1. For a single slit of width "a" the first minima of the interference pattern of a monochromatic light of wavelength λ occurs at an angle of (λ/a) because the light from centre of the slit differs by a half of a wavelength.
Whereas a double slit experiment at the same angle of (λ/a) and slits separation "a" produces maxima because one wavelength difference in path length from these two slits is produced.

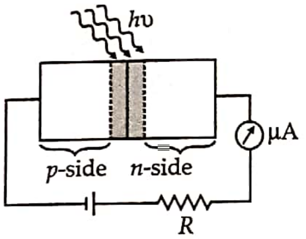
2. Frequency of incident radiation is

$$\upsilon = \frac{c}{\lambda} = \frac{3\times10^8}{2000\times10^{-10}} = 1.5\times10^{15}\text{ Hz}$$

The work function of the metal is

$$\phi_0 = h\upsilon - eV_s$$
$$= 6.6\times10^{-34}\times1.5\times10^{15} - 1.6\times10^{-19}\times1.5 = 7.5\times10^{-19}\text{J}$$

3. Working of photodiode : A junction diode made from light sensitive semiconductor is called a photodiode. A photodiode is a p-n junction diode arranged in reverse biasing.



The number of charge carriers increases when light of suitable frequency is made to fall on the p-n junction, because new electron holes pairs are created by absorbing the photons of suitable frequency. Intensity of light controls the number of charge carriers. Due to this property photodiodes are used to detect optical signals.

OR

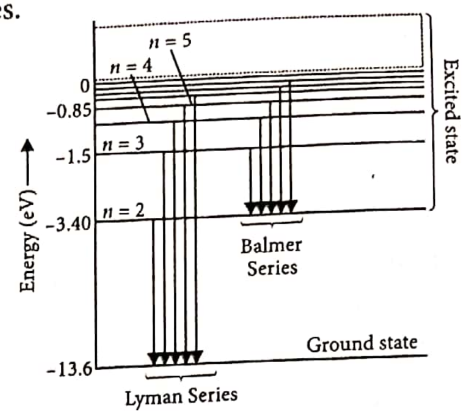
Current in diode is 5 times that in R_1.
Current through R_1 is

$$I_1 = \frac{V}{R_1} = \frac{6}{1\times10^3}\text{ A} = 6\text{ mA}$$

So total current drawn from battery
$= 6\text{ mA} + 30\text{ mA} = 36\text{ mA}$
Potential difference across $R = 24$ volt
So $V = IR$; $24 = 36\times10^{-3} R$; $R = 2000/3\ \Omega$

4. (i) An electron undergoes transition from 2nd excited state to the first excited state is Balmer series and then to the ground state is Lyman series.

(ii) The wavelength of the emitted radiations in the two cases.



For $n_2 \to n_1$
$\Delta E = (-3.40 + 13.6) = 10.20$ eV

$$\lambda_2 = \frac{6.626\times10^{-34}\times3\times10^8}{10.2\times1.6\times10^{-19}}$$

$$\lambda_2 = \frac{19.878\times10^{-7}}{10.2\times1.6} = 1.218\times10^{-7}\text{m} = 1218\text{ Å}$$

For $n_3 \to n_2$
$\Delta E = (-1.5 + 3.4) = 1.9$ eV

$$\lambda_1 = \frac{19.878\times10^{-7}}{1.9\times1.6} = 6.538\times10^{-7}\text{ m} = 6538\text{ Å}$$

The ratio $\frac{\lambda_1}{\lambda_2} = \frac{6538}{1218} = 5.36$

5. The maximum kinetic energy is given as

$$K_{max} = h\upsilon - \phi_0 = h\upsilon - h\upsilon_o = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

where λ_0 = threshold wavelength

or $\frac{1}{2}mv^2 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$

Here, $hc = 4.14\times10^{-15}$ eV s $\times 3\times10^8$ m s^{-1} = 12420 eV Å

$$\therefore \frac{1}{2}mv^2 = 12420\left[\frac{1}{2536} - \frac{1}{3250}\right]\text{eV} = 1.076\text{ eV}$$

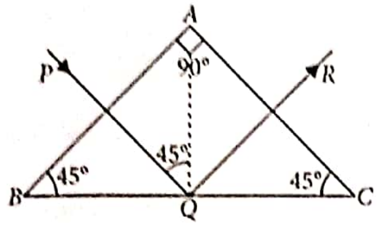
$$v^2 = \frac{2.152\text{ eV}}{m} = \frac{2.152\times1.6\times10^{-19}}{9.1\times10^{-31}}$$

$\therefore\ v \approx 6\times10^5$ m s^{-1}

6. (a) Gamma rays has the highest frequency in the electromagnetic waves. These rays are of the nuclear origin and are produced in the disintegration of radioactive atomic nuclei and in the decay of certain subatomic particles. They are used in the treatment of cancer and tumours.
(b) Ultraviolet rays lie near the high-frequency end of visible part of $e.m.$ spectrum. These rays are used to

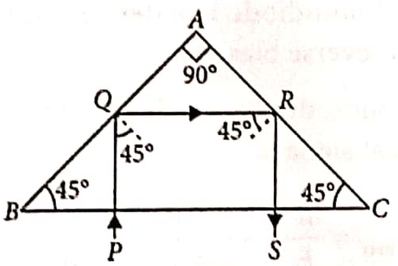
preserve food stuff. The harmful effect from exposure to ultraviolet (UV) radiation can be life threatening, and include premature aging of the skin, suppression of the immune systems, damage to the eyes and skin cancer.

7. (i) To deviate a ray of light through 90° :

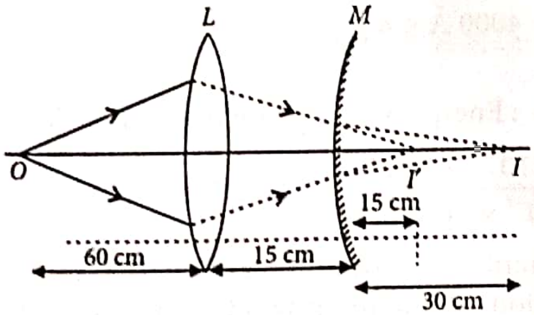


A totally reflecting prism is used to deviate the path of the ray of light through 90°, when it is inconvenient to view the direct light. In Michelson's method to find velocity of light, the direct light from the octagonal mirror is avoided from direct viewing by making use of totally reflecting prism.

(ii) To deviate a ray of light through 180° : When the ray of light comes to meet the hypotenuse face BC at right angles to it, it is refracted out of prism as such along the path RS. The path of the ray of light has been turned through 180° due to two total internal reflections.



OR



For the convex lens,

$u = -60$ cm, $f = +20$ cm

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ gives $v = +30$ cm

For the convex mirror

$u = +(30 - 15)$ cm $= 15$ cm, $f = +\frac{20}{2}$ cm $= 10$ cm

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ gives $v = +30$ cm

Final image is formed at the distance of 30 cm from the convex mirror (or 45 cm from the convex lens) to the right of the convex mirror.

The final image formed is a virtual image.

8. $\lambda = 6000$ Å $= 6000 \times 10^{-10}$ m $= 6 \times 10^{-7}$ m, $\theta_1 = 30°$, $m = 1$

(i) For first maximum, $\sin\theta_m = \frac{\left(m+\frac{1}{2}\right)\lambda}{a}$

$$\sin\theta_1 = \frac{3\lambda}{2a} \text{ or } a = \frac{3\lambda}{2\sin\theta_1} = \frac{3\times6\times10^{-7}}{2\times\sin 30°}$$

$= 1.8 \times 10^{-6}$ m $= 1.8$ μm

(ii) For first minimum,

$$\sin\theta_m = \frac{m\lambda}{a} \therefore \sin\theta_1 = \frac{\lambda}{a}$$

$$\Rightarrow a = \frac{\lambda}{\sin\theta_1} = \frac{6\times10^{-7}}{\sin 30°} = 1.2\times10^{-6}\text{ m} = 1.2\ \mu\text{m}$$

9. Number of atoms in 2 g of deuterium $= 6.023 \times 10^{23}$

$\therefore$ Number of atoms in 2 kg (= 2000 g) of deuterium

$$= \frac{6.023 \times 10^{23}}{2} \times 2000 = 6.023 \times 10^{26}$$

Energy released in the fusion of two deuterium nuclei = 3.27 MeV

$\therefore$ Total released in the fusion of 2 kg of deuterium

$$E = \frac{3.27}{2} \times 6.023 \times 10^{26}\text{ MeV}$$

$$= \frac{3.27 \times 6.023 \times 10^{26} \times 1.6 \times 10^{-13}}{2}\text{ J} = 15.75 \times 10^{13}\text{ J}$$

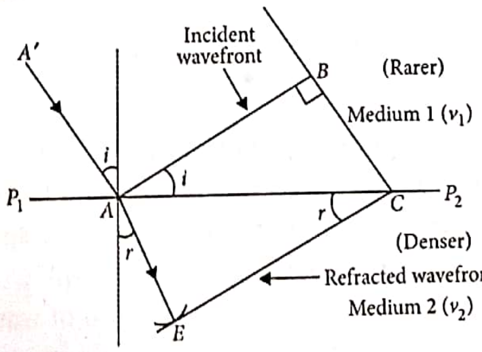
Power of bulb, $P = 100$ W $= 100$ J/s

$\therefore$ Time for which the bulb will glow is

$$t = \frac{E}{P} = \frac{15.75 \times 10^{13}\text{ J}}{100\text{ J/s}} = 15.75 \times 10^{11}\text{ s}$$

$$= \frac{15.75 \times 10^{11}}{60 \times 60 \times 24 \times 365}\text{ years} = 5 \times 10^4\text{ years}$$

10. Snell's law of refraction : Let P_1P_2 represents the surface separating medium 1 and medium 2 as shown in figure.



Let v_1 and v_2 represents the speed of light in medium 1 and medium 2 respectively. We assume a plane wavefront AB propagating in the direction $A'A$ incident on the interface at an angle i. Let t be the time taken by the wavefront to travel the distance BC.

$\therefore \quad BC = v_1 t$ [$\because$ distance = speed × time]

In order to determine the shape of the refracted wavefront, we draw a sphere of radius $v_2 t$ from the point A in the second medium (the speed of the wave in second medium is v_2).

Let CE represents a tangent plane drawn from the point C. Then

$AE = v_2 t$

$\therefore$ CE would represent the refracted wavefront.

In ΔABC and ΔAEC, we have

$$\sin i = \frac{BC}{AC} = \frac{v_1 t}{AC} \text{ and } \sin r = \frac{AE}{AC} = \frac{v_2 t}{AC}$$

where i and r are the angles of incident and refraction respectively.

$$\therefore \quad \frac{\sin i}{\sin r} = \frac{v_1 t}{AC} \cdot \frac{AC}{v_2 t}$$

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2}$$

If c represents the speed of light in vacuum, then

$$\mu_1 = \frac{c}{v_1} \text{ and } \mu_2 = \frac{c}{v_2}$$

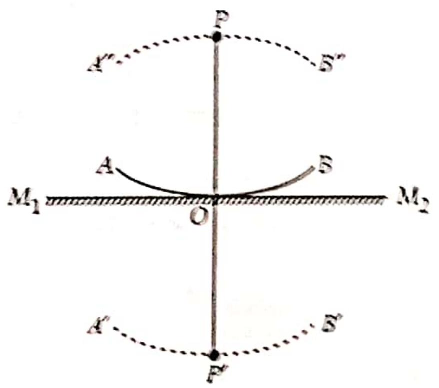
$$\Rightarrow \quad v_1 = \frac{c}{\mu_1} \text{ and } v_2 = \frac{c}{\mu_2}$$

where μ_1 and μ_2 are the refractive indices of medium 1 and medium 2.

$$\therefore \quad \frac{\sin i}{\sin r} = \frac{c/\mu_1}{c/\mu_2} \Rightarrow \frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} \Rightarrow \mu_1 \sin i = \mu_2 \sin r$$

This is the Snell's law of refraction.

OR



In figure, P is a point object placed at a distance r from a plane mirror M_1M_2. With P as centre and $PO = r$ as radius, draw a spherical arc; AB. This is the spherical wavefront from the object, incident on M_1M_2.

If mirrors were not present, the position of wavefront AB would be $A'B'$ where $PP' = 2r$. In the presence of the mirror, wave front AB would appear as $A''PB''$, according to Huygen's construction. As it is clear from the figure $A'B'$ and $A''B''$ are two spherical arcs located symmetrically on either side of M_1M_2. Therefore, $A'P'B'$ can be treated as reflected image of $A''PB''$. From simple geometry, we find $OP = OP'$, which was to be proved.

11. Frequency of light in both mediums remains constant, *i.e.*, $\upsilon_g = \upsilon_w$

$$\text{or} \quad \frac{v_g}{\lambda_g} = \frac{v_w}{\lambda_w} \qquad \left(\because \upsilon = \frac{v}{\lambda}\right)$$

$$\text{or} \quad \frac{c}{\mu_g \lambda_g} = \frac{c}{\mu_w \lambda_w} \qquad \left(\because v = \frac{c}{\mu}\right)$$

$$\text{or} \quad \mu_g \lambda_g = \mu_w \lambda_w \qquad \text{...(i)}$$

Let there be n waves in 8 cm thickness of glass slab, then

$$\lambda_g = \frac{8 \text{ cm}}{n}$$

$$\text{Similarly, } \lambda_w = \frac{10 \text{ cm}}{n}$$

Putting these values in eqn. (i), we get

$$\mu_g \times \frac{8 \text{ cm}}{n} = \frac{4}{3} \times \frac{10 \text{ cm}}{n} \qquad \left(\because \mu_w = \frac{4}{3} \text{ (given)}\right)$$

$$\text{or} \quad \mu_g = \frac{5}{3}$$

12. (i) **(a)** : Photodiode is a device which is always operated in reverse bias.

(ii) **(a)**: A photodiode is a device which is used to detect optical signals.

(iii) **(c)** : $\lambda_{max} = \frac{hc}{E} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{2.5 \times 1.6 \times 10^{-19}}$

$= 5000$ Å

$\therefore \quad \lambda = 4000$ Å $< \lambda_{max}$

(iv) **(b)** : Energy of incident photon, $E = \frac{hc}{\lambda}$

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{6 \times 10^{-7} \times 1.6 \times 10^{-19}} = 2.06 \text{ eV}$$

The incident radiation can be detected by a photodiode if energy of incident photon is greater than the band gap.

As $D_2 = 2$ eV, therefore D_2 will detect these radiations.

(v) **(c)** : Let E_g be the required bandwidth. Then

$$E_g = \frac{hc}{\lambda}$$

Here, $hc = 1240$ eV nm, $\lambda = 500$ nm

$$\therefore \quad E_g = \frac{1240 \text{ eV nm}}{500 \text{ nm}} = 2.48 \text{ eV}$$