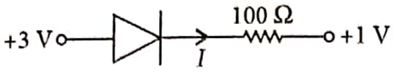
SOLUTIONS

1. 

In the given circuit, the junction diode is forward biased and offers zero resistance.

Current, $I = \dfrac{3\text{ V} - 1\text{ V}}{100\ \Omega} = 0.02\text{ A}$

2. Here, $\mu = 1.6$, $A = 60°$

As, $\mu = \dfrac{\sin\left(\dfrac{A+\delta_m}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$

$\therefore \quad \sin\left(\dfrac{60°+\delta_m}{2}\right) = 1.6\sin\left(\dfrac{60°}{2}\right)$

$\Rightarrow \sin\left(\dfrac{60°+\delta_m}{2}\right) = 0.8 \Rightarrow \delta_m = 46.3°$

OR

Position of first minimum in diffraction pattern $y = \dfrac{D\lambda}{a}$

So slit width, $a = \dfrac{D\lambda}{y} = \dfrac{1\times 500\times 10^{-9}}{2.5\times 10^{-3}} = 2\times 10^{-4}\text{ m}$

3. Here, $\rho = 0.50\ \Omega$ m, $\mu_e = 0.39$ m^2/V s, $\mu_h = 0.11$ m^2/V s

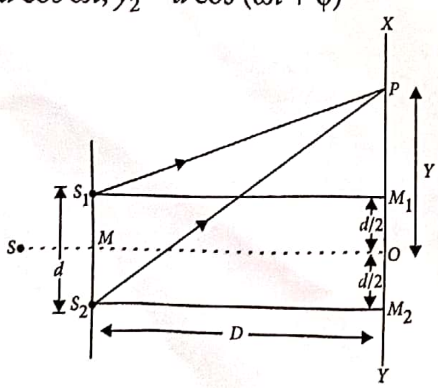
The resistivity of intrinsic semiconductor is

$$\rho = \frac{1}{en_i(\mu_e + \mu_h)} \Rightarrow n_i = \frac{1}{\rho e(\mu_e + \mu_h)}$$

Substituting the given values, we get

$$n_i = \frac{1}{(0.5)(1.6\times 10^{-19})(0.39+0.11)} = 2.5\times 10^{19}/\text{m}^3$$

4. $y_1 = a\cos\omega t$, $y_2 = a\cos(\omega t + \phi)$



where ϕ is phase difference between them.

Resultant displacement at point P will be,

$y = y_1 + y_2 = a\cos\omega t + a\cos(\omega t + \phi)$

$= a[\cos\omega t + \cos(\omega t + \phi)]$

$$= a\left[2\cos\frac{(\omega t + \omega t + \phi)}{2}\cos\frac{(\omega t - \omega t - \phi)}{2}\right]$$

$$y = 2a\cos\left(\omega t + \frac{\phi}{2}\right)\cos\left(\frac{\phi}{2}\right) \qquad \text{...(i)}$$

Let $y = 2a\cos\left(\dfrac{\phi}{2}\right) = A$, the equation (i) becomes

$$y = A\cos\left(\omega t + \frac{\phi}{2}\right)$$

where A is amplitude of resultant wave,

Now, $A = 2a\cos\left(\dfrac{\phi}{2}\right)$

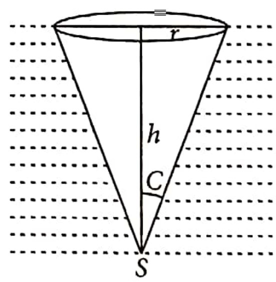
On squaring, $A^2 = 4a^2\cos^2\left(\dfrac{\phi}{2}\right)$

Hence, resultant intensity,

$$I = 4I_0\cos^2\left(\frac{\phi}{2}\right) \qquad [\because I_0 = a^2]$$

5. (a) Microwaves are suitable for radar systems used in aircraft navigation.
These waves are produced by special vacuum tubes, namely Klystrons, Magnetrons and Gunn diodes.
(b) Infra-red waves are used to treat muscular pain. These waves are produced by hot bodies and molecules.
(c) X-rays are used as a diagnostic tool in medicine. These are produced when high energy electrons are stopped suddenly on a metal of high atomic number.

6.



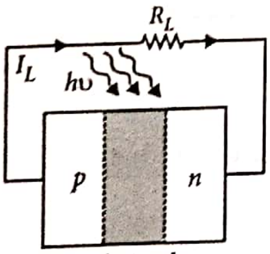
The light rays starting from bulb can pass through the surface if angle of incidence at surface is less than or equal to critical angle (C) for water air interface. If h is the depth of bulb from the surface, the light will emerge only through a circle of radius r given by

$$r = \frac{h}{\sqrt{\mu^2 - 1}}$$

Area of water surface $= \dfrac{\pi h^2}{\mu^2 - 1}$

$$= \frac{22}{7}\times\frac{(0.80)^2}{(1.33)^2 - 1} = 2.6\text{ m}^2$$

7. (a) Bulb B_1 will glow, as diode D_1 is forward biased. Bulb B_2 will not glow as diode D_2 is reverse biased.
(b) A solar cell works on the principle of photovoltaic effect according to which when light photons of energy greater than energy band gap of a semiconductor are incident on p-n junction of that semiconductor, electron-hole pairs are generated which give rise to an emf.
Generation of emf : Three basic processes are involved in the generation of emf by a solar cell when solar radiations are incident on it. These are:
(i) The generation of electron-hole pairs close to the junction due to incidence of light with photo energy $h\upsilon \geq E_g$.
(ii) The separation of electrons and holes due to the electric field of the depletion region. So, electrons are swept to n-side and holes to p-side.
(iii) The electrons reaching the n-side are collected by the front contact and holes reaching p-side are collected by the back contact. Thus, p-side becomes positive and n-side become negative giving rise to a photo voltage.



Depletion layer

When an external load R_L is connected as shown in figure, a photocurrent I_L begins to flow through the load.

8. Einstein's photoelectric equation : According to Einstein, when light is incident on metal surface, incident photons are absorbed completely by valence electrons of atoms of metal on its surface. Energy $h\upsilon$ of each photon is partially utilized by an electron to become free or to overcome its "work function" W_0 and rest of the absorbed energy provides the maximum kinetic energy to the photoelectron during the emission. *i.e.*

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

(i) The minimum value of the frequency of incident radiation below which the photoelectric emission stops *i.e.* kinetic energy of photoelectron is zero is called threshold frequency (υ_0).

Threshold frequency, $\upsilon_0 = \dfrac{W}{h}$

$$\frac{1}{2}mv_{max}^2 = K.E._{max} = h\upsilon - W_0$$

or, $K.E._{max} = eV_0$

(ii) When work done by collecting electrode potential on a photoelectron is equal to its maximum kinetic energy then the electrode potential is known as stopping potential.

Stopping potential, $V_0 = \dfrac{K.E._{max}}{e}$

OR

For non-relativistic electron, wavelength

$$\lambda_e = \frac{h}{p} = \frac{h}{\sqrt{2m_e E_e}} \quad ...(i)$$

Also for non-relativistic proton, wavelength

$$\lambda_p = \frac{h}{p} = \frac{h}{\sqrt{2m_p E_p}} \quad ...(ii)$$

Given, kinetic energy of electron = 5 times kinetic energy of proton *i.e.*, $E_e = 5E$ and $m_p = 2000m_e$
From equation (i) and (ii)

$$\Rightarrow \frac{\lambda_e}{\lambda_p} = \frac{\sqrt{2m_p E_p}}{\sqrt{2m_e E_e}} = \frac{\sqrt{2 \times 2000 m_e \times E_p}}{\sqrt{2 \times m_e \times 5E_p}}$$

or $\dfrac{\lambda_e}{\lambda_p} = \sqrt{400} = 20 \Rightarrow \lambda_e = 20\lambda_p$

9. Energy released = $\Delta m \times 931$ MeV
$\Delta m = 4m\,({}^1_1\text{H}) - m\,({}^4_2\text{He})$
Energy released
$Q = [4m\,({}^1_1\text{H}) - m\,({}^4_2\text{He})] \times 931$ MeV
$= [4 \times 1.007825 - 4.002603] \times 931$ MeV $= 26.72$ MeV.

10. We know that fringe width of central maximum in Fraunhoffer diffraction, $\beta_0 = \dfrac{2\lambda D}{d}$

$\therefore$ Angular width of central maximum, $\theta = \dfrac{\beta_0}{D} = \dfrac{2\lambda}{d}$
On differentiating both sides, we get

$$\Delta\theta = \frac{2\Delta\lambda}{d} \Rightarrow d = \frac{2\Delta\lambda}{\Delta\theta}$$

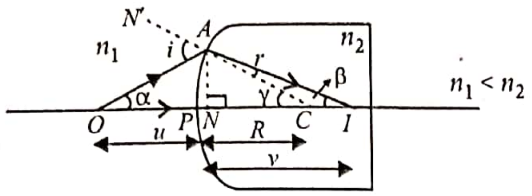
Now, $\Delta\lambda = \left(\dfrac{c}{\upsilon_1} - \dfrac{c}{\upsilon_2}\right) = \dfrac{3\times10^8}{4\times10^{14}} - \dfrac{3\times10^8}{5\times10^{14}}$

$= 10^{-6}(0.75 - 0.6) = 0.15 \times 10^{-6} = 1.5 \times 10^{-7}$ m

$\therefore$ Width of the slit, $d = \dfrac{2\times1.5\times10^{-7}}{0.6} = 5\times10^{-7}$ m

11. Refraction at convex spherical surface :

When object is in rarer medium and image formed is real.



In ΔOAC, $i = \alpha + \gamma$

and in ΔAIC, $\gamma = r + \beta$ or $r = \gamma - \beta$

$\therefore$ Using Snell's law $^1n_2 = \frac{\sin i}{\sin r} \approx \frac{i}{r} = \frac{\alpha + \gamma}{\gamma - \beta}$

or $\frac{n_2}{n_1} = \frac{\alpha+\gamma}{\gamma-\beta}$ or $n_2\gamma - n_2\beta = n_1\alpha + n_1\gamma$

or $(n_2 - n_1)\gamma = n_1\alpha + n_2\beta$ ...(i)

As α, β and γ are small and P and N lie close to each other,

So, $\alpha \approx \tan\alpha = \frac{AN}{NO} \approx \frac{AN}{PO}$

$\beta \approx \tan\beta = \frac{AN}{NI} \approx \frac{AN}{PI}$

$\gamma \approx \tan\gamma = \frac{AN}{NC} \approx \frac{AN}{PC}$

On using them in equation (i), we get

$(n_2 - n_1)\frac{AN}{PC} = n_1\frac{AN}{PO} + n_2\frac{AN}{PI}$

or $\frac{n_2 - n_1}{PC} = \frac{n_1}{PO} + \frac{n_2}{PI}$

where, $PC = +R$, radius of curvature

$PO = -u$, object distance

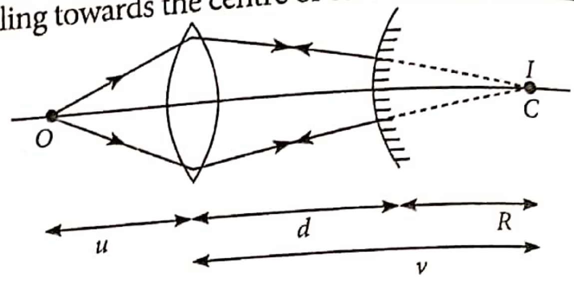
$PI = +v$, image distance

So $\frac{n_2 - n_1}{R} = \frac{n_1}{-u} + \frac{n_2}{v}$ or $\frac{n_2 - n_1}{R} = \frac{n_2}{v} - \frac{n_1}{u}$

This gives formula for refraction at spherical surface when object is in rarer medium.

OR

Since the final image coincides with the object, the rays from the object are retracing its path. So, the refracted rays are falling towards the centre of curvature of the mirror.



From lens formula,

$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{10} + \frac{1}{-12} \Rightarrow v = 60$ cm

$\therefore$ $R = v - d = 60 - 10 = 50$ cm

$\therefore$ $f = \frac{R}{2} = 25$ cm

12. (i) **(d) :** For Balmer series, $n_1 = 2$; $n_2 = 3, 4, \ldots$ (lower) (higher)

Therefore, in transition (VI), photon of Balmer series is absorbed.

(ii) **(c) :** In transition II,

$E_2 = -3.4$ eV, $E_4 = -0.85$ eV,

$\Delta E = 2.55 \text{ eV} \Rightarrow \Delta E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{\Delta E} = 487$ nm

(iii) **(d) :** Wavelength of radiation = 1030 Å

$\Delta E = \frac{12400}{1030 \text{ Å}} = 12.0$ eV

So, difference of energy should be 12.0 eV (approx.)

Hence for $n_1 = 1$ to $n_2 = 3$

$E_{n_3} - E_{n_1} = -1.51 \text{ eV} - (-13.6 \text{ eV}) \approx 12$ eV

Therefore, transition V will occur.

(iv) **(a) :** $T^2 \propto r^3$ and $r \propto n^2 \Rightarrow T^2 \propto n^6 \Rightarrow T \propto n^3$

$\frac{T_1}{T_2} = \left(\frac{n_1}{n_2}\right)^3 \Rightarrow 8 = \left(\frac{n_1}{n_2}\right)^3$ or $\frac{n_1}{n_2} = 2$

(v) **(b)**

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