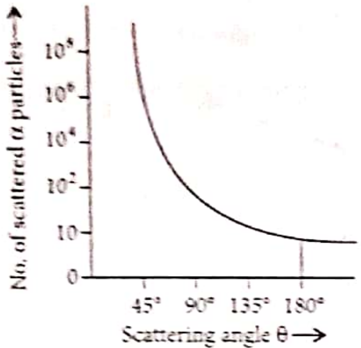
< SOLUTIONS >

1. A light emitting diode is simply a forward biased *p-n* junction which emits spontaneous light radiation. At the junction, energy is released in the form of photons due to the recombination of the excess minority charge carrier with the majority charge carrier.

Advantages :

(i) Low operational voltage and less power.

(ii) Fast action and no warm up time required.

2. 

A very small fraction of α-particles are scattered at $\theta > 90°$ because the size of nucleus is very small nearly 1/8000 times the size of atom. So, a few α-particles experience a strong repulsive force and turn back.

Conclusions :

(i) Entire positive charge and most of the mass of the atom is concentrated in the nucleus with the electrons some distance away.

(ii) Size of the nucleus is about 10^{-15} m to 10^{-14} m, while size of the atom is 10^{-10} m, so the electrons are at distance 10^4 m to 10^5 m from the nucleus, and being large empty space in the atom, most α particles go through the empty space.

OR

(a) $\lambda = 496 \text{ nm} = 496 \times 10^{-9}$ m

$$E = \frac{hc}{\lambda} = \frac{6.62\times10^{-34}\times3\times10^{8}}{496\times10^{-9}} \text{ J}$$

$$= \frac{6.6\times10^{-34}\times3\times10^{8}}{496\times10^{-9}\times1.6\times10^{-19}} = 2.5 \text{ eV}$$

This energy corresponds to the transition $A(n = 4$ to $n = 3)$ for which the energy change = 2 eV

(b) Energy of emitted photon is given by,

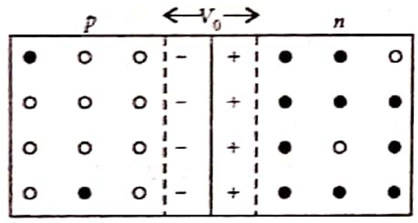
$$E = \frac{hc}{\lambda} \quad \therefore \quad \lambda_{max} \propto \frac{1}{E_{min}}$$

Transition *A*, for which the energy emission is minimum, corresponds to the emission of radiation of maximum wavelength.

3.

	Intrinsic Semiconductors	Extrinsic Semiconductors
(i)	These are pure semiconducting tetravalent crystals.	These are semi-conducting tetravalent crystals doped with impurity atoms of group III or V.
(ii)	Their electrical conductivity is low.	Their electrical conductivity is high.
(iii)	There is no permitted energy state between valence and conduction bands.	There is permitted energy state of the impurity atom between valence and conduction bands.

4. Two processes that take place in the formation of a *p-n* junction are diffusion and drift.



When *p-n* junction is formed, then at the junction free electrons from *n*-type diffuse over to *p*-type, thereby filling in the holes in *p*-type. Due to this a layer of positive charge is built on *n*-side and a layer of negative charge is built on *p*-side of the *p-n* junction. This layer sufficiently grows up within a very short time of the junction being formed, preventing any further movement of charge carriers (*i.e.*, electrons and holes) across the junction. Thus a potential difference V_0 of the order of 0.1 to 0.3 V is set up across the *p-n* junction called potential barrier or junction barrier. The thin region around the junction containing immobile positive and negative charges is known as depletion layer.

5. Since $\frac{hc}{\lambda} = K_{max} + \phi$

For case I: $\frac{hc}{\lambda_1} = K + \frac{hc}{\lambda_T} \Rightarrow hc\left[\frac{1}{\lambda_1} - \frac{1}{\lambda_T}\right] = K$ ...(i)

For case II: $\frac{hc}{\lambda_2} = 2K + \frac{hc}{\lambda_T} \Rightarrow hc\left[\frac{1}{\lambda_2} - \frac{1}{\lambda_T}\right] = 2K$ ...(ii)

Substituting (i) in (ii),

$$hc\left[\frac{1}{\lambda_2}-\frac{1}{\lambda_T}\right]=2hc\left[\frac{1}{\lambda_1}-\frac{1}{\lambda_T}\right]$$

$$\Rightarrow \lambda_T=\frac{\lambda_1\lambda_2}{2\lambda_2-\lambda_1}$$

6. Given $m = 2$ kg, $P = 800$ W.

Here two deuterium nuclei produce 3.27 MeV energy $= 5.232 \times 10^{-13}$ J

$\therefore$ Energy per nuclei $=\frac{5.232\times10^{-13}}{2}=2.616\times10^{-13}$ J

No. of deuterium atom in 2 kg

$=\frac{6.023\times10^{23}\times2000}{2}=6.023\times10^{26}$ atom

$\therefore$ Total energy $= 6.023\times10^{26}\times2.616\times10^{-13}$ $= 15.75\times10^{13}$ J

$$\text{Power}=\frac{\text{Energy}}{\text{Time}}\Rightarrow t=\frac{15.75\times10^{13}}{800}=1.96\times10^{11}\text{ s}$$

$$=\frac{1.96\times10^{11}}{365\times24\times60\times60}=6.2\times10^{3}\text{ years}$$

7. As given

$E = 10\cos(10^7t + kx)$

Comparing it with standard equation of e.m. wave,

$E = E_0\cos(\omega t + kx)$

Amplitude $E_0 = 10$ V/m and $\omega = 10^7$ rad/s

$$\because\ c=\upsilon\lambda=\frac{\omega\lambda}{2\pi}\text{ or }\lambda=\frac{2\pi c}{\omega}=\frac{2\pi\times3\times10^8}{10^7}=188.4\text{ m}$$

$$\text{Also, } c=\frac{\omega}{k}\text{ or } k=\frac{\omega}{c}=\frac{10^7}{3\times10^8}=0.033\text{ rad/m}$$

The wave is propagating along y direction.

OR

$B_x = (4.0\times10^{-6}\text{ T})\sin[(1.57\times10^7\text{ m}^{-1})y+\omega t]$

Comparing the given equation with

$B_x = B_0\sin(ky+\omega t)$

We get, $B_0 = 4.0\times10^{-6}$ T

Intensity of light is

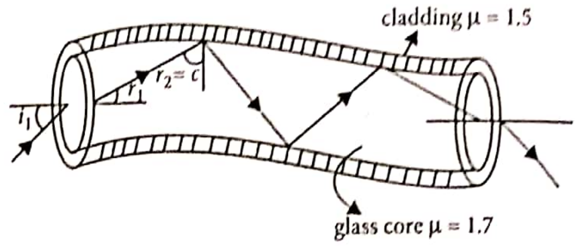
$$I=\frac{1}{2\mu_0}B_0^2c=\frac{(4.0\times10^{-6})^2\times(3\times10^8)}{2\times4\pi\times10^{-7}}$$

$= 1.9\times10^3\text{ W/m}^2 = 1.9\text{ kW/m}^2$

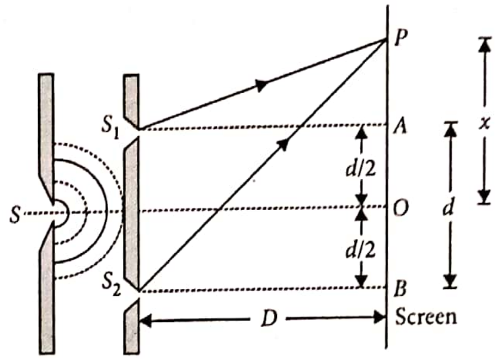
8. Optical fibre is made up of very fine quality glass or quartz of refractive index about 1.7.

A light beam incident on one end of an optical fibre at appropriate angle refracts into the fibre and undergoes repeated total internal reflection.

This is because the angle of incidence is greater than critical angle. The beam of light is received at other end of fibre with nearly no loss in intensity. To send a complete image, the image of different portion is send through separate fibres and thus a complete image can be transmitted through an optical fibre.



9.



Consider a point P on the screen at distance x from the centre O. The nature of the interference at the point P depends on path difference,

$p = S_2P - S_1P$

From right-angled ΔS_2BP and ΔS_1AP,

$(S_2P)^2 - (S_1P)^2 = [S_2B^2 + PB^2] - [S_1A^2 + PA^2]$

$$=\left[D^2+\left(x+\frac{d}{2}\right)^2\right]-\left[D^2+\left(x-\frac{d}{2}\right)^2\right]$$

or $(S_2P - S_1P)(S_2P + S_1P) = 2xd$

$$\text{or}\quad S_2P-S_1P=\frac{2xd}{S_2P+S_1P}$$

In practice, the point P lies very close to O, therefore $S_1P \simeq S_2P \simeq D$.

$$\text{Hence, } p=S_2P-S_1P=\frac{2xd}{2D}$$

$$\text{or}\quad p=\frac{xd}{D}$$

Positions of bright fringes : For constructive interference,

$$p=\frac{xd}{D}=n\lambda$$

$$\text{or}\quad x=\frac{nD\lambda}{d}\quad\text{where } n = 0, 1, 2, 3, ...$$

Positions of dark fringes : For destructive interference,

$$p = \frac{xd}{D} = (2n-1)\frac{\lambda}{2}$$

or $x = (2n-1)\frac{D\lambda}{2d}$ where $n = 1, 2, 3$

Width of a dark fringe = Separation between two consecutive bright fringes

$$= x_n - x_{n-1} = \frac{nD\lambda}{d} - \frac{(n-1)D\lambda}{d} = \frac{D\lambda}{d}$$

Width of bright fringe = Separation between two consecutive dark fringes

$$= x'_n - x'_{n-1} = (2n-1)\frac{D\lambda}{2d} - [2(n-1)-1]\frac{D\lambda}{2d} = \frac{D\lambda}{d}$$

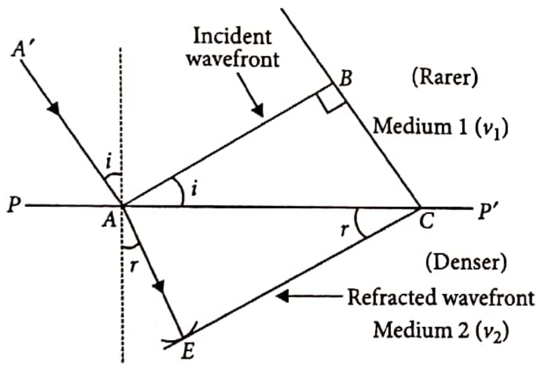
Clearly, both the bright and dark fringes are of equal width.

Hence the expression for the fringe width in Young's double slit experiment can be written as

$$\beta = \frac{D\lambda}{d}$$

OR

Snell's law of refraction : Let PP' 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.

$\therefore$ $BC = v_1 t$ [$\because$ 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

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

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

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

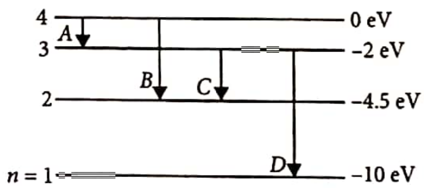
$$\Rightarrow v_1 = \frac{c}{\mu_1} \text{ and } v_2 = \frac{c}{\mu_2}$$

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.

10.



The wavelength of emitted radiation from state ($n = 4$) to the state ($n = 2$) is

$$\lambda = \frac{hc}{(E_4 - E_2)} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{[0-(-4.5)] \times 1.6 \times 10^{-19}}$$

$= 2.75 \times 10^{-7}$ m $= 275 \times 10^{-9}$ m $= 275$ nm

Hence, transition shown by arrow B corresponds to emission of wavelength = 275 nm.

(i) The maximum wavelength of emitted radiation from state $n = 4$ to $n = 3$ is

$$\lambda = \frac{hc}{[0-(-2)]\text{ eV}}$$

$$\Rightarrow \lambda = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{2 \times 1.6 \times 10^{-19}}$$

$= 6.18 \times 10^{-7}$ m $= 618 \times 10^{-9}$ m $= 618$ nm

Hence transition A corresponds to maximum wavelength.

(ii) The minimum wavelength of emitted radiation from state $n = 3$ to $n = 1$ is

$$\lambda = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{[-2\text{ eV} - (-10\text{ eV})]} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{8 \times 1.6 \times 10^{-19}}$$

$\lambda = 1.55 \times 10^{-7}$ m $= 155$ nm

Hence transition D corresponds to minimum wavelength.

11. According to lens maker's formula

$$\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

$$\frac{1}{f}=(\mu-1)\left(\frac{1}{R}-\frac{1}{-R}\right)=(1.5-1)\left(\frac{2}{R}\right)=\frac{1}{R}$$

Two similar equi-convex lenses of focal length f each are held in contact with each other.

The focal length F_1 of the combination is given by

$$\frac{1}{F_1}=\frac{1}{f}+\frac{1}{f}=\frac{2}{f}\ ;\ F_1=\frac{f}{2}=\frac{R}{2} \quad \text{... (i)}$$

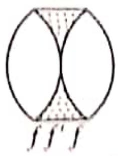
For glycerin in between lenses, there are three lenses, one concave and two convex.

Focal length of the concave lens is given by

$$\frac{1}{f'}=(1.5-1)\left(\frac{-2}{R}\right)=-\frac{1}{R}$$

Now, equivalent focal length of the combination is,

$$\frac{1}{F_2}=\frac{1}{f}+\frac{1}{f'}+\frac{1}{f}\ ;\ \frac{1}{F_2}=\frac{1}{R}-\frac{1}{R}+\frac{1}{R}=\frac{1}{R}$$



$$F_2=R \quad \text{... (ii)}$$

Dividing equation (i) by (ii), we get $\frac{F_1}{F_2}=\frac{1}{2}$

12. (i) **(b)** : Infrared rays can be converted into electric energy as in solar cell.

(ii) **(d)** : Radiowaves have longest wavelength.

(iii) **(c)** : Cathode rays are invisible fast moving streams of electrons emitted by the cathode of a discharge tube which is maintained at a pressure of about 0.01 mm of mercury.

(iv) **(c)** : γ-rays have minimum wavelength.

(v) **(a)** : $\lambda_{micro}>\lambda_{Infra}>\lambda_{ultra}>\lambda_{gamma}$

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