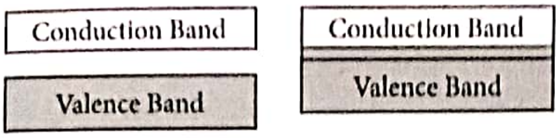
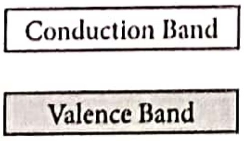
1. Metals : For metals, the valence band is completely filled and the conduction band can have two possibilities-either it is partially filled with an extremely small energy gap between the valence and conduction bands or it is empty, with the two bands overlapping each other as shown in the figure.



On applying even an small electric field, metals can conduct electricity.

Insulators : For insulators, the energy gap between the conduction and valence bands is very large. Also, the conduction band is practically empty, as shown in the figure.



When an electric field is applied across such a solid, the electrons find it difficult to acquire such a large amount of energy to reach the conduction band. Thus, the conduction band continues to be empty. That is why no current flows through insulators.

2. In pure germanium, $n_i = n_e = n_h = 3 \times 10^{16}\ \text{m}^{-3}$

In doped germanium, $n_i^2 = n_e n_h$

$$\therefore\ n_e = \frac{n_i^2}{n_h} = \frac{(3\times10^{16}\text{m}^{-3})^2}{4.5\times10^{22}\text{m}^{-3}} = \frac{9\times10^{32}}{4.5\times10^{22}}\ \text{m}^{-3}$$

$$= 2\times10^{10}\ \text{m}^{-3}$$

Thus, the electron density in doped germanium will be $2\times10^{10}\ \text{m}^{-3}$.

3. The volume of the nucleus is directly proportional to the number of nucleons (mass number) constituting the nucleus.

$$\frac{4}{3}\pi R^3 \propto A \qquad \text{Where } R \to \text{radius}$$

$$R \propto A^{1/3} \qquad A \to \text{Mass number}$$

$$R = R_0 A^{1/3}$$

OR

$$\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} \text{ or } \frac{A_1}{A_2} = \left(\frac{R_1}{R_2}\right)^3$$

$$\therefore\ \frac{A_1}{A_2} = \left(\frac{1}{3}\right)^3 = \frac{1}{27}$$

Hence the ratio of their masses is $\frac{m_1}{m_2} = \frac{1}{27}$

According to law of conservation of linear momentum magnitude of p_1 = magnitude of p_2

$$\text{i.e., } m_1v_1 = m_2v_2 \text{ or } \frac{v_1}{v_2} = \frac{m_2}{m_1} = \frac{27}{1}$$

4. Radius of a charged particle moving in a constant magnetic field is given by

$$R = \frac{mv}{qB} \text{ or } R^2 = \frac{m^2v^2}{q^2B^2} = \frac{2m\left(\frac{1}{2}mv^2\right)}{q^2B^2} = \frac{2m(\text{K.E.})}{q^2B^2}$$

$$\Rightarrow \text{K.E.} = \frac{q^2B^2R^2}{2m} \quad \therefore\ \text{K.E}_{max} = \frac{q^2B^2R^2_{max}}{2m} = 0.80\ \text{eV}$$

Energy of photon corresponding transition from orbit $3 \to 2$ in hydrogen atom.

$$E = 13.6\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 1.89\ \text{eV}$$

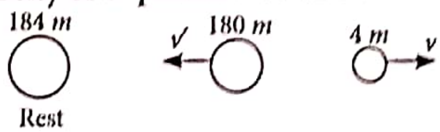
Using Einstein photoelectric equation,

$$E = \text{K.E.}_{max} + \phi \Rightarrow 1.89 = 0.8 + \phi \Rightarrow \phi = 1.09 \approx 1.1\ \text{eV}$$

5. Mass number, $A = 184$

$Q_{value} = 5.5$ MeV

Let the velocity of α-particle is v and for 180 m, it is v'.



Use conservation of momentum,

$$184\ m \times 0 = 180\ mv' - 4mv$$

$$v' = \frac{4v}{180} \qquad \text{...(i)}$$

Now using conservation of energy,

$$\frac{1}{2}(4m)v^2 + \frac{1}{2}(180m)v'^2 = 5.5\ \text{MeV}$$

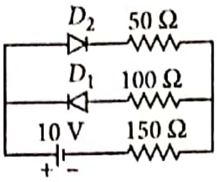
$$\frac{1}{2}\cdot 4mv^2\left[1 + 45\times\left(\frac{4}{180}\right)^2\right] = 5.5\ \text{MeV (Using (i))}$$

$$\text{Here K}\cdot\text{E}_\alpha = \frac{1}{2}(4mv^2)$$

$$\text{K}\cdot\text{E}_\alpha\left(1 + 45\times\left(\frac{4}{180}\right)^2\right) = 5.5\ \text{MeV}$$

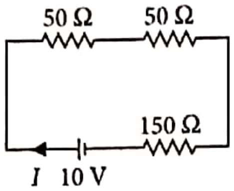
$$\text{K}\cdot\text{E}_\alpha = \frac{5.5}{1+45\left(\frac{4}{180}\right)^2} = 5.38\ \text{MeV}$$

6. In the circuit, diode D_1 is reverse biased and offers infinite resistance, diode D_2 is forward biased and offers 50 Ω resistance. The equivalent circuit is shown in the figure.



Total resistance of the circuit,

$R = 50\ \Omega + 50\ \Omega + 150\ \Omega = 250\ \Omega$



The current in the circuit,

$$I = \frac{V}{R} = \frac{10\ \text{V}}{250\ \Omega} = 0.04\ \text{A}$$

So, current through the resistance 150 Ω is 0.04 A.

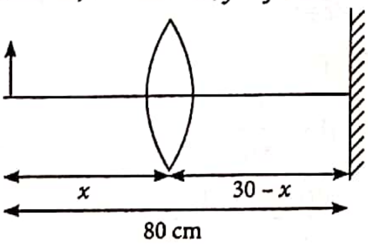
7. (a) : Focal length of a concave lens is negative. Using lens maker's formula,

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

Here, $\mu_l = 1.5$, $\mu_m = 1.65$

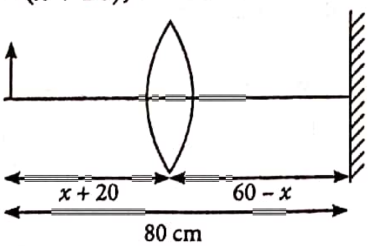
Also, $\frac{\mu_l}{\mu_m} < 1$, so $\left(\frac{\mu_l}{\mu_m} - 1\right)$ is negative and focal length of the given lens becomes positive. Hence, it behaves as a convex lens.

(b) Case I : $u = -x$, $v = 80 - x$, $f = f$



$$\therefore\ \frac{1}{f} = \frac{1}{V} - \frac{1}{u} = \frac{1}{80 - x} + \frac{1}{x} \qquad \text{...(i)}$$

Case II : $u = -(x + 20)$, $v = 60 - x$



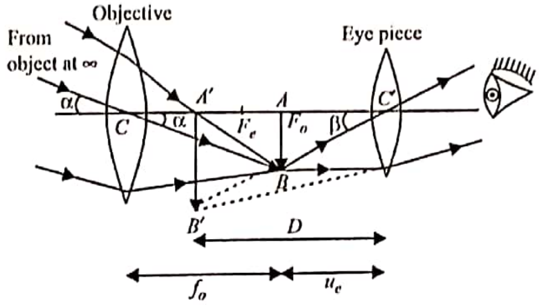
$$\frac{1}{f} = \frac{1}{60 - x} + \frac{1}{x + 20} \qquad \text{...(ii)}$$

From (i) and (ii)

$$\frac{1}{80 - x} + \frac{1}{x} = \frac{1}{60 - x} + \frac{1}{x + 20} \Rightarrow x = 30\ \text{cm}$$

$$\therefore\ \frac{1}{f} = \frac{1}{80 - 30} + \frac{1}{30} \Rightarrow f = 18.75\ \text{cm}$$

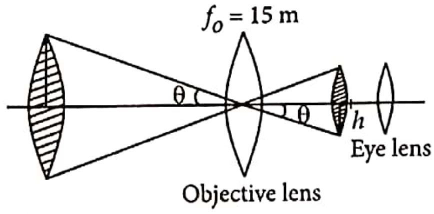
OR



Here, f_o = 15 m = 1500 cm and f_e = 1.0 cm Angular magnification by the telescope in normal adjustment

$$m = \frac{f_o}{f_e} = \frac{1500\ \text{cm}}{1.0\ \text{cm}} = 1500$$

The image of the moon by the objective lens is formed on its focus only as the moon is nearly at infinite distance as compared to focal length.



i.e., Radius of moon $R_m = \frac{3.48}{2} \times 10^6$ m

$R_m = 1.74 \times 10^6$ m

Distance of object = Radius of lunar orbit

$R_0 = 3.8 \times 10^8$ cm

Distance of image for objective lens is the focal length of objective lens, $f_0 = 15$ m

Radius of image of moon by objective lens can be calculated.

$$\tan\theta = \frac{R_m}{R_0} = \frac{h}{f_o}$$

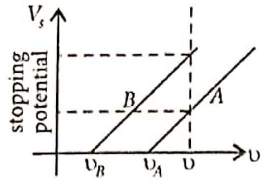
$$h = \frac{R_m \times f_o}{R_0} = \frac{1.74 \times 10^6 \times 15}{3.8 \times 10^8} = 6.87 \times 10^{-2}\ \text{m}.$$

Diameter of the image of the moon,

$= 2h = 13.74 \times 10^{-2}$ m = 13.74 cm

8. We know,

$K_{max} = eV_s = h(\upsilon - \upsilon_0)$



or, $V_s = \frac{h}{e}\upsilon - \frac{h}{e}\upsilon_0$

(i) From the graph for the same value of υ, stopping potential is more for material B.

as $V_s = \frac{h}{e}(\upsilon - \upsilon_0)$

$\therefore$ V_s is higher for lower value of υ_0. Here $\upsilon_B < \upsilon_A$ so $V_{SB} > V_{SA}$.

(ii) Slope of the graph is given by $\frac{h}{e}$ which is constant for all the materials. Hence slope of the graph does not depend on the nature of the material used.

9. $E_y = 2.5\frac{\text{N}}{\text{C}} \times \cos\left[\left(2\pi \times 10^6 \frac{\text{rad}}{\text{m}}\right)t - \left(\pi \times 10^{-2}\frac{\text{rad}}{\text{s}}\right)x\right]$

$E_z = 0, E_x = 0$

The wave is moving in the positive direction of x.

This is in the form $E_y = E_0\cos(\omega t - kx)$

$\omega = 2\pi \times 10^6$

$2\pi\upsilon = 2\pi \times 10^6 \Rightarrow \upsilon = 10^6$ Hz

10. (i) Reflection and refraction arise through interaction of incident light with atomic constituents of matter which vibrate with the same frequency as that of the incident light. Hence frequency remains unchanged.

(ii) Energy carried by a wave depends on the frequency of the wave, not on the speed of wave propagation.

(iii) For a given frequency, intensity of light in the photon picture is determined by

$$I = \frac{\text{Energy of photons}}{\text{area} \times \text{time}} = \frac{n \times h\upsilon}{A \times t}$$

Where n is the number of photons incident normally on crossing area A in time t.

OR

(a) Angular width, $\theta = \frac{\lambda}{d}$ or $d = \frac{\lambda}{\theta}$

Here, $\lambda = 600$ nm $= 6 \times 10^{-7}$ m

$\theta = 0.1° = \frac{0.1 \times \pi}{180}$ rad $= \frac{\pi}{1800}$ rad, $d = ?$

$\therefore\ d = \frac{6 \times 10^{-7} \times 1800}{\pi} = 3.44 \times 10^{-4}$ m

(b) Frequency of a light depends on its source only. So, the frequencies of reflected and refracted light will be same as that of incident light.

Reflected light is in the same medium (air) so its wavelength remains same as 500 Å.

Wavelength of refracted light, $\lambda_r = \frac{\lambda}{\mu_w}$

μ_w = refractive index of water.

So, wavelength of refracted wave will be decreased.

11. (a) (i) Here $a = 1 \times 10^{-4}$ m, $D = 1.5$ m

$\lambda = 6000$ Å $= 6000 \times 10^{-10}$ m

The distance between the two dark bands on each side of central band is equal to width of the central bright band, *i.e.*, $\frac{2D\lambda}{a}$

$= \frac{2 \times 1.5 \times 6000 \times 10^{-10}}{1 \times 10^{-4}} = 18$ mm

(ii) Angular spread $= \frac{\lambda}{a} = \frac{6000 \times 10^{-10}}{1 \times 10^{-4}}$

$= 6 \times 10^{-3}$ m $= 6$ mm

(b) Resolving power $= \frac{d}{1.22\lambda}$, where d is the diameter of the objective lens.

12. (i) **(d):** Refractive index of a medium depends upon nature and temperature of the medium, wavelength of light.

(ii) **(a) :** Here $\nu = 5 \times 10^{14}$ Hz; $\lambda = 450 \times 10^{-9}$m

$c = 3 \times 10^8$ m s^{-1}

Refractive index of the liquid,

$$\mu = \frac{c}{v} = \frac{c}{\nu\lambda} = \frac{3 \times 10^8}{5 \times 10^{14} \times 450 \times 10^{-9}}$$

$\mu = 1.33$

(iii) **(b) :** Here $i = 60°$; $\mu = 1.5$

By snell's law, $\mu = \frac{\sin i}{\sin r}$

$\sin r = \frac{\sin i}{\mu} = \frac{\sin 60°}{1.5} = \frac{0.866}{1.5}$

$\sin r = 0.5773$ or $r = \sin^{-1}(0.58)$

(iv) **(c) :** As object is at the centre of the sphere, the image must be at the centre only.

$\therefore$ Distance of virtual image from centre of sphere = 6 cm.

(v) **(c) :** Speed of light in second medium is different than that in first medium