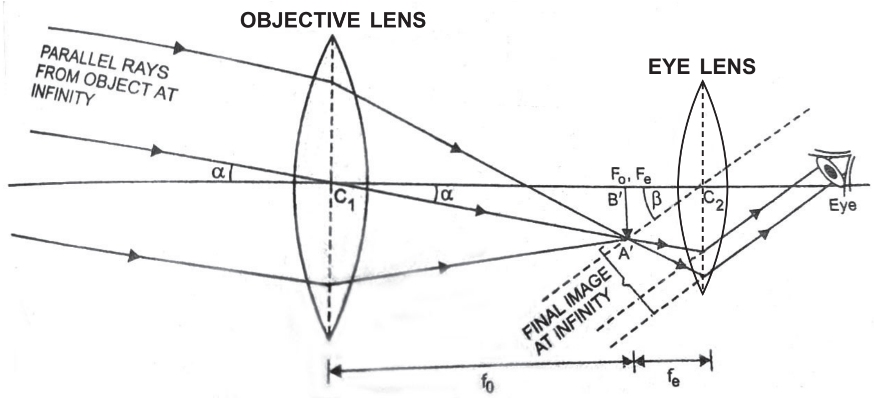
$\therefore$ $$\varepsilon = BA\omega\sin\omega t$$

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

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

(*c*) No, a moving coil galvanometer cannot detect the current generated by an AC generator directly. This is because a moving coil galvanometer is designed to detect direct current (DC).

33.



Magnifying power is defined as the ratio of angle subtended at the eye by the final image to the angle subtended at the eye by the object directly, when final image and object, both lie at infinity.

To increase the magnifying power, following two factors are considered.

- Focal length of the objective lens must be increased.
- Focal length of the eyepiece lens must be decreased.

Limitations of refracting telescope over reflecting telescope:

(*i*) Refracting type telescope suffers from chromatic aberration.

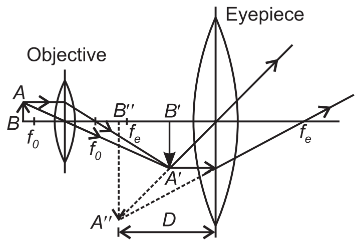
(*ii*) They have small resolving power.

We can minimise these limitations using reflecting type telescope because–

- It is free from chromatic aberration as there is no refraction.
- The aperture of mirror can be kept larger in comparison to the aperture of lenses, because their grinding/polishing is easier and they can easily be provided with mechanical support. With larger aperture the resolving power of telescope increases.

Or

(*a*) **Ray dagram:** When image formed at least distance of distinct vision (near point)



Compound microscope

(*b*) **Expression for magnification when image is formed at near point:**

If the magnification produced by the objective lens is m_o and that produced by the eye lens is m_e, then the total magnification produced by the compound microscope is

$$m = m_o \times m_e$$

where $$m_e = 1 + \frac{D}{f_e}$$

Here f_e is the focal length of the eye lens and D is the distance of distinct vision.

$$m_o = \frac{v_o}{-u_o}$$

$\therefore$ $$m = \frac{v_o}{-u_o}\left(1 + \frac{D}{f_e}\right)$$

(*c*) Angular magnification of eyepiece,

$$m_e = \frac{25}{f_e} + 1$$

It increases, if f_e is taken smaller.

Magnification of objective, $m_o = \frac{v}{u}$

As the object is kept closer to the focus of the objective lens, $u \approx f_o$. Thus, to increase the magnification, f_o should be smaller.