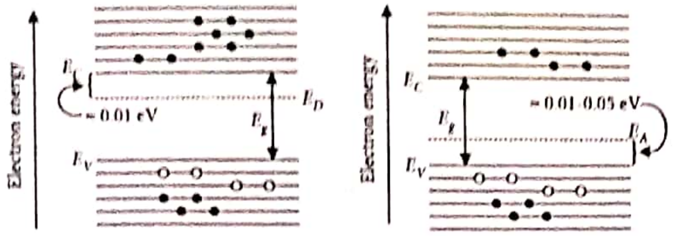
SOLUTIONS

1. The required energy band diagrams are given below:



(a) Energy band diagram of *n* type semiconductor at $T > 0$ K

(b) Energy band diagram of *p*-type semiconductor at $T > 0$ K

2. The force at a distance *r* is

$$F = -\frac{dU}{dr} = -2ar$$

Suppose *r* be the radius of n^{th} orbit. The necessary centripetal force is provided by the above force. Thus,

$$\frac{mv^2}{r} = 2ar \qquad ...(i)$$

Further, the quantisation of angular momentum gives,

$$mvr = \frac{nh}{2\pi} \qquad ...(ii)$$

Solving, equations (i) and (ii) for *r*, we get

$$r = \left(\frac{n^2h^2}{8am\pi^2}\right)^{1/4}$$

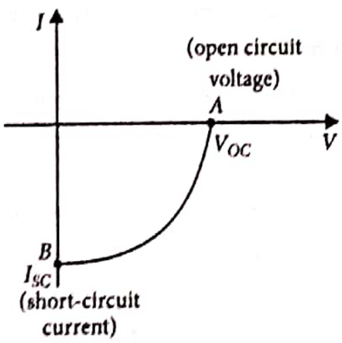
OR

Using Einstein's photoelectric equation, $eV = h\upsilon - \phi$

On differentiation, we get $e\Delta V = h\Delta\upsilon$

or $h = \frac{e\Delta V}{\Delta\upsilon} = \frac{1.6\times10^{-19}\times(1.23-0)}{(8-5)\times10^{14}} = 6.56\times10^{-34}$ J s

3.



(i) *V-I* curve is drawn in the fourth quadrant, because a solar cell does not draws current but supply current to the load.

(ii) In *V-I* curve, the point *A* indicates the maximum voltage V_{OC} being supplied by the given solar cell when no current is being drawn from it. V_{OC} is called the open circuit voltage.

(iii) In *V-I* curve, the point *B* indicates the maximum current I_{SC} which can be obtained by short circuiting the solar cell without any load resistance. I_{SC} is called the short circuit current.

4. (i) The kinetic energy (E_k) of the electron in an orbit is equal to negative of its total energy (*E*).

$E_k = -E = -(-1.5) = 1.5$ eV

(ii) The potential energy (E_p) of the electron in an orbit is equal to twice of its total energy (*E*).

$E_p = 2E = -1.5 \times 2 = -3.0$ eV

(iii) Here, ground state energy of the H-atom $= -13.6$ eV

When the electron goes from the excited state to the ground state, energy emitted is given by

$E = -1.5 - (-13.6) = 12.1$ eV $= 12.1 \times 1.6 \times 10^{-19}$ J

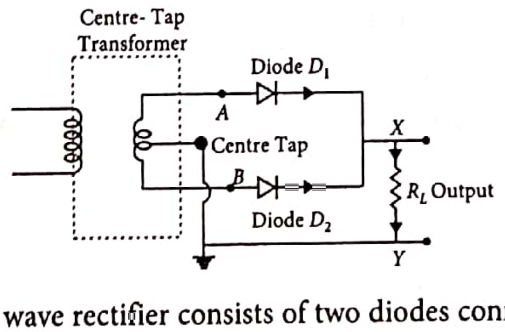
Now, $E = \frac{hc}{\lambda}$

$$\lambda = \frac{hc}{E} = \frac{6.62\times10^{-34}\times3\times10^{8}}{12.1\times1.6\times10^{-19}}$$

$\lambda = 1.025 \times 10^{-7}$ m

$\lambda = 1025$ Å

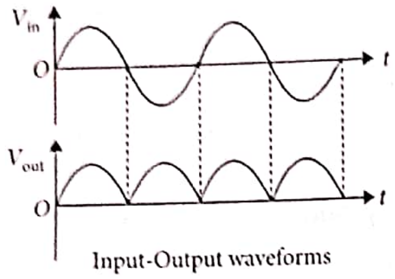
5. Two *p–n* junction diodes can be used to make full wave rectifier which is used to convert alternating current into direct current.



A full wave rectifier consists of two diodes connected in parallel across the ends of secondary winding of a center tapped step down transformer. The load resistance R_L is connected across secondary winding and the diodes between *A* and *B* as shown in the circuit.

During positive half cycle of input a.c., end *A* of the secondary winding becomes positive and end *B* negative. Thus diode D_1 becomes forward biased, whereas diode D_2 reverse biased. So diode D_1 allows the current to flow through it, while diode D_2 does not, and current in the circuit flows from D_1 and through load R_L from X to Y.

During negative half cycle of input a.c., end A of the secondary winding becomes negative and end B positive, thus diode D_1 becomes reverse biased, whereas diode D_2 forward biased. So diode D_1 does not allow the current to flow through it but diode D_2 does, and current in the circuit flows from D_2 and through load R_L from X to Y.



Input-Output waveforms

Since in both the half cycles of input a.c., electric current through load R_L flows in the same direction, so d.c. is obtained across R_L. Although direction of electric current through R_L remains same, but its magnitude changes with time, so it is called pulsating d.c.

6. Fusion reaction, ${}_1^2H + {}_1^2H \longrightarrow {}_2^3He + n$

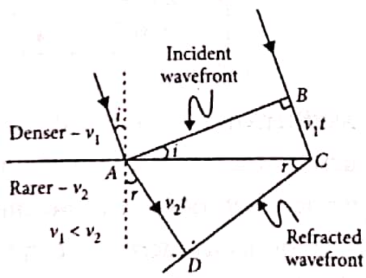
Energy released = final $B.E.$ – initial $B.E.$

$= 7.73 - (2.23 + 2.23) = 3.27$ MeV.

7. Refractive index (μ) : Refractive index of a medium is defined as the ratio of the speed of light in vacuum to the speed of light in that medium. *i.e.*,

$$\mu = \frac{c}{v} = \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}}$$

Given figure shows the refraction of a plane wavefront at a rarer medium *i.e.*, $v_2 > v_1$



Let the angles of incidence and refraction be i and r respectively.

From right ΔABC, we have,

$$\sin \angle BAC = \sin i = \frac{BC}{AC}$$

From right ΔADC, we have,

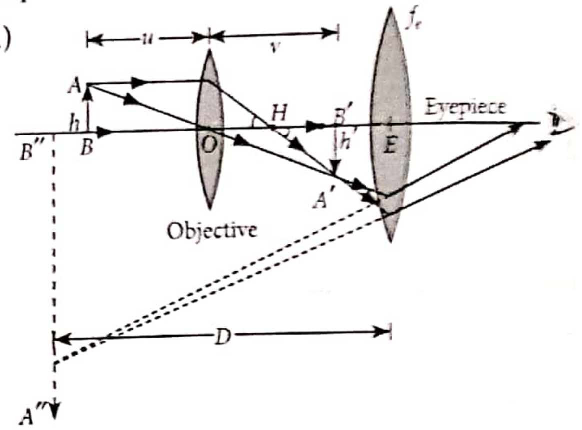
$$\sin \angle DCA = \sin r = \frac{AD}{AC}$$

$$\therefore \quad \frac{\sin i}{\sin r} = \frac{BC}{AD} = \frac{v_1 t}{v_2 t}$$

$$\text{or} \quad \frac{\sin i}{\sin r} = \frac{v_1}{v_2} = {}^1\mu_2 \quad \text{(a constant)}$$

This verifies Snell's law of refraction. The constant ${}^1\mu_2$ is called the refractive index of the second medium with respect to first medium.

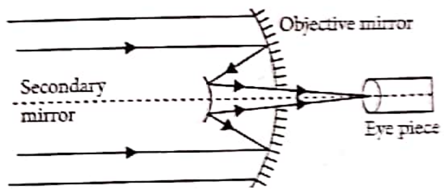
8. (a)



(b) For constructing compound microscope, L_3 should be used as objective and L_2 as eyepiece because both the lenses of microscope have short focal lengths and the focal length of objective lens should be smaller than the eyepiece lens.

OR

(a)



(b) Advantages :

(i) It is free from chromatic aberration.

(ii) Its resolving power is greater than refracting type telescope due to larger aperture of mirror.

(c) (i) The objective of a telescope have a larger focal length to obtain large magnifying power and greater intensity of image.

(ii) The aperture of objective lens of a telescope is taken as large because this increases the light gathering capacity of the objective from the distant object. Consequently, a brighter image is formed.

9. (a) Two features of Einstein's photoelectric equation:

(i) Below threshold frequency υ_0 corresponding to W_0, no emission of photoelectrons takes place.

(ii) As the number of photons in light depend on its intensity, and one photon liberates one photoelectron.

So number of emitted photoelectrons depend only on the intensity of incident light for a given frequency.

(b) Below threshold frequency no emission takes place. As there is no photoemission from surface P *i.e.*, the frequency of incident radiation is less than the threshold frequency for surface P.

From surface Q photoemission is possible *i.e.*, the frequency of incident radiation is equal or greater than threshold frequency. As the kinetic energy of photo electrons is zero *i.e.*, the energy of incident radiation is just sufficient to pull out the electron from the surface Q.

Work function for surface Q, $W_Q = h\upsilon$.

As K.E. = 0 ; $\upsilon = \upsilon_0 = 10^{15}$ Hz

$W_Q = 6.6 \times 10^{-34} \times 10^{15} = 6.6 \times 10^{-19}\text{ J} = 4.125\text{ eV}$

10. Image is formed behind the lens.

$\therefore \quad v = +8$ m

As the image is real, $m = \frac{I}{O} = \frac{v}{u} = -\frac{1}{3}$

$u = -3v = -3(8\text{ m}) = -24$ m

According to lens formula

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{8} - \frac{1}{-24} = \frac{1}{f}$ or $f = 6$ m

Refractive index of the material of the lens is

$$\mu = \frac{\text{Wavelength of the light in free space}}{\text{Wavelength of light inside the lens}} = \frac{\lambda_0}{\frac{2}{3}\lambda_0} = \frac{3}{2}$$

According to lens maker's formula

$$\frac{1}{f} = \frac{(\mu - 1)}{R} \quad \text{or} \quad R = f(\mu - 1) \quad \ldots(i)$$

Substituting the value of μ and f in eqn. (i), we get

$R = (6\text{ m})(1.5 - 1) = 3$ m

11. (a)

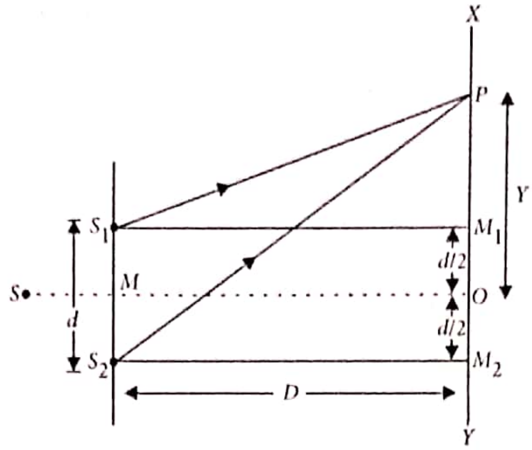
	Uses	Part of electromagnetic spectrum	Frequency range
(i)	In radar system	Microwaves	3×10^8 Hz to 3×10^{11} Hz
(ii)	In eye surgery	Ultraviolet	8×10^{14} Hz to 8×10^{16} Hz

(b) In *e.m.* waves, the ratio of amplitudes of electric and magnetic field is always constant and is equal to the speed of *e.m.* waves. *i.e.*

$c = \frac{E_0}{B_0}$ (where E_0 and B_0 are peak values)

OR

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



where ϕ is phase difference between them. Resultant displacement at point P will be,

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

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

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

$$y = 2a\cos\left(\omega t + \frac{\phi}{2}\right)\cos\left(\frac{\phi}{2}\right) \quad \ldots(i)$$

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

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

where A is amplitude of the resultant wave.

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

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

(b) Condition for constructive interference,

$\cos\Delta\phi = +1$

$2\pi\frac{\Delta x}{\lambda} = 0, 2\pi, 4\pi\ldots$

or $\Delta x = n\lambda$; $n = 0, 1, 2, 3, \ldots$

Condition for destructive interference, $\cos\Delta\phi = -1$

$2\pi\frac{\Delta x}{\lambda} = \pi, 3\pi, 5\pi\ldots$

or $\Delta x = (2n - 1)\lambda/2$

where $n = 1, 2, 3\ldots$

12. (i) **(d) :** Total internal reflection is the basis for following phenomenon:

(a) Sparkling of diamond.

(b) Optical fibre communication.

(c) Instrument used by doctors for endoscopy.

(ii) **(d) :** Total internal reflection (TIR) is the phenomenon that involves the reflection of all the incident light of the boundary. TIR only takes place

when both of the following two conditions are met:
The light is in the more denser medium and approaching the less denser medium.
The angle of incidence is greater than the critical angle.

(iii) (c) : If incidence of angle, i = critical angle C, then angle of refraction, $r = 90°$

(iv) (b) : In optical fibres, core is surrounded by cladding, where the refractive index of the material of the core is higher than that of cladding to bound the light rays inside the core.

(v) (b) : From Snell's law, $\sin C = {}_1n_2 = \frac{v_1}{v_2}$

where, C = critical angle = 30° and v_1 and v_2 are speed of light in medium and vacuum, respectively.
We know that, $v_2 = 3 \times 10^8$ m s^{-1}

$$\therefore \quad \sin 30° = \frac{v_1}{3\times10^8}$$

$$\Rightarrow \quad v_1 = 3\times10^8 \times \frac{1}{2} \Rightarrow v_1 = 1.5\times10^8 \text{ m s}^{-1}$$