Certified that we have evaluated this answer book according to the correct set of question paper and strictly as per the marking scheme.
Consider a Young's double slit experiment with slits at a distance 'd' and separation between slits and screen 'b'. Let light waves from coherent source meet with phase difference $\Phi$ at $P$.

Let the waves be,

$$y_1 = a \sin(\omega t)$$

and,

$$y_2 = b \sin(\omega t + \Phi)$$

Resultant displacement,

$$y = y_1 + y_2 = a \sin(\omega t) + b \sin(\omega t + \Phi)$$
\[ = a \sin \omega t + b (\sin \omega t \cos \phi + \cos \omega t \sin \phi) \]
\[ = (a + b \cos \phi) \sin \omega t + b \sin \phi \cos \omega t \]

deleting,
\[ a + b \cos \phi = R \cos \theta \quad \text{--- 1} \]
\[ b \sin \phi = R \sin \theta \quad \text{--- 2} \]

\[ \therefore y = R \cos \theta \sin \omega t + R \sin \theta \cos \omega t \]
\[ y = R \sin (\omega t + \theta) \]

Thus, resultant wave will also be of same type with amplitude \( R \).

Squaring and adding 1 & 2
\[ R^2 = (a + b \cos \phi)^2 + (b \sin \phi)^2 \]
\[ R = \sqrt{a^2 + b^2 + 2ab \cos \phi} \]

For \( R \) to be maximum,
\[ \cos \phi = \pm 1 \]
\[ \phi = 0, \pi, 2\pi, 3\pi, \ldots \]
\[ \phi = 2n\pi \]

\( \delta \) Phase difference, \( \Delta \phi = n\pi \)
For minima,
\[ \cos \phi = -1 \]
\[ \phi = \pi, 3\pi, \ldots \]
\[ \phi = \left( \frac{2n-1}{2} \right) \pi \], where \( n = 1, 2, 3, \ldots \)

\[ \text{Phase difference, } \Delta x = \left( \frac{2n-1}{2} \right) \pi \]

Fringe width is the distant.

For bright fringe, the two waves should meet with zero phase difference and for dark fringe waves should meet in opposite phase.

Path difference, \( \Delta = S_{2P} - S_{1P} \)

\[ (S_{2P})^2 = D^2 + \left( y - \frac{d}{2} \right)^2 \]

\[ S_{1P} = D \left[ 1 + \left( \frac{y - \frac{d}{2}}{D} \right)^2 \right]^{\frac{1}{2}} = D + \left( y - \frac{d}{2} \right) \frac{1}{2D} \]
Similarly, \( S_2 \alpha = D + \left( \frac{y + \frac{d}{2}}{2} \right)^2 \)

Phase difference = \( S_2 \alpha - S_1 \alpha \)
\[
= \left( \frac{y + \frac{d}{2}}{2} \right)^2 - \left( \frac{y - \frac{d}{2}}{2} \right)^2
\]
\[
= \frac{y d}{D}
\]

\( \Delta \alpha = \frac{y d}{D} \)

\( s \alpha \theta = \frac{\Delta \alpha}{d} \quad \therefore \quad \theta = \frac{\Delta \alpha}{d} \cdot \lambda \)

Fringe width is the separation between two consecutive crests or two consecutive troughs.

\[
\beta = \frac{y_{n+1}^* - y_n}{n+1} \lambda D - n \lambda D = \frac{\lambda d}{D}
\]
b) Given:
\[
\frac{I_{\text{max}}}{I_{\text{min}}} = 25
\]

\[
\left(\frac{\sqrt{I_1} + \sqrt{I_2}}{\sqrt{I_1} - \sqrt{I_2}}\right)^2 = \frac{25}{q}
\]

\[
\frac{\sqrt{I_1}}{\sqrt{I_2}} + \frac{1}{\sqrt{I_2}} = \frac{5}{3}
\]

\[
\sqrt{\frac{I_1}{I_2}} = 4
\]

\[
\frac{I_1}{I_2} = 16:1
\]

\[
R_{\theta} \Rightarrow \frac{W_1}{W_2} = 16:1
\]
There are two combs $S_1$ and $S_2$. When $S_1$ is connected to a high tension battery, then due to its pointed ends, it will induce the air in the neighbourhood of it. Thus, positive charge is sprinkled on the belt which moves up and reaches near comb $S_2$. Positive negative charge will be induced on one side of $S_2$ and on other side positive charge which will appear on the outer shell. The pointed ends of $S_2$ will ionise the air and neutralise the belt. The process is repeated and hence the outer sphere can acquire a lot of charge without its potential being raised so much. The ion source present inside the shell get accelerated and hit the target.

Consider two spheres $S_1$ and $S_2$ with radii $R$ and $r$, such that $R > r$ and they are connected to each other.

Let charge on smaller sphere be $q$ and on larger sphere be $Q$. 

\[
\begin{align*}
q &= Q, \\
\text{and } r &= R.
\end{align*}
\]
\[ V_R = \frac{q}{4\pi\varepsilon_0 R} + \frac{Q}{4\pi\varepsilon_0 R} \]  
\[ V_n = \frac{q}{4\pi\varepsilon_0 R} + \frac{D}{4\pi\varepsilon_0 R} \]

From \( 1 \) \& \( 2 \),
\[ V_n - V_R = \frac{q}{4\pi\varepsilon_0} \left[ \frac{1}{n} - \frac{1}{R} \right] \]
\[ V_n - V_R > 0 \]
\[ V_n > V_R \]

Hence, inner sphere will always be in higher potential, irrespective of the charge on the outer sphere.

Thus, charge will always move from inner to outer sphere. This phenomenon is used in Van de Graaff Generator.

* Uses

* It is used to study crystal structure of the target molecule.
26. a) Consider a charged particle with charge $q$ moving with a speed $v$ in a uniform magnetic field $B$. The component perpendicular to the direction of motion is:

\[ B = \frac{qE}{m} \]

Where $m$ is the mass of the particle.
Time period, \[ T = \frac{2\pi v}{\omega} \]

\[ = \frac{2\pi m}{gB} \quad \text{(1)} \]

\[ T = \frac{2\pi m}{gB} \]

\[ \Rightarrow \quad \text{Frequency,} \quad f = \frac{gB}{2\pi m} \]

As the expression for \( f \) doesn't contain \( V \) and \( E \),

\[ \Rightarrow \quad \text{frequency is independent of velocity and energy} \]

b) **Construction of Cyclotron**

It consists of two dee-shaped hollow conductors \( D_1 \) and \( D_2 \). A high oscillating electric field is applied across the dees and magnetic field with the help of a strong iron magnet is applied through deflecting window, the accelerated charged \( \ldots \)
particle comes out and hits the target. There is charge source between the dees.

**Working**

The charge to be accelerated is provided between the dees by the charge source. Let

- Let initially \( D_1 \) is positive and \( D_2 \) is negative. So, charge will be accelerated towards \( D_2 \). As soon as the charge comes inside \( D_2 \), it will experience no electrostatic force due to electrostatic shielding, but the perpendicular magnetic field makes it move in a semi-circle and move out of \( D_2 \). As soon as the charge comes out, the polarities of the dees will change and it will be accelerated towards \( D_1 \). This process continues and charge gets accelerated between the dees. This time matching between charge moving via semi-circle and change of polarities is called cyclotron's resonance condition.

Thus, the highly accelerated charge particle moves out of deflecting window and hits the target.
1) As shown above, in conductors and the valence band and conduction band are overlapping. In semi-conductors, the band gap energy is small, and in insulators, band gap energy is large.
26. Given: \( V = 5 \times 10^4 \) V

De-Broglie wavelength, \( \lambda = \frac{h}{p} \)

\[
\lambda = \frac{\frac{1}{\sqrt{2mE}}}{\sqrt{2meV}}
\]

\[
= \frac{h}{\sqrt{2meV}}
\]

\[
= \frac{12.27 \text{ Å}}{\sqrt{5 \times 10^4}}
\]

\[
= \frac{12.27 \text{ Å}}{2.17 \times 10^2}
\]

\[
= 5.6 \times 10^{-12} \text{ m}
\]

ii) There are no free electrons in insulators. In semiconductors, some charge carriers at temperature greater than 0 K and in conductors, there are large number of charge carriers.
R.P. of a

For a microscope:

\[ R.P. = \frac{2 \mu \sin \theta}{\lambda} \]

As Numerical Aperture i.e. \( \mu \sin \theta \) is same

\[ R.P. \propto \frac{1}{\lambda} \]

\[ \frac{(R.P.)_e}{(R.P.)_{\text{ee}}} = \frac{\lambda_{\text{ee}}}{\lambda_e} \]

As \( \lambda_{\text{ee}} > \lambda_e \)

\[ (R.P.)_e > (R.P.)_{\text{ee}} \]

Hence, resolving power of electron microscope is more.
25. The two basic modes of communication are:

i) Ground communication
ii) Space communication

The process in which amplitude of high-frequency carrier wave is varied in accordance with low-frequency baseband signal is called amplitude modulation.

It is done for the following purposes:

i) To decrease the length of antenna
ii) To increase power gain
iii) To avoid confusion due to reception of more than one signal

![Diagram of Amplitude Modulation]

- Low-frequency baseband signal
- High-frequency carrier wave
- Amplitude-modulated wave
For convex lens,
\[ u = -\infty \]
\[ \frac{1}{f} = \frac{1}{u} \]
\[ \frac{1}{f} = \frac{1}{-\infty} \]
\[ f = -\infty \]

Applying lens formula,
\[ \frac{1}{v} - \frac{1}{u} = \frac{1}{f} \]
\[ \frac{1}{v} = \frac{1}{-\infty} \]
\[ v = 20 \text{ cm} \]

For concave lens,
\[ u = - (50 - 2D) = -30 \text{ cm} \]
\[ f = -10 \text{ cm} \]
Applying mirror formula,
\[ \frac{1}{v} + \frac{1}{u} = \frac{1}{f} \]
\[ v = \frac{uf}{u-f} = \frac{30 \times 15}{-15} \]
\[ = -15 \text{ cm} \]

Therefore, final image will be formed at a distance 15 cm in front of the concave mirror.

23. The qualities in Aarti are:
   
   i) Concern for her sister;
   
   ii) Day to day use of her knowledge;
   
   iii) Presence of mind.

b) Radioisotopes when used to diagnose the brain, they emit different kinds of radioactive waves which are also called
Consider a solenoid of self-inductance L, length L, and number of turns N. A current i(t) flows through it.

The induced EMF e is given by:

\[ e = -N \frac{\partial \Phi}{\partial t} \]

where \( \Phi \) is the magnetic flux through the solenoid.

The inductive EMF is proportional to the rate of change of the magnetic flux through the solenoid.

For a steady-state alternating current, the induced EMF will also be alternating.

Total work done,

\[ W = \int eI dt \]

\[ = \int L I I \]

\[ = \frac{1}{2} LI^2 \]

This work done will be stored in the inductor in the form of magnetic energy.

\[ \theta = \frac{1}{2} LI^2 \]

Molecule or atom present in atmosphere

Polarised light having vibrations in one plane

Observer

b) $I_0 \rightarrow \frac{I_0}{2} = I_1$, $I_2 = I_1$, $I_3$
When unpolarised light with intensity $I_0$ falls on $P_1$, then it gets polarised, so

$$I_1 = \frac{I_0}{2}$$

This light will be incident on $P_2$.

Applying Malus' law,

$$I_3 = I_1 \cos^2 45° = \frac{I_0}{2} \times \frac{1}{2} = \frac{I_0}{4}$$

This light will be incident on $P_3$.

$$I_2 = I_3 \cos^2 45° = \frac{I_0}{4} \times \frac{1}{2} = \frac{I_0}{8}$$

Intensities through $P_1$, $P_2$ and $P_3$ are $\frac{I_0}{2}$, $\frac{I_0}{8}$ and $\frac{I_0}{4}$.
a) The connections between the resistors are made of thick copper strips so that they may have negligible resistance which will not affect the true reading.

b) It is preferred to obtain balance point in the middle of the meter bridge wire because the meter bridge is most sensitive in this condition.

c) For the meter bridge wires, Constantan or magnesium wires are used as they have high resistivity and slow value of temperature coefficient of resistance.
Applied voltage is
\[ V = V_0 \sin \omega t \]

Let the alternating instantaneous value of current flowing be
\[ I = I_0 \sin (\omega t + \phi) \]

Instantaneous power loss
\[ P = VI \]
\[ = V_0 I_0 \sin \omega t \sin (\omega t + \phi) \]
\[ = V_0 I_0 \sin \omega t \left( \sin \omega t \cos \phi + \cos \omega t \sin \phi \right) \]
\[ = V_0 I_0 \left( \sin^2 \omega t \cos \phi + \frac{1}{2} \sin 2\omega t \sin \phi \right) \]

Average power dissipated, \( P_{av} = \int_0^T P(t) \, dt \)
\[ = \frac{1}{T} \int_0^T \left\{ V_0 I_0 \left( \sin^2 \omega t \cos \phi + \frac{1}{2} \sin 2\omega t \sin \phi \right) \right\} \, dt \]
\[ = \frac{V_0 I_0}{T} \left[ \int_0^T \cos \phi \left( \frac{1 - \cos 2\omega t}{2} \right) \, dt \pm \frac{1}{2} \int_0^T \sin \phi \sin 2\omega t \, dt \right] \]
\[ = \frac{V_0 I_0}{2T} \left\{ \cos \phi \left[ \frac{t - \cos 2\omega t}{2} \right]_0^T \pm \frac{1}{2} \sin \phi \left[ \frac{\sin 2\omega t}{2 \omega} \right]_0^T \right\} \]
\[ P_{av} = \frac{V_0 I_0}{2} \cdot T \cos \phi \]

\[ = \frac{V_0 I_0}{2} \cos \phi \]

\[ P_{av} = V_{rms} I_{rms} \cos \phi \]

i) If no power is dissipated,
\[ P_{av} = 0 \]
\[ \therefore \cos \phi = 0 \]
\[ \Phi = 90^\circ \]

⇒ Circuit is pure inductive or pure capacitive.

ii) Maximum power is dissipated when
\[ \cos \phi = 1 \]
\[ \Phi = 0^\circ \]

⇒ Circuit is pure resistive.
19. Consider a capacitor of capacitance $C$ and it is charged to a potential $V$.

Energy of capacitor, $U_i = \frac{1}{2}CV^2$

Now another capacitor is connected with it. Let the common potential be $V'$.

As charge remains constant,

$$CV = CV' + CV'$$

$$V' = CV - \frac{V}{2}$$

Final energy,

$$U_f = \frac{1}{2}CV'^2 + \frac{1}{2}C\left(V'\right)^2$$

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

Ratio of final energy and initial energy, $\frac{U_f}{U_i} = \frac{1}{2} = 1:2$
If current $I$ is flowing then,

$$V = E - Ir$$

with increase in current $V$ reduces.

When $I \rightarrow 0$, $V \rightarrow E$

As shown according to the eqn $V = E - Ir$

when $I = 0$, then $E = V$

$y$-intercept will depict the EMF of the cell.

Also, $I_{\text{max}} = \frac{E}{r}$
Internal resistance, \( r = \frac{E}{I_{\text{max}}} \)

Knowing \( E \) (y-intercept) and \( I_{\text{max}} \) (x-intercept), internal resistance can be calculated.

The alternating signal is passed through p-n junction diode as shown above.

Let initially alternating signal be passed in such a way that the diode gets forward biased. So, it will conduct electricity and the output waveform will be of same kind.

When negative portion of wave passes through diode,
then it will get reverse biased and will not conduct. So, no output waveform is obtained.

As output wave is obtained during half of the time, so it is called half wave rectification.
The transistor will work as an amplifier when \( V_o > V_i \).

i.e. in active region when emitter-base junction is forward biased and collector output is reverse biased.

1) Paramagnetic Substance

2) Diamagnetic Substance
As the value of susceptibility $\chi_m$ for paramagnetic substance is positive, so electric field lines prefer to pass through it, but for diamagnetic it is negative so field lines prefer to pass through the surrounding medium.

13.

i) Transmitter

It is a device used for communication which transmits the signal by even amplifying it.

ii) Modulator

It is a device which merges the same high-frequency carrier wave and slow-frequency baseband signal, is modulator.
12. That light ray will not pass through AC for which

\[ i > i_c \]

\[ \sin i > \sin i_c \]

\[ \frac{\sin 45}{\sin i} > 1 \]

\[ \frac{1}{\sqrt{2}} > \frac{1}{\mu} \]

\[ \mu > \sqrt{2} \]

\[ \mu > 1.41 \]

Hence, ray '2' will suffer total internal reflection and ray '1' will pass through face AC.

For ray '1',

\[ \frac{\sin 30}{\sin \theta} = \frac{1}{\mu} \]

\[ \sin 30 = 1 \]

\[ \sin \theta = 1 \]

\[ \theta = 90^\circ \]

For ray '2',

\[ \sin 45 = \mu \]

\[ \sin 45 = \frac{1}{\sqrt{2}} \]

\[ \mu = 1.41 \]
10. Consider an e⁻ moving with radius \( r \) and speed \( v \).

**Centripetal force = Force of attraction**

\[
\frac{mv^2}{r} = \frac{k e^2}{r^2}
\]

\[
\omega = \frac{e}{mr}
\]

**\( v = \frac{k e^2}{mr^2} \)**

11. Consider an atom with total number of protons \( Z \) and atomic number \( Z \). Let an e⁻ be revolving around the nucleus with speed \( v \) and radius \( r \).

**Centripetal force = Force of attraction**

\[
\frac{mv^2}{r} = \frac{Ze \times e}{4\pi\varepsilon_0 r^2}
\]

\[
\omega = \frac{Z e^2}{mr^2}
\]

**\( v = \frac{Z e^2}{mr} \)**
\[
\nu = \frac{Ze^2}{4\pi\epsilon_0 mv^2}
\]

But \( v = \frac{2\pi k Z e^2}{nh} \)

Radius, \( r_n = \frac{kZe^2}{4\pi\epsilon_0 m} \frac{n^2 \hbar^2}{4\pi^2 k^2 Z^2 e^4} \)

Radius of \( n \)th orbit, \( r_n = \frac{n^2 \hbar^2}{16\pi^3 k_0^2 4Ze^2 n^2 rm} \)

10. Formal electrostatic potential (Coulomb's Law)

\[ \oint B \cdot dl = \mu_0 I \]

For b/w the plates of capacitor,

\[ I = 0 \]

\[ \oint B \cdot dl = 0 \]

which is not possible.
9. Given:

\[ A = 2.5 \times 10^{-3} \, \text{m}^2 \]
\[ I = 1.8 \, \text{A} \]
\[ n \leq 9 \times 10^{28} \, \text{m}^{-3} \]

Modified amperes circuital law is

\[ \oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 (I + I_D) \]

where, \( I_D \) = Displacement Current = \( \varepsilon_0 \frac{d\mathbf{E}}{dt} \)

\[ I = n A \varepsilon \varepsilon_0 \]

\[ V_d = \frac{I}{n A \varepsilon_0} = \frac{1.8}{9 \times 10^{28} \times 2.5 \times 10^{-7} \times 1.6 \times 10^{-19}} = 0.5 \, \text{mA} \]
8. It is experimentally difficult to detect neutrinos because these are massless and changeless.

7. This belongs to a wave in infrared region

6. Work function, \[ W = h\nu_0, \]
   \[ W \propto \nu_0 \]
   Metal A has higher work function because \[ \nu_0' > \nu_0 \]

5. \[ \frac{1}{f} = (1.5 - 1) \left[ \frac{1}{R_1} - \frac{1}{R_2} \right] \]
   When immersed in water
   \[ \frac{1}{f_w} = (1.5 - 1) \left[ \frac{1}{R_1} - \frac{1}{R_2} \right] > 0 \]
   \[ f_w > 0 \]
   lens will behave as converging.
4. Electric field lines move from positive charge to negative charge, that is why they do not form closed loops.

3. AC is preferred over DC because:
   i) there is less power loss in transmission of AC
   ii) AC can be stepped up or down but not DC

2. \[ F = \frac{\mu_0 I_1 I_2 L}{4\pi r^2}; \]

When \( I_1 = I_2 = 1\, \text{A} \) and \( L = 1\, \text{m} \)

then, \( F = 10^{7}\, \text{N} \)

i.e. One ampere is that amount of current which when through a 1 m long conductor placed at a distance of 1 m from a conductor carrying the same amount of current in same direction.
repels & attracts it with a force equal to $10^{-7} \text{N}$.

When current increases, flux in upward direction increases so by Lenz' law, current in circular coil should be **clockwise**.