SOLUTIONS

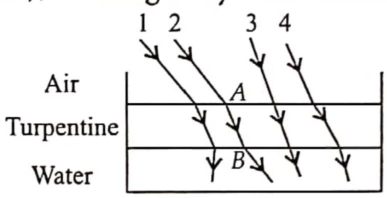
1. For electron of energy E,

de-Broglie wavelength, $\lambda_e = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$

For photon of energy, $E = h\upsilon = \frac{hc}{\lambda_p} \Rightarrow \lambda_p = \frac{hc}{E}$

$\therefore \frac{\lambda_e}{\lambda_p} = \frac{h}{\sqrt{2mE}} \times \frac{E}{hc} = \frac{1}{c}\left(\frac{E}{2m}\right)^{1/2}$

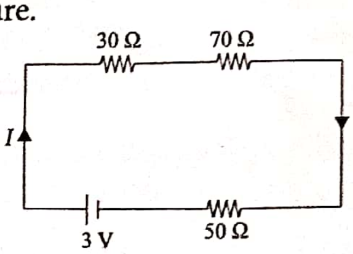
2. In the figure, the path shown for the ray 2 is correct. The ray suffers two refractions : At A, ray goes from air to turpentine, bending towards normal. At B, ray goes from turpentine to water (*i.e.*, from denser to rarer medium), bending away from normal.



3. Depletion layer : The small region in the vicinity of the junction which is depleted of free charge carriers and has only immobile ions is called the depletion layer.
Barrier potential : Due to accumulation of negative charges in the p-region and positive charges in the n-region sets up a potential difference across the junction sets up. This acts as a barrier and is called potential barrier V_B which opposes the further diffusion of electrons and holes across the junction.
(i) When there is an increase in doping concentration, the applied potential difference causes an electric field which acts opposite to the potential barrier. This results in reducing the potential barrier and hence the width of depletion layer decreases.
(ii) In forward biasing the width of depletion layer reduced and the external applied field is able to overcome the strong electric field of depletion layer. In reverse biasing the width of depletion layer increases and the electric field of depletion layer become more stronger.

OR

Here, diode D_1 is reverse biased and diode D_2 is forward biased. Equivalent circuit can be drawn as shown in figure.



Net resistance of the circuit, $R_N = 30\ \Omega + 70\ \Omega + 50\ \Omega = 150\ \Omega$

$\therefore$ Current in the circuit, $I = \frac{V}{R_N} = \frac{3\text{ V}}{150\ \Omega} = \frac{1}{50}$ A

So, voltage drop across 50 Ω resistance,

$V_{50\Omega} = IR = \frac{1}{50} \text{ A} \times 50\ \Omega = 1 \text{ V}$

4. According to Bohr's second postulate quantization of angular momentum

$$mv_n r_n = n\frac{h}{2\pi} \quad \text{or} \quad r_n = \frac{nh}{2\pi m v_n} \quad \text{...(i)}$$

where h is the Planck's constant
Circumference of the electron in the n^{th} orbital state in hydrogen atom,

$$2\pi r_n = 2\pi \frac{nh}{2\pi m v_n} \quad \text{(Using (i))}$$

$$2\pi r_n = n\frac{h}{mv_n} \quad \text{...(ii)}$$

But de Broglie wavelength of the electron

$$\lambda = \frac{h}{mv_n} \quad \text{...(iii)}$$

From (ii) and (iii), we get
$\therefore \quad 2\pi r_n = n\lambda$

5. Frequency of electromagnetic wave does not change with change in medium but wavelength and velocity of wave changes with change in medium.
Velocity of electromagnetic wave in vacuum

$$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = \upsilon\lambda_{\text{vacuum}} \quad \text{...(i)}$$

Velocity of electromagnetic wave in the medium

$$v_{\text{medium}} = \frac{1}{\sqrt{\mu_0\mu_r\varepsilon_0\varepsilon_r}} = \frac{c}{\sqrt{\mu_r\varepsilon_r}}$$

where μ_r and ε_r be relative permeability and relative permittivity of the medium.
For dielectric medium, $\mu_r = 1$

$$\therefore \quad v_{\text{medium}} = \frac{c}{\sqrt{\varepsilon_r}}$$

Here, $\varepsilon_r = 4.0$

$$\therefore \quad v_{\text{medium}} = \frac{c}{\sqrt{4}} = \frac{c}{2} \quad \text{...(ii)}$$

Wavelength of the wave in medium

$$\lambda_{\text{vaccum}} = \frac{c}{\upsilon} = \frac{3\times10^8}{3\times10^6} = 100$$

$$\lambda_{medium} = \frac{v_{medium}}{\upsilon} = \frac{c}{2\upsilon} = \frac{\lambda_{vacuum}}{2} = \frac{100}{2} = 50 \text{ m}$$

(Using (i) and (ii))

6. Clearly, equivalent focal length of equiconvex lens and water lens, $f = x$

Focal length of equiconvex lens $f_1 = y$

Focal length f_2 of water lens is given by

$$\frac{1}{f_2} = \frac{1}{f} - \frac{1}{f_1} = \frac{1}{x} - \frac{1}{y} = \frac{y-x}{xy}$$

or $f_2 = \dfrac{xy}{y-x}$

The water lens formed between the plane mirror and the equiconvex lens is a planoconcave lens. For this lens,

$R_1 = -R$ and $R_2 = \infty$

Using lens maker's formula, $\dfrac{1}{f_2} = (\mu - 1)\left[\dfrac{1}{R_1} - \dfrac{1}{R_2}\right]$

or $\dfrac{y-x}{xy} = (\mu-1)\left[\dfrac{1}{-R} - \dfrac{1}{\infty}\right]$

or $\mu - 1 = \dfrac{(x-y)R}{xy}$ or $\mu = 1 + \dfrac{(x-y)R}{xy}$.

7. Einstein's photoelectric equation is given below.

$$h\upsilon = \frac{1}{2}mv_{max}^2 + W_0$$

where υ = frequency of incident radiation

$\frac{1}{2}mv_{max}^2$ = maximum kinetic energy of an emitted electron

W_0 = work function of the target metal

Three salient features observed are

(i) Below threshold frequency υ_0 corresponding to W_0, no emission of photoelectrons takes place.

(ii) As energy of a photon depends on the frequency of light, so the maximum kinetic energy with which photoelectron is emitted depends only on the energy of photon or on the frequency of incident radiation.

(iii) For a given frequency of incident radiation, intensity of light depends on the number of photons per unit area per unit time and one photon liberates one photoelectron, so number of photoelectrons emitted depend only on its intensity.

OR

According to the Einstein's photoelectric equation, $E = W_0 + \frac{1}{2}mv^2$

When frequency of incident light is $2\upsilon_0$.

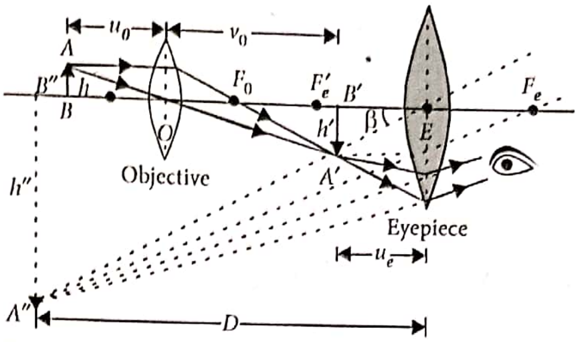
$$h(2\upsilon_0) = h\upsilon_0 + \frac{1}{2}mv_1^2 \Rightarrow h\upsilon_0 = \frac{1}{2}mv_1^2 \quad \text{...(i)}$$

When frequency of incident light is $5\upsilon_0$

$$h(5\upsilon_0) = h\upsilon_0 + \frac{1}{2}mv_2^2 \Rightarrow 4h\upsilon_0 = \frac{1}{2}mv_2^2 \quad \text{...(ii)}$$

Dividing (i) by (ii), $\dfrac{1}{4} = \dfrac{v_1^2}{v_2^2}$ or $\dfrac{v_1}{v_2} = \dfrac{1}{2}$.

8. (a)



(b) Separation between eye-piece and the objective, $L = 14$ cm,

$m = -20$, $m_e = 5$, $D = 20$ cm, $f_o = ?$, $f_e = ?$

Magnification of eye-piece when image is formed at the least distance for clear vision

$$m_e = \left(1 + \frac{D}{f_e}\right) \Rightarrow 5 = \left(1 + \frac{20}{f_e}\right)$$

$$\Rightarrow 4 = \frac{20}{f_e} \Rightarrow f_e = 5 \text{ cm}$$

Net magnification of the compound microscope when image is formed at the least distance for clear vision

$$m = -\frac{L}{f_o}\left(1 + \frac{D}{f_e}\right) \Rightarrow -20 = -\frac{14}{f_o}\left(1 + \frac{20}{5}\right)$$

$$\Rightarrow 10 = \frac{7}{f_o}(5) \Rightarrow f_o = \frac{35}{10} = 3.5 \text{ cm}$$

9. $\dfrac{(Ze)(2e)}{4\pi\varepsilon_0(r_0)} = \text{K.E.}$

$$\therefore \quad r_0 = \frac{2Ze^2}{4\pi\varepsilon_0(K.E.)} \qquad (\because Z = 80, K.E. = 8 \text{ MeV})$$

$$r_0 = \frac{9\times10^9 \times 2 \times 80 \times (1.6\times10^{-19})^2}{8\times10^6 \times (1.6\times10^{-19})} \text{m}$$

$$r_0 = \frac{18\times1.6\times10^{-10}\times80}{8\times10^6} = 2.88\times10^{-14} \text{ m}$$

$$\because \quad r_0 \propto \frac{1}{\text{K.E.}}$$

If K.E. becomes twice then $r_0' = \dfrac{r_0}{2}$

i.e. distance of closest approach becomes half.

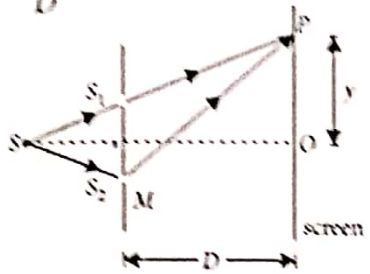
10. (a) Given : $SS_2 - SS_1 = \dfrac{\lambda}{4}$

Now path difference between the two waves from slit S_1 and S_2 on reaching point P on screen is

$\Delta x = (SS_2 + S_2P) - (SS_1 + S_1P)$

or $\Delta x = (SS_2 - SS_1) + (S_2P - S_1P)$

or $\Delta x = \frac{\lambda}{4} + \frac{yd}{D}$, where d is the slits separation.



For constructive interference at point P, path difference, $\Delta x = n\lambda$ or $\frac{\lambda}{4} + \frac{yd}{D} = n\lambda$

or $\frac{yd}{D} = \left(n - \frac{1}{4}\right)\lambda$ ...(i)

where $n = 0, 1, 2, 3, ...$

(b) From equation (i), $y_n = \left(n - \frac{1}{4}\right)\frac{\lambda D}{d}$

and $y_{n-1} = \left(n - 1 - \frac{1}{4}\right)\frac{\lambda D}{d}$

The fringe width is given by separation of two consecutive bright fringes.

$$\beta = y_n - y_{n-1} = \left(n - \frac{1}{4}\right)\frac{\lambda D}{d} - \left(n - 1 - \frac{1}{4}\right)\frac{\lambda D}{d} = \frac{\lambda D}{d}$$

OR

(a) The angular width of central maximum is given by

$2\theta_0 = \frac{2\lambda}{a}$, ...(i)

where the letters have their usual meanings.

(i) Effect of slit width : From the equations (i), it follows that $\beta_0 \propto \frac{1}{a}$. Therefore, as the slit width is increased, the width of the central maximum will decrease.

(ii) Effect of distance between slit and screen (D) : From the equation (i), it follows that $2\theta_0$ is independent of D. So the angular width will remain same whatever the value of D.

(b) Difference between interference and diffraction

	Interference	Diffraction
1.	Interference is caused by superposition two waves starting from two coherent sources.	Diffraction is caused by superposition of a number of waves starting from the slit.
2.	All bright and dark fringes are of equal width.	Width of central bright fringe is double of all other maxima.
3.	All bright fringes are of same intensity.	Intensity of bright fringes decreases sharply as we move away from central bright fringe.
4.	Dark Fringes are perfectly dark.	Dark fringes are not perfectly dark.

11. (i) $\beta = \frac{\lambda D}{d} = \frac{5000 \times 10^{-10} \times 1}{1 \times 10^{-3}} = 0.5$ mm

(ii) $y = (2n-1)\frac{\lambda D}{d}, n = 5 \Rightarrow y = 2.25$ mm

(iii) At $y = \frac{1}{3}$ mm, $y << D \Rightarrow \Delta x = \frac{yd}{D}$

$$\Delta\phi = \frac{2\pi}{\lambda}\Delta x = 2\pi\frac{dy}{\lambda D} = \frac{4\pi}{3}$$

Now, resultant intensity

$$I = I_1 + I_2 + 2\cos\Delta\phi = 4I_0 + I_0 + 2\sqrt{4I_0^2}\cos\Delta\phi$$

$$= 5I_0 + 4I_0\cos\frac{4\pi}{3} = 3I_0$$

(iv) $\frac{d}{\lambda} = \frac{10^{-3}}{0.5 \times 10^{-6}} = 2000$

$n = 1000$ is not $<< 2000$

Hence, now $\Delta x = d\sin\theta$ must be used.

$\therefore$ $d\sin\theta = n\lambda = 1000\lambda \Rightarrow \sin\theta = 1000\frac{\lambda}{d} = \frac{1}{2}$

$\Rightarrow \theta = 30°$

$y = D\tan\theta = \frac{1}{\sqrt{3}}$ m

12. (i) **(c)** : In insulator, energy band gap is > 3 eV

(ii) **(b)**: In conductor, separation between conduction and valence bands is zero and in insulator, it is greater than 1 eV. Hence in semiconductor the separation between conduction and valence band is 1 eV.

(iii) **(a)**: According to band theory the forbidden gap in conductors $E_g \approx 0$, in insulators $E_g > 3$ eV and in semiconductors $E_g < 3$ eV.

(iv) **(a)**: The four valence electrons of C, Si and Ge lie respectively in the second, third and fourth orbit. Hence energy required to take out an electron from these atoms (*i.e.* ionisation energy E_g) will be least for Ge, followed by Si and highest for C. Hence, the number of free electrons for conduction in Ge and Si are significant but negligibly small for C.

(v) **(b)**

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