CHAPTER 09 AND 10 [RAY AND WAVE OPTICS]

QUESTION NUMBER	ANSWER
01	D
02	C
03	C
04	B
05	B
06	B
07	D
08	A,B
09	A,B
10	C
11	D
12	B
13	B
14	A
15	D
16	C
17	A
18	A
19	$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ ½ $\frac{1}{f} = \left(\frac{\mu_m}{\mu_w} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ ½ $\frac{\mu_m}{\mu_w} = \frac{1.25}{1.33}$ $\frac{\mu_m}{\mu_w} = 0.98$ ½ The value of $(\mu - 1)$ is negative and 'f' will be negative. So it will behave like diverging lens. ½
20	SOLVED
21	$\beta = \frac{D\lambda}{d}$, *i.e.*, $\beta \propto \lambda$; the wavelength of blue light is less than that of red light; hence if red light is replaced by blue light, the fringe width decreases, *i.e.*, fringes come closer.
22	Here, $R = +20$ cm, $n_1 = 1.0$, $n_2 = 1.5$, $u = -30$ cm Using, $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$ $\frac{1.5}{v} - \frac{1.0}{-30} = \frac{1.5 - 1.0}{20}$ $\Rightarrow \frac{1.5}{v} + \frac{1}{30} = \frac{0.5}{20} = \frac{1}{40}$ $\Rightarrow \frac{1.5}{v} = \frac{1}{40} - \frac{1}{30}$ $\Rightarrow \frac{1.5}{v} = \frac{3-4}{120}$ $\Rightarrow \frac{1.5}{v} = \frac{-1}{120}$ $\Rightarrow$ $v = \mathbf{-180.0\ cm}$
23	Let focal length of converging and diverging lenses be $+f$ and $-f$ respectively. Power of converging lens $P_1 = \frac{1}{f}$ Power of diverging lens $P_2 = -\frac{1}{f}$ $\therefore$ Power of combination $P = P_1 + P_2 = \frac{1}{f} - \frac{1}{f} = \mathbf{0}$ $\therefore$ Focal length of combination $F = \frac{1}{P} = \frac{1}{0} = \infty$ (infinite)

24

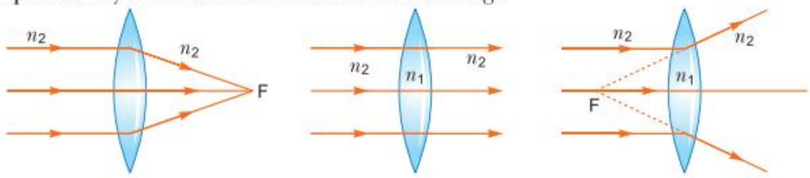
$$\frac{1}{f}=\left(\frac{n_1}{n_2}-1\right)\left(\frac{1}{R_2}+\frac{1}{R_2}\right)$$

In case (*i*) $n_1 > n_2$, the lens behaves as convergent lens.

In case (*ii*) $n_1 = n_2$, the lens behaves as a plane plate.

In case (*iii*) $n_1 < n_2$, the lens behaves as a divergent lens.

The path of rays in all the three cases is shown in fig.



(*i*) $n_1 > n_2$ (*ii*) $n_1 = n_2$ (*iii*) $n_1 < n_2$

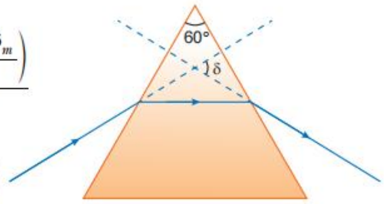
25

We know that

$$n=\frac{n_2}{n_1}=\frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$$

$$\Rightarrow \frac{1.6}{\frac{4\sqrt{2}}{5}}=\frac{\sin\left(\frac{60^\circ+\delta_m}{2}\right)}{\sin\frac{60^\circ}{2}} \quad \Rightarrow \frac{5\times 1.6}{4\sqrt{2}}=\frac{\sin\left(\frac{60^\circ+\delta_m}{2}\right)}{\sin 30^\circ}$$

$$\Rightarrow \frac{8\times 0.5}{4\sqrt{2}}=\sin\left(\frac{60^\circ+\delta_m}{2}\right) \quad \Rightarrow \frac{1}{\sqrt{2}}=\sin\left(\frac{60^\circ+\delta_m}{2}\right)$$



$$\Rightarrow \sin(45^\circ)=\sin\left(\frac{60^\circ+\delta_m}{2}\right) \quad \Rightarrow \frac{60^\circ+\delta_m}{2}=45^\circ \quad \Rightarrow \delta_m=90^\circ-60^\circ=30^\circ$$

$\therefore \delta_m = 30^\circ$

26

SOLVED

27

(*a*) This is because coherent sources are needed to ensure that the positions of maxima and minima do not change with time.

If the phase difference between wave, reaching at a point change with time intensity will change and sustained interference will not be obtained.

(*b*) We know

$$I = 4\,I_0\cos^2\frac{\phi}{2}$$

for path difference λ, phase difference $\phi = 2\pi$

Intensity of light $= K$

Hence, $K = 4I_0\cos^2\pi = 4I_0$

For path difference $\frac{\lambda}{3}$, Phase difference $\phi=\frac{2\pi}{3}$

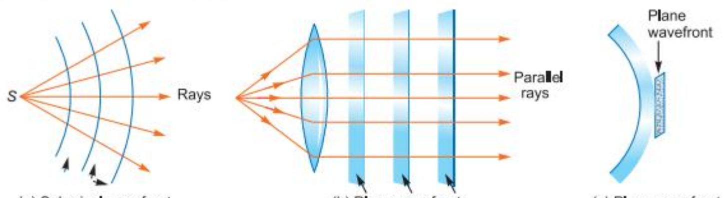
Intensity of light $I'=4I_0\cos^2\frac{\phi}{2}=4I_0\cos^2\frac{\pi}{3}=I_0$

$$\Rightarrow \quad I'=\frac{K}{4}$$

OR

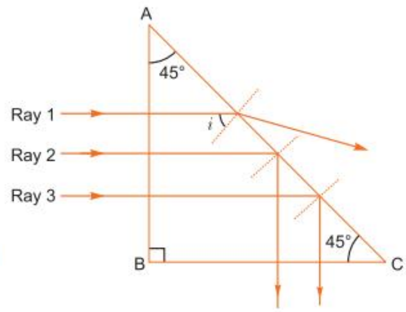
(*a*) The wavefront will be **spherical** of increasing radius, fig. (*a*).

(*b*) The rays coming out of the convex lens, when point source is at focus, are parallel, so wavefront is **plane,** fig. (*b*).



(a) Spherical wavefront (b) Plane wavefront (c) Plane wavefront

(*c*) The wavefront starting from star is spherical. As star is very far from the earth, so the wavefront intercepted by earth is a very small portion of a sphere of large radius; which is **plane** (*i.e.*, wavefront intercepted by earth is plane), fig. (*c*).

28	(*i*) When a ray of light travels from an optically denser medium into a rarer medium at an angle greater than the critical angle, it reflects back into the denser medium. This phenomenon is called total internal reflection. Conditions for total internal reflection: (*a*) Light must travel from denser medium to rarer medium. (*b*) Angle of incidence in denser medium must be greater than critical angle. (*ii*) $\frac{1}{n} = \frac{\sin i}{\sin r}$, for total internal reflection to occur $i \geq i_c$; at critical angle, angle of refraction, $r = 90°$ hence $\frac{1}{n} = \frac{\sin i_c}{\sin 90°} \Rightarrow n = \frac{1}{\sin i_c}$ (*iii*) (*a*) Mirage (*b*) optical fibre (*c*) sparkling of diamond (*d*) shinning of air bubbles in water (*e*) totally reflecting prism. (*Any one*)
29	For first lens, $u_1 = -30$ cm, $f_1 = +10$ cm $\therefore$ From lens formula, $\frac{1}{f_1} = \frac{1}{v_1} - \frac{1}{u_1}$ $\Rightarrow \frac{1}{v_1} = \frac{1}{f_1} + \frac{1}{u_1} = \frac{1}{10} - \frac{1}{30} = \frac{3-1}{30}$ $\Rightarrow v_1 = 15$ cm The image formed by the first lens serves as the object for the second. This is at a distance of (15 – 5) cm = 10 cm to the right of the second lens. Though the image is real, it serves as a virtual object for the second lens, which means that the rays appear to come from it for the second lens. For second lens, $f_2 = -10$ cm, $u_2 = 15 - 5 = +10$ cm $\therefore \frac{1}{v_2} = \frac{1}{f_2} + \frac{1}{u_2} = -\frac{1}{10} + \frac{1}{10} \Rightarrow v_2 = \infty$ The virtual image is formed at an infinite distance to the left of the second lens. This acts as an object for the third lens. For third lens, $f_3 = +30$ cm, $u_3 = \infty$ From lens formula, $\frac{1}{v_3} = \frac{1}{f_3} + \frac{1}{u_3} = \frac{1}{30} + \frac{1}{\infty}$ $v_3 = $ **30 cm** The final image is formed at a distance 30 cm to the right of third lens.
30	The ray incident perpendicularly on side *AB*, so it will pass out normally through *AB*. On face AC, $i = 45°$ For total internal reflection to take place at face AC, Angle of incidence > critical angle $45° > i_c$ $\sin 45° > \sin i_c$ $\Rightarrow \frac{1}{\sqrt{2}} > \frac{1}{n} \quad \left[\therefore i_c = \sin^{-1}\left(\frac{1}{n}\right)\right]$ $\Rightarrow \sqrt{2} < n \Rightarrow 1.414 < n$ Hence, rays 2, 3 will undergo TIR and path of ray will be as shown. Ray 1 is refracted from AC. 

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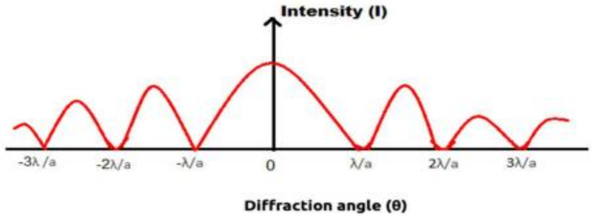
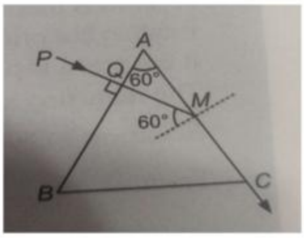


1

Width of central maximum is twice that of any secondary maximum 1



1

Given : $\angle A = 60^0$, $\angle i = 0^0$

At M : $\sin C = \frac{1}{\mu} = \frac{\sqrt{3}}{2} = \sin 60^0$

$\therefore \quad C = 60^0$ 1

So the ray PM after refraction from the face AC grazes along AC.

$\therefore \angle e = 90^0$

From $\quad \angle i + \angle e = \angle A + \angle \delta$

Or $\quad 0^0 + 90^0 = 60^0 + \angle\delta$

$\therefore \delta = 90^0 - 60^0 = 30^0$ 1

OR

(i) The interference pattern has a number of equally spaced bright and dark bands. The diffraction pattern has a central bright maximum which is twice as wide as the other maxima. The intensity falls as we go to successive maxima away from the centre, on either side. 1

(ii) We calculate the interference pattern by superposing two waves originating from the two narrow slits. The diffraction pattern is a superposition of a continuous family of waves originating from each point on a single slit. 1

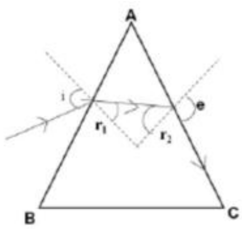
(i) $\mu = \dfrac{\sin\left(\dfrac{A+\delta_m}{2}\right)}{\sin\left(\dfrac{A}{2}\right)} = \dfrac{\sin\left(\dfrac{60+30}{2}\right)}{\sin\left(\dfrac{60^o}{2}\right)} = \sqrt{2}$ 1½

Also $\mu = \dfrac{c}{\upsilon} \Rightarrow \upsilon = \dfrac{3\times10^8}{\sqrt{2}} m/s$

(ii) At face AC, let the angle of incidence be r_2. For grazing ray,

$e = 90^o$

$\Rightarrow \mu = \dfrac{1}{\sin r_2} \Rightarrow r_2 = \sin^{-1}\left(\dfrac{1}{\sqrt{2}}\right) = 45^o$ 1½



Let angle of refraction at face AB be r_1.

Now $r_1 + r_2 = A$

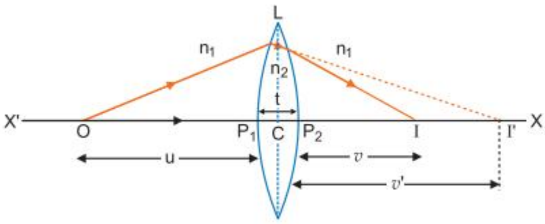
$\therefore r_1 = A - r_2 = 60^o - 45^o = 15^o$

Let angle of incidence at this face be i

$\mu = \dfrac{\sin i}{\sin r_1} \Rightarrow \sqrt{2} = \dfrac{\sin i}{\sin 15^o}$

$\therefore i = \sin^{-1}\left(\sqrt{2} \,.\, \sin 15^o\right) = 21.5^0$

32	**Lens Maker's Formula:** Suppose L is a thin lens. The refractive index of the material of lens is n_2 and it is placed in a medium of refractive index n_1. The optical centre of lens is C and $X'X$ is the principal axis. The radii of curvature of the surfaces of the lens are R_1 and R_2 and their poles are P_1 and P_2 The thickness of lens is t, which is very small. O is a point object on the principal axis of the lens. The distance of O from pole P_1 is u. The first refracting surface forms the image of O at I' at a distance v' from P_1. From the refraction formula at spherical surface $$\frac{n_2}{v'}-\frac{n_1}{u}=\frac{n_2-n_1}{R_1} \quad ...(i)$$ The image I' acts as a virtual object for second surface and after refraction at second surface, the final image is formed at I. The distance of I from pole P_2 of second surface is v. The distance of virtual object (I') from pole P_2 is $(v'-t)$. For refraction at second surface, the ray is going from second medium (refractive index n_2) to first medium (refractive index n_1), therefore from refraction formula at spherical surface $$\frac{n_1}{v}-\frac{n_2}{(v'-t)}=\frac{n_1-n_2}{R_2} \quad ...(ii)$$ For a thin lens t is negligible as compared to v' therefore from (ii) $$\frac{n_1}{v}-\frac{n_2}{v'}=-\frac{n_2-n_1}{R_2} \quad ...(iii)$$ Adding equations (i) and (iii), we get $$\frac{n_1}{v}-\frac{n_1}{u}=(n_2-n_1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$ or $$\frac{1}{v}-\frac{1}{u}=\left(\frac{n_2}{n_1}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$ *i.e.* $$\frac{1}{v}-\frac{1}{u}=({}_1n_2-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad ...(iv)$$ where ${}_1n_2=\frac{n_2}{n_1}$ is refractive index of second medium (*i.e.*, medium of lens) with respect to first medium. If the object O is at infinity, the image will be formed at second focus *i.e.*, if $u=\infty$, $v=f_2=f$ Therefore from equation (iv) $$\frac{1}{f}-\frac{1}{\infty}=({}_1n_2-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$ *i.e.,* $$\frac{1}{f}=({}_1n_2-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad ...(v)$$ This formula is called ***Lens-Maker's formula***.

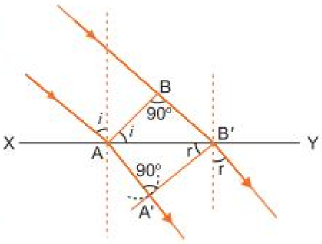


33

(a) **Wavefront:** A wavefront is a locus of all particles of medium vibrating in the same phase.

Huygen's Principle: Refer point 1 of basic concepts.

Proof of Snell's law of Refraction using Huygen's wave theory: When a wave starting from one homogeneous medium enters the another homogeneous medium, it is deviated from its path. This phenomenon is called **refraction**. In transversing from first medium to another medium, the frequency of wave remains unchanged but its speed and the wavelength both are changed. Let XY be a surface separating the two media '1' and '2'. Let v_1 and v_2 be the speeds of waves in these media.



Suppose a plane wavefront AB in first medium is incident obliquely on the boundary surface XY and its end A touches the surface at A at time $t = 0$ while the other end B reaches the surface at point B' after time-interval t. Clearly $BB' = v_1 t$. As the wavefront AB advances, it strikes the points between A and B' of boundary surface. According to Huygen's principle, secondary spherical wavelets originate from these points, which travel with speed v_1 in the first medium and speed v_2 in the second medium.

First of all secondary wavelet starts from A, which traverses a distance $AA' (= v_2 t)$ in second medium in time t. In the same time-interval t, the point of wavefront traverses a distance $BB' (= v_1 t)$ in first medium and reaches B', from, where the secondary wavelet now starts. Clearly $BB' = v_1 t$ and $AA' = v_2 t$.

Assuming A as centre, we draw a spherical arc of radius $AA' (= v_2 t)$ and draw tangent $B'A'$ on this arc from B'. As the incident wavefront AB advances, the secondary wavelets start from points between A and B', one after the other and will touch $A'B'$ simultaneously. According to Huygen's principle $A'B'$ is the new position of wavefront AB in the second medium. ***Hence A'B' will be the refracted wavefront.***

First law: As AB, $A'B'$ and surface XY are in the plane of paper, therefore the perpendicular drawn on them will be in the same plane. As the lines drawn normal to wavefront denote the rays, therefore we may say that the incident ray, refracted ray and the normal at the point of incidence all lie in the same plane.

This is the first law of refraction.

Second law: Let the incident wavefront AB and refracted wavefront $A'B'$ make angles i and r respectively with refracting surface XY.

In right-angled triangle $AB'B$, $\angle ABB' = 90°$

$$\therefore \quad \sin i = \sin \angle BAB' = \frac{BB'}{AB'} = \frac{v_1 t}{AB'} \quad \text{...(i)}$$

Similarly in right-angled triangle $AA'B'$, $\angle AA'B' = 90°$

$$\therefore \quad \sin r = \sin \angle AB'A' = \frac{AA'}{AB'} = \frac{v_2 t}{AB'} \quad \text{...(ii)}$$

Dividing equation (i) by (ii), we get

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \text{constant} \quad \text{...(iii)}$$

As the rays are always normal to the wavefront, therefore the incident and refracted rays make angles i and r with the normal drawn on the surface XY *i.e.* i and r are the angle of incidence and angle of refraction respectively. According to equation (iii):

The ratio of sine of angle of incidence and the sine of angle of refraction for a given pair of media is a constant and is equal to the ratio of velocities of waves in the two media. This is the second law of refraction, and is called the Snell's law.

(b) (i) If the radiation of certain frequency interact with the atoms/molecules of the matter, they start to vibrate with the same frequency under forced oscillations.

Thus, the frequency of the scattered light (Under reflection and refraction) equals to the frequency of incident radiation.

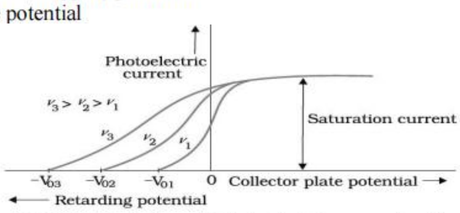
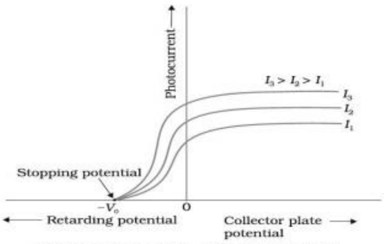
(ii) No, energy carried by the wave depends on the frequency of the wave, but not on the speed of the wave.

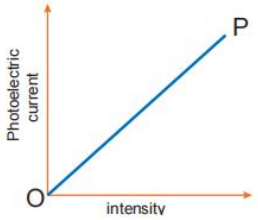
34	(i)	When the image is formed at infinity, we can see it with minimum strain in the ciliary muscles of the eye.	1
	(ii)	The multi-component lenses are used for both objective and the eyepiece to improve image quality by minimising various optical aberrations in lenses.	1
	(iii)	(a)The compound microscope is used to observe minute nearby objects whereas the telescope is used to observe distant objects.	1
		(b) In compound microscope the focal length of the objective is lesser than that of the eyepiece whereas in telescope the focal length of the objective is larger than that of the eyepiece.	1
		OR	
	(iii)	(a) The image formed by reflecting type telescope is brighter than that formed by refracting telescope.	1
		(b) The image formed by the reflecting type telescope is more magnified than that formed by the refracting type telescope.	1

CHAPTER 08 AND 11 [E.M. WAVE AND DUAL NATURE]

QUESTION NUMBER	ANSWER
01	SOLVED
02	SOLVED
03	SOLVED
04	SOLVED
05	SOLVED
06	SOLVED
07	SOLVED
08	SOLVED
09	D
10	λ_1 -Microwave ½ λ_2 - ultraviolet ½ λ_3 - infrared ½ Ascending order - $\lambda_2<\lambda_3<\lambda_1$ ½
11	SOLVED
12	SOLVED
13	SOLVED

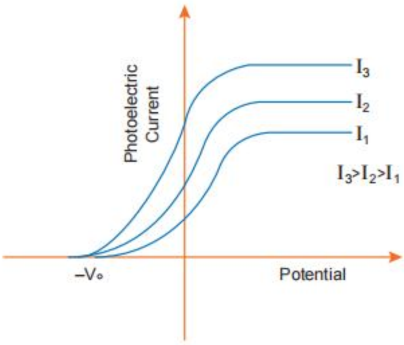
QUESTION NUMBER	ANSWER
01	C
02	B
03	A
04	D
05	D
06	A
07	D
01	The energy of the incident photon, $E = h\nu = \frac{hc}{\lambda}$ $= \frac{6.63\times10^{-34}\times3\times10^{8}}{412.5\times10^{-9}}$ J $= \frac{0.048\times10^{-17}}{1.6\times10^{-19}}$ eV $=$ **3 eV** Metals having work function less than energy of the incident photon will show photoelectric effect. Hence, only Na and K will show photoelectric emission.
02	SOLVED

01	From the observations made (parts A and B) on the basis of Einstein's photoelectric equation, we can draw following conclusions: 1. For surface A, the threshold frequency is more than 10^{15} HZ, hence no photoemission is possible. 2. For surface B the threshold frequency is equal to the frequency of given radiation. Thus, photo-emission takes place but kinetic energy of photoelectrons is zero. 3. For surface C, the threshold frequency is less than 10^{15} Hz. So photoemission occurs and photoelectrons have some kinetic energy **OR** A - cut off or stopping potential X - anode potential  **FIGURE** Variation of photoelectric current with collector plate potential for different frequencies of incident radiation.  **FIGURE** Variation of photocurrent with collector plate potential for different intensity of incident radiation.	 1 1 1 ½ ½ 1 1
02	(*i*) Threshold frequency of P is 3×10^{14} Hz. Threshold frequency of Q is 6×10^{14} Hz. Clearly Q has higher threshold frequency. (*ii*) Work function of metal Q, $\phi_0 = h\nu_0$ $= (6.6 \times 10^{-34}) \times 6 \times 10^{14}$ J $= \frac{39.6 \times 10^{-20}}{1.6 \times 10^{-19}}$ eV $=$ **2.5 eV** (*iii*) Maximum kinetic energy, $K_{max} = h\nu - h\nu_0$ $= h(\nu - \nu_0)$ $= 6.6 \times 10^{-34}\,(8 \times 10^{14} - 6 \times 10^{14})$ $= 6.6 \times 10^{-34} \times 2 \times 10^{14}$ J $= \frac{6.6 \times 10^{-34} \times 2 \times 10^{14}}{1.6 \times 10^{-19}}$ eV $\therefore \quad K_{max} = \mathbf{0.83\ eV}$	
03	de Broglie wavelength $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mqV}}$ where, m = mass of charge particle, q = charge of particle, V = potential difference (*i*) $\lambda^2 = \frac{h^2}{2mqV} \Rightarrow V = \frac{h^2}{2mq\lambda^2}$ $\therefore \quad \frac{V_p}{V_\alpha} = \frac{2m_\alpha q_\alpha}{2m_p q_p} = \frac{2 \times 4m 2q}{2mq} = \frac{8}{1}$ $\therefore \quad V_p : V_\alpha = \mathbf{8 : 1}$	

	(ii) $\lambda = \frac{h}{mv}, \lambda_p = \frac{h}{m_p v_p}, \lambda_\alpha = \frac{h}{m_\alpha v_\alpha}$ $\lambda_p = \lambda_\alpha \Rightarrow \frac{h}{m_p v_p} = \frac{h}{m_\alpha v_\alpha}$ $\frac{v_p}{v_\alpha} = \frac{m_\alpha}{m_p} = \frac{4}{1} = \mathbf{4:1}$
04	(i) de Broglie wavelength $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mqV}}$ For same V, $\lambda \alpha \frac{1}{\sqrt{mq}}$ $\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha}{m_p q_p}} = \sqrt{\frac{4m_p}{m_p} \cdot \frac{2e}{e}}$ $= \sqrt{8} = 2\sqrt{2}$ Clearly, $\lambda_p > \lambda_\alpha$. Hence, proton has a greater de-Broglie wavelength. (ii) Kinetic energy, $K = qV$ For same V, $K \alpha q$ $\frac{K_p}{K_\alpha} = \frac{q_p}{q_\alpha} = \frac{e}{2e} = \frac{1}{2}$ Clearly, $K_p < K_\alpha$. Hence, proton has less kinetic energy.
01	**Working:** When a monochromatic radiations of suitable frequency obtained from source S fall on the photosensitive plate C, the photoelectrons are emitted from C, which gets accelerated towards the plate A (collector) if it is kept at positive potential. These electrons flow in the outer circuit resulting in the photoelectric current. Due to it, the microammeter shows a deflection. The reading of microammeter measures the photoelectric current. This experimental arrangement can be used to study the variation of photoelectric current with the following quantities. (i) **Effect of intensity of the incident radiation:** By varying the intensity of the incident radiations, keeping the frequency constant, it is found that the photoelectric current varies linearly with the intensity of the incident radiation. Also, the number of photoelectrons emitted per second is directly proportional to the intensity of the incident radiations. 

(ii) **Effect of potential of plate A w.r.t place C:** It is found that the photoelectric current increases gradually with the increase in positive potential of plate A.

At one stage for a certain positive potential of plate A, the photoelectric current becomes maximum or saturates. After this if we increase the positive potential of plate A, there will be no increase in the photoelectric current.



This maximum value of current is called saturation current: The saturation current corresponds to the state when all the photoelectrons emitted from C reach the plate A.

Now apply a negative potential on plate A w.r.t. plate C. We will note that the photoelectric current decreases, because the photoelectrons emitted from C are repelled and only energetic photoelectrons are reaching the plate A.

By increasing the negative potential of plate A, the photoelectric current decreases rapidly and becomes zero at a certain value of negative potential V_0 on plate A.

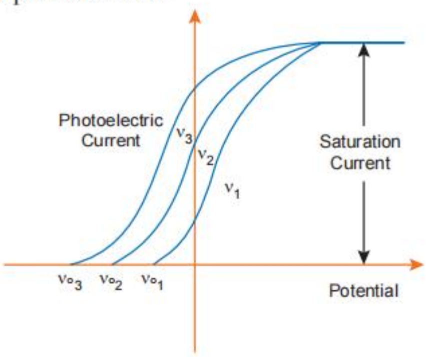
This maximum negative potential V_0, given to the plate A w.r.t. plate C at which the photoelectric current becomes zero is called stopping potential or cut off potential.

$$K_{max} = eV_0 = \frac{1}{2} m V_{max}^2$$

where e = charge on electron, m = mass of electrons

V_{max} = maximum velocity of emitted photoelectrons.

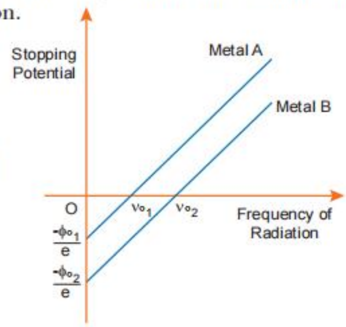
The value of stopping potential is independent of the intensity of the incident radiation. It means, the maximum kinetic energy of emitted photoelectrons depends on the radiation source and nature of material of plate C but is independent of the intensity of incident radiation.



(iii) **Effect of frequency of the incident radiation:** When we take the radiations of different frequencies but of same intensity, then the value of stopping potential is different for radiation of different frequency.

The value of stopping potential is more negative for radiation of higher incident frequency. The value of saturation current depends on the intensity of incident radiation but is independent of the frequency of the incident radiation.

(iv) **Effect of frequency on stopping potential:** For a given photosensitive material, the stopping potential varies linearly with the frequency of the incident radiation.



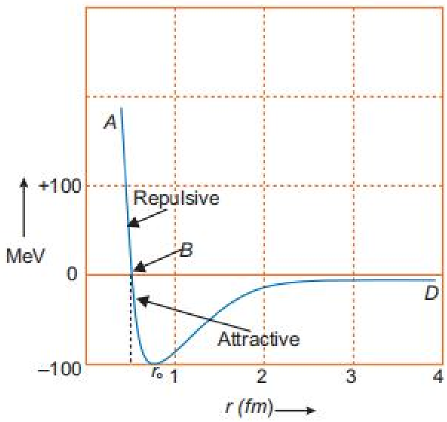
For every photosensitive material, there is a certain minimum cut off frequency ν_0 (threshold frequency) for which the stopping potential is zero.

The intercept on the potential axis $= -\frac{\phi_0}{e} = -\frac{h\nu_0}{e}$.

Hence, work function $\phi_0 = e \times$ magnitude of intercept on the potential axis

CHAPTER 12 AND 13 [ATOM AND NUCLEI]

QUESTION NUMBER	ANSWER	
01	B	
02	B	
03	C	
04	C	
05	A	
06	C	
07	C	
08	D	
09	B	
10	B	
11	A	
12	A	
13	A	
14	From the relation $R = R_0A^{1/3}$, where R_0 is a constant and A is the mass number of a nucleus $R_{Fe}/R_{Al} = (A_{Fe}/A_{Al})^{1/3}$ $= (125/27)^{1/3}$ $R_{Fe} = 5/3\ R_{Al}$ $= 5/3 \times 3.6$ $= 6$ fermi **OR** Given short wavelength limit of Lyman series $\frac{1}{\lambda_L} = R\left(\frac{1}{1^2} - \frac{1}{\infty}\right)$ $\frac{1}{913.4\ Å} = R\left(\frac{1}{1^2} - \frac{1}{\infty}\right)$ $\lambda_L = \frac{1}{R} = 913.4\ Å$ For the short wavelength limit of Balmer series $n_1=2,\ n_2 = \infty$ $\frac{1}{\lambda_B} = R\left(\frac{1}{2^2} - \frac{1}{\infty}\right)$ $\lambda_B = \frac{4}{R} = 4 \times 913.4\ Å$ $= 3653.6\ Å$	½ ½ ½ ½ ½ ½ ½ ½
15	The line with the longest wavelength of the Balmer series is called H_α. $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$ where λ = wavelength $R = 1.097 \times 10^7\ m^{-1}$ (Rydberg constant) When the electron jumps from the orbit with $n = 3$ to $n = 2$, we have $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) \Rightarrow \frac{1}{\lambda} = \frac{5}{36}R$ The frequency of photon emitted is given by $\nu = \frac{c}{\lambda} = c \times \frac{5}{36}R$ $= 3 \times 10^8 \times \frac{5}{36} \times 1.097 \times 10^7$ Hz $= \mathbf{4.57 \times 10^{14}}$ **Hz**	

16	SOLVED
17	(a) The symbol 'b' represents **impact parameter** and 'θ' represents the **scattering angle**. (b) (i) When $\theta = 0°$, the **impact parameter** will be maximum and represent the **atomic size.** (ii) When $\theta = \pi$ radians, the impact parameter 'b' will be minimum and represent the nuclear size.
18	SOLVED
19	SOLVED
20	$\therefore \quad \frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{1}{8}\right)^{1/3} = \mathbf{\frac{1}{2}}$
21	SOLVED
22	Let r be the centre to centre distance between the alpha particle and the nucleus (Z = 80). When the alpha particle is at the stopping point, then $K = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(2e)}{r}$ or $r = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2Ze^2}{K}$ $= \frac{9\times10^9\times2\times80\,e^2}{4.5\text{ MeV}} = \frac{9\times10^9\times2\times80\times(1.6\times10^{-19})^2}{4.5\times10^6\times1.6\times10^{-19}}$ $= \frac{9\times160\times1.6}{4.5}\times10^{-16} = 512\times10^{-16}\text{ m}$ $\mathbf{= 5.12 \times 10^{-14}\ m}$
23	In nuclear reaction $^2_1H + ^2_1H \longrightarrow ^3_2He + n + 3.27\text{ MeV}$ Cause of the energy released: (i) Binding energy per nucleon of ^3_2He becomes more than the (BE/A) of ^2_1H. (ii) Mass defect between the reactant and product nuclei $\Delta E = \Delta m\, c^2$ $= [2m(^2_1H) - m(^3_2He) + m(n)]c^2$
24	 Conclusions: (i) The potential energy is minimum at a distance r_0 of about 0.8 fm. (ii) Nuclear force is attractive for distance larger than r_0. (iii) Nuclear force is repulsive if two are separated by distance less than r_0. (iv) Nuclear force decreases very rapidly at r_0/equilibrium position.

25

At the suggestion of Rutherford, in 1911, H. Geiger, and E. Marsden performed an important experiment called Geiger-Marsden experiment (or Rutherford's scattering experiment). It consists of

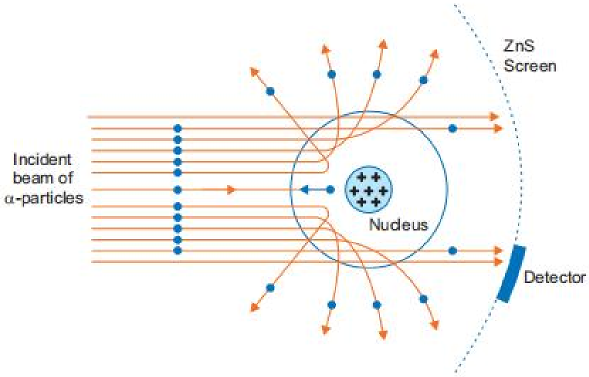
1. **Source of α-particles:** The radioactive source polonium emits high energetic alpha (α) particles. Therefore, polonium is used as a source of α-particles. This source is placed in an enclosure containing a hole and a few slits A_1, A_2, ..., etc., placed in front of the hole. This arrangement provides a fine beam of α-particles.
2. **Thin gold foil:** It is a gold foil of thickness nearly 10^{-6} m, α-particles are scattered by this foil. The foil taken is thin to avoid multiple scattering of α-particles, *i.e.*, to ensure that α-particle be deflected by a single collision with a gold atom.
3. **Scintillation counter:** By this the number of α-particles scattered in a given direction may be counted. The entire apparatus is placed in a vacuum chamber to prevent any energy loss of α-particles due to their collisions with air molecules.

Method: When α-particle beam falls on gold foil, the α-particles are scattered due to collision with gold atoms. This scattering takes place in all possible directions. The number of α-particles scattered in any direction is counted by scintillation counter.

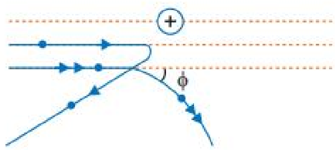
Observations and Conclusions

(*i*) Most of α-particles pass through the gold foil undeflected. This implies that "most part of the atom is hollow."

(*ii*) α-particles are scattered through all angles. Some α-particles (nearly 1 in 2000), suffer scattering through angles more than 90°, while a still smaller number (nearly 1 in 8000) retrace their path. This implies that when fast moving positively charged α-particles come near gold-atom, then a few of them experience such a strong repulsive force that they turn back. On this basis Rutherford concluded that whole of positive charge of atom is concentrated in a small central core, called the nucleus.



The distance of closest approach of α-particle gives the estimate of nuclear size. If Ze is charge of nucleus, E_k–kinetic energy of α particle, $2e$–charge on α-particle, the size of nucleus r_0 is given by

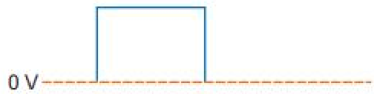
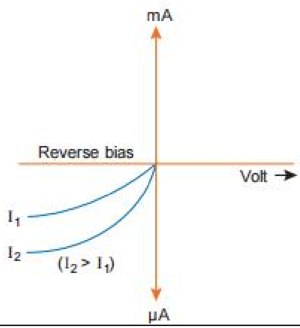


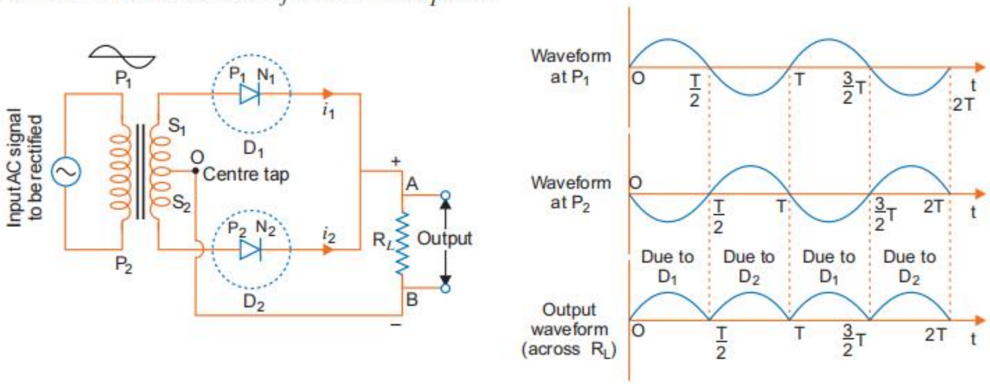
$$E_k = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(2e)}{r_0} \quad \Rightarrow \quad r_0 = \frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{E_k}$$

Calculations show that the size of nucleus is of the order of 10^{-14} m, while size of atom is of the order of 10^{-10}m; therefore the size of nucleus is about $\frac{10^{-14}}{10^{-10}} = \frac{1}{10,000}$ times the size of atom.

(*iii*) The negative charges (electrons) do not influence the scattering process. This implies that nearly whole mass of atom is concentrated in nucleus.

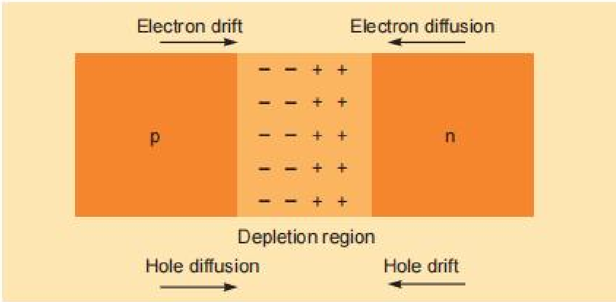
CHAPTER 14 [SEMICONDUCTOR]

QUESTION NUMBER	ANSWER
01	A
02	C
03	C
04	D
05	B
06	B
07	D
08	C
09	C
10	A,C
01	C
02	A
03	A
01	To keep the reading of ammeter constant value of R should be **increased** as with the increase in temperature of a semiconductor, its resistance **decreases** and current tends to increase. 1 1 **OR** B - reverse biased ½ In the case of reverse biased diode the potential barrier becomes higher as the battery further raises the potential of the n side. ½ C -forward biased ½ Due to forward bias connection the potential of P side is raised and hence the height of the potential barrier decreases. ½
02	SOLVED
03	SOLVED
04	
05	Photodiode is used for detecting optical signals. It is operated in reverse biasing. **I-V Characteristics:** 
06	**B : Reverse biased** Justification: When an external voltage V is applied across the semiconductor diode such that n-side is positive and p-side is negative, the direction of applied voltage is same as the direction of barrier potential. As a result, the barrier height increases and the depletion region widens due to the change in the electric field. The effective barrier height under reverse bias is (V_0+V). **C : Forward biased** Justification: When an external voltage V is applied across a diode such that p-side is positive and n-side is negative, the direction of applied voltage (V) is opposite to the barrier potential (V_0). As a result, the depletion layer width decreases and the barrier height is reduced. The effective barrier height under forward bias is $(V_0 - V)$.

07	SOLVED
01	Given $n_e = 2 \times 10^8 / m^3$, $n_h = 4 \times 10^{10} / m^3$ (*i*) The majority charge carriers in doped semiconductor are holes, so semiconductor obtained is *p*-type semiconductor. (*ii*) $n_e n_h = n_i^2 \Rightarrow n_e = \frac{n_i^2}{n_h} = \frac{(2 \times 10^8)^2}{4 \times 10^{10}} = \mathbf{10^6/m^3}$ New electron concentration $= 10^6 / m^3$ hole concentration $= 4 \times 10^{10} / m^3$ (*iii*) Energy gap decreases on doping.
02	LED is fabricated by (*i*) heavy doping of both the *p* and *n* regions. (*ii*) providing a transparent cover so that light can come out. **Working:** When the diode is forward biased, electrons are sent from $n \to p$ and holes from $p \to n$. At the junction boundary, the excess minority carriers on either side of junction recombine with majority carriers. This releases energy in the form of photon $h\nu = E_g$. **GaAs (Gallium Arsenide):** Band gap of semiconductors used to manufacture LED's should be 1.8 eV to 3 eV. These materials have band gap which is suitable to produce desired visible light wavelengths. **Advantages** (*i*) Low operational voltage and less power consumption. (*ii*) Fast action and no warm-up time required. (*iii*) Long life and ruggedness. (*iv*) Fast on-off switching capability.
03	SPECIAL MASS PHYSICS EDUCATION SOLUTION
04	SPECIAL MASS PHYSICS EDUCATION SOLUTION
01	**Working:** The ac input voltage across secondary S_1 and S_2 changes polarity after each half cycle. Suppose during the first half cycle of input ac signal, the terminal S_1 is positive relative to centre tap *O* and S_2 is negative relative to *O*. Then diode D_1 is forward biased and diode D_2 is reverse biased. Therefore, diode D_1 conducts while diode D_2 does not. The direction of current (i_1) due to diode D_1 in load resistance R_L is directed from *A* to *B* In next half cycle, the terminal S_1 is negative and S_2 is positive relative to centre tap *O*. The diode D_1 is reverse biased and diode D_2 is forward biased. Therefore, diode D_2 conducts while D_1 does not. The direction of current (i_2) due to diode D_2 in load resistance R_L is still from *A* to *B*. Thus, the current in load resistance R_L is in the same direction for both half cycles of input ac voltage. Thus *for input ac signal the output current is a continuous series of unidirectional pulses.*  In a full wave rectifier, if input frequency is *f* hertz, then output frequency will be 2*f* hertz because for each cycle of input, two positive half cycles of output are obtained.

02

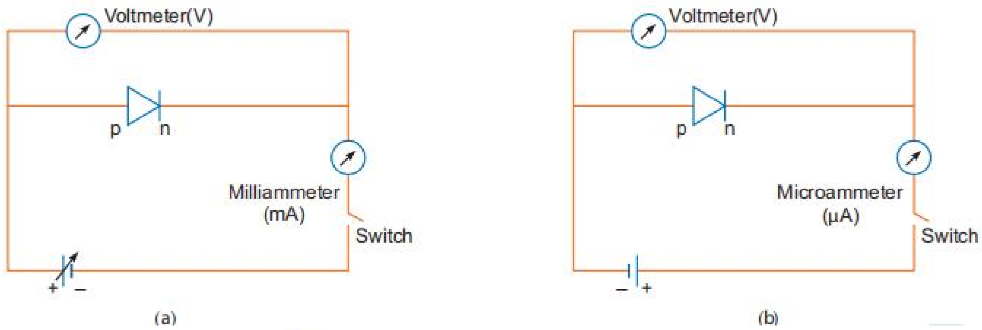
(*a*)

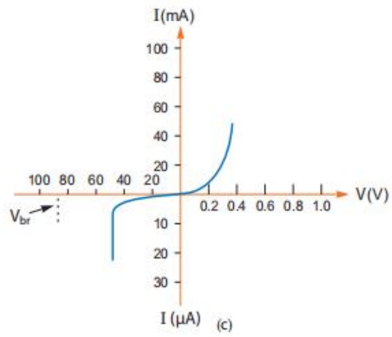


Two processes occur during the formation of a *p-n* junction are diffusion and drift. Due to the concentration gradient across *p* and *n*-sides of the junction, holes diffuse from *p*-side to *n*-side ($p \rightarrow n$) and electrons diffuse from *n*-side to *p*-side ($n \rightarrow p$). This movement of charge carriers leaves behind ionised acceptors (negative charge immobile) on the *p*-side and donors (positive charge immobile) on the *n*-side of the junction. This space charge region on either side of the junction together is known as depletion region.

(*b*) The circuit arrangement for studying the *V–I* characteristics of a diode are shown in Fig. (*a*) and (*b*). For different values of voltages the value of current is noted. A graph between *V* and *I* is obtained as in Figure (*c*).

From the *V–I* characteristic of a junction diode it is clear that it allows current to pass only when it is forward biased. So if an alternating voltage is applied across a diode the current flows only in that part of the cycle when the diode is forward biased. This property is used to rectify alternating voltages.





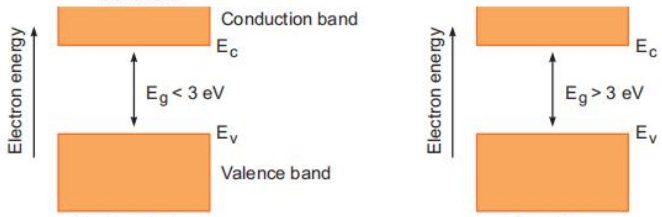
(*i*) **Minority Carrier Injection:** Due to the applied voltage, electrons from *n*-side cross the depletion region and reach *p*-side (where they are minority carriers). Similarly, holes from *p*-side cross this junction and reach the *n*-side (where they are minority carriers). This process under forward bias is known as minority carrier injection.

(*ii*) **Breakdown Voltage:** It is a critical reverse bias voltage at which current is independent of applied voltage.

03

Energy Bands: In a solid, the energy of electrons lie within certain range. The energy levels of allowed energy are in the form of bands, these bands are separated by regions of forbidden energy called band gaps.

Conductor



Semiconductor   Insulator

Distinguishing features:

(*a*) In conductors: Valence band and conduction band overlap each other.
In semiconductors: Valence band and conduction band are separated by a small energy gap.
In insulators: They are separated by a large energy gap.

(*b*) In conductors: Large number of free electrons are available in conduction band.
In semiconductors: A very small number of electrons are available for electrical conduction.
In insulators: Conduction band is almost empty *i.e.*, no electron is available for conduction.

Effect of Temperature:

(*i*) **In conductors:** At high temperature, the collision of electrons become more frequent with the atoms/molecules at lattice site in the metals as a result the conductivity decreases (or resistivity increases).

(*ii*) **In semiconductors:** As the temperature of the semiconducting material increases, more electron hole pairs becomes available in the conduction band and valance band, and hence the conductivity increases or the resistivity decreases.

(*iii*) **In insulators:** The energy band between conduction band and valance band is very large, so it is unsurpassable for small temperature rise. So, there is no change in their behaviour.

01	**(i)**	LEDs are made up of compound semiconductors and not by the elemental conductor because the band gap in the elemental conductor has a value that can detect the light of a wavelength which lies in the infrared (IR) region.	1
	(ii)	1.8 eV to 3 eV	1
	(iii)	LED is reversed biased that is why it is not glowing.	2
		OR	
		V-I Characteristic curves of pn junction diode in forward biasing and reverse biasing.	1+ 1