1. If p-type and n-type semiconductor are heavily doped. Then due to diffusion of electrons from n-region to p-region, and of holes from p-region to n-region, a depletion region formed of size of order less than 1 μm. The electric field directing from n-region to p-region produces a reverse bias voltage of about 5 V and electric field becomes very large.

$$\vec{E} = \frac{\Delta V}{\Delta x} = \frac{5V}{1\,\mu\text{m}} \approx 5\times10^6 \text{ V/m}$$

2. Given; $n_e = 5 \times 10^{18}\ \text{m}^{-3}$, $n_h = 5 \times 10^{19}\ \text{m}^{-3}$, $\mu_e = 2\ \text{m}^2\ \text{V}^{-1}\ \text{s}^{-1}$, $\mu_h = 0.01\ \text{m}^2\ \text{V}^{-1}\text{s}^{-1}$

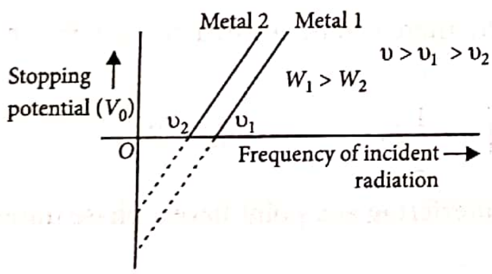
Then conductivity,

$\sigma = e\,(n_e\mu_e + n_h\mu_h)$

Putting values, we get

$$\sigma = 1.6 \times 10^{-19}(5 \times 10^{18} \times 2 + 5 \times 10^{19} \times 0.01)$$
$$= 1.6 \times 10^{-19}(10^{19} + 0.05 \times 10^{19}) = 1.68\ (\Omega\text{-m})^{-1}$$

3. The graph showing the variation of stopping potential (V_0) with the frequency of incident radiation (υ) for two different photosensitive materials having work functions W_1 and W_2 ($W_1 > W_2$) is shown in figure.



(i) Slope of the line $= \dfrac{\Delta V}{\Delta\upsilon} = \dfrac{h}{e}$ $\quad [\because e\Delta V = h\Delta\upsilon]$

$\therefore$ Slope of the line $= \dfrac{h}{e}$ *i.e.*, it is a constant quantity and does not depend on nature of metal surface.

(ii) Intercept of graph 1 on the stopping potential axis

$$= \frac{\text{work function}(W)}{e} = -\frac{h\upsilon_0}{e}$$

$\therefore$ Intercept of the line depends upon the stopping function of the metal surface.

OR

On the basis of experiments on photoelectric effect, three observed features are :

(i) The emission of photoelectrons takes place only when the frequency of the incident radiations is above a certain critical value called threshold frequency υ_0, which is characteristic of that metal emitting electrons. Above threshold frequency υ_0, maximum kinetic energy with which photoelectrons are emitted is directly proportional to frequency υ of incident radiation.

(ii) The maximum kinetic energy with which a photoelectron is emitted from a metallic surface is independent of the intensity of light and depends only upon its frequency.

4. Properties of nuclear force are :

(i) Nuclear forces are short range forces and are strongly attractive within a range of 1 fermi to 4.2 fermi.

(ii) Nuclear forces above 4.2 fermi are negligible, whereas below 1 fermi, they become repulsive in nature. It is this repulsive nature below 1 fermi, which prevents the nucleus from collapsing under strong attractive force.

(iii) Nuclear forces are charge independent. The same magnitude of nuclear force act between a pair of protons, pair of proton and neutron and pair of neutrons. The attractive nuclear force is due to exchange of π mesons (π^0, π^+, π^-) between them.

5. Distance of 2nd order maximum from the centre of the screen

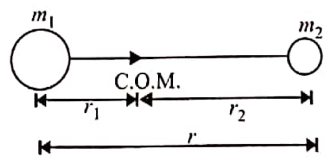
$$x = \frac{5}{2}\frac{D\lambda}{d}$$

Here, $D = 0.8$ m, $x = 15$ mm $= 15 \times 10^{-3}$ m

$\lambda = 600$ nm $= 600 \times 10^{-9}$ m

$$\therefore\ d = \frac{5}{2}\cdot\frac{D\lambda}{x} = \frac{5}{2}\times\frac{0.8\times600\times10^{-9}}{15\times10^{-3}} = 80\ \mu\text{m}$$

6. A diatomic molecule consists of two atoms of masses m_1 and m_2 at a distance r apart. Let r_1 and r_2 be the distances of the atoms from the centre of mass.



The moment of inertia of this molecule about an axis passing through its centre of mass and perpendicular to a line joining the atoms is

$$I = m_1r_1^2 + m_2r_2^2 \text{ as } m_1r_1 = m_2r_2 \Rightarrow r_1 = \frac{m_2}{m_1}r_2$$

$$\because\ r_1 + r_2 = r \quad \therefore\ r_1 = \frac{m_2}{m_1}(r - r_1) \Rightarrow r_1 = \frac{m_2 r}{m_1 + m_2}$$

Similarly, $r_2 = \dfrac{m_1 r}{m_1 + m_2}$

Therefore, the moment of inertia can be written as

$$I = m_1\left(\frac{m_2 r}{m_1+m_2}\right)^2 + m_2\left(\frac{m_1 r}{m_1+m_2}\right)^2 = \frac{m_1 m_2}{m_1+m_2}r^2 \quad ...(i)$$

According to Bohr's quantisation condition

$$L = \frac{nh}{2\pi} \quad \text{or} \quad L^2 = \frac{n^2h^2}{4\pi^2} \quad ...(ii)$$

Rotational energy, $E = \dfrac{L^2}{2I}$ $\therefore E = \dfrac{n^2h^2}{8\pi^2 I}$ (Using (ii))

$$= \frac{n^2h^2(m_1+m_2)}{8\pi^2(m_1m_2)r^2} \quad \text{(Using (i))}$$

$$= \frac{n^2\hbar^2(m_1+m_2)}{2m_1m_2r^2} \quad \left(\because \hbar = \frac{h}{2\pi}\right)$$

7. For equilateral prism $A = 60°$

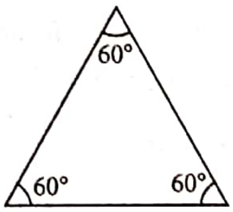
For minimum angle of deviation,

$i + e = A + \delta_m$

$2i = A + \delta_m$

$$\frac{2\times 3A}{4} = A + \delta_m$$

$$\delta_m = \frac{3A}{2} - A = \frac{A}{2}$$

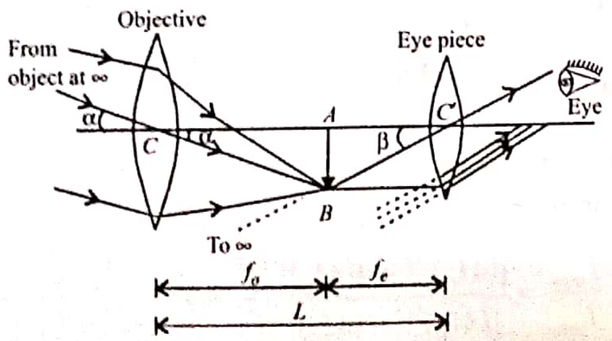


$$\because \mu = \frac{\sin\left(\dfrac{A + \frac{A}{2}}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$$

$$\Rightarrow \mu = \frac{\sin\left(\dfrac{3A}{4}\right)}{\sin\left(\dfrac{A}{2}\right)} = \frac{\sin 45°}{\sin 30°} = \frac{0.7071}{0.5} = 1.414$$

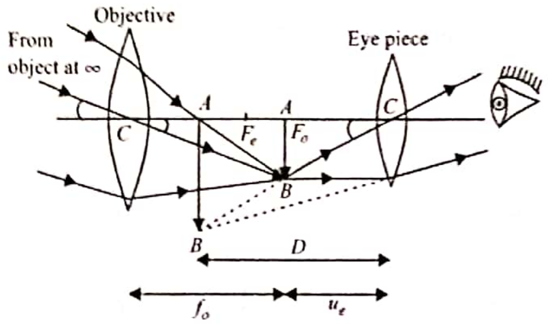
$$v = \frac{c}{\lambda} = \frac{3\times 10^8}{1.414} = 2.1216\times 10^8 \text{ m s}^{-1}$$

When final image is formed at infinity :



Magnification, $M = -\dfrac{f_0}{f_e}$

When the final image is formed at least distance of distinct vision :



Magnification, $M = -\dfrac{f_0}{f_e}\left(1 + \dfrac{f_e}{D}\right)$

8. (i) Momentum of photon

$$p = \frac{h}{\lambda} = \frac{6.6\times 10^{-34}}{1\times 10^{-9}} = 6.6\times 10^{-25} \text{ kg m s}^{-1}$$

Momentum of electron

$$p = \frac{6.6\times 10^{-34}}{1\times 10^{-9}} = 6.6\times 10^{-25} \text{ kg m s}^{-1}$$

(ii) Energy of photon

$$E = \frac{hc}{\lambda} = \frac{6.6\times 10^{-34}\times 3\times 10^8}{1\times 10^{-9}} = 1.98\times 10^{-16} \text{ J}$$

(iii) Kinetic energy of electron

$$E_e = \frac{p^2}{2m} = \frac{(6.6\times 10^{-25})^2}{2\times 9.1\times 10^{-31}} = 2.39 \times 10^{-19} \text{ J}$$

9. As per the figure,

The image formed by lens L_1 is at P. Therefore, using lens formula $\dfrac{1}{f} = \dfrac{1}{v} - \dfrac{1}{u}$

As per the parameters given in the question

$u = -15$ cm, $f_{L_1} = 20$ cm

So, the image distance will be

$$\frac{1}{v} - \frac{1}{(-15)} = \frac{1}{20}; \; v = -60 \text{ cm}$$

Now, this image is acting as an object for the lens L_2. We can again use the lens formula and other parameters given in the question and question figure to find the focal length of lens L_2.

$$\frac{1}{v_{L_2}} - \frac{1}{u_{L_2}} = \frac{1}{f_{L_2}}$$

Here, $u_{L_2} = v + (-20) = -60 - 20 = -80$ cm

$v_{L_2} = 80$ cm

$$\frac{1}{80}-\frac{1}{(-80)}=\frac{1}{f_{L_2}}$$

$f_{L_2}=40$ cm

So, the focal length of the lens $L_2 = 40$ cm.

10. (i) Consider a plane perpendicular to the direction of propagation of the wave. An electric charge, on the plane will be set in motion by the electric and magnetic fields of *e.m.* wave, incident on this plane. This illustrates that *e.m.* waves carry energy and momentum.

(ii) Microwaves are produced by special vacuum tube like the klystron, magnetron and gunn diode.

The frequency of microwaves is selected to match the resonant frequency of water molecules, so that energy is transformed efficiently to the kinetic energy of the molecules.

(iii) Uses of infra-red waves :

(a) They are used in night vision devices during warfare. This is because they can pass through haze, fog and mist.

(b) Infra-red waves are used in remote switches of household electrical appliances.

OR

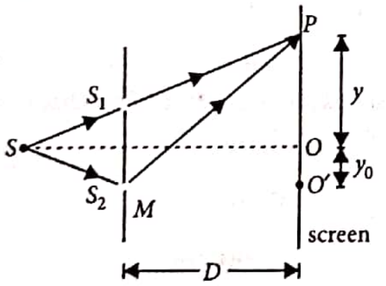
(a) Given : $SS_2 - SS_1 = \frac{\lambda}{4}$

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 $\Delta x = \frac{\lambda}{4}+\frac{yd}{D}$



(i) 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 $n = 0, 1, 2, 3,...,$

(ii) For destructive interference at point P, path difference

$\Delta x=(2n-1)\frac{\lambda}{2}$ or $\frac{\lambda}{4}+\frac{yd}{D}=(2n-1)\frac{\lambda}{2}$

or $\frac{yd}{D}=\left(2n-1-\frac{1}{2}\right)\frac{\lambda}{2}=(4n-3)\frac{\lambda}{4}$ ...(ii)

where $n = 1, 2, 3, 4,...$

For central bright fringe, putting $n = 0$ in equation (i), we get

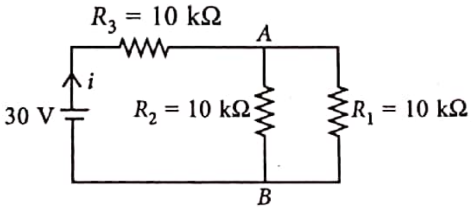
$\frac{yd}{D}=-\frac{\lambda}{4}$ or $y=\frac{-\lambda D}{4d}$

(b) The negative sign indicates that central bright fringe will be observed at a point O' below the centre O of screen.

11. In forward biasing, the diode offers negligible resistance to the circuit. So, the diode will act as a simple wire only. Therefore, the circuit can be redrawn as follows :

Here, R_1 and R_2 are in parallel.

$R_P=\frac{10\times 10}{10+10}=5\ \text{k}\Omega$



Now, R_3 and R_p are in series.

$\therefore\ R_{eq} = 5 + 10 = 15\ \text{k}\Omega$

So, current, $i=\frac{V}{R_{eq}}=\frac{30}{15\times 10^3}=2\times 10^{-3}$

Voltage across R_3, $V' = iR_3 = 2\times 10^{-3}\times 10\times 10^3 = 20$ V

So, $V_{AB} = 30 - 20 = 10$ V

12. (i) **(b)**: As $z=\frac{\lambda D}{2d}$

At S_4 : $\frac{\Delta x}{d}=\frac{z}{D}$

$\Rightarrow\ \Delta x=\frac{\lambda D}{2d}\frac{d}{d}=\frac{\lambda}{2}$

(ii) **(c)** : $z=\frac{\lambda D}{d}$

Δx at S_4 : $\Delta x=\frac{\lambda D}{d}\frac{d}{d}=\lambda$

Hence, maxima at S_4 as well as S_3.

Resultant intensity at S_4, $I = 4I_0$

$$\therefore\ \frac{I_{max}}{I_{min}}=\frac{[(4I_0)^{1/2}+4(4I_0)^{1/2}]^2}{[(4I_0)^{1/2}-(4I_0)^{1/2}]^2}=\infty$$

(iii) **(a)**: When the screen is placed perpendicular to the line joining the sources, the fringes will be concentric circles.

(iv) **(b)**: Constructive interference occurs when the path difference $(S_1P - S_2P)$ is an integral multiple of λ.

or $S_1P - S_2P = n\lambda$, where $n = 0, 1, 2, 3, ...$

(v) **(d)**: Here, $A_1 = 3A, A_2 = 2A$ and $\phi = 60°$

The resultant amplitude at a point is

$$R = \sqrt{A_1^2 + A_2^2 + 2A_1A_2 \cos\phi}$$

$$= \sqrt{(3A)^2 + (2A)^2 + 2 \times 3A \times 2A \times \cos 60°}$$

$$= \sqrt{9A^2 + 4A^2 + 6A^2} = A\sqrt{19}$$

As, Intensity $\propto$ (Amplitude)^2

Therefore, intensity at the same point is

$I \propto 19A^2$

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