CHAPTER

1

Ray Optics

SECTION-A

Plane Mirror & Spherical Mirror

1. Reflection at Plane Surface

- **Light :** It is that form of energy which makes objects visible to our eye.
- **Optics :** The branch of physics which deals with the nature of light, its sources, properties, effects and vision is called **optics**.

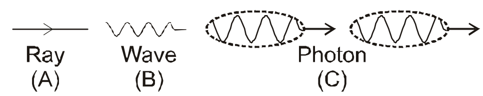
  There are two branches of Optics.

(1) **Geometrical Optics :** It treats propagation of light in terms of rays and is valid only if wavelength of light is much lesser than the size of obstacles.

It concerns with the image formation and deals with the study of simple facts such as rectilinear propagation, laws of reflection and refraction by geometrical methods

(2) **Physical Optics :** It is further divided into two parts, viz, wave optics and quantum optics.

- **Wave optics :** It treats propagation of light in terms of wave. It concerns with explanation of the observed phenomena such as interference, diffraction and polarization. In it light is treated as a wave.
- **Quantum Optics :** It treats light as a particle (localized energy packet) called photon to deal with photoelectric effect Raman effect and LASER, etc.



Reflection of Light :

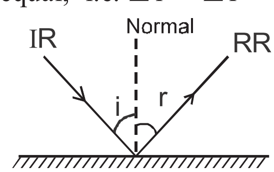
When light rays strike the boundary of two media, a part of light is turned back into the same medium. This phenomenon is called Reflection of Light. **Or** It is the phenomenon of change in the path of light without change in medium.

2. Laws of Reflection

(1) The incident ray, the reflected ray and the normal at the point of incidence lie in the same plane.

This plane is called the **plane of incidence (or plane of reflection)**.

(2) The angle of incidence (the angle between normal and the incident ray) and the angle of reflection (the angle between the reflected ray and the normal) are equal, i.e. $\angle i = \angle r$



- As a result of reflection, the speed, wavelength, frequency and colour of light remain the same but its intensity, in general, decreases.
- There is a phase change of π rad if reflection takes place from an optically denser medium.

Regular & diffused Reflection :

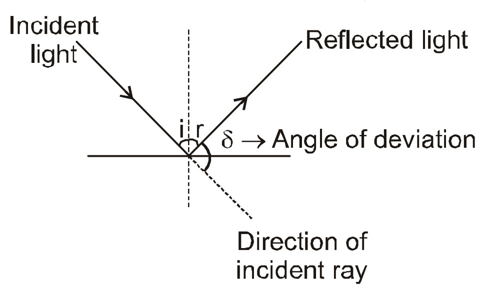
- Reflection from a smooth plane surface is called **regular reflection.**

  In this type of reflection, a beam of parallel rays is reflected as a beam of parallel rays.
- Reflection from a rough plane surface is called **irregular reflection.**

  In this type of reflection, a beam of parallel rays gets diffused on reflection.

3. Angle of Deviation :

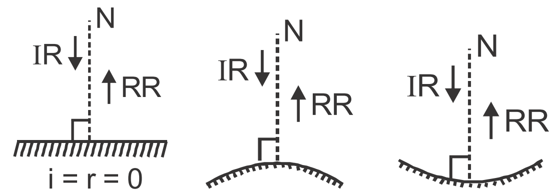
It is the angle by which the light ray rotates after reflection from any surface



- On reflection from a plane mirror, a rays is deviated through an angle $\delta = (180 - 2i) = 2\alpha$

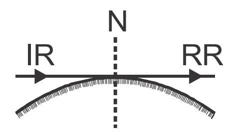
  Here, α is the glancing angle (i.e., angle between the plane mirror and the incident ray)

- **Normal Incidence :** The light is incident normally, $i = r = 0^o$ & $\delta = 180^o$



- **Grazing Incidence :** The light strikes tangentially.

  $i = r = 90^o$ & $\delta = 0^o$



Vector form of law of reflection

Let $\hat{e}_i$ = unit vector along the incident ray,

$\hat{e}_r$ = unit vector along the reflected ray,

$\hat{t}$ = unit vector along tangential direction,

$\hat{n}$ = unit vector along outward normal

Let

$\therefore \quad \hat{e}_i = \sin\theta\hat{i} - \cos\theta\hat{n} = \quad ...(i)$

$\hat{e}_r = \sin\theta\hat{i} + \cos\theta\hat{n} \quad ...(ii)$

From equation (i) and (ii), we get,

$\hat{e}_r - \hat{e}_i = 2\cos\theta\,\hat{n} \quad ...(iii)$

Also, $\hat{e}_i \cdot \hat{n} = (1)(1)\cos(\pi - \theta) = -\cos\theta$

By putting the value of cosθ in equation (iii),

$\hat{e}_r - \hat{e}_i = -2(\hat{e}_i \cdot \hat{n})\hat{n} \quad \therefore$

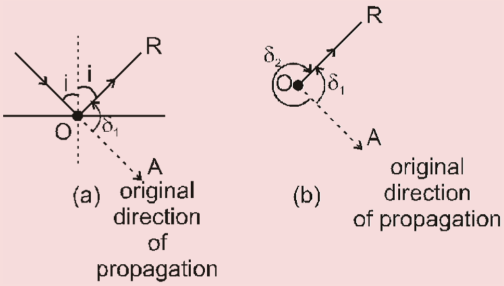
$\hat{e}_r = \hat{e}_i - 2(\hat{e}_i \cdot \hat{n})\hat{n}$

It is the vector form of the law of reflection.

Example 1

Show that for a light ray incident at an angle 'i' on getting reflected, the angle of deviation is $\delta = \pi - 2i$ or $\pi + 2i$.

Sol.



From figure (b) it is clear that light ray bends either by δ_1 anticlockwise or by δ_2 $(= 2\pi - \delta_1)$ clockwise. From figure (a) $\delta_1 = \pi - 2i$

$\therefore\ \delta_2 = \pi + 2i$.

Example 2

A ray of light is incident on a plane mirror along a vector $a\hat{i} + b\hat{j} - c\hat{k}$. The normal on incidence point is along $\dfrac{\hat{i}+\hat{j}}{\sqrt{2}}$. Find a unit vector along the reflected ray.

Sol. Here $\hat{e}_i = \dfrac{a\hat{i} + b\hat{j} - c\hat{k}}{\sqrt{a^2+b^2+c^2}}$ and $\hat{n} = \dfrac{\hat{i}+\hat{j}}{\sqrt{2}}$

Also, $\hat{e}_r = \hat{e}_i - 2(\hat{e}_i.\hat{n})\hat{n}$

$$\therefore\ \hat{e}_r = \frac{a\hat{i} + b\hat{j} - c\hat{k}}{\sqrt{a^2+b^2+c^2}} - 2\left[\frac{a+b}{\sqrt{a^2+b^2+c^2}\sqrt{2}}\right]\frac{\hat{i}+\hat{j}}{\sqrt{2}}$$

$$= \frac{1}{\sqrt{a^2+b^2+c^2}}[-b\hat{i} - a\hat{j} - c\hat{k}]$$

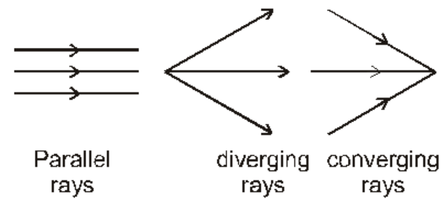
4. Ray, Object & Image:

Ray

The straight line path followed by light in a homogeneous medium is called ray.

A bundle of rays is called a **beam**.

A narrow beam is called a **pencil of light**.



Object (O) :

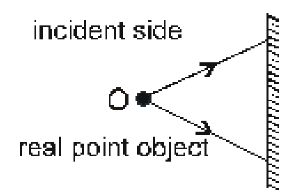
- An object is a source of light rays.
- An object may be a point or an extended.
- It is the point of intersection of incident rays.
- Objects are of two types - Real & Virtual

Real Object

- An object is real if two or more incident rays actually emit or appear to emit.
- It is the point of divergence.
- It lies on incident side.
- The real object actually present.

Virtual Object

- It is the apparent point of convergence.
- It lies on opposite to incident side.
- If not intercepted by an optical element will meet at a point.



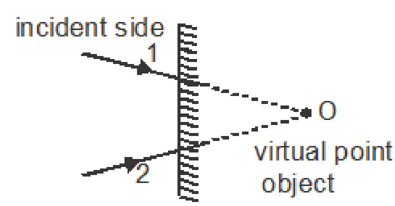


Image (I) :

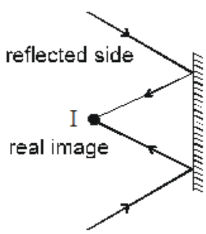
- The **Image** is a point of intersection of **reflected** rays or **refracted** rays.
- Objects are of two types - Real & Virtual

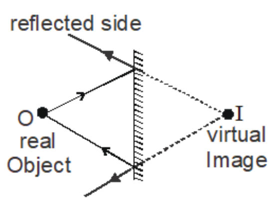
Real Image

- Real images are formed when the reflected or refracted rays actually meet or converge at a point.
- A real image can be obtained on screen.
- Both real and virtual objects can form real images.
- It lies on reflected or refracted side.

Virtual Image

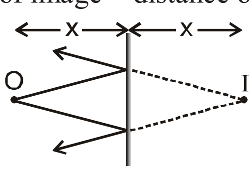
- Virtual images are formed when the reflected or refracted rays do not meet at a point but appear to meet or diverge at a point.
- Both real and virtual objects can form Virtual images.
- It lies opposite on reflected or refracted side.
- A virtual image cannot be obtained on screen but they can seen by our eye.



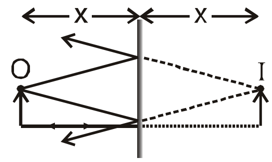


SOME FACTS REGARDING PLANE MIRROR

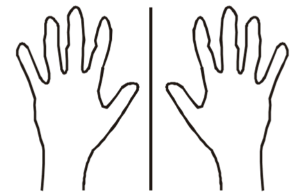
- The focal length and radius of curvature of a plane mirror are infinite. i.e., $f = \infty$, $R = \infty$ and its power is zero.
- Distance of image = distance of object



- Size of image = size of object
  Magnification = unity



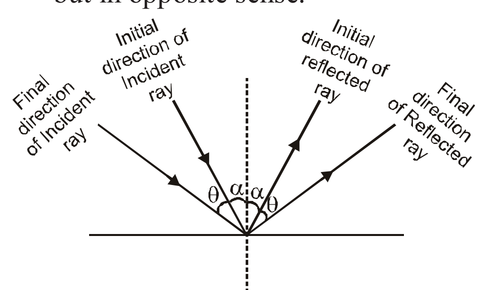
- Image is erect and virtual.
- There is a lateral inversion in the image. The left side of the object appears as the right side of the image.



- A plane mirror may form a virtual as well as real image.
- If a person is standing in a hall whose celling and two adjacent walls are plane mirrors, in all **7 images** of the person will be formed.
  However, the person can see, at the most, 6 images simultaneously at any instant.

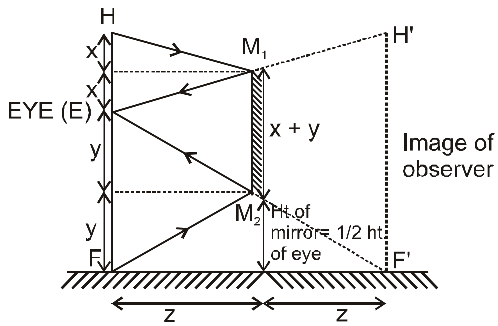
ROTATION OF INCIDENT RAY

- From the diagram, it is clear that if Incident ray rotates by an angle 'θ', the reflected ray also rotates by angle 'θ' but in opposite sense.



5. Length of Mirror required to view complete object

(A) The minimum size of a plane mirror, required to see the full image of an observer is **half the size** of that observer.



H = head, F = feet

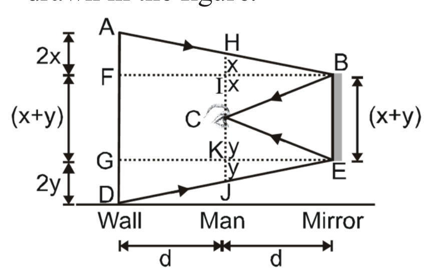
Alternate :

Δ E M_1 M_2 and Δ E H′F′ are similar

$\therefore \quad \dfrac{M_1M_2}{H'F'} = \dfrac{z}{2z}$ or

$M_1 M_2 = H'F'/2 = HF/2$

(B) A man is standing exactly at midway between a wall and a mirror and he want to see the full height of the wall (behind him) in a plane mirror (in front of him). The minimum length of mirror in this case should be H/3, where H is the height of wall. The ray diagram in this case is drawn in the figure.



In triangles HBI and IBC,

HI = IC = x(say).

Now in triangles HBI and ABF,

$\dfrac{AF}{HI} = \dfrac{FB}{BI}$ or $\dfrac{AF}{x} = \dfrac{2d}{d}$

or AF = 2x

Similarly we can prove that DG = 2y,

If CK = KJ = y.

Now, we can see that height of the wall is 3(x + y) while that of the mirror is (x + y) .

Example 3

A person of height 160 cm wants to see his compete image what is the minimum length of plane mirror is required.

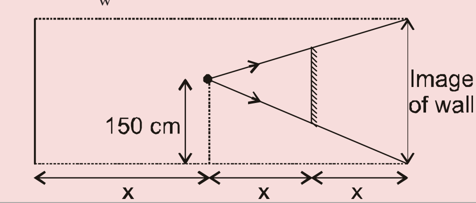
Sol. To see his own image min length of mirror required $= \dfrac{H}{2} = 80$ cm

Example 4

A man of height 150 cm is standing midway between a wall of height 4m & a plane mirror. what is the minimum length of the mirror required to see the complete image of the wall

Sol. $\dfrac{y}{150\text{cm}} = \dfrac{2x}{3x} \Rightarrow \quad y = 100$ cm

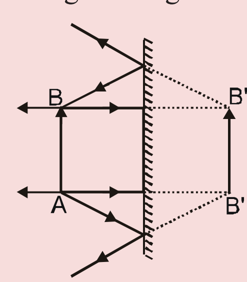
Also $\dfrac{\ell_m}{\ell_w} = \dfrac{x}{3x} \Rightarrow \ell_m = \dfrac{4}{3}$ m



Example 5

Draw the Image of the object using ray diagram. If object of height 2cm is 20cm Away from a plane mirror.

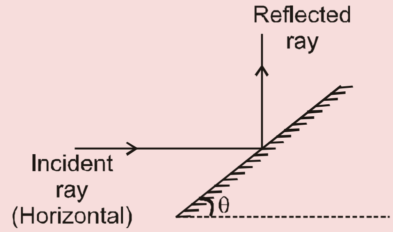
Sol. Height of Image = Height of object = 2 cm



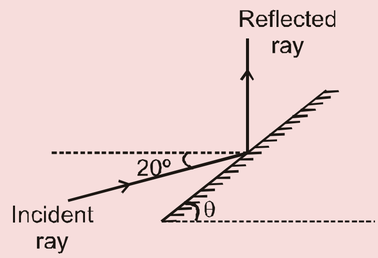
Example 6

Find the angle 'θ' made by plane mirror with horizontal if the reflected ray is vertical in the following cases

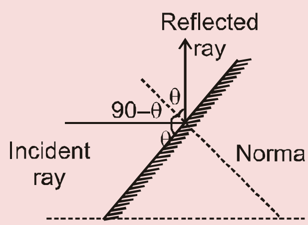
(a)



(b)

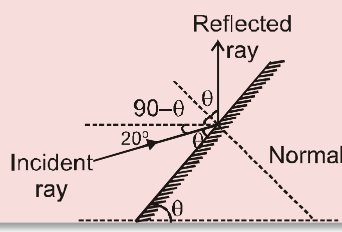


Sol. (a) As $\angle i = \angle r$ so $90 - \theta = \theta \Rightarrow \theta = 45^o$



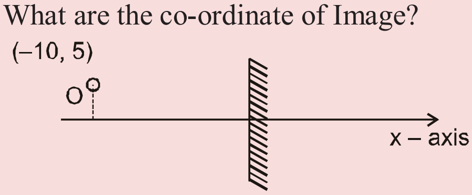
(b) As $\angle i = \angle r \Rightarrow 90 - \theta + 20^o = \theta$

$\Rightarrow \theta = 55^o$



Example 7

What are the co-ordinate of Image?



Sol. For the image formed by a plane mirror

Image formed will be virtual & erect

i.e. the image will lie in 1st quadrant

$d_{object} = d_{image}$ (i.e. x co-ordinate of image = +10)

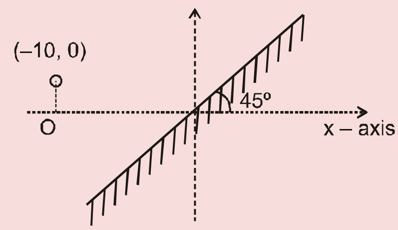
Height of object = Height of image

(i.e. Yco-ordinate of image= 5)

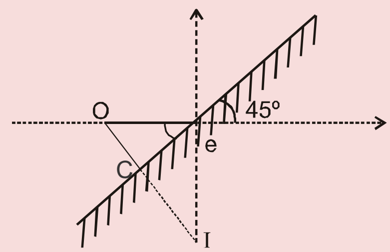
So co-ordinate of image = (10, 5)

Example 8

What are the co-ordinate of Image?

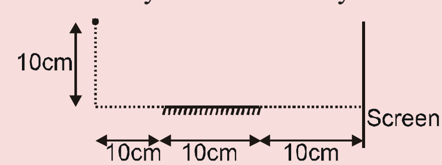


Sol. OC =IC=10 So co-ordinate of image are (0, –10)

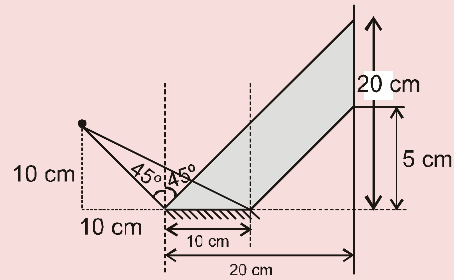


Example 9

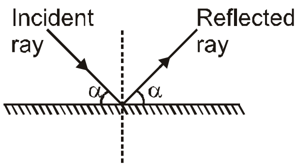
A point light source is arranged as shown, Find the length of the screen which will be illuminated by the reflected rays from the mirror



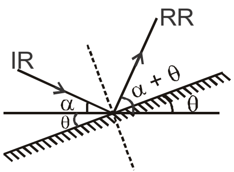
Sol. Length of shaded part = 15 cm



6. Rotation of Plane Mirror



.. (1)

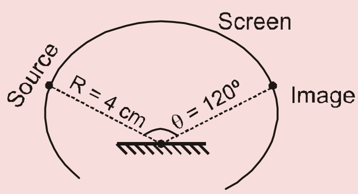


...(2)

- If Mirror is rotated by an angle 'θ' the reflected ray rotates by an angle 2θ in same direction.
- At any instant, if the angular velocity of mirror will be ω_M. Then angular velocity of reflected ray will be $2\omega_M$.

Example 10

A mirror is arranged at the centre of a circular screen as shown if the mirror starts rotating in anticlockwise direction with an angular speed of $\frac{\pi}{24}$ rad/s. Then find out



(A) Angular velocity of Image

(B) Linear velocity of image

(C) Time elapsed when image overlaps with the source.

Sol. (A) $\omega_{image} = \omega_{reflected\ ray}$

$= 2\omega_{mirror}$ (in same sense)

So $\omega_{image} = \frac{\pi}{12}$ rad/sec.

(B) $V_{Image} = R\omega_{Image} = \frac{\pi}{3}$ cm/sec.

(C) $\theta = 120^\circ = \frac{2\pi}{3}$

$\omega_{Image} = \frac{\pi}{12}$ rad/sec. $\Rightarrow$ $t = \frac{\theta}{\omega_{Image}} = 8$sec.

7. Some facts regarding two inclined Plane mirror

When two plane mirrors are kept facing each other at angle θ and an object is placed between them, multiple images of the object are formed as a result of multiple successive reflections.

(i) If $\frac{360^\circ}{\theta}$ = even number;

Number of image = $\frac{360^\circ}{\theta} - 1$

(ii) If $\frac{360^\circ}{\theta}$ = odd number;

Number of image = $\frac{360^\circ}{\theta} - 1$,

if the object is placed on the angle bisector.

(iii) If $\frac{360^\circ}{\theta}$ = odd number;

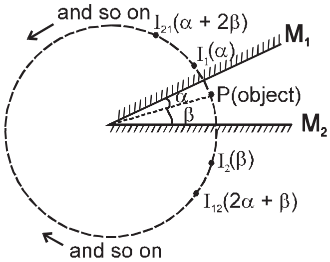
Number of image = $\frac{360^\circ}{\theta}$,

if the object is not placed on the angle bisector.

Locating all the images :

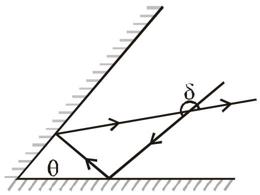
If rays after getting reflected from one mirror strike second mirror, the image formed by first mirror will function as an object for second mirror, and this process will continue for every successive reflection.

Consider two plane mirrors M_1 and M_2 inclined at an angle $\theta = \alpha + \beta$ as shown in figure.



Deviation Produced :

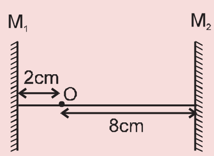
If a ray gets reflected once from each of two mirrors inclined at an angle θ, the deviation produced is independent of angle of incidence and is given as $\delta = 360^\circ - 2\theta$



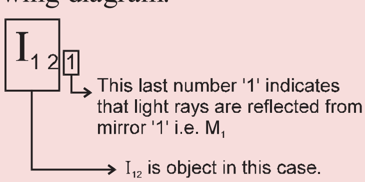
If two plane mirrors are inclined to each other at 90º, the emergent ray is always antiparallel to incident ray if it suffers one reflection from each whatever be the angle of incidence.

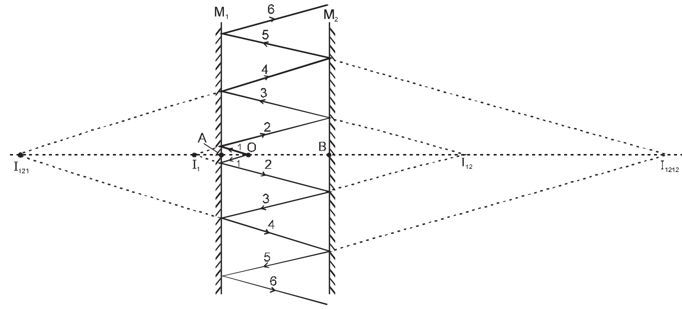
Example 11

Figure shows a point object placed between two parallel mirrors. Its distance from M_1 is 2 cm and that from M_2 is 8 cm. Find the distance of images from the two mirrors considering reflection on mirror M_1 first.



Sol. : To understand how images are formed see the following figure and table. You will require to know what symbols like I_{121} stands for. See the following diagram.





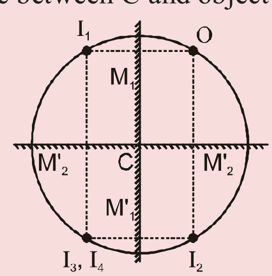
Incident	Reflected	Reflected	Object	Image	Object distance	Image distance
Rays 1	M	Rays 2	O	I_1	$AO = 2cm$	$AI_1 = 2$ cm
Rays 2	M	Rays 3	I_1	I_{12}	$BI_1 = 12$ cm	$BI_{12} = 12$ cm
Rays 3	M	Rays 4	I_{12}	I_{12}	$AI_{12} = 22cm$	$AI_{121} = 22cm$
Rays 4	M	Rays 5	I_{12}	I_{12}	$BI_{121} = 32cm$	$BI_{1212} = 32cm$

Similarly images will be formed by the rays striking mirror M_2 first. Total number of images $= \infty$.

Example 12

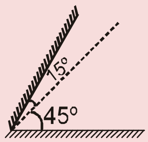
An object is placed between two plane mirrors inclined at 90º angle. How many images will be formed?

Sol. The number of images formed by two mutually perpendicular mirrors ($\theta = 90^\circ$) will be 3. All these three images will lie on a circle with centre at C at the point of intersection of mirror M_1 and M_2 and whose radius is equal to the distance between C and object O.



Example 13

Find out total no. of images formed & their locations



Sol. Location of Images formed by M_1 with respect to M_2 are

75º, 165º, 195º, 285º, 315º

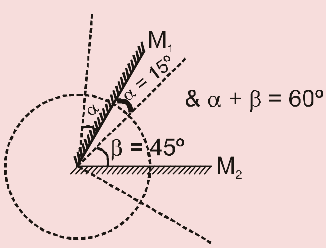
Location of Images formed by M_2 at angles with respect to M_2 are

$360^\circ - 45^\circ = 315^\circ$; $315^\circ - 2(15^\circ) = 285^\circ$

$285^\circ - 2(45)^\circ = 195^\circ$; $195^\circ - 2(15^\circ) = 165^\circ$

$165^\circ - 2(45^\circ) = 75^\circ$.

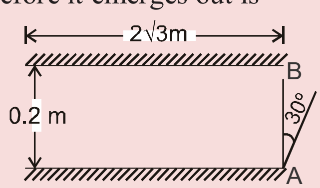
So all images are commonly located (i.e.



overlapping) Final no. of images formed = 5

Example-14

Two plane mirrors A and B are aligned parallel to each other as shown in figure. A light ray is incident at an angle of 30º at a point just inside one end of A. The plane of incidence coincides with the plane of the figure. The maximum numbers of times the ray undergoes reflections (including the first one) before it emerges out is

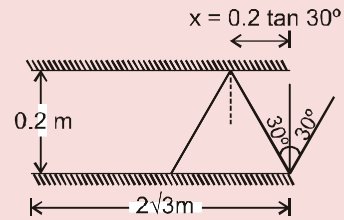


(1) 28 (2) 30

(3) 32 (d) 34

Sol. Let number of reflection be n then

$n\,(0.2 \tan 30^\circ) = 2\sqrt{3} \;\Rightarrow n = 30$



Example-15

Out of the following, which statements are correct.

(i) Two plane mirrors are inclined to each other at an angle of 60º. If a ray of light incident on the first mirror is parallel to the second mirror, it is reflected from the second mirror parallel to the first mirror

(ii) A bird flying high up in the air does not cast a shadow on the ground because layers of atmosphere are dense

(iii) if a ray reflected successively from two plane mirrors inclined at a certain angle undergoes a deviation of 300º, then the number of images observable is 11

(iv) A clock indicates a time of 3 : 25 on seeing it in a plane mirror, the time appears as 8 : 35.

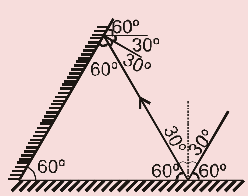
(1) (i) and (iv)

(2) (ii) and (iii)

(3) (i), (ii) and (iv)

(4) (i), (ii) and (iv)

Sol. For (i)

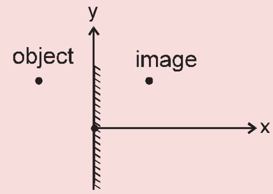


For (ii) : A bird flying high up in the air does not cast a shadow on the ground because size of bird is very small than the size of sun.

For (iii) : If angle between mirrors be θ then $360^o - 2\theta = 300^o$ so

$\theta = 30^o$ so no. of images $= \dfrac{360^o}{30^o} - 1 = 11$

For (iv) : Time appears in plane mirror $= 12{:}00 - 3 : 25 = 8 : 35$



8. Relation between velocity of object, Image & Mirror

Taking Mirror in YZ Plane &
Normal to Polished Surface as x-axis.
From mirror property :

$x_{IM} = -\, x_{OM}$, $y_{IM} = y_{OM}$ and $z_{IM} = z_{OM}$

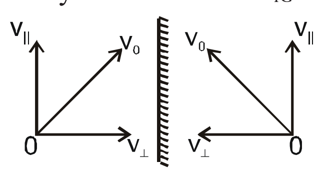
Here x_{IM} means 'x' coordinate of image with respect to mirror. Similarly, others have meaning.

Differentiating w.r.t time , we get

$v_{(IM)x} = -\, v_{(OM)x}$; $v_{(IM)y} = v_{(OM)y}$; $v_{(IM)z} = v_{(OM)z}$

$\Rightarrow$ for x axis $v_{IG} = -\,(v_{OM} + v_{MG})$

but for y axis and z axis $v_{iG} = v_{oG}$



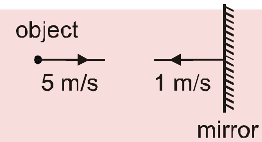
Here : v_{IG} = velocity of image w.r.t ground.

Also, we can say that

$$\left.\begin{aligned}\left(\overline{v}_{\perp}\right)_{I_x} &= -\left(\overline{v}_{\perp}\right)_{O_x}\\ \left(\overline{v}_{\parallel}\right)_{I_x} &= \left(\overline{v}_{\parallel}\right)_{O_x}\end{aligned}\right\}$$

Example-16

An object moves with 5 m/s towards right while the mirror moves with 1m/s towards the left as shown. Find the velocity of image.



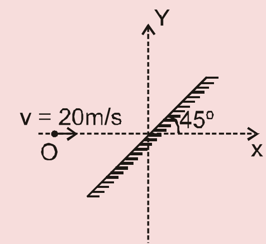
Sol. Take $\rightarrow$ as + direction. $v_i - v_m = v_m - v_0$

$v_i - (-1) = (-1) - 5$ $\quad\therefore\quad$ $v_i = -\,7\text{m/s}$

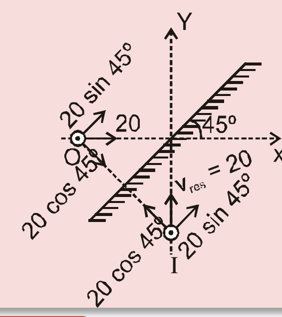
$\Rightarrow$ 7 m/s and direction towards left.

Example 17

What is the velocity of image if the object moves along x-axis with a velocity of 20 m/s as shown in the arrangement.

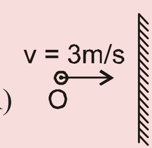


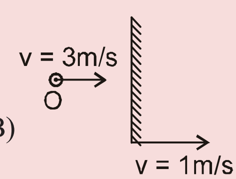
Sol. As understood from the diagram, velocity of Image will be 20 m/s $\hat{j}$

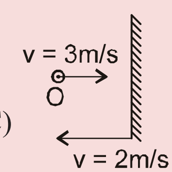


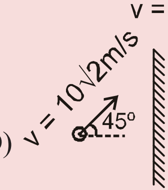
Example-18

Find the velocity of image in the given arrangement

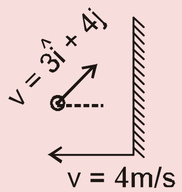
(A) 

(B) 

(C) 

(D) 

(E)



Sol. (A) $\vec{v}_{IM} = -\vec{v}_{OM} = \vec{v}_{IG}$ (As Mirror is at rest)

$\vec{v}_{IG} = -3\hat{i}$

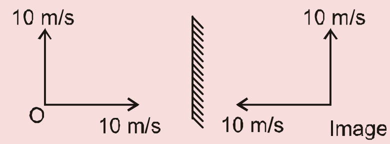
(B) $\vec{v}_{OG} = 3\hat{i}, \vec{v}_{MG} = 1\hat{i} \Rightarrow \vec{v}_{OM} = 2\hat{i}$

So $\vec{v}_{IM} = -2\hat{i}$ Now $\vec{v}_{IG} = \vec{v}_{IM} + \vec{v}_{MG} = -\hat{i}$

(C) $\vec{v}_{OM} = 5\hat{i},\ \vec{v}_{IM} = -5\hat{i}$

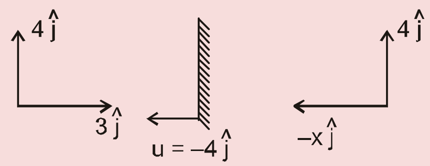
So, $\vec{v}_{IG} = -5\hat{i} + 2\hat{i} = -7\hat{i}$

(D)



$\vec{v}_{IG} = -10\hat{i} + 10\hat{j}$

(E)



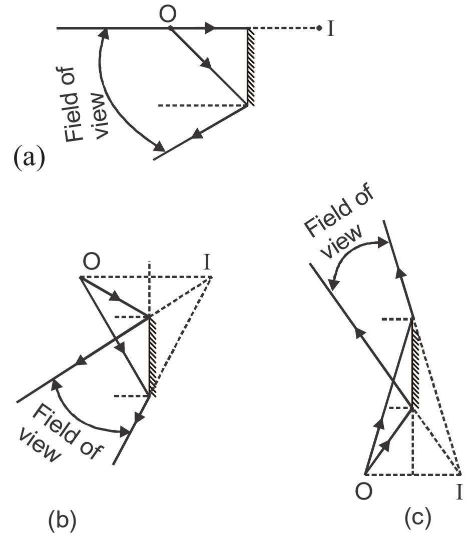
Along x-direction

$(\vec{v}_{IM})_x = -7\hat{i}\ ;\ (\vec{v}_{IG})_x = -11\hat{i}$

So, $\vec{v}_{IG} = -11\hat{i} + 4\hat{j}$

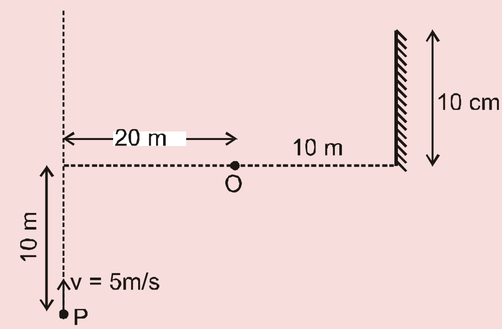
9. Field of View :

- A mirror whatever may be the size of it forms the images of all objects lying in front of it.
- But every object has its own field of view for the given mirror.
- The field of view is the region between the extreme reflected rays and
- It depends on the location of the object in front of the mirror.
- If our eye lies in the field of view then only we can see the image of the object.
- The field of view of an object placed at different locations in front of a plane mirror are shown in figure below.



Example 19

For how much time, the observer 'O' will be able to see the image of person



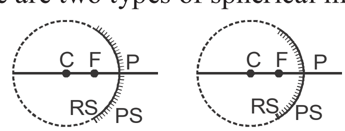
Sol. Path of image seen by the observer

$$\frac{10}{x} = \frac{10}{40} \Rightarrow x = 40 \text{ m so time} = \frac{40}{5} = 8\text{s}$$

REFLECTION AT SPHERICAL SURFACE

10. Thin Spherical Mirrors

- It is a segment of a spherical shell whose one surface is polished.
- There are two types of spherical mirror.



PS : Polished surface & RS : Reflecting surface

(1) Concave Mirror :

- In this mirror reflection takes place from the inner surface and outer surface is polished or silvered.
- It converges the light rays.
- It is used as a shaving mirror, in search light, in cinema projector, in telescope by ENT specialists etc.

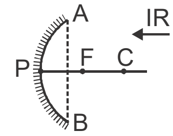
(2) Convex Mirror :

- In this mirror reflection takes place from the outer surface and the inner surface is polished or silvered.
- It diverges the light rays.
- It is used in road lamps, side mirror in vehicles etc.

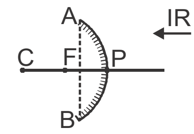
11. Terms & Definitions :

- **Center of Curvature (C) :** It is the centre of the spherical surface of which the mirror is a part.
- **Radius of Curvature (R) :** It is the radius of spherical surface of which of the mirror is a part (distance CP) .
- **Pole (P) :** It is the center of the mirror surface.
- **Principal Axis (CP) :** It is the line joining the Pole to the Center of Curvature of the mirror.
- **Aperture (A) :** It is the diameter of the mirror (AB).

  For spherical mirror aperture is circular area .
- **Principal Focus (F) :** It is the point on the principal axis, through which a ray of light parallel to the principal axis, after reflection, passes (concave mirror) or appears to pass (convex mirror).
- **Focal Length (f) :** It is the distance between the pole P and the principal focus F.
- **Focal plane :** A plane passing through focus and perpendicular to principal axis is called focal plane



Concave Mirror



Convex Mirror

12. Types of Rays:

(1) Paraxial Rays :

- Rays very close to optical axis.
- They are nearly parallel to principal axis.
- They make very small angles of incidence.

  $\sin\theta \approx \theta$, $\cos\theta \approx 1$ & $\tan\theta = \theta$
- For this, consider only mirror of small aperture.
- All formulae are applicable only for paraxial rays.

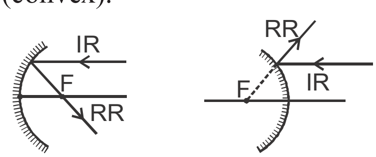
(2) Marginal Rays :

- The rays far away from optical axis are marginal rays.
- All lens & mirror formulae are not applicable for it.

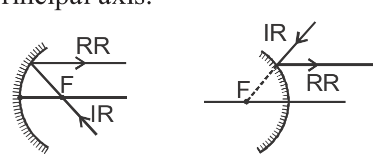
13. Ray Tracing :

Four types of rays are used for Image formation..

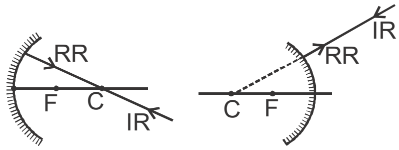
- **Ray-1** : A ray parallel to principal axis after reflection either actually passes through the principal focus F (concave) or appears to diverge from it (convex).



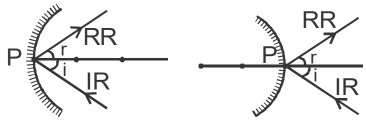
- **Ray-2** : A ray passing through the principal focus F or appears to converge at F is reflected parallel to the principal axis.



- **Ray-3** : A ray through the centre of curvature strikes the mirror normally and is reflected back along the same path.



- **Ray-4** : A ray striking at pole P is reflected symmetrically back in the opposite side of principal axis.



Symbols :

u = object distance, v = image distance

f = focal length , R = radius of curvature

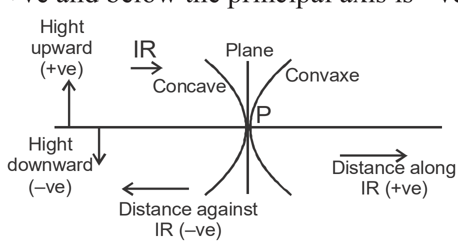
v_O = velocity of object, v_I = velocity of image

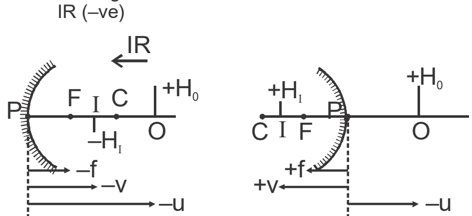
P = power, m = magnification

I = image length, O = object length

Sign- Convention :

- All measurements taken from the pole.
- Measurement along the direction of ray is taken as +ve and opposite the ray is taken as –ve.
- Measurement above the principal axis is taken as +ve and below the principal axis is –ve.





14. Important Relations :

- For a spherical mirror of small aperture, the focal length is half of the radius of curvature

$\Rightarrow \quad f = R/2$

- **Mirror formula :** For all spherical mirrors,

$$\frac{1}{u}+\frac{1}{\upsilon}=\frac{2}{R}=\frac{1}{f}$$

$$\Rightarrow \quad f=\frac{uv}{u+v}\ ;\ v=\frac{uf}{u-f}\ ;\ u=\frac{vf}{v-f}$$

- **Power** (P) : It is the ability to deviate the path of the rays striking it.

$$P=-\frac{1}{f}=-\frac{100}{f(m)}\text{Diopter(D)}$$

- **Magnification :** It is defined as the ratio of height of image to the height of object.

It is of three types

(1) Linear (Lateral, Transverse) Magnification (m)

When an object is placed perpendicular to the principal axis and is given as

$$m=\frac{I_h}{O_h}=-\frac{v}{u}=\frac{f}{f-u}=\frac{f-v}{f}$$

(a) If $|m|>1$, the image is enlarged,

(b) If $|m|=1$, the image is of same size,

(c) If $|m|<1$, the image is reduced,

(d) If $m>0$, the image is erect,

(e) If $m<0$, the image is inverted.

(2) Longitudinal (Axial) Magnification (m_L)

When an object is placed along the principal axis and is given as

$$m_L=\frac{I_L}{O_L}=-\frac{(v_2-v_1)}{(u_2-u_1)}=-\frac{\Delta v}{\Delta u}$$

If length of the object is small,

$$m_L=-\frac{dv}{du}=-\left(\frac{v}{u}\right)^2=-m^2=\left(\frac{f}{f-u}\right)^2=\left(\frac{f-v}{f}\right)^2$$

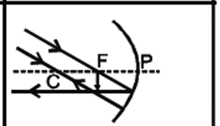
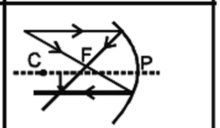
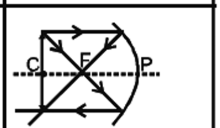
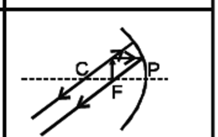
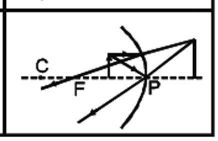
(3) Areal Magnification (m_A)

When a two dimensional object is placed with its plane perpendicular to the principal axis and is given as

$$m_A = \frac{I_A}{O_A} = \left(\frac{v}{u}\right)^2 = m^2$$

$$= \left(\frac{f}{f-u}\right)^2 = \left(\frac{f-v}{f}\right)^2$$

Image formation by spherical Mirrors :

Object Position	Image position & nature	Diagram
1. When object is placed at infinity (i.e. u = ∞)	At F on same side real inverted very small in size |m| << |–1|	
2. When object is placed between infinity and C (i.e. u > 2f)	Between F and C on same side real and inverted small in size |m| < |–1|	
3. When object is placed at centre of curvature (i.e. u = 2f)	At C on same side Real inverted Equal in size m = –1	
4. When object is placed between C and focus (i.e. f < u < 2f)	Between 2f and ∞ on same side real & inverted larger in size |m| > |–1|	
5. When object is placed at focus (i.e. u = f)	At ∞ on same side real inverted Very large in size |m| >> |–1|	
6. When object is placed at focus and pole (i.e. u < f)	Behind the mirror virtual erect large in size |m| > |+1|	

Concave mirror :

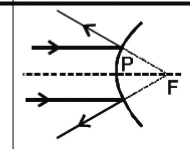
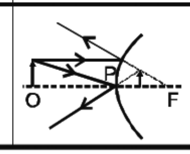
Image formed by concave mirror

- May be real or virtual
- May be inverted or erect,
- May be smaller, larger or equal in size of object Depending upon the distance of the object from the mirror

Convex mirror :

Image formed convex mirror of a real object is

- Always virtual erect and
- Smaller in size Depending upon the location of the object and mirror.
- Never forms enlarged image of a real object

Object Position	Image position & nature	Diagram
1. When object is placed at infinity (i.e. u = ∞)	At F behind the mirror virtual Erect Very small in size |m| << |+1|	
2. When object is placed anywhere on the principal axis	Between P and F behind the mirror virtual erect small in size |m| < |+1|	

Convex mirror never forms enlarged image of a real object

Example-20

Where should an object be placed in front of a concave mirror of focal length 15 cm to have a magnification of 3 in case of : (a) Real image (b) Virtual image

Sol. The mirror equation is given by $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

(a) In case of real image

$$m = \frac{-v}{u} = -3 \quad \text{So, } v = 3u \quad \Rightarrow \frac{-v}{u} = -3$$

$$\Rightarrow \frac{4}{3u} = \frac{1}{-15} \quad \Rightarrow \quad u = -20\text{cm}$$

(b) In case of virtual image

$$m = \frac{-v}{u} = +3;\ v = -3u$$

$$-\frac{1}{3u}+\frac{1}{u}=\frac{1}{-15} \Rightarrow \frac{2}{3u}=\frac{1}{-15} \quad \Rightarrow \quad u = -10\text{cm}$$

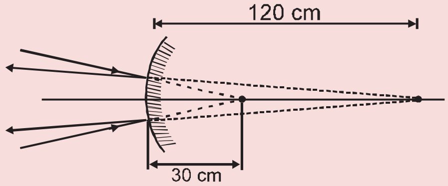
Example 21

Converging rays are incident on a convex spherical mirror so that their extensions intersect 30 cm behind the mirror on the optical axis. The reflected rays form a diverging beam so that their extensions intersect the optical axis 1.2 m from the mirror. Determine the focal length of the mirror.

Sol. In this case, $u = +30$

$\Rightarrow \quad v = +120$

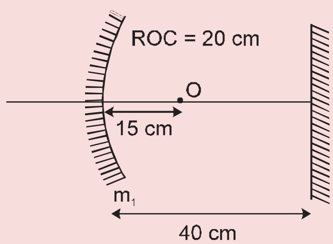
$\therefore \quad \frac{1}{f} = \frac{1}{v} + \frac{1}{u} = \frac{1}{120} + \frac{1}{30}$



$f = 24$ cm

Example 22

Find the position of final image after three successive reflections taking first reflection on m_1.



Sol. **I reflection :**

Focus of mirror $= -10$ cm $\Rightarrow u = -15$ cm

Applying mirror formula : $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$\Rightarrow v = -30$ cm.

For II reflection on plane mirror : $u = -10$ cm

$\therefore \quad v = 10$ cm

For III reflection on curved mirror again :

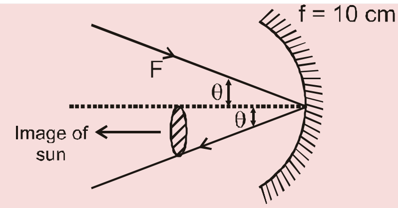
$u = -50$ cm ; $f = -10$ cm

Applying mirror formula : $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$;

$v = -12.5$ cm.

Example 23

Focal length of a concave mirror is f_0. If the sun subtends on angle θ at pole of mirror, find the diameter of the image



Sol. Let x be the diameter of the image & the rays are coming from a very large distance they can be considered as paraxial rays

So $\tan\theta \approx \theta = \frac{x}{f} \Rightarrow x = f\theta$

Example 24

Where an object has to be placed in front of a convex mirror (focal length f_0) such that the image of the object is n times the size of object

Sol. Magnification 'm' $= \frac{f}{f-u} = n \Rightarrow f = nf - nu$

$\Rightarrow u = -\frac{(f - nf)}{n}$

Note here –ve sign denotes real object.

Example 25

An object of length 10 cm is placed at right angles to the principal axis of a mirror of radius of curvature 60 cm such that its image is virtual erect and has a length 6 cm. What kind of mirror it is and also determine the position of the object?

Sol. Since the image is virtual erect and of a smaller size, the given mirror is convex (concave mirror does not form an image with the said description).

Given, $R = +60$ cm $\therefore$ $f = \frac{R}{2} = 30$ cm

Transverse magnification,

$m = \frac{I}{O} = \frac{6}{10} = \frac{3}{5}$

Further, $m = -\frac{v}{u} = \frac{3}{5} = \quad \therefore v = -\frac{3u}{5}$

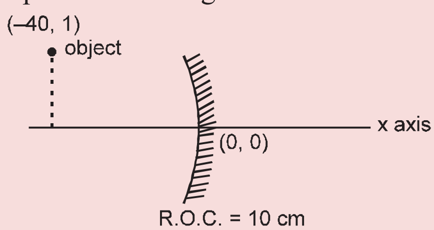
Using, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f} \Rightarrow \frac{-5}{3u}+\frac{1}{u}=\frac{1}{30}$

$\Rightarrow \frac{-5+3}{3u}=\frac{1}{30} \quad \because \quad u=-20cm$

Thus the object is at a distance 20 cm (from the pole) in front of the mirror.

Example 26

Figure shows a spherical concave mirror with its pole at (0, 0) and principle axis along x-axis. There is a point object at (–40 cm, 1cm), find the position of image.



Sol. According to sign convention,

$u=-40$ cm; $h_1=+1$ cm; $f=-5$ cm.

$\frac{1}{v}+\frac{1}{u}=\frac{1}{f} \Rightarrow \frac{1}{v}+\frac{1}{-40}=\frac{1}{-5}$;

$v=\frac{-40}{7}$ cm. ; $\frac{h_2}{h_1}=\frac{-v}{u}$

$\Rightarrow h_2=-\frac{-v}{u}\times h_1=\frac{-\left(-\frac{40}{7}\right)\times 1}{-40}=-\frac{1}{7}$ cm.

$\therefore$ The position of image is

$\left(\frac{-40}{7}cm, -\frac{1}{7}cm\right)$

Example 27

A point object is placed 60 cm from pole of a concave mirror of focal length 10 cm on the principal axis. Find

(a) The position of image

(b) If object is shifted 1 mm towards the mirror along principle axis find the shift in image. Explain the result.

Sol. (a) $u=-60$ cm ; $f=-10$cm

$v=\frac{fu}{u-f}=\frac{-10(-60)}{-60-(-10)}=\frac{600}{-50}=-12$ cm.

(b) $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

Differentiating, we get $dv=-\frac{v^2}{u^2}du$

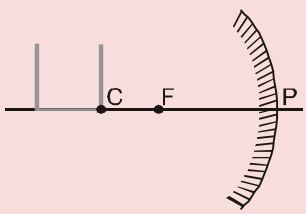
$=-\left(\frac{-12}{-60}\right)^2[1 \text{ mm}]=-\frac{1}{25}$ mm

[$\because$ du = 1mm; sign of du is +ve because it is shifted in +ve direction defined by sign convention.]

• –ve sign of dv indicates that the image will shift towards negative direction.

Example 28

A U-shaped wire of each side 10cm is placed before a concave mirror having radius of curvature 20 cm as shown below. Find the total length of the image of the wire formed.



Sol. One side of the U-shaped wire is at centre of curvature. Therefore, its image coincides with it and is of the same size i.e. 10 cm.

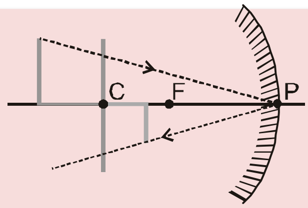
The opposite side of the wire is at a distance 20 + 10 = 30 cm from the mirror.

Using mirror equation with $f=-\frac{20}{2}=-10$ cm

and $u=-30$ cm, we get

$\frac{1}{v}+\frac{1}{-30}=\frac{1}{-10}$ or $\frac{1}{v}=\frac{1}{30}-\frac{1}{10}=-\frac{1}{15}$

$\Rightarrow \quad v=-15$ cm



i.e. the image is formed 15 cm in front of the mirror and is therefore real and inverted. Also magnification is

$$m = -\frac{v}{u} = -\frac{-15}{-30} = -\frac{1}{2}$$

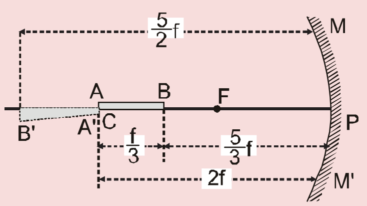
i.e. the size of the image is $\frac{1}{2} \times 10 = 5$ cm.

The shape of the full image of the U-shaped wire is shown in the figure and its total length is $10 + 5 + 5 = 20$ cm.

Example 29

A thin rod of length f / 3 is placed along the principal axis of a concave mirror of focal length f such that its image which is real and elongated, just touches the rod. What is magnification?

Sol. $\because$ image is real and enlarged, the object must be between C and F. One end A' of the image coincides with the end A of rod itself,



So $v_A = u_A$, $\frac{1}{v_A} + \frac{1}{v_A} = \frac{1}{-f}$

i.e., $v_A = u_A = -2f$

So it clear that the end A is at C.

$\because$ the length of rod is $\frac{f}{3}$

$\therefore$ Distance of the other end B from P is u_B

$$= 2f - \frac{f}{3} = \frac{5}{3}f$$

If the distance of image of end B from P is v_B

then $\frac{1}{v_B} + \frac{1}{-\frac{5}{3}f} = \frac{1}{-f}$ i.e., $v_B = -\frac{5}{2}f$

$\therefore$ The size of the image

$$|v_B| - |v_A| = \frac{5}{2}f - 2f = \frac{1}{2}f$$ and

magnification

$$m = \frac{v_B - v_A}{u_B - u_A} = \frac{\frac{1}{2}f}{-\frac{1}{3}f} = -\frac{3}{2}$$

Negative sign implies that image is inverted with respect to object and so it is real.

Example 30

An object of area 25 cm^2 is kept perpendicular to the principal axis of a convex mirror ($f = 20$ cm)at a distance of 30 cm from the pole. Find the area of image.

Sol. For convex mirror $m = \frac{f}{f-u}$; Here $f = +20$ cm, $u = -30$ cm, so $m = \frac{2}{5}$

Area of image = m^2 (Area of object) = 4 cm^2

15. Graph between (1/v) vs (1/u):

Concave Mirror :

Case 1 : When the image is real, i.e., object lies between f and infinity.

The mirror formula

Becomes $\frac{1}{v} = -\frac{1}{u} + \frac{1}{f}$

Comparing with $y = -x + c$,

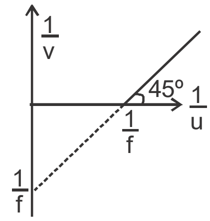
The desired graph will be a straight line

With slope –1 and intercept equal to $\frac{1}{f}$.

The corresponding graph is shown in Figure.

Case 2. When the image is virtual, i.e., object lies between F and P.

The mirror formula thus



becomes $\frac{1}{v} = \frac{1}{u} - \frac{1}{f}$

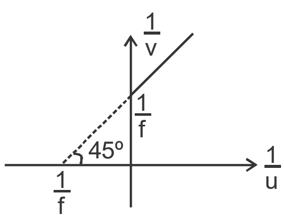
Comparing it with y $y = x - c$

The desired graph is a straight line

With slope + 1 and intercept $-\frac{1}{f}$.

The graph is thus shown in Figure.

Convex Mirror :



Case 3. The image is always virtual.

The mirror formula

Becomes, $\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$

Comparing with $y = x + c$,

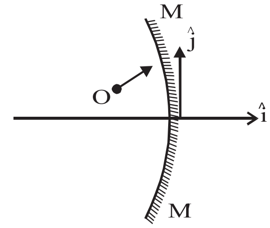
The desired graph is a straight line

of slope + 1 and intercept $\frac{1}{f}$.

The graph is thus shown in Figure.

16. Velocity of Image :

Principal axis has been taken to be along x–axis and Aperture plane along y-axis.



(A) (Longitudinal velocity) : Velocity along axis

When an object is coming from infinite towards the focus of concave mirror

$\because \quad \frac{1}{v} + \frac{1}{u} = \frac{1}{f} \quad \Rightarrow \quad -\frac{1}{v^2}\frac{dv}{dt} - \frac{1}{u^2}\frac{du}{dt} = 0$

$\Rightarrow \quad \vec{v}_{Ix} = -\left(\frac{v^2}{u^2}\right)\vec{v}_{Ox} = -m^2\,\vec{v}_{Ox}$

Here, $v_{Ix} = \frac{dv}{dt}$ = velocity of image along principal axis

$v_{Ox} = \frac{du}{dt}$ = velocity of object along principal-axis

- **Consider an example for a concave mirror :**

Suppose the object is moved from infinity towards pole.

(i) When the object lies between ∞ and C ,

i.e.,$v < u$ $\quad \therefore \quad |v_1| < |v_O|$

(ii) When the object is at C, image is also at C,

i.e., $v = u$ $\quad \therefore \quad v_I = v_O$.

(iii) When the object lies between C and F.

i.e., $v > u$, $\quad \therefore \quad |v_I| > |v_O|$

(iv) When the object lies between F and P.

i.e., $v > u$, $\quad \therefore \quad |v_I| > |v_O|$

(v) When the object is at P, image is also at P,

i.e., $v = u$ $\quad \therefore \quad |v_I| = |v_O|$

(B) (Transverse velocity) :

Velocity perpendicular to axis

$\because \quad m = \frac{h_I}{h_0} = -\frac{v}{u} = \frac{f}{f-u} \quad \Rightarrow \quad h_I = \left(\frac{f}{f-u}\right)h_0$

Taking differentiation w.r.t

$$\frac{dh_I}{dt}=\left(\frac{f}{f-u}\right)\frac{dh_0}{dt}+\frac{f\,h_0}{(f-u)^2}\frac{du}{dt}$$

$$\Rightarrow \qquad \vec{v}_{Iy}=\left[(m)\vec{v}_{Oy}+\left(m^2\frac{h_O}{f}\right)\vec{v}_{Ox}\right]\hat{j}$$

$$\left[\begin{array}{l}\dfrac{dh_I}{dt}=\text{velocity of image}\perp^r\text{ to principal-axis}\\ \dfrac{dh_O}{dt}=\text{velocity of object }\perp^r\text{ to principal-axis}\end{array}\right]$$

Example 31

Suppose while sitting in a parked car, you notice a man approaching the car from behind in the side view mirror of R = 1 m. If the man is running at a speed of 4 m/s, how fast the image of the man appear to move when the man is 10 m away.

Sol. For convex mirror, R = +1m and f = +0.5 m. from the mirror formula, we get

$$\frac{1}{v}+\frac{1}{-10}=\frac{1}{0.5}$$

Then $\frac{1}{v}=+\frac{1}{10}+\frac{1}{0.5}=\frac{21}{10}$

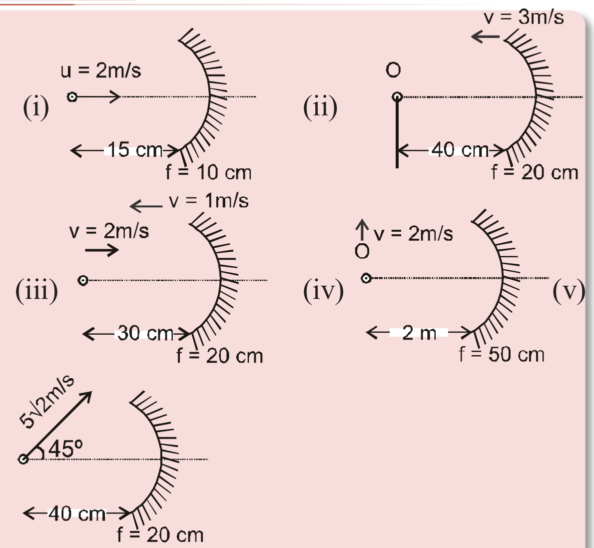
or $\qquad v=\frac{10}{21}$ » 0.5 m

As velocity of man is

$\frac{du}{dt}=-4$ m/s $\therefore$ Velocity of image $=\frac{v^2}{u^2}\times(-4)$

Example 32

Calculate the velocity of image (a) relative to mirror (b) Relative to ground (c) Relative to object in the following cases



Sol. (i) Here, f = –10 cm, u = –15cm & $\vec{v}_{OM}=2$ m/s

$$m=\frac{f}{f-u}=\frac{-10}{-10+15}=-2$$

Also $\vec{v}_{IM}=-m^2\vec{v}_{OM}$ (Along x – direction)

$\vec{v}_{IM}=-8$m/s

Since Mirror is at rest $\vec{v}_{IG}=\vec{v}_{IM}=-8$m/s

Also $\vec{v}_{IO}=\vec{v}_{IM}-\vec{v}_{OM}=-10$ m/s

(ii) Here $v_{OM}=3$ m/s, u = –40cm, f = –20cm

$m=\frac{f}{f-u}=-1 \qquad \vec{v}_{IM}=-m^2\,\vec{v}_{OM}=-3$ m/s

$\vec{v}_{IG}=\vec{v}_{IO}=-6$m/s

(iii) Here $\vec{v}_{OG}$ = 2m/s, $\vec{v}_{MG}$ = –1m/s, u = –30cm,

f = –20 cm, $m=\frac{f}{f-u}=-2$

Now $\vec{v}_{IM}=-m^2\vec{v}_{OM}$

So $\qquad \vec{v}_{IM}=-4\,(2-(-1)]=-12$ m/s

$\vec{v}_{IG}=\vec{v}_{IM}+\vec{v}_{MG}=-13$m/s

$\vec{v}_{IO}=\vec{v}_{IM}-\vec{v}_{OM}=-12-13=-15$m/s

(iv) Here the object is moving transversely (i.e. in $\perp^r$-direction)

So, $u = -200$ cm, $f = -50$ cm, $(\vec{v}_{OM})_x = 0$,

$(\vec{v}_{OM})_y = +2 m/s$

$$m = \frac{f}{f-u} = -\frac{1}{3}$$

Along x-axis

$(\vec{v}_{IM})_x = -m^2 (\vec{v}_{OM})_x = 0$

Along Y-axis

$$(\vec{v}_{IM})_Y = \left[m(\vec{v}_{OM})_y + \frac{m^2 h_0}{f} (\vec{v}_{OM})_x \right]$$

$$(\vec{v}_{IM})_y = -\frac{1}{3}(2) + 0 = -\frac{2}{3} m/s$$

(v) Here $(\vec{V}_{OM})_x = 5$ m/s $(\vec{V}_{OM})_y = 5 m/s$

$u = -40 cm, f = -20 cm ; h_0 = 0 \quad m = \frac{f}{f-u} = -1$

Along x-axis $(\vec{v}_{IM})_x = -m^2 (\vec{v}_{OM})_x = -5 m/s$

Along y-axis :

$$(\vec{v}_{IM})_y = \left[m(\vec{v}_{OM})_y + \frac{m^2 h_0}{f} (\vec{v}_{OM})_x \right]$$

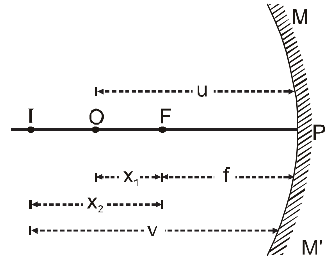
$= -5 + 0 = -5 m/s$

$\vec{v}_{IM} = (-5\hat{i} - 5\hat{j})$

17. Newton's Formula :

- Consider an object placed in front of a concave mirror of focal length f at a distance x_1 from the focus. If a real image is formed at a distance x_2 from the focus, then $x_1 \cdot x_2 = f^2$

  This is known as Newton's formula.
- It implies that the position of an object and its real image are interchangeable.
- This formula does not apply to convex mirror.



Example 33

An object is placed 20 cm before the focus of a concave mirror (f = 10 cm). Where the image will be formed & what will be the magnification of the image.

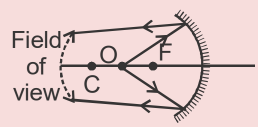
Sol. By Newton's formula,

$x_1 x_2 = f^2$; $20 x_2 = 10^2 \quad \Rightarrow x_2 = 5$ cm

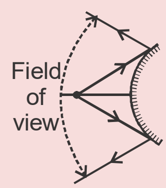
So location of image = 10 + 5 = 15 cm Away from pole

$$m = \frac{-v}{u} = -\frac{(-15)}{-30} = \frac{-1}{2}$$

Field of View :



Concave



Convex

SECTION - B :- Refraction at Plane Surface, Snell's Law, Apparent Depth and T.I.R.

REFRACTION AT PLANE SURFACE

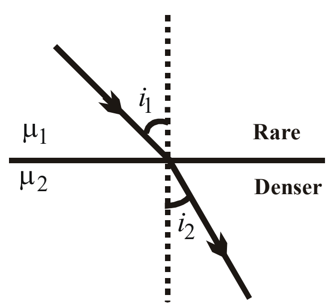
18. Refraction of Light:

- When a ray of light is incident on the boundary between two transparent media (interface), a part of it passes into the second medium with a change in direction. This phenomenon is called **refraction.**
- When light passes from one medium to another, a part of ray is reflected back into the first medium and the rest passes into the second medium.

- When it passes into the second medium, its direction of travel is changed.
- It either bends towards the normal or away from the normal.
- The cause of refraction is the difference in the speeds of light for two media.
- Greater the difference in the speeds of light in the two media, greater will be the amount of bending.
- A medium in which speed of light is more is called an **optically rarer** medium.
- The medium in which speed of light is less is called the **optically denser** medium.
- In free space, speed of light is $c = 3\times10^8\ ms^{-1}$
- In any material medium, speed of light $v < c$

19. Laws of Refraction :

There are two laws of refraction :



1. For two particular media, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant, i.e.

$$\frac{\sin i_1}{\sin i_2} = \text{constant}$$

This is known as **Snell's law.**

2. The incident ray, the reflected ray, the normal and the refracted ray all lie in the same plane.

Refractive index

- It is the optical property of a medium.
- It is the medium characteristic which decides speed of light in it.
- It is of two types -

(1) Absolute Refractive Index (μ) or (n)

It is defined as the ratio of speed of light in vacuum to the speed of light in that medium.

$$\mu = \frac{c}{v} \Rightarrow c = \mu v = \text{constant} \Rightarrow \mu \propto 1/v$$

$\mu = 1$, (min value), for vacuum :

$\mu \approx 1$ ($\equiv 1.003$), for air :

$\mu = 1.33$ (=4/3), for water :

$\mu = 1.50$ (=3/2), for glass :

$\mu = 2.40$, for diamond.

(2) Relative Refractive Index (μ_{21})

- It is defined as the ratio of two refractive index.
- When light travels from medium one to medium two then refractive index of medium two w.r.t. medium one is written as

$$\mu_{21} = {}_1\mu_2 = \frac{\mu_2}{\mu_1}$$

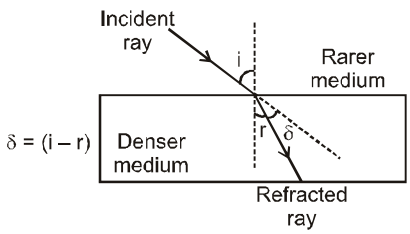
- In Snell's Law, the constant ratio $\frac{\sin i_1}{\sin i_2}$ is called the **relative refractive index** of med-2 with respect to med-1. Thus ${}_1\mu_2 = \mu_{21} = \frac{\mu_2}{\mu_1} = \frac{\sin i_1}{\sin i_2}$
- Now, we can write Snell's law as,
  $\mu \,.\, \sin i$ = constant
  For two media $\mu_1 \,.\, \sin i_1 = \mu_2 \,.\, \sin i_2$
- The general form of Snell's law can be written as.

$$\mu_{21} = {}_1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{\sin i_1}{\sin i_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

Here, v_1 is the speed of light in medium 1 and v_2 is the speed in medium 2. Similarly, λ_1 and λ_2 are the corresponding wavelengths.

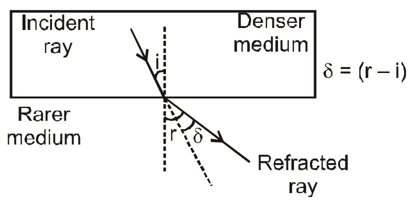
- Deviation of ray : $\delta = |i - r|$

- When light travels from one medium to another, then speed of light (v), wavelength (λ), amplitude and Intensity changes.
  But frequency (v) and colour of light do not change.
- A light ray passes from an optically rarer to an optically denser medium, it bends towards the normal.
- Here, $\mu_2 > \mu_1$ So, $i_1 > i_2$ ($i > r$) & $v_1 > v_2$ & $\lambda_1 > \lambda_2$.



- A light ray bends away from the normal while passing from a denser medium to a rarer medium.
- Here, So, $i_1 < i_2$ ($i < r$) & $v_1 < v_2$ & $\lambda_1 < \lambda_2$.

$\mu_2 < \mu_1$



Cauchy's equation :

- The absolute refractive index depends upon wavelength of light according to the relation

$$\mu = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + ...$$

Where, A, B, C are constants, depends on medium.

- As λ increases , μ decreases.
- For white light - VIBGYOR (seven colour)

$$\lambda_V < \lambda_I < \lambda_B < \lambda_G < \lambda_Y < \lambda_O < \lambda_R$$

- Thus, $\mu_V > \mu_I > \mu_B > \mu_G > \mu_Y > \mu_O > \mu_R$
- $\lambda_{Red} > \lambda_{violet}$, & $\mu_{Red} < \mu_{violet}$

Number of Waves (N) in a Medium :

$$N_{Vacuum} = \frac{d}{\lambda}$$

In medium, $N_m = \dfrac{d}{\lambda_m} = \dfrac{\mu_m d}{\lambda} = \mu_m \cdot N_{vacuum}$

Dependence of RI :

Refractive index of a material depends upon four factors as follows:

- (i) Material
- (ii) Wavelength of light by obeying **Cauchy's formula.**
- (iii) Temperature : When temperature of medium is increased, then refractive index decreases
- (iv) Density : When density of medium is decreased, then refractive index also decreases
- (v) Surrounding media :
  If light travels from y to x,
  R.I. = ${}^y\mu_x = \mu_{xy} = {}_y\mu_x$

  $${}^x\mu_y = \frac{1}{{}^y\mu_x} \Rightarrow {}^x\mu_y \times {}^y\mu_x = 1$$

Principle of reversibility :

- When a light ray, after suffering 'N' number of reflections and refractions, will has its final path reversed, i.e., it travels back along its entire initial path.

Optical Path :

- It is the path travelled by light in vacuum in the same time when it travel in the medium.
- The actual path covered by light in a medium is called **geometrical path**.
- Relation :

$$\text{Optical Path} = \text{Refr..Index} \times \text{Geometrical Path}$$

$$x_{optical} = \mu \cdot l_{geometrical}$$

Example 34

Refractive index of glass with respect to water is 1.125. Find the absolute refractive index of water, if the absolute refractive index of glass is 1.5.

Sol. The refractive index of glass with respect to water is ${}_w\mu_g = \dfrac{\mu_g}{\mu_w}$ or $\mu_w = \dfrac{\mu_g}{{}_w\mu_g} = \dfrac{1.5}{1.125} = 1.33$

Example 35

The velocity of light in air is 3×10^8 m/s. Find the velocity of light in glass of refractive index 1.5. If the wavelength of yellow light in air is 6000Å, find its wavelength in the glass.

Sol. Let c_1 and c_2 be the velocities of light in air and glass respectively.

Using the definition of refractive index.

$$\mu = \frac{c_1}{c_2} \text{ or } c_2 = \frac{c_1}{\mu}$$

$$c_2 = \frac{3\times10^8}{1.5} = 2 \times 10^8 \text{ m/s}$$

Since frequency remains same when light passes from one medium to another.

Therefore $c_1 = \lambda_1 f$; $c_2 = \lambda_2 f$

$$\text{Now } \mu = \frac{c_1}{c_2} = \frac{\lambda_1}{\lambda_2}$$

$$\text{Or } \lambda_2 = \frac{\lambda_1}{\mu} = \frac{6000}{1.5} = 4000 \text{ Å}$$

Example 36

Light of wavelength 4000 Å in medium 1 is incident on a plane boundary between media 1 and 2. As it enters from medium 1 into 2, its speed increases by 25% and its frequency in medium 2 is found to be 5×10^{14} Hz. Find absolute refractive indices of media 1 and 2.

(1) $\mu_1 = 1.2$ and $\mu_2 = 1.5$

(2) $\mu_1 = 1.5$ and $\mu_2 = 1.2$

(3) $\mu_1 = 1.2$ and $\mu_2 = 1.6$

(4) $\mu_1 = 1.6$ and $\mu_2 = 1.2$

Sol. Frequency, being a characteristic of light does not change with change of medium. However wavelength and speed both change as the medium changes. here frequency of light in medium 2 is 5×10^{14} Hz.

Hence, frequency of given light in medium 1 is also 5×10^{14} Hz. Further wavelength in medium 1 being 4000 Å (given), speed of light in medium 1,

$v_1 = (5 \times 10^{14})\,(4000 \times 10^{-10})$ m/sec.

$v_1 = 2 \times 10^8$ m/sec.

Speed of light in medium 2 is 25% more than in medium 1, hence of speed of light in medium 2,

$$v_2 = v_1 + \frac{25}{100} v_1 = \frac{5v_1}{4}$$

$$\therefore \quad v_2 = \frac{5}{4} \times 2 \times 10^8 = 2.5 \times 10^8 \text{ m/sec}$$

Absolute refractive index of medium 1,

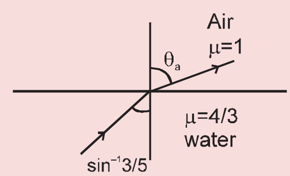
$$\mu_1 = \frac{c}{v_1} = \frac{3\times10^8}{2\times10^8} \quad \therefore \quad \mu_1 = 1.5$$

and absolute refractive index of medium 2,

$$\mu_2 = \frac{c}{v_2} = \frac{3\times10^8}{2.5\times10^8} \quad \therefore \quad \mu_2 = 1.2$$

Example-37

Find the angle θ_a made by the light ray when it gets refracted from water to air, as shown in figure.



Sol. Apply, Snell's Law

$$\mu_W \sin\theta_W = \mu_a \sin\theta_a \;;\; \frac{4}{3}\times\frac{3}{5} = 1 \sin\theta_a \;;\sin\theta_a = \frac{4}{5};\quad \theta_a = \sin^{-1}\frac{4}{5}$$

Example 38

Find the speed of light in medium 'a' if speed of light in medium 'b' is $\frac{c}{3}$ where c = speed of light in vacuum and light refracts from medium 'a' to medium 'b' making 45º and 60º respectively with the normal.

Sol. Apply, Snell's Law

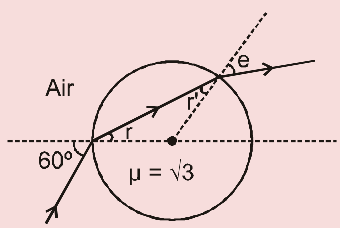
$\mu_a \sin\theta_a = \mu_b \sin\theta_b$

$\frac{c}{v_a}\sin\theta_a = \frac{c}{v_b}\sin\theta_b$.

$\frac{c}{v_a}\sin 45^\circ = \frac{c}{c/3}\sin 60^\circ \Rightarrow v_a = \frac{\sqrt{2}c}{3\sqrt{3}}$

Example 39

A light ray is incident on a glass sphere at an angle of incidence 60º as shown. Find the angles r, r'e and the total deviation after two refractions.



Sol. Applying Snell's law

$1\sin 60^\circ = \sqrt{3}\sin r$ or $r = 30^\circ$

From symmetry, r' = r = 30º

Again applying Snell's law at second surface 1 $\sin e = \sqrt{3}\sin r'$ or $e = 60^\circ$

Deviation at first surface is $\delta_1 = i - r = 60^\circ - 30^\circ = 30^\circ$ (clockwise)

Deviation at second surface is $\delta_2 = e - r' = 60^\circ - 30^\circ = 30^\circ$ (clockwise)

Therefore total deviation is $\delta_1 + \delta_2 = 60^\circ$

Single Refraction by a plane interface:
(Real Depth, apparent depth & Normal shift)
Case-1 : Object in denser & observer in rarer

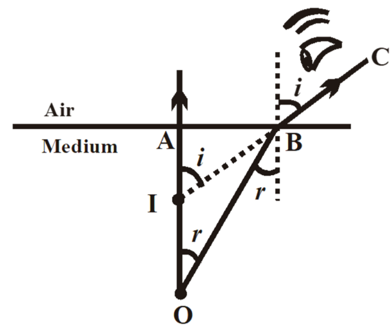
- If an object is placed below the surface of water or under a glass slab, it appears to be raised.
  i.e. the apparent depth is less than the real depth. This is due to refraction.
- Refractive index can also be given as

$$\text{R.I.} = \frac{\text{Real Depth}}{\text{Apparent Depth}} \Rightarrow \mu = \frac{H_R}{H_A}$$

$$\Rightarrow \quad H_A = \frac{H_R}{\mu} \quad \text{or } H_R = \mu \,.\, H_A$$

- Speed : $v_R = \mu . v_A$
- The normal shift of image is

$$y = H_R - H_A = H_R\left(1 - \frac{1}{\mu}\right)$$



(a)

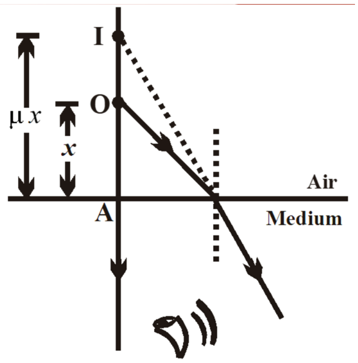
Case-2 : Object in rarer & observer in denser

- If an object is placed above the surface of water and observer is under the water, it appears to be farther.
  The apparent height is more than the real height. This is due to refraction.
  Refractive index can also be given as

$$\text{R.I.} = \frac{\text{Apparent Depth}}{\text{Real Depth}} \Rightarrow \mu = \frac{H_A}{H_R}$$

$$\Rightarrow \quad H_R = \frac{H_A}{\mu} \text{ or } H_A = \mu . H_R$$

- Speed : $v_A = \mu . v_R$
- The normal shift of image is
  $y = H_A - H_R = H_R(\mu - 1)$



(c)

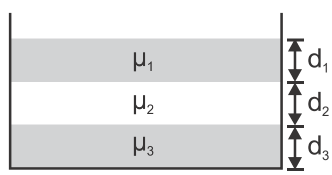
If a beaker is filled with immiscible transparent liquids of refractive indices μ_1, μ_2, μ_3 and individual depth d_1, d_2, d_3 respectively, then

- The apparent depth of the beaker is found to be:

$$D_{apparent} = \frac{d_1}{\mu_1} + \frac{d_2}{\mu_2} + \frac{d_3}{\mu_3}$$

- The effective R.I. of Liquid is found to be :

$$\mu_{effective} = \frac{d_{Real}}{d_{Appa}} = \frac{(d_1 + d_2 + d_3)}{\left(\frac{d_1}{\mu_1} + \frac{d_2}{\mu_2} + \frac{d_3}{\mu_3}\right)}$$



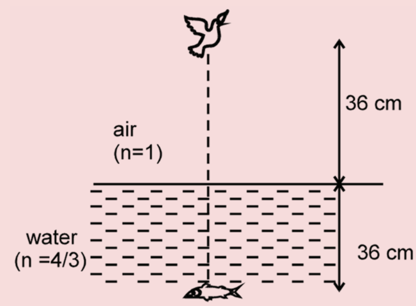
- In case of two liquids if $d_1 = d_2$, then effective R.I. $\mu = \frac{2\mu_1\mu_2}{\mu_1 + \mu_2}$

Example 40

An object lies 100 cm inside water .It is viewed from air nearly normally. Find the apparent depth of the object.

Sol. $d' = \frac{d}{n_{relative}} = \frac{100}{\frac{4/3}{1}} = 75$ cm

Example 41



See the figure

(i) Find apparent height of the bird for fish.

(ii) Find apparent depth of fish for bird.

(iii) At what distance will the bird appear to the fish.

(iv) At what distance will the fish appear to the bird

(v) If the velocity of bird is 12 cm/sec downward and the fish is 12 cm/sec in upward direction, then find out their relative velocities with respect to each other.

Sol. (i) $d'_B = \frac{36}{\frac{1}{\left(\frac{4}{3}\right)}} = \frac{36}{3/4} = 48$ cm

(ii) $d'_F = \frac{36}{4/3} = 27$ cm

(iii) For fish : $d_B = 36 + 48 = 84$ cm

(iv) For bird : $d_F = 27 + 36 = 63$ cm.

(v) Velocity of fish with respect to bird

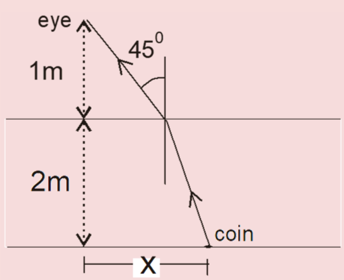
$$= 12 + \left(\frac{12}{4/3\!\!\diagup 1}\right) = 21 \text{ cm/sec.}$$

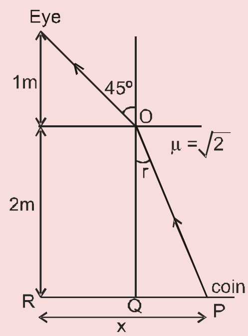
Velocity of bird with respect to fish

$$= 12 + \left(\frac{12}{3/4\!\!\diagup 1}\right) = 28 \text{ cm/sec.}$$

Example 42

A coin lies at the bottom of a lake 2m deep at a horizontal distance x from the spotlight (a source of thin parallel beam of light) situated 1 m above the surface of a liquid of refractive index $\mu = \sqrt{2}$ Find x. If coin can be viewed from the source of spotlight





Sol. $\sqrt{2} = \dfrac{\sin 45^\circ}{\sin r} \Rightarrow \sin r = \dfrac{1}{2} \Rightarrow r = 30^o$

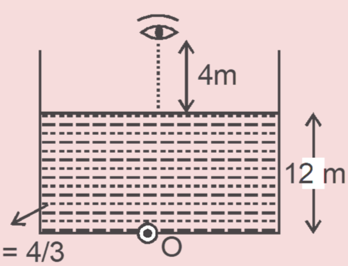
$x = RQ + QP$

$= 1m + 2\tan 30^\circ$ m

$= \left(1 + \dfrac{2}{\sqrt{3}}\right)$ m

Example 43

Find distance of image from interface and from observer.



Sol. $n_1 = 4/3$ $\qquad$ $n_2 = 1$

$u = 12$ $\qquad$ $v = ?$

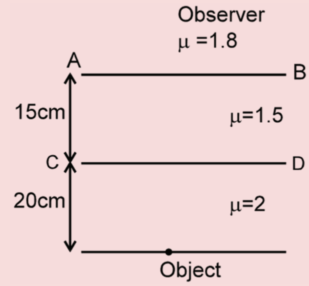
$\dfrac{n_1}{u} = \dfrac{n_2}{v}$ $\qquad$ $\dfrac{4}{3 \times 12} = \dfrac{1}{v}$

$\Rightarrow v = 9$ m $\qquad$ from interface

$\therefore$ from observer $\qquad$ $9 + 4 = 13$

Example 44

Find the apparent depth of object seen below surface AB as shown in figure.



Sol. $D_{app} = \sum \dfrac{d}{\mu} = \dfrac{20}{\left(\dfrac{2}{1.8}\right)} + \dfrac{15}{\left(\dfrac{1.5}{1.8}\right)} = 18 + 18 = 36\text{cm}.$

20. Refraction through a slab

It is the Double refraction from Plane Interface. When light passes through a parallel slab, having same medium on both sides, then

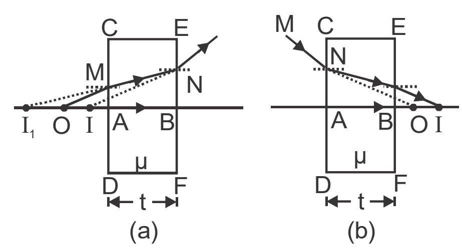
- Emergent ray is parallel to the incident ray.

Normal Shift :

- Here two cases are possible.

(i) For Divergent Ray in figure-a.

The object shifted towards slab with a normal shift $OI = \left(1 - \dfrac{1}{\mu}\right) \cdot t$



(ii) For Convergent Ray in figure-b.

The object shifted away from slab with a normal shift $OI = \left(1 - \dfrac{1}{\mu}\right) \cdot t$

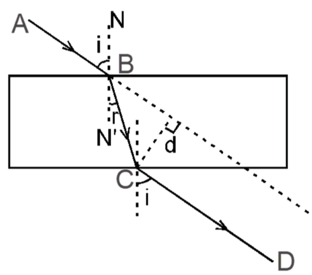
Lateral shift :

When a light ray passes through parallel slab, the emergent ray(CD) is parallel to incident ray(AB).

- But the emergent ray is displaced laterally by a distance d, which depends on μ, t(thickness of slab) and i .
- Its value is given by the relation,

$$d=\frac{\sin(i-r)}{\cos r}\cdot t \quad d=\left[1-\frac{\cos i}{\sqrt{\mu^2-\sin^2 i}}\right]t\cdot\sin i$$

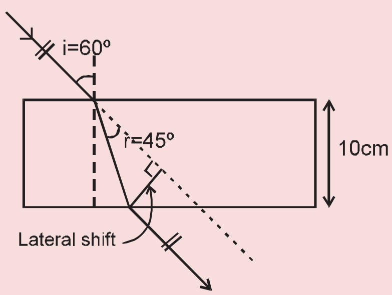
- For small angles of incidence, $d=i\cdot\left(1-\frac{1}{\mu}\right)t$.



Example 45

Find the lateral shift of light ray while it passes through a parallel glass slab of thickness 10 cm placed in air. The angle of incidence in air is 60º and the angle of refraction in glass is 45º.

Sol. $d=\frac{t\sin(i-r)}{\cos r}=\frac{10\sin(60^\circ-45^\circ)}{\cos 45^\circ}$



$=\frac{10\sin 15^\circ}{\cos 45^\circ}=10\sqrt{2}\sin 15^\circ$

Image shift in Mirror :

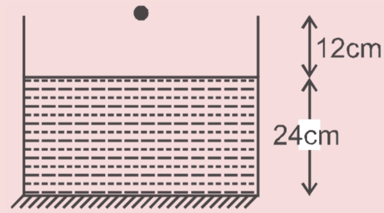
When any refracting medium is placed in front of a mirror, the rays will be refracted twice

(a) Refraction of incident ray, causing the shift of object with respect to mirror & the image of the object will be formed according to the shifted position

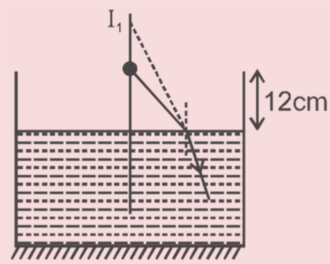
(b) Refraction of reflected rays from mirror, causing the image of shifted object to suffer another shift. This will be final image.

Example 46

Find the distance of final image from water surface after all refractions & reflections.



Sol. **Ist Method :** After first refraction image I_1



$h_{I_1}=\mu(12)=\frac{4}{3}\times 12=16$ cm

Their image behave like object for reflection through mirror so object direction for mirror is $16+24=40$ cm

After reflection from mirror Image I_2 is form at 40 cm below the plane reflecting surface.

After reflection rays goes from water to air and I_2 behave like object for their refraction.

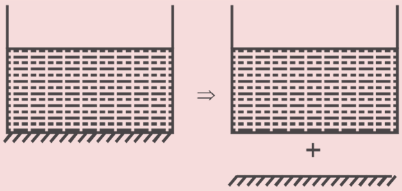
So object direction from plane refracting water surface is

$d_0=(40+24)$cm $=64$ cm

Now App. depth or position of final image from water surface $d_{App}=\frac{64}{4/3}=48$ cm from water surface.

Final image is virtual and 48 cm below water surface.

II^nd Method : We can assumed water as a slab and reflecting surface at a plane mirror.



Whenever ray positions through water slab shift $(1 - \frac{1}{\mu})t$ place along the direction of incident ray.

(a) When ray travel in downward direction downward shift take place shift $= 24\left(1-\frac{3}{4}\right)$

= 6cm increase

(b) Because this shift object distance for mirror is $\mu = 24 + 6 = 30$

So image form by mirror is

$u = 24 + 6 = 30$

So image form by mirror is 30 cm below the mirror

(c) When reflected ray travel in upward direction has passer through water and again shift will take place in upward direction.

Shift = 6 cm (↑)

After their shift find image is below

(30 – 6) = 24 cm

So final image from free surface of water is

24 + 24 cm = 48 cm (virtual)

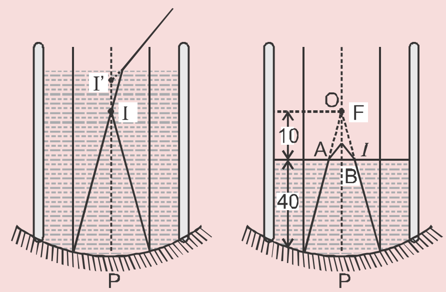
Example 47

A concave mirror of radius of curvature one meter is placed at the bottom of a tank of water. The mirror forms an image of the sun when it is directly overhead. Calculate the distance of images from the mirror when height of water (a) 80 cm and (b) 40 cm in the tank.

Sol. (a) The focal length of the mirror is f =(R/2) = (100/2) = 50 cm and the sun is at infinity, i.e. $u = \infty$; so from mirror formula we have

$$\frac{1}{v} + \frac{1}{-\infty} = \frac{1}{-50} \qquad \text{i.e. } v = -50 \text{ cm}$$

So when the length of water column in the tank is 80 cm, the image of sun will be 50 cm from the mirror But this will not be the final image as there will also be shift due to the presence of medium so $d_{app} = \frac{30}{\mu} = 22.5$ cm from the level of water so the distance of final image from mirror = 50 + (30 – 22.5) = 57.5 cm



(A) (B)

(b) When water is filled in the tank up to a height of 40 cm, the image formed by the mirror will act as virtual object for water surface AC which will form its image at I such that

$$\frac{d_{AC}}{d_{AP}} = \frac{\mu_1}{\mu_2} \qquad \text{i.e.} \qquad \frac{BO}{BI} = \frac{(4/3)}{1}$$

$$\text{i.e.} \qquad BI = 10 \times \left(\frac{3}{4}\right) = 7.5 \text{ cm}$$

So, the distance of image from mirror

= 40 + 7.5 = 47.5

Alternative to part (b) :

$\mu \sin i = 1 \sin r$

$$\text{i.e} \qquad \frac{4}{3} \times \frac{AB}{BO} = 1 \times \frac{AB}{BI}$$

$$\text{i.e} \qquad BI = \frac{3}{4} \times 10 = 7.5 \text{ cm}$$

So, PI = PB + BI = 40 + 7.5 = 47.5 cm

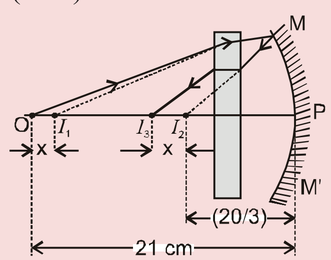
Example 48

An object is placed 21 cm in front of a concave mirror of radius of curvature 10 cm. A glass slab of thickness 3 cm and refractive index 1.5 is then placed close to the mirror in the space between the object and the mirror. Find the position of the final image. Assume the slab is 1 cm away from mirror .

Sol. As the glass slab will produce a shift

$$x = t\left[1-\frac{1}{\mu}\right] = 3\left[1-\frac{2}{3}\right] = 1\text{cm}$$

So, the image I_1 of O formed by the glass slab will be at a distance (21 – 1) = 20 cm from the mirror as shown in figure. This image will act as an object for the concave mirror of focal length (10/2) = 5 cm.



So, $\frac{1}{v}+\frac{1}{-20}=\frac{1}{-5}$ i.e. $v = -\frac{20}{3}$ cm

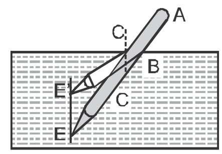
i.e. the concave mirror will form an image I_2 of virtual object I_1 at a distance (20/3) cm in front of it. This image will form an image I_3 of object I_2 producing a shift x away from the plate. So the distance of final image from the point P of mirror MM' will be

$$PI_3 = PI_2 + I_2I_3 = \left(\frac{20}{3}\right) + 1 = 7.67 \text{ cm}$$

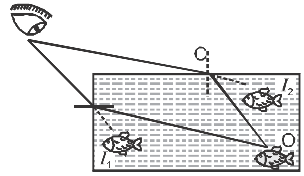
in front of the mirror

APPLICATION OF REFRACTION :

(i) Bending of an Object



(A)



(B)

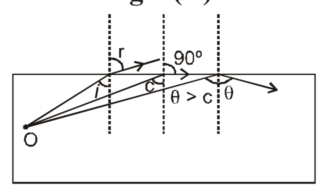
(ii) Visibility of two images of an object

(iii) Twinkling of stars

(iv) Oval shape of sun in the morning and evening

21. Total Internal Reflection [TIR]

- When a ray of light goes from denser to rarer medium it bends away from the normal.
- As the angle of incidence in denser medium increases, the angle of refraction in rarer medium also increases.
- At a certain angle of incidence, the angle of refraction becomes 90º, this angle of incidence is called **critical angle (C)**.



Taking Snell's Law, $\frac{\sin i}{\sin r} = \frac{1}{\mu}$

(when i = C, r = 90º)

$$\mu = \frac{1}{\sin C} \ ; \ \sin C = \frac{1}{\mu} \ ; \ C = \sin^{-1}\left(\frac{1}{\mu}\right)$$

- Greater the refractive index lesser will be the critical angle.
- When angle of incidence exceeds the critical angle then light ray comes back in to the same medium after reflection from interface.

  This phenomenon is called **total internal reflection (TIR)**

Condition for TIR :

(i) The ray incidence at the interface from denser medium.

(ii) The angle of incidence must be greater than critical angle.

Dependence of critical angle :

(i) Critical angle depends upon wavelength as

$$\lambda = f\left(\frac{1}{\mu}\right) \propto \sin C$$

$\lambda_R > \lambda_v \Rightarrow \mu_R < \mu_V$ and so $C_R > C_V$

(ii) With temperature rise , μ decreases therefore, critical angle C increases

(iii) For 'glass-air' pair critical angle is 42º, for 'water-air' pair critical angle is 49º and for 'diamond-air' pair critical angle is 24º.

S.No	Medium	μ of medium w.r.t. air	Critical angle (C)
1	Water	1.33	48.75º
2	Crown	1.52	41.14º
3	Flint glass	1.65	37.30º
4	Diamond	2.42	24.40º

Example 49

Find the max. angle that can be made in glass medium ($\mu = 1.5$) if a light ray is refracted from glass to vacuum.

Sol. $1.5 \sin C = 1 \sin 90^\circ$, $\sin C = 2/3$,

$C = \sin^{-1} 2/3$

Example 50

Find the angle of refraction in a medium ($\mu = 2$) if light is incident in vacuum, making angle equal to twice the critical angle.

Sol. Since the incident light is in rarer medium. Total Internal Reflection cannot take place.

$$C = \sin^{-1}\frac{1}{\mu} = 30^\circ \qquad \therefore \qquad i = 2C = 60^\circ$$

Applying Snell's Law. $1 \sin 60^\circ = 2 \sin r$

$$\sin r = \frac{\sqrt{3}}{4} \Rightarrow r = \sin^{-1}\left(\frac{\sqrt{3}}{4}\right).$$

Example 51

What should be the value of refractive index n of a glass rod placed in air, so that the light entering through the flat surface of the rod does not cross the curved surface of the rod.

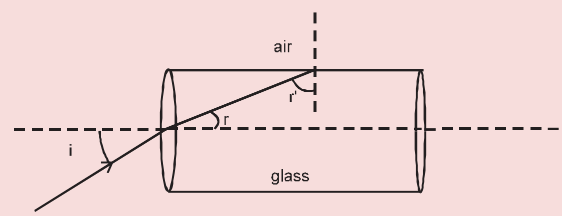
Sol. It is required that all possible r' should be more than critical angle. This will be automatically fulfilled if minimum r' is more than critical angle.

Angle r' is minimum when r is maximum i.e. C.

Therefore the minimum value of r' is 90-C.

Taking condition : $90^\circ - C > C$ or $C < 45^\circ$

$$\sin C < \sin 45^\circ \ ; \qquad \frac{1}{n} < \frac{1}{\sqrt{2}} \text{ or } n > \sqrt{2}.$$



Example 52

Find the critical angle of a denser medium of refractive index 1.65 for its interface with air ($\sin^{-1}(0.6061) = 37^\circ.\ 18'$)

Sol. $\mu = \dfrac{1}{\sin C}$; $\quad \sin C = \dfrac{1}{1.65} = 0.6061$

$\Rightarrow C = 37^\circ.18'$

Application of TIR :

(A) Field of vision of fish

A fish inside the water can see the whole world through a cone with an apex angle twice the critical angle for air water interface.

The radius of the base of the cone,

$$R = h \tan C = \frac{h}{\sqrt{\mu^2 - 1}} \ ; \text{ for water } R = \left(\frac{3}{\sqrt{7}}\right)h$$

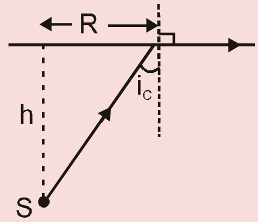
The area of the base of the cone, $A = \dfrac{\pi h^2}{(\mu^2 - 1)}$;

for water $R = \left(\dfrac{9\pi}{7}\right)h^2$

Where μ is the refractive index of the water.

Example 53

A point source is placed at a depth h below the surface of water (refractive index = μ).The medium above the surface of water is air (μ =1).Find the area on the surface of water through which light comes in air from water.



Sol. $\dfrac{\pi h^2}{\mu^2 - 1}$

Light comes in air from water where refraction takes place.

$\sin i_C = \dfrac{R}{\sqrt{R^2 + h^2}} = \dfrac{1}{\mu}$ $\quad \mu^2 R^2 = R^2 + h^2 R^2$

$= \dfrac{h^2}{\mu^2 - 1}$ $\qquad$ Area $= \pi R^2 = \dfrac{\pi h^2}{\mu^2 - 1}$

(B) Optical Fiber :

Optical fiber consists of many long high quality composite glass / quartz fibers. Each fiber consists of a core and cladding.

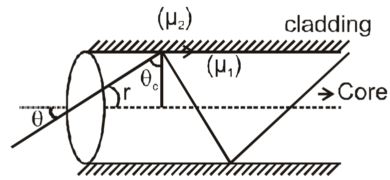
The refractive index of the material of the core (μ_1=1.7) is higher then that of the cladding (μ_2=1.5).

When the light is incident on one end of the fiber at a small angle, the light passes inside undergoes repeated TIRs along the fiber and finally comes out.

The angle of incidence is always larger than the critical angle of core material with respect to its cladding

Light can pass through along the fiber even if it is bent.

Expression of Incidence angle



$1 \times \sin\theta = \mu_1 \sin r$ $\qquad$ ...(1)

$\mu_1 \sin\theta_c = \mu_2 \sin r$

$\mu_1 \sin(90 - r) = \mu_2$ $\qquad$ ...(2)

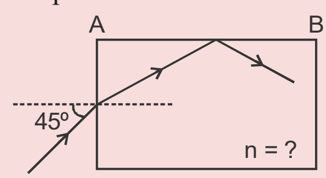
$\mu_1 \cos r = \mu_2$

$\therefore \quad \sin^2 r + \cos^2 r = 1 \;\Rightarrow\; \sin 2\theta + \mu_2^2 = \mu_1^2$

$\sin\theta = \sqrt{\mu_1^2 - \mu_2^2}$

Example 54

Find refractive index of the glass slab for which TIR takes place on AB



Sol. $n_1 = \sqrt{n_2^2 + \sin^2\theta}$; $\sin\theta = \sqrt{n^2 - 1}$

$\dfrac{1}{2} = n^2 - 1$ $\qquad \therefore \qquad n = \sqrt{\dfrac{3}{2}}$

or $\quad 1 \sin 45 = n \sin r$

$\dfrac{1}{\sqrt{2}} = n \sin r$ $\qquad$ ....(1)

$3 = 2n^2$ $\qquad$ $n\sin\theta_c = 1 \sin 90$

$n = \sqrt{\dfrac{3}{2}}$ $\qquad$ $n = \dfrac{1}{\cos r}$ $\qquad$ ...(2)

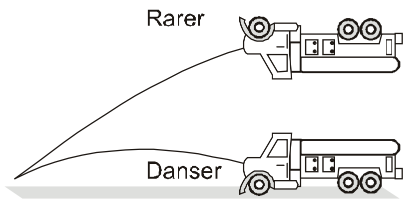
$\therefore \sin^2 r + \cos^2 r = 1 \quad \therefore \dfrac{1}{2n^2} + \dfrac{1}{n^2} = 1$

$\Rightarrow n > \sqrt{\dfrac{3}{2}}$

(C) Optical Looming :

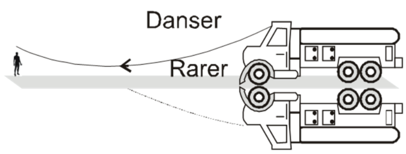
It is an optical illusion in cold countries where an object lying on the ground appears to be hanging in the air.

This happens because a ray from the object going upward suffers TIR and returns back towards the ground as shown, since the refractive index of air falls off with height due to temperature difference.



(D) Mirage :

It is an optical illusion in deserts in which the image gives the impression of reflection from a pond of water.



(E) Brilliance of diamond :

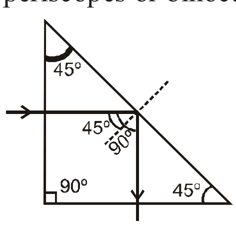
Due to repeated TIRs diamond sparkles.

Diamonds are skillfully cut with many facets in such a way that much of the incident light undergoes multiple TIR within the diamond before passing out again in the air.

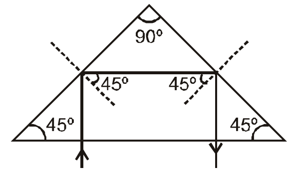
(F) Porro Prism :

It is used to deviate light rays through 90º & 180^0 and also to erect the image.

A right angled isosceles prism, which is used in periscopes or binoculars.



Deviation = 90º



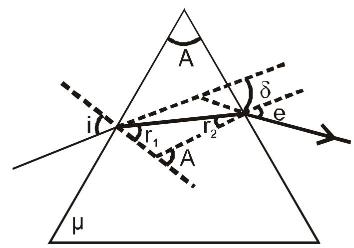
Deviation = 180º

Section - C :- Prism and Dispersion of Light

22. PRISM

Prism is a transparent medium bounded by refracting surfaces, such that the incident surface and emergent surface are plane and non parallel.

Ray Diagram through a prism



Here : 'i' is angle of incidence, 'e' is angle of emergence, 'A' is angle of prism or refracting angle of prism, 'r_1' and 'r_2' are angles of refraction, 'δ' is angle of deviation

General Formula

(i) Angle of prism : $A = r_1 + r_2$

(ii) Total deviation : $\delta = \delta_1 + \delta_2$

$\delta = (i - r_1) + (e - r_2)$ $\therefore$ $\delta = i + e - A$

(iii) Prism formula : $A + \delta = i + e$

Deviation through a prism

Total deviation : $\delta = i + e - A$

For thin prism, $i = \mu r_1$ & $e = \mu r_2$

So, $\delta = (\mu - 1) A$

Deviation by thin prism depends upon angle of prism (A) and refractive index of prism (μ)

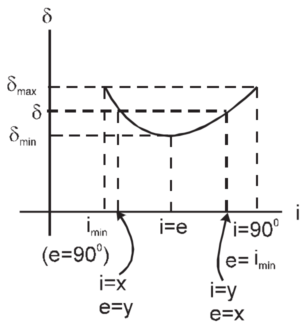
Deviation is different for different colour of light

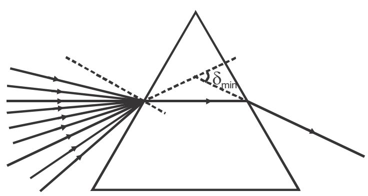
Since $\mu_R < \mu_O < \mu_Y < \mu_G < \mu_B < \mu_I < \mu_V$

So, $\delta_R < \delta_O < \delta_Y < \delta_G < \delta_B < \delta_I < \delta_V$

Minimum Deviation

- It is found that the angle of deviation (δ) varies with angle of incidence (i).
- There are two angle of incidence for which δ is same.
- For one angle of incidence it has a minimum value (δ_m).
- The variation of (δ) versus (i) is shown in diagram.





At mimumum deviation (δ_m),
The ray passes symmetrically through the prism.
Important results

(i) $i = e$ (ii) $r_1 = r_2$

(iii) $r = \dfrac{A}{2}$ (iv) $i = \dfrac{A+\delta_m}{2}$ (v)

$$\mu = \frac{\sin i}{\sin r} = \frac{\sin\dfrac{A+\delta_m}{2}}{\sin\dfrac{A}{2}}$$

(vi) Ray inside the prism is parallel to the base of prism for equilateral and isosceles prism

Example 55

Refracting angle of a prism A = 60º and its refractive index is, n = 3/2, what is the angle of incidence i to get minimum deviation. Also find the minimum deviation. Assume the surrounding medium to be air (n = 1).

Sol. For minimum deviation, $r_1 = r_2 = \dfrac{A}{2} = 30^\circ$.

Applying Snell's law at 1st surface

$$1 \times \sin i = \frac{3}{2}\sin 30^\circ \quad \Rightarrow i = \sin^{-1}\left(\frac{3}{4}\right)$$

$$\Rightarrow \quad \delta_{min} = 2\sin^{-1}\left(\frac{3}{4}\right) - \frac{\pi}{3}$$

Example 56

For a prism if $\mu = \text{cosec}\left(\dfrac{A}{2}\right)$ then find δ_m

Sol.
$$\mu = \frac{\sin\left(\dfrac{A+\delta_m}{2}\right)}{\sin\left(\dfrac{A}{2}\right)} ; \quad \frac{1}{\sin\left(\dfrac{A}{2}\right)} = \frac{\sin\left(\dfrac{A+\delta_m}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$$

$$90^\circ = \frac{A+\delta_m}{2} \quad \Rightarrow 180 - A = \delta_m.$$

Example 57

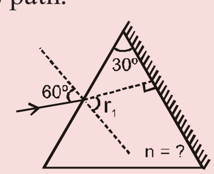
Find the deviation caused by a prism having refracting angle 4º and refractive index $\dfrac{3}{2}$.

if angle of incidence is very small

Sol. $\delta = (3/2 - 1) \times 4^0 = 2^\circ$

Example 58

Find refractive index of the prism if light retraces its path.



Sol. For retrace, the path angle of incidence at reflecting surface is 0. So $r_2 = 0$

$A = r_1 + r_2$; $A = r_1 = 30^\circ$

$$\sin 60 = n \sin 30 \Rightarrow \frac{\sqrt{3}}{2} = n\left(\frac{1}{2}\right) \quad \Rightarrow n = \sqrt{3}$$

Example 59

If one face of a prism of prism angle 30° and $\mu = \sqrt{2}$ is silvered, the incident ray retraces its initial path. What is the angle of incidence?

(1) 30° (2) 45°

(3) 60° (4) 75°

Sol. As incident ray retraces its path the ray is incident normally on the silvered face of the prism as shown in figure.

Further, as in ΔAED

$30^\circ + 90^\circ + \angle D = 180^\circ$

$\angle D = 60^\circ$

Now as by construction

$\angle D + \angle r = 90^\circ$

$\angle r = 90^\circ - 60^\circ = 30^\circ$

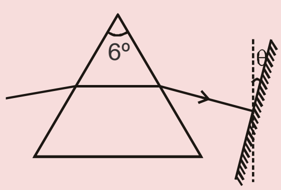
So, from Snell's law at surface AC

$2 \sin i = \sqrt{2} \sin 30^\circ = \sqrt{2} \times (1/2) = (1/\sqrt{2})$

So, $i = \sin^{-1}(1/\sqrt{2}) = 45^\circ$

Example 60

If incident ray is horizontal & plane mirror is vertical, find angle by which plane mirror should be rotated so that reflected ray should be horizontal

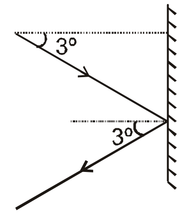


Sol. Deviation of ray by prism,

$$\delta = (\mu - 1) A = \left(\frac{3}{2} - 1\right) 6^\circ = 3^\circ$$

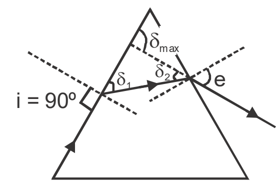
So to keep the ray horizontal

The deviation produced by the mirror should be 3° but in opposite direction so as to keep $d_{net} = 0$



As we know if ray is deviated by 3°, then we apply, if mirror is rotated by 'θ' then the ray will rotate by 2θ. So 2θ = 3° (to bring the reflected ray horizontal) $\Rightarrow \theta = 1.5$

Maximum Deviation



The value of maximum deviation is

$$\delta_{max} = \frac{\pi}{2} + \left[\sin^{-1}\left(\frac{\sin(A - C)}{\sin C}\right)\right] - A$$

Here $i = 90^0$, $r_1 = C$,

$$r_2 = A - C \quad \& \quad e = \sin^{-1}\left(\frac{\sin(A - C)}{\sin C}\right)$$

Condition for no emergence

For this, TIR must take place at the second surface

For any angle of incidence,

$A \geq 2C$ & $\mu > \text{cosec}(A/2)$

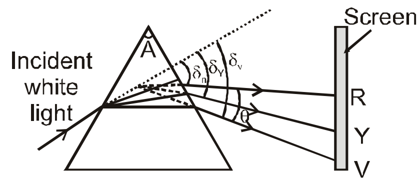
Here, A is called Limiting Angle of prism.

For normal incidence (i=0),

$A \geq C$ & $\mu > \text{cosec}(A)$

23. Dispersion Through Prism

- The splitting & spreading of white light into its constituent colours is called dispersion of light.
- Dispersion takes place because the refractive index of medium for different wavelengths is different.
- The pattern of colour components of light is called the **spectrum** of light.



Angular dispersion (θ) :

- It is the angular separation between extreme colours $\theta = \delta_v - \delta_R = (\mu_v - \mu_R)A$
- It depends upon μ and A.

Average (mean) deviation :

- Yellow colour is called as mean colour $\mu_Y = (\mu_V + \mu_R)/2$
- Deviation of yellow colour light is known as mean deviation $\delta_y = (\mu_y - 1)\,A$

Dispersive power (ω) :

- It is the characteristic of the prism.
- Dispersive power of a prism is defined as ratio of angular dispersion to the average deviation.

$$\omega = \frac{\theta}{\delta_Y} = \frac{\delta_V - \delta_R}{\delta_y} = \frac{\mu_V - \mu_R}{\mu_y - 1} = \frac{d\mu}{\mu - 1}$$

- It depends μ only and not on A .

Combination of Prisms :

- A single prism produces both deviation and dispersion.
- Consider two prisms (made of crown and flint glass) of refracting angles A & A' and dispersive powers ω & ω' respectively.
- They are placed in contact by two refracting angles are reversed with respect to each other.
- The mean deviation produced

  $\delta_1 = (\mu_Y - 1)\,A$ & $\delta_2 = (\mu'_Y - 1)\,A'$

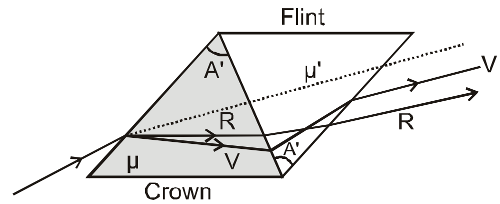
  $\delta_{net} = \delta_1 - \delta_2 = (\mu_Y - 1)\,A - (\mu'_Y - 1)\,A'$
- The net angular dispersion produced

  $\theta = \delta_V - \delta_R = (\mu_V - \mu_R)\,A - (\mu'_V - \mu'_R)\,A'$

  $= (\mu_Y - 1)\,\omega A - (\mu'_Y - 1)\,\omega' A'$
- **Two important combinations**

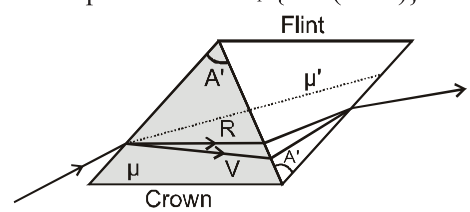
Dispersion without deviation :

- It is called chromatic or direct vision prism.
- Here, $\delta = 0,\ \theta \neq 0$
- Condition $\dfrac{A'}{A} = -\dfrac{(\mu_Y - 1)}{(\mu'_Y - 1)}$
- Net dispersion $\theta = \delta_1\,(\omega - \omega')$



Deviation without dispersion :

- It is called achromatic prism.
- Here, $\theta = 0,\ \delta \neq 0$
- Condition, $\dfrac{A'}{A} = -\dfrac{(\mu_V - \mu_R)}{(\mu'_V - \mu'_R)} = \dfrac{(\mu_Y - 1)\,\omega}{(\mu'_Y - 1)\,\omega'}$
- Net dispersion $\delta = \delta_1\,\{1 - (\omega/\omega')\}$



Example 61

The refractive indices of flint glass for red and violet light are 1.613 and 1.632 respectively. Find the angular dispersion produced by a thin prism of flint glass having refracting angle 5°.

Sol. Deviation of the red light is $\delta_r = (\mu_r - 1)A$ and deviation of the violet light is $\delta_v = (\mu_v - 1)A$.

The dispersion $= \delta_v - \delta_r = (\mu_v - \mu_r)A$
$= (1.632 - 1.613) \times 5^0 = 0.095^\circ$

Example 62

Refractive index of glass for red and violet colours are 1.50 and 1.60 respectively. Find
(a) The ref. index for yellow colour, (approx.)
(b) Dispersive power of the medium.

Sol. (a) $\mu_r = \dfrac{\mu_v + \mu_R}{2} = \dfrac{1.50 + 1.60}{2} = 1.55$

(b) $\omega = \dfrac{\mu_v - \mu_R}{\mu_r - 1} = \dfrac{1.60 - 1.50}{1.55 - 1} = 0.18.$

Example 63

Two small angled prism A and B deviate the blue rays are 6º and 8º and the red rays by 4º and 6º respectively. Which prism has a greater dispersive power?

Sol. (a) Angular dispersion of A = 6º – 4º = 2º

Mean deviation of A = $\dfrac{6+4}{2} = 5^{\circ}$

Dispersive power of A = $\dfrac{2}{5}$ = 0.4

(b) Angular dispersion of B = 8º – 6º = 2º

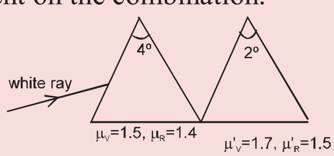
Mean deviation of B = $\dfrac{8+6}{2}$ = 7º

Dispersive power of B = $\dfrac{2}{7}$ = 0.2857

Hence, dispersive power of A is greater than that of B.

Example 64

If two prisms are combined, as shown in figure, find the total angular dispersion and angle of deviation suffered by a white ray of light incident on the combination.



Sol. Both prisms will turn the light rays towards their bases and hence in same direction.

Therefore turnings caused by both prisms are additive.

Total angular dispersion = θ + θ' = $(\mu_V - \mu_R)$ A + $(\mu'_V - \mu'_R)$ A'

= (1.5 – 1.4) 4º + (1.7 – 1.5)2º = 0.8°

Total deviation = δ + δ′

$$= \left(\frac{\mu_V + \mu_R}{2} - 1\right)A + \left(\frac{\mu'_V + \mu'_R}{2} - 1\right)A'$$

$$= \left(\frac{1.5+1.4}{2} - 1\right) 0.4^{\circ} + \left(\frac{1.7+1.5}{2} - 1\right) 0.2^{\circ}$$

= (1.45 – 1) 0.4º + (1.6 – 1) 0.2º

= 0.45 × 0.4º + 0.6 × 0.2º = 1.80 + 1.2 = 3.0º

Two thin prisms are combined to form an achromatic combination. For I prism A = 4º, μ_R = 1.35, μ_Y = 1.40, μ_v = 1.42. for II prism μ'_R= 1.7, μ'_Y = 1.8 and μ'_R = 1.9 find the prism angle of II prism and the net mean deviation.

Sol. Condition for achromatic combination. θ = θ'

$(\mu_V - \mu_R)A = (\mu'_V - \mu'_R)A'$

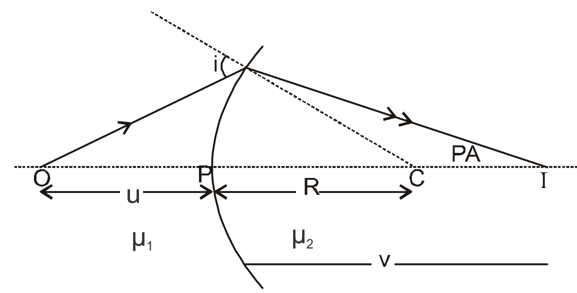
$$\therefore \quad A' = \frac{(1.42 - 1.35)4^{\circ}}{1.9 - 1.7} = 1.4^{\circ}$$

$\delta_{Net} = \delta \sim \delta' = (\mu_Y - 1)A \sim (\mu'_Y - 1)A'$

= (1.40 – 1) 4º ~ (1.8 – 1) 1.4° = 0.48º

SECTION - D : Refraction from Spherical

24. Refraction at spherical surface



- **Relation among μ_1 , μ_2 , u , v and R :**

  When object placed in medium μ_1

  $$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{(\mu_2 - \mu_1)}{R}$$

  Where R = Radius of curvature of surface; μ_1 = R.I. of incidence medium ; μ_2 = R.I. of refracted medium

- **Magnification :**

  $$m = \frac{h_I}{h_0} = \frac{R-v}{R-u} = \left(\frac{\mu_1}{\mu_2}\right)\left(\frac{v}{u}\right)$$

- **Focus :**

  (a) First focus : When object is placed at first focus, image is formed at infinity

  Taking, $u = f_1$, $v = \infty$

Apply, $\dfrac{\mu_2}{\infty} - \dfrac{\mu_1}{f_1} = \dfrac{(\mu_2 - \mu_1)}{R}$

We get $f_1 = -\left(\dfrac{\mu_1 R}{\mu_2 - \mu_1}\right)$

For Glass $f_{1G} = -2R$ & for Water $f_{1W} = -3R$

(b) Second Focus : When the rays are coming from a very distant point, they get converged / diverged at second focus

Taking, $u = \infty$, $v = f_2$

Apply, $\dfrac{\mu_2}{\infty} - \dfrac{\mu_1}{f_1} = \dfrac{(\mu_2 - \mu_1)}{R}$;

We get, $f_2 = \left(\dfrac{\mu_1 R}{(\mu_2 - \mu_1)}\right)$

For Glass, $f_{1G} = 2R$ & for Water $f_{1W} = 3R$

(c) Velocity of image

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{(\mu_2 - \mu_1)}{R}$$

Differentiating with respect to t

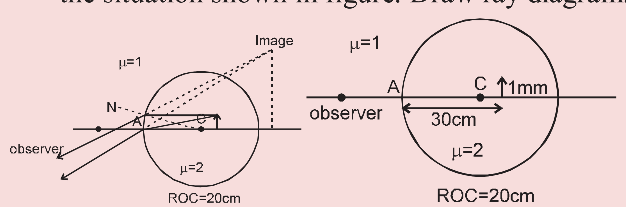
$$\mu_2\left(-\frac{1}{v^2}\frac{dv}{dt}\right) - \mu_1\left(-\frac{1}{u^2}\frac{du}{dt}\right) = 0$$

$$\Rightarrow \quad \frac{dv}{dt} = \left(\frac{\mu_1}{\mu_2}\right)\left(\frac{v}{u}\right)^2\left(\frac{du}{dt}\right);$$

$$v_{im} = \left(\frac{\mu_1}{\mu_2}\right)\left(\frac{v}{u}\right)^2 v_{om}$$

Example 66

Find the position, size and nature of image, for the situation shown in figure. Draw ray diagram.



Sol. For refraction near point A, $u = -30$;

$R = -20$; $n_1 = 2$; $n_2 = 1$.

Applying refraction formula

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

$$\frac{1}{v} - \frac{2}{-30} = \frac{1-2}{-20} \Rightarrow \quad v = -60 \text{ cm}$$

$$m = \frac{h_2}{h_1} = \frac{n_1 v}{n_2 u} = \frac{2(-60)}{1(-30)} = 4 \quad \therefore h_2 = 4 \text{ mm.}$$

So image is virtual.

Example 67

Light from a point source in air falls on a spherical glass surface ($\mu = 1.5$ and radius of curvature $= 30$ cm). The distance of the light source from the glass surface is 90 cm. At what position the image is formed?

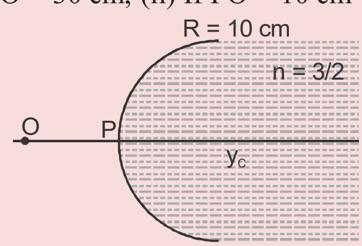
Sol. Here $u = -90$ cm, $v = ?$, $R = +30$ cm, $\mu_1 = 1$, and $\mu_2 = 1.5$. We then have

$$\frac{1.5}{v} + \frac{1}{90} = \frac{1.5-1}{30} \quad \text{or} \quad v = +270 \text{ cm}$$

The image is formed at a distance of 270 cm from the glass surface in the direction of incident light.

Example 68

Find position nature magnification of image if (i) PO = 30 cm; (ii) If PO = 10 cm



Sol. (i) Here $u = -30$

by refraction formula

$$\frac{3}{2v} + \frac{1}{30} = \frac{\frac{3}{2} - 1}{10}; \quad v = 90 \text{ cm}$$

Image is real $m = \dfrac{1}{3/2}\left(\dfrac{90}{-30}\right)$; $m = -2$

(ii) $\dfrac{3}{2v} - \dfrac{1}{-10} = \dfrac{\frac{3}{2}-1}{10} = \dfrac{1}{2\times 10}$

$\Rightarrow \quad \dfrac{3}{2v} = \dfrac{1}{20} - \dfrac{2}{20} = \dfrac{-1}{20}$

$v = -30$ cm (virtual)

$\Rightarrow \quad m = \dfrac{2}{3}\times\dfrac{-30}{-10} \quad \Rightarrow \quad m = +2$ (Inv)

Example 69

Show that for refraction at a concave spherical surface (separating glass-air-medium), the distance of the object should be greater than three times the radius of curvature of the refracting surface for the image to the real.

Sol. $\mu_1 = 1.50$, $\mu_2 = 1$, u and R are negative.

$\dfrac{\mu_2}{v} - \dfrac{\mu_1}{u} = \dfrac{\mu_2-\mu_1}{R} \qquad \Rightarrow \dfrac{1}{v} + \dfrac{3}{2u} = \dfrac{1}{2R}$

$\dfrac{1}{v} = \dfrac{1}{2R} - \dfrac{3}{2u}$

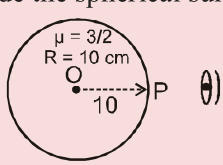
$\dfrac{1}{v} = \dfrac{1.50}{-u} = \dfrac{1-1.50}{-R}, \; \dfrac{1}{v} + \dfrac{3}{2v} = \dfrac{1}{2R}$

$\therefore \quad \dfrac{1}{v} = \dfrac{1}{2R} - \dfrac{3}{2u}$

For v to be positive $\dfrac{1}{2R} > \dfrac{3}{2u}$ or $u > 3R$

Example 70

In the given arrangement object is placed at the centre then find position of the image as viewed from outside the spherical surface



Sol. (i) $\dfrac{1}{v} + \dfrac{3}{2\times 10} = \dfrac{1}{20}$

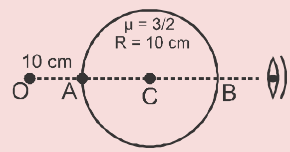
$\dfrac{1}{v} = +\dfrac{1}{20} - \dfrac{3}{20} \quad \Rightarrow \quad v = -10$ cm

When object is at centre (of any cube, circle....) then their is no shift it will be always at center.

(ii) $m = \left(\dfrac{n_1}{n_2}\right)\dfrac{v}{u} \Rightarrow m = 1.5$ times (greater)

Example-71

Find distance of final image from point B



Sol. For A

$\mu_1 = 1 \qquad \mu_2 = 3/2$

$R = 10 \qquad u = -10$

$\dfrac{\mu_2}{v} - \dfrac{\mu_1}{u} = \dfrac{\mu_2-\mu_1}{R} \Rightarrow v = -30$ cm

For B

$\mu_1 = 3/2 \qquad \mu_2 = 1$

$R = -10 \qquad u = -50$

$\dfrac{\mu_2}{v} - \dfrac{\mu_1}{u} = \dfrac{\mu_2-\mu_1}{R} \Rightarrow v = 50$ cm

25. LENS

A lens is a piece of transparent material with two refracting surfaces such that at least one is curved and refractive index of its material is different from that of the surroundings.

Types of Lenses :

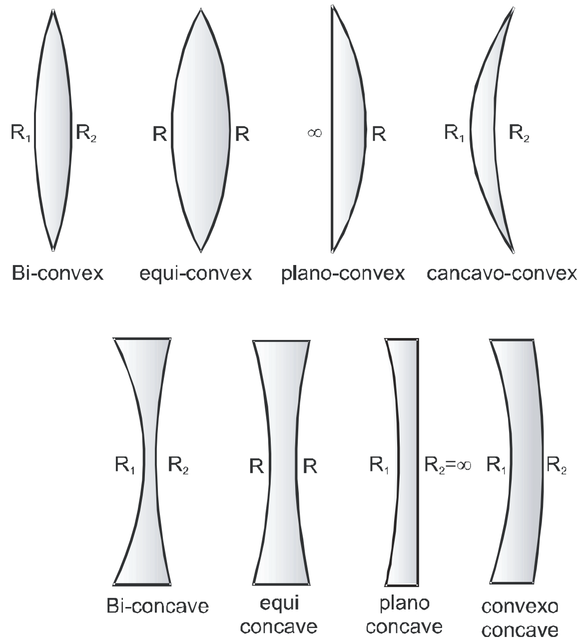
(i) CONVEX or CONVERGING LENS :

- A thin spherical lens with refractive index greater than that of surroundings behaves as a convergent or convex lens.
- Geometrically its central portion is thicker than marginal one.

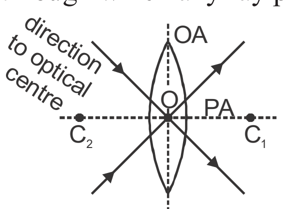
(ii) CONCAVE or DIVERGING LENS :

- Geometrically the central portion of a lens is thinner than marginal.
- It diverges parallel rays behaves as divergent or concave lens.
- Concave or convex lens : Geometrical concept

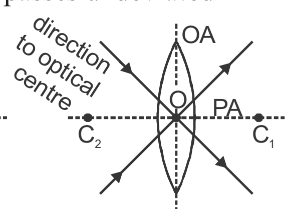
- Converging or diverging lens : Optical concept
  Figure shows 4 convex and 4 concave lenses.



- **Optical Centre :** O is a point for a given lens through which any ray passes undeviated

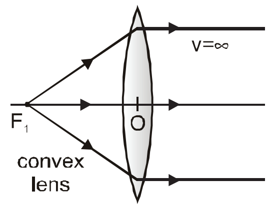


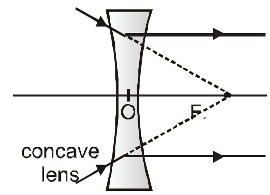
Convex lens



Convex lens

- **Principal Axis :** $C_1 C_2$ is a line passing through optical centre and perpendicular to the lens.
- **Optical Axis :** It is a line passing through optic centre and perpendicular to the principal axis.
- **Principal Focus :** A lens has two surfaces and hence two focal points. First focal point is an object point on the principal axis for which image is formed at infinity.

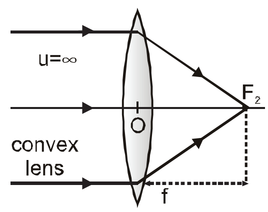


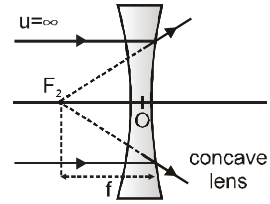


While second focal point is an image point on the principal axis for which object lies at infinity. Second point is known as **Principal focus**.

Focal length of convex lens is (+ve)

Focal length of concave lens is (–ve)





- **Focal Length f** is defined as the distance between optical centre of a lens and the point where the parallel beam of light converges or appears to converge.
- **Aperture :** In reference to a lens, aperture means the effective diameter (light gathering).
  Intensity of image formed by a lens which depends on the light passing through the lens will depend on the square of aperture, i.e., $I \propto (\text{Aperture})^2$

Rules for Image Formation :

- A ray passing through optical centre proceeds undeviated through the lens.
- A ray passing through first focus F_1 or directed towards it, after refraction from the lens, becomes parallel to the principal axis.
- A ray passing parallel to the principal axis after refraction passes through or appears to pass through second focus F_2 .

Image formation for convex lens (Convergent lens):

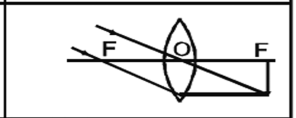
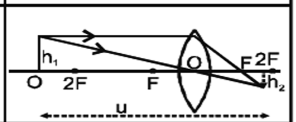
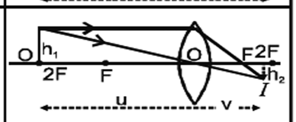
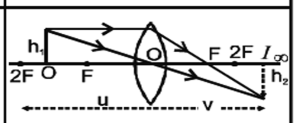
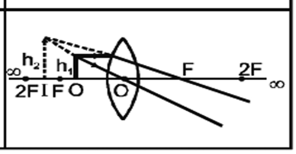
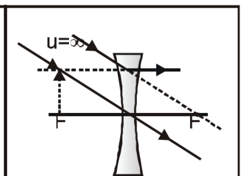
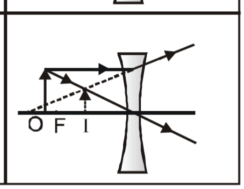
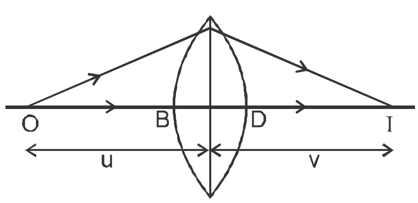
Object Position	Image position	Diagram
1. Object is placed at infinity at F real	Inverted very small in size m << –1	
2. Object is placed in between ∞ – 2F Image real (F – 2F)	Inverted small in size (diminished) m < –1	
3. Object is placed at 2F Image real (at 2F)	Inverted equal of same size (m = –1)	
4. Object is placed between 2F – F Image Real (2F – ∞)	Inverted enlarger m > 1	
5. Object is placed in between F – O Image: virtual (in front of lens)	erected enlarged (m > + 1)	

Image formation for concave lens :

Image is virtual, diminished, erect, towards the object, m = +ve

Object is placed at infinity at F real	Virtual erected dimenished (m<<+1)	
Object is placed infront of lens Image between F and Optical centre	Virtual erected dimenished (m < +1)	

Lens Formula & Lens Maker's formula :



If R_1 and R_2 are radii of curvature of first and second refracting surfaces of a thin lens of focal length f and refractive index μ (w.r.t. surrounding medium) then the relation between f, μ, R_1 and R_2 is known as **lens maker's formula**.

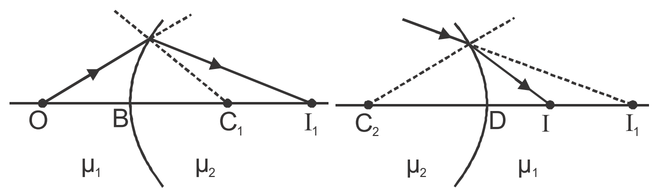
$$\frac{1}{f} = (\mu_{rel} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

The image formation can be seen in terms of two steps :

The first refracting surface forms the image I_1 of the object O. The image I_1 acts as a virtual object for the second surface that forms the image at I.

For the first interface ABC, we get

$$\frac{\mu_1}{OB} + \frac{\mu_2}{BI_1} = \frac{\mu_2 - \mu_1}{BC_1} \quad ....(i)$$



A similar procedure applied to the second interface ADC gives,

$$-\frac{\mu_2}{DI_1} + \frac{\mu_1}{DI} = \frac{\mu_2 - \mu_1}{DC_2} \quad ...(ii)$$

For a thin lens, $BI_1 = DI_1$. Adding Eqs. (i) and (ii), we get

$$\frac{\mu_1}{OB} + \frac{\mu_1}{DI} = (\mu_2 - \mu_1)\left(\frac{1}{BC_1} + \frac{1}{DC_2}\right) \quad ...(iii)$$

Suppose the object is at infinity, i.e. OB → ∞, and DI = f, the focal length of the lens. Then

$$\frac{\mu_1}{f} = (\mu_2 - \mu_1)\left(\frac{1}{BC_1} + \frac{1}{DC_2}\right) \quad ...(iv)$$

A lens has two foci, F_1 and F_2. on either side of it.

By the sign convention,

$BC_1 = +R_1$, $\qquad DC_2 = -R_2$

So Eq. (iv) can be written as

$$\frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

This equation is known as the **lens maker's formula**.

It is useful to design lenses of desired focal length using surfaces of suitable radii of curvature.

From Eqs. (iii) and (iv) we get

$$\frac{\mu_1}{OB}+\frac{\mu_1}{DI}=\frac{\mu_1}{f}$$

Again, in the thin lens approximation, B and D are both close to the optical centre of the lens. Applying the sign convention.

BO = –u, DI = +v, we get

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

This is the thin **lens formula** used to locate the image of an object.

In short

$$f=\frac{vu}{u-v} \text{ \& } v=\frac{fu}{f+u} \text{ \& } u=\frac{fv}{f-v}$$

26. Focal Length of Lens

IN DIFFERENT MEDIUM

Consider a lens of RI (μ_G), is immersed in a liquid of RI (μ_L) then its focal length (f_L) is given by

$$\frac{1}{f_L}=\left(\frac{\mu_G}{\mu_L}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

If is the focal length of lens in air , then

$$\frac{1}{f_A}=\left(\frac{\mu_G}{\mu_A}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

Taking ratio

$$\frac{f_L}{f_A}=\frac{\mu_G-1}{\mu_G/\mu_L-1}=\left(\frac{\mu_G-1}{\mu_G-\mu_L}\right)\mu_L$$

Important cases

(i) If $\mu_G > \mu_L$, then f_L and f_A are of same sign i.e., the nature of lens remains constant. But $f_L > f_A$ i.e., focal length increases & power decreases.

(ii) If $\mu_G < \mu_L$, then f_L and f_A are of opposite sign i.e., the nature of lens changes i.e., a convex lens becomes diverging & a concave lens becomes converging.

(iii) If $\mu_G = \mu_L$, then $f_L = \infty$ i.e., the lens behaves as a plane glass plate and becomes invisible in the liquid.

For two different liquid

$$\frac{f_{L2}}{f_{L1}}=\frac{(\mu_G/\mu_{L1})-1}{(\mu_G/\mu_{L2})-1}=\left(\frac{\mu_G-\mu_{L1}}{\mu_G-\mu_{L2}}\right)\frac{\mu_{L2}}{\mu_{L1}}$$

FOCAL LENGTH OF LENS

If medium are different on both sides

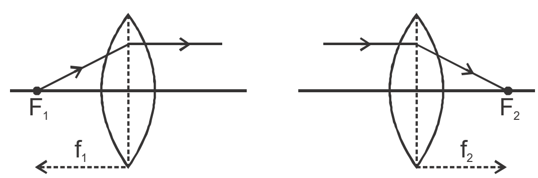
In such cases lens maker's formula is not applicable because there different medium on both side of lens

Consider rays are incident from left, then applying refraction equation for both the spherical surfaces, the final result will be

$$\frac{\mu_3}{v}-\frac{\mu_1}{u}=\left(\frac{\mu_2-\mu_1}{R_1}\right)+\left(\frac{\mu_3-\mu_2}{R_2}\right)$$

(i) If object is placed at focus, image will be formed at infinity ($u=-f_1$ & $v=\infty$) so we can write

$$\frac{\mu_1}{f_1}=\frac{\mu_2-\mu_1}{R_1}+\frac{\mu_3-\mu_2}{R_2} \quad \text{(first focal length)}$$



(ii) Also for distant object, image will be formed at focus ($v = f_2$ & $u = -\infty$) so we can write

$$\frac{\mu_3}{f_2}=\frac{\mu_2-\mu_1}{R_1}+\frac{\mu_3-\mu_2}{R_2} \quad \text{(second focal length)}$$

(iii) So both focal length of the lens can be related as $\frac{\mu_1}{f_1}=\frac{\mu_3}{f_2}$

FOCAL LENGTH OF LENS

If geometry are different

(i) For equibiconvex lens,

$$R_1 = +R \text{ and } R_2 = -R;\ f = \frac{R}{2(\mu-1)}$$

(ii) For equibiconcave lens,

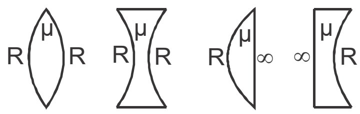
$$R_1 = -R \text{ and } R_2 = -R;\ f = \frac{R}{2(\mu-1)}$$

(iii) For plano-convex lens,

$$R_1 = -R \text{ and } R_2 = \infty;\ f = \frac{R}{2(\mu-1)}$$

(iv) For Plano-concave lens,

$$R_1 = \infty \text{ and } R_2 = R;\ f = -\frac{R}{2(\mu-1)}$$



27. Magnification:

It is the ratio of the size of image to the size of object.

(i) Transverse (Lateral or Linear) Magnification (m):

The object is placed perpendicular to principal axis.

It is defined by

$$m = \frac{\text{Image Height}}{\text{Object Height}} = \frac{h_I}{h_O} = \frac{v}{u}$$

$$m = \frac{v}{u} = \frac{f}{f+u} = \frac{f-v}{f}$$

(ii) Longitudinal (axial) Magnification (m_L):

The object is placed along the principal axis.

It is defined by ,

$$m_L = \frac{\text{Image Length}}{\text{Object Length}} = \frac{L_I}{L_O} = \frac{v_2 - v_1}{u_2 - u_1}$$

For very small object

$$m_L = \frac{dv}{du} = \left(\frac{v}{u}\right)^2 = \left(\frac{f}{f+u}\right)^2 = \left(\frac{f-v}{f}\right)^2 = m^2$$

(iii) Areal (area) Magnification (m_A) :

It is defined by, $m_A = \frac{A_I}{A_0} = \frac{ma \cdot mb}{a \cdot b} = m^2$

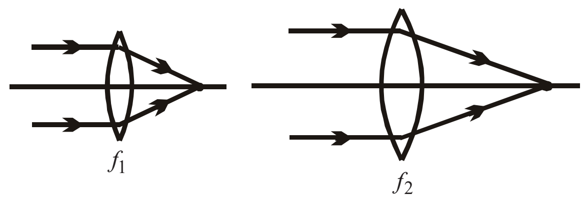
28. Optical Power

It is the ability of the instrument to deviate the path of rays passing through it.

For converging system power is positive (+ve)

For diverging system power is negative (-ve)

The shorter the focal length of a lens (or a mirror) the more it converges or diverges light.



As shown in the figure. $f_1 < f_2$

and hence the power $P_1 > P_2$,

as bending of light in case 1 is more than that of case 2.

For a lens, $P\,(\text{in dioptre}) = \frac{1}{f\,(\text{metre})}$

and for a mirror, $P\,(\text{in dioptre}) = \frac{-1}{f\,(\text{metre})}$

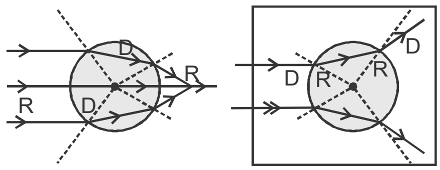
The power is expressed in **diopters**(D) .

Lens / Mirror	Focal length (f)	Power (P)	Converging / Diverging
Convex lens	+ve	+ve	converging
Convex mirror	+ve	–ve	diverging
Concave lens	–ve	–ve	diverging
Concave mirror	–ve	+ve	converging

Thus, convex lens and concave mirror have positive power or they are converging in nature. Concave lens and convex mirror have negative power or they are diverging in nature.

Behavior of a transparent sphere

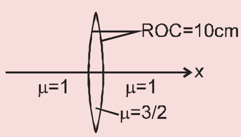
- A water drop or glass sphere in air, due to refraction, behaves as a convergent lens.
- While an air bubble in water or spherical cavity in glass behaves as a divergent lens.
- This is illustrated by self explanatory figure (A) and (B) respectively.



(A) Convergent behaviour (B) Divergent behaviour

Example 72

Find the focal length of the lens shown in the figure.



converging lens

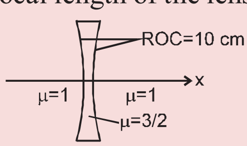
Sol. $\because \quad \frac{1}{f} = (n_{rel} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$$\Rightarrow \quad \frac{1}{f} = (3/2 - 1)\left(\frac{1}{10} - \frac{1}{(-10)}\right)$$

$$\Rightarrow \quad \frac{1}{f} = \frac{1}{2} \times \frac{2}{10} \quad \Rightarrow \quad f = +\,10 \text{ cm.}$$

Example 73

Find the focal length of the lens shown in figure

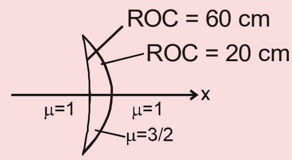


Sol. $\frac{1}{f} = (n_{rel} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \left(\frac{3}{2} - 1\right)$

$$\Rightarrow \quad \left(\frac{1}{-10} - \frac{1}{10}\right) \quad \Rightarrow \quad f = -\,10 \text{ cm}$$

Example 74

Find the focal length of the lens shown in figure



(a) If the light is incident from left side.

(b) If the light is incident from right side.

Sol. (a) $\frac{1}{f} = (n_{rel} - 1) = \left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \left(\frac{3}{2} - 1\right)$

$$\left(\frac{1}{-60} - \frac{1}{-20}\right) \quad \Rightarrow \quad f = 60 \text{ cm}$$

(b) $\frac{1}{f} = (n_{rel} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \left(\frac{3}{2} - 1\right)$

$$\left(\frac{1}{20} - \frac{1}{60}\right) \quad \Rightarrow \quad f = 60 \text{ cm}$$

Example 75

Focal length of convex lens is 10 cm, its refractive index is 3/2 find its focal length when it is kept in a medium of refractive index 1.4

Sol. $\frac{1}{f_L} = \left(\frac{\mu_L - \mu_M}{\mu_M}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

If a lens is placed into two different mediums then

$$\frac{(f_L)_1}{(f_L)_2} = \left[\frac{\mu_L - \mu_{M_2}}{\mu_L - \mu_{M_1}}\right]\left[\frac{\mu_{M_1}}{\mu_{M_2}}\right]$$

$$\Rightarrow \frac{10}{f} = \frac{0.1}{0.5}\left(\frac{1}{1.4}\right) \Rightarrow f = 70 \text{ cm}$$

Example 76

Find the position, nature and magnification of image if object is placed in front of converging lens (f = 10 cm). The distance of object from the pole is : (a) 30 cm (b) 5 cm

Sol. (a) u = –30 cm, f = +10 cm,

by lens formula $v = \dfrac{uf}{f+u} = 15$ cm

v = positive, so image is real,

$$m = \frac{v}{u} = \frac{15}{-30} = -\frac{1}{2}$$

So image is small and inverted (m = negative)

(b) u = –5 cm, f = +10 cm,

by lens formula $v = \dfrac{uf}{f+u} = -10$ cm

v = negative, so image is virtual,

$$m = \frac{v}{u} = \frac{-10}{-5} = 2$$

So image is magnified and erect (m = positive)

Example 77

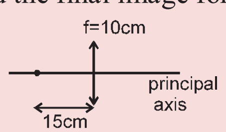
Point object is placed on the principal axis of a thin lens with parallel curved boundaries i.e., having same radii of curvature. Discuss about the position of the image formed.

Sol. $\dfrac{1}{f} = (n_{rel} - 1)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right) = 0 \quad [\because R_1 = R_2]$

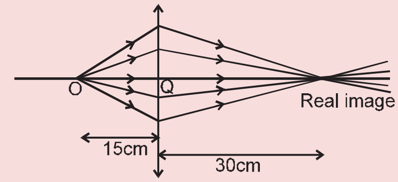
$\dfrac{1}{v} - \dfrac{1}{u} = 0$ or $v = u$ i.e. rays pass without appreciable bending.

Example 78

Figure shown a point object and a converging lens. Find the final image formed.



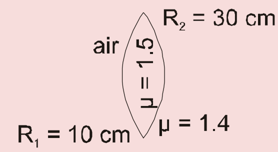
Sol. $\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f} \Rightarrow \dfrac{1}{v} - \dfrac{1}{-15} = \dfrac{1}{10}$



$\dfrac{1}{v} = \dfrac{1}{10} - \dfrac{1}{15} = \dfrac{1}{30}$ v = + 30 cm

Example 79

Find both the focal length of the lens in the given situation



Sol. $\dfrac{\mu_1}{f_1} = \dfrac{\mu_2 - \mu_1}{R_1} + \dfrac{\mu_3 - \mu_2}{R_2}$

Here $\mu_1 = 1$, $\mu_2 = 1.5$, $\mu_3 = 1.4$

$R_1 = +10$, $R_2 = -30$

$\dfrac{1}{f_1} = \dfrac{0.5}{10} + \dfrac{0.1}{30} \Rightarrow f_1 = 18.75$ cm

Also ; $\dfrac{\mu_1}{f_1} = \dfrac{\mu_3}{f_2}$

$\dfrac{1}{18.75} = \dfrac{1.4}{f_2} \Rightarrow f_2 = 26.25$cm

Example-80

An extended real object of size 2 cm is placed perpendicular to the principal axis of a converging lens of focal length 20 cm. The distance between the object and the lens is 30 cm.

(i) Find the lateral magnification produced by the lens.

(ii) Find the height of the image.

(iii) Find the change in lateral magnification, if the object is brought closer to the lens by 1 mm along the principal axis.

Sol. Using $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$ and $m=\frac{v}{u}$

we get $m=\frac{f}{f+u}$ ....(A)

$\therefore \quad m=\frac{+20}{+20+(-30)}=\frac{+20}{-10}=-2$

–ve sign implies that the image is inverted.

(ii) $\frac{h_2}{h_1}=m$

$\therefore \quad h_2 = mh_1 = (-2)(2) = -4$ cm

(iii) Differentiating (A) we get

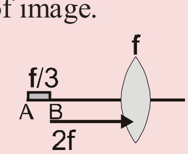
$$dm=\frac{-f}{(f+u)^2}\,du$$

$$=\frac{-(20)}{(-10)^2}(0.1)=\frac{-2}{100}=-.02$$

Note that the method of differential is valid only when changes are small.

Example 81

As shown in figure, an object of $\frac{f}{3}$ length is placed along principal axis at distance 2f, find the length of image.



Sol. $v_B=\frac{uf}{u+f}=\frac{-2f^2}{-2f+f}=2f$

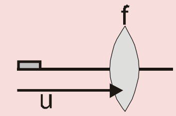
$$v_A=\frac{uf}{u+f}=\frac{-7f^2}{\left(\frac{-7f}{3}+\frac{3f}{3}\right)}=\frac{-7f}{-4f}=\frac{7f}{4f}$$

The length of image is $= v_B - v_A$

$$2f-\frac{7f}{4}=\frac{f}{4}$$

Example 82

As shown in figure, a small object of length b is placed along principal axis at distance u_0 find length of image. (focal length of lens is f_0)



Sol. $\mu=-\mu_0 \therefore \quad m_L = m^2L$

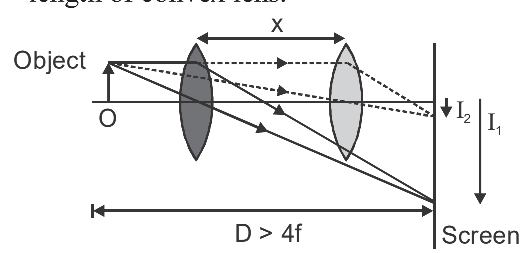
$$m_L=\frac{L_I}{L_O}=\frac{f^2}{(f+u)^2}=\left(\frac{f_0}{f_0-\mu_0}\right)$$

$$L_I=\left[\frac{f_0^{\,2}}{(f_0-u_0)^2}\right]b$$

DISPLACEMENT method :

(to determine the focal length of a convex lens)

- If the distance D between an object and screen is greater than 4 times the focal length of a convex lens, then there are two positions of the lens between the object and screen at which a sharp image of the object is formed on the screen.
- This method is called **displacement method**
- It is used in laboratory to determine the focal length of convex lens.



There are following results :

(i) If $D<4f$, then no position of the lens is possible.

(ii) If $D=4f$ then only one position is possible.

(iii) If $D>4f$, there are two positions of lens for which real image is formed on the screen.

(iv) Focal length of the lens,

$$f=\frac{D^2-x^2}{4D}=\frac{x}{m_1-m_2}$$

(v) Magnifications, $m_1 = \frac{I_1}{O}$ & $m_2 = \frac{I_2}{O}$ &

$m_1 \cdot m_2 = 1$

(vi) Size of object, $O = \sqrt{I_1 I_2}$

Example 83

For two positions of a converging lens between an object and a screen which are 96 cm apart, two real images are formed. If the ratio of the lengths of the two images is 4.84, calculate the focal length of the lens.

Sol. Here $\frac{m_1}{m_2} = 4.84$

$$\left(\frac{a+d}{a-d}\right)^2 = 4.84 \qquad \Rightarrow \frac{a+d}{a-d} = \frac{2.2}{1}$$

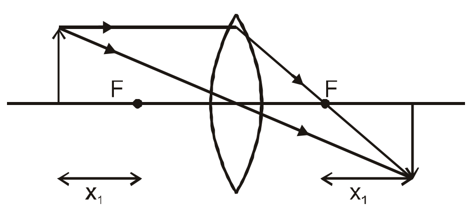
Putting a = 96 cm gives d = 36 cm

$$\therefore f = \frac{a^2 - d^2}{4a} = 20.625 \text{ cm}$$

NEWTON'S FORMULA OF FOCAL LENGTH:

If the distance of object and image are not measured from optical centre, but from first and second principal foci then Newton's formula for focal length is

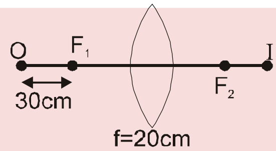
$$f^2 = x_1 x_2$$



Example 84

Find out the distance of image from the optical centre of converging lens (f = 20 cm), if object is placed 30 cm away from first focus of lens.

Sol.



$f^2 = x_1 x_2 \Rightarrow (20)^2 = (30)(v - 20) \Rightarrow v = 33.3$ cm

SPEED : OBJECT & IMAGE

(A) Parallel to Principal axis (w.r.t. lens)

Since $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Taking differentiation

$$\left(-\frac{1}{v^2}\frac{dv}{dt}\right) - \left(-\frac{1}{u^2}\frac{du}{dt}\right) = 0$$

$$\frac{dv}{dt} = \left(\frac{v}{u}\right)^2 \frac{du}{dt} \quad \text{Thus,} \quad v_{IM} = m^2 v_{OM}$$

(B) Perpendicular to Principal axis

$$m = \frac{h_I}{h_0} = \frac{v}{u} \quad \& \quad h_I = \left(\frac{v}{u}\right) h_0 = \frac{fh_0}{f+u}$$

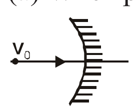
Taking differentiation

$$\frac{dh_I}{dt} = \frac{f}{(f+u)}\left(\frac{dh_0}{dt}\right) + fh_0 \left(-\frac{1}{(f+u)^2}\right)\frac{du}{dt}$$

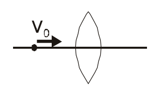
$$(v_\perp)_{IM} \frac{f}{(f+u)} = (v_\perp)_{OM} - \frac{fh_0}{(f+u)^2}\left(v_{\parallel}\right)_{OM}$$

In short :

(a) When particle is moving along principal axis.

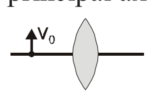


$v_I = -m^2 v_0$



$v_I = m^2 v_0$

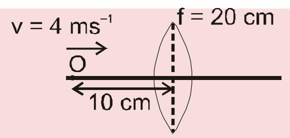
(b) When object is moving perpendicular to principal axis.

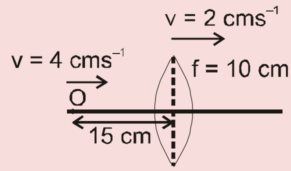


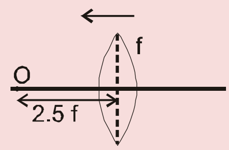
$v_I = m v_0$

Example 85

Find the velocity of image for the following situations

(i) 

(ii) 

(iii) 

Sol. (i) $m = \dfrac{f}{f+u} = \dfrac{20}{20+(-10)} = 2$

$v_{IL} = m^2 v_{OL}$

$v_{IL} = 2^2(4) = 16\ ms^{-1}$

(ii) $m = \dfrac{f}{f+u} = -2$

$v_{IL} = m^2 v_{OL}$

$v_I - 2 = (-2)^2\ (4 - 2) = 10\ cms^{-1}$

(iii) $m = \dfrac{f}{f+u} = \dfrac{-2}{3}$

$v_{IL} = m^2 v_{OL}$

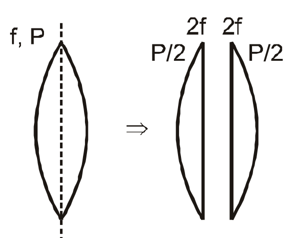
$v_I + v = (-2/3)^2\ (0 + v)$

$v_I = \dfrac{-5v}{9}$

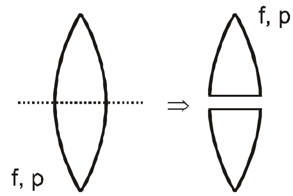
CUTTING THE LENS :

A symmetric lens is cut in the following ways

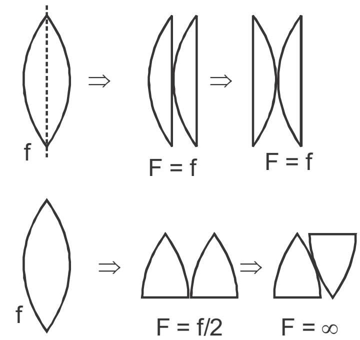
- A symmetric lens is cut along **optical axis** in two equal parts.
- Intensity of image formed by each part will be same as that of complete lens,
- but the focal length is double the original for each part.



- A symmetrical lens is cut along **principal axis** in two equal parts.
- Intensity of image by each part will be half compared to that of complete lens,
- but the focal length remains same for each part.



- Combined focal length of parts of a lens.



SILVERING of a lens :

Suppose one of the surfaces of a lens is silvered. An incident ray will be first refracted, then reflected at silvered surface , and then refracted again to form the image. It behaves as a combination of two lenses and one mirror.

Therefore the system behaves as a spherical mirror having effective power

$P = P_L + P_M + P_L = 2P_L + P_M$

& $\dfrac{1}{F} = \dfrac{2}{F_L} + \dfrac{1}{F_M}$

(i) If the plane surface of Plano-convex lens is silvered, it behaves as a concave mirror of focal length $F = \dfrac{R}{2(\mu - 1)}$

(ii) If the curved surface of Plano-convex lens is silvered, it behaves as a concave mirror of focal length $F = \dfrac{R}{2\mu}$

(iii) If one surface of double convex lens is silvered, it behaves as a concave mirror of focal length

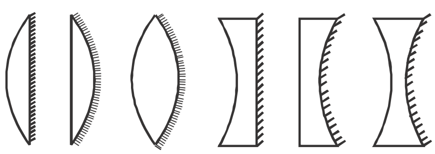
$$F = -\frac{R}{2(2\mu-1)}$$

(iv) If the plane surface of Plano-concave lens is silvered, it behaves as a convex mirror of focal length $F = \frac{R}{2(\mu-1)}$

(v) If the curved surface of Plano-concave lens is silvered, it behaves as a convex mirror of focal length $F = \frac{R}{2\mu}$

(vi) If one surface of double concave lens is silvered, it behaves as a convex mirror of focal length

$$F = \frac{R}{2(2\mu-1)}$$



29. Combination of Lenses :

(i) When lenses are in contact

- Two thin lens are placed in contact to each other, their combination behaves like a single lens of focal length

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

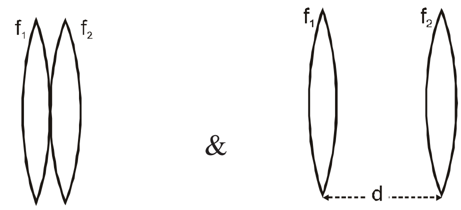
for more lenses , $\frac{1}{F} = \sum_{i=1}^{n} \frac{1}{f_i} = \frac{1}{f_1} + \frac{1}{f_2} + ...$

Power of combination

$$P = \sum_{i=1}^{n} P_i = P_1 + P_2 + ...$$

Magnification of combination

$$M = \prod_{i=1}^{n} m_i = m_1 \times m_2 \times ...$$



(ii) When lenses are separated

- If two converging lenses are separated by a distance d and the incident light rays are parallel to the common principal axis ,then the combination behaves like a single lens of focal length given by the relation

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$$

Position of equivalent lens is

$-\frac{d \cdot F}{f_1}$ with respect to 2^{nd} lens

Power of combination $P = P_1 + P_2 - d\ P_1 P_2$

Magnification of combination $M = m_1 \times m_2$

The system behaves as

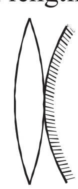
(a) Convex lens, if $f_1 + f_2 > d$

(b) Concave lens, if $f_1 + f_2 < d$

(c) glass slab, if $f_1 + f_2 = d$

Combination of lenses and mirror :

- The combination of lens and mirror behaves like a mirror of focal length 'f' given by

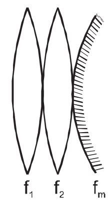


$$\frac{1}{f} = \frac{1}{F_m} - \frac{2}{F_\ell}$$

If lenses are more then one, 'f' is given by

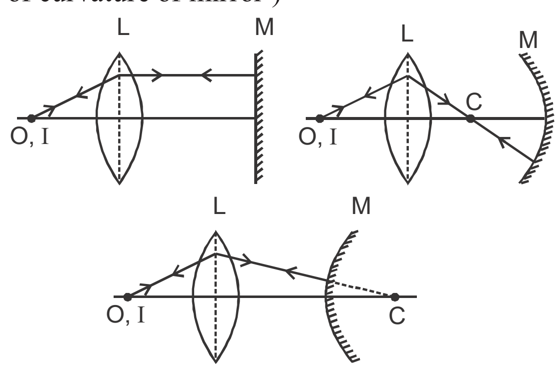
$$\frac{1}{f} = \frac{1}{F_m} - 2\left(\sum \frac{1}{f_\ell}\right)$$

For the following figure



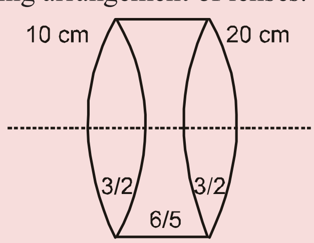
$$\frac{1}{f}=\frac{1}{F_m}-2\left(\frac{1}{f_1}+\frac{1}{f_2}\right)$$

- In some cases, object and image are formed at same place. For this, after refraction, ray must retrace their path i.e., incident normally on the mirror. (image by lens must be formed at centre of curvature of mirror)



Example 86

Find the focal length of equivalent system of following arrangement of lenses.



Sol. $\frac{1}{f_1}=\left(\frac{3}{2}-1\right)\left(\frac{1}{10}+\frac{1}{10}\right)=\frac{1}{2}\times\frac{2}{10}=\frac{1}{10}$

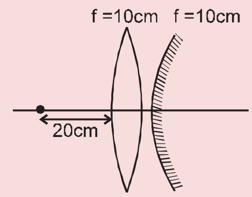
$$\frac{1}{f_2}=\left(\frac{6}{5}-1\right)\left(\frac{-1}{10}-\frac{1}{20}\right)$$

$$=\frac{1}{5}\times\left(\frac{-30}{10\times 20}\right)=\frac{-3}{100}$$

$$\Rightarrow \qquad \frac{1}{f_3}=\left(\frac{8}{5}-1\right)\left(\frac{1}{20}+\frac{1}{20}\right)=\frac{3}{50}$$

Example 87

Find the position of final image formed. (The gap shown in figure is of negligible width)



Sol. $\frac{1}{f_{eq}}=\frac{1}{10}-\frac{2}{10}=\frac{-1}{10} \qquad \Rightarrow \qquad f_{eq}=-10\text{ cm}$

$$\frac{1}{v}+\frac{1}{-20}=\frac{1}{-10} \qquad \Rightarrow \qquad v=-20\text{ cm}$$

Hence image will be formed on the object itself

Example 88

Let the plane surface of a plano-convex lens be silvered as shown. Find its equivalent power and focal length.

Sol. Let the radius of curvature of the curved surface of the lens be R and refractive index be μ.

Focal length of the lens is

$$\frac{1}{f_L}=(\mu-1)\left[\frac{1}{R}-\frac{1}{\infty}\right]=\frac{\mu-1}{R}$$

Focal length of the plane mirror formed is ∞

Hence power of the combination is

$P = P_L + P_M + P_L$

$$=\frac{\mu-1}{R}+O+\frac{\mu-1}{R}=2\frac{\mu-1}{R}$$

and equivalent focal length

$$f=\frac{-1}{P}=-\frac{R}{2(\mu-1)}$$

Example 89

Let the curved surface of the plano-convex lens is silvered as shown below. Find its equivalent power and focal length.

Sol. In this case

$$\frac{1}{f_L} = (\mu - 1)\left[\frac{1}{\infty} - \frac{1}{-R}\right] = \frac{(\mu-1)}{R}$$

And $f_M = \dfrac{(-R)}{2}$

So, $P_L = \dfrac{1}{f_L} = \dfrac{(\mu-1)}{R}$ and $P_M = \dfrac{1}{f_M} = \dfrac{2}{R}$

And power of system

$P = P_L + P_M + P_L = 2P_L + P_M$

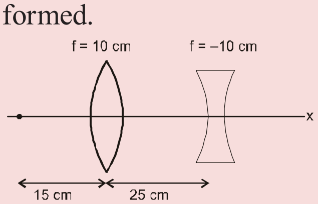
i.e. $P = \dfrac{2(\mu-1)}{R} + \dfrac{2}{R} = \dfrac{2\mu}{R}$

So, $f = \dfrac{1}{P} = \dfrac{R}{2\mu}$

30. Image formation due to multiple lenses & mirror:

Example-90

In the following figure, find the position of final image formed.



Sol. For converging lens

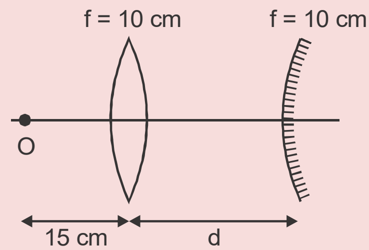
$u = -15\text{cm},\ f = 10$ cm $\quad \therefore\ v = \dfrac{fu}{f+u} = 30$ cm

For diverging lens

$u = 5$ cm; $f = -10$ cm $\quad \therefore\ v = \dfrac{fu}{f+u} = 10$ cm

Example 91

What should be the value of 'd' so that its image is formed on the object itself ?

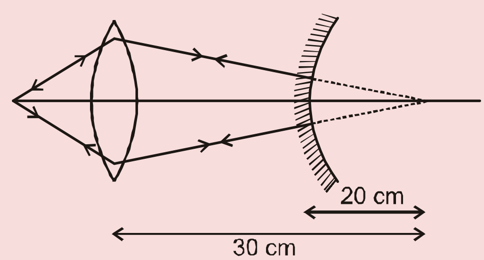


Sol. Using lens formula we can obtain position of the image formed by lens as

$$\frac{1}{v} - \frac{1}{-15} = \frac{1}{10} \qquad \therefore \qquad v = +30 \text{ cm}$$

For a point object and the above arrangement, it is necessary that the rays must retrace its path for image to be formed at the object itself. There are two possible cases for retracing. Either the rays fall normally on the convex mirror or fall at the pole of the mirror.

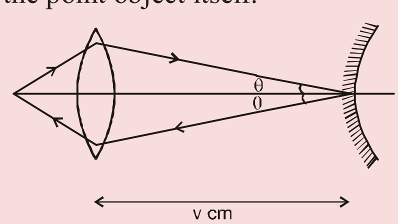
Case -I : Let the rays strike the mirror normally. The rays will retrace the point object itself.



$\therefore \quad d = 30 - 20 = 10$ cm

Case -II : Let the rays strike the pole of the mirror.

The rays will retrace its path back to the object as shown below and the image will be formed on the point object itself.



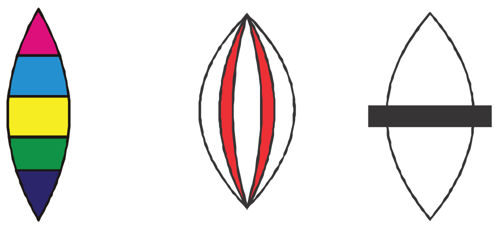
$\therefore \quad d = v = 30$ cm

LENS of DIFFERENT MATERIALS:

A lens have number of layers of different R.I.

(i) If the layers are parallel to principal axis then it will have as many focal lengths and will form as many images as there are number of layers.

(ii) If the layers are parallel to optical axis then it will have only one focal length and will form only one image.



(iii) If some portion of a lens is covered with black paper full image will be formed by brightness will be reduced.

Example 92

Image of a donkey is obtained using a convex lens with black stripes painted on it at regular intervals will the image of donkey be like a zebra? Explain.

Sol. As every part of a lens forms complete image if any portion is obstructed, full image will be formed but brightness (intensity) will be reduced. Therefore if a lens is painted with black stripes at regular intervals and a donkey is seen through it, the donkey will not appear as a zebra but will remain a donkey with reduced intensity.

DEFECTS IN IMAGES :

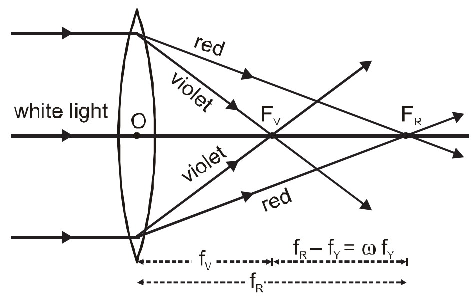
- Actual image formed by an optical system is usually imperfect.
- This defects of images are called **aberrations**.
- The defect may be due to light or optical system.
- (i) If the defect is due to light it is called **chromatic aberration,** and

  (ii) If due to optical system **monochromatic aberration**.

(a) Longitudinal Chromatic Aberration:

The image of an object formed by a lens is usually colored and blurred. This defect of image is called chromatic aberration. This defect arises due to the fact the focal length of a lens is different for different colours. For a lens.

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



As μ is maximum for violet while minimum for red, violet is focused nearest to the lens while red farthest from it.

The difference between f_R and f_v is a measured of longitudinal chromatic aberration (LCA). thus,

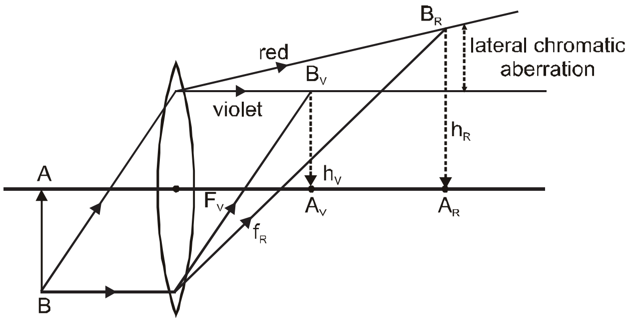
LCA = $f_R - f_v = -df = f.\omega$

where $\omega = \dfrac{d\mu}{\mu - 1}$ = dispersive power

For a single lenses neither f nor ω can be zero. Thus, we cannot have a single lens free from chromatic aberration.

(b) Transverse Chromatic Aberration :

- As the focal-length of the lens varies from colour to colour, the magnification $m = \left[\dfrac{f}{u+f}\right]$ produced by the lens also varies from colour to colour.



- Therefore, for a finite-size white object AB, the images of different colours formed by the lens are of different sizes.
- The formation of images of different colours in different sizes is called (lateral) transverse chromatic aberration.
- The difference in the height of the red image $B_R A_R$ and the violet image $B_V A_V$ is known as transverse chromatic aberration (TCA).

  $TCA = h_R - h_V$

(c) **Achromatism :** If two or more lens combined together in such a way that this combination produce image at a same point then this combination is known as achromatic combination of lenses.

$$\frac{\omega}{f_y} + \frac{\omega'}{f'_y} = 0 \quad \Rightarrow \quad \frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} = 0$$

$$\Rightarrow \quad \frac{\omega_1}{\omega_2} = -\frac{f_1}{f_2}$$

For combination of lens. $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$ (Apply sign convention in numerical)

(d) **Monochromatic aberration :**

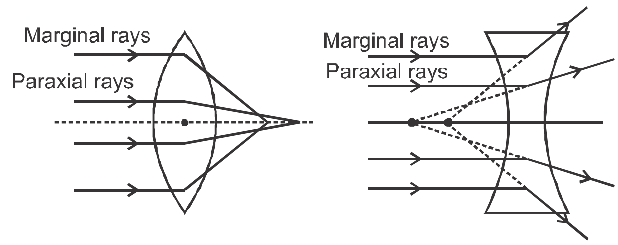
- This is the defect in image due to optical system.
- Monochromatic aberration is of many types such as spherical coma, distortion, curvature and astigmatism.
- Here we shell limit ourselves to spherical aberration only.

Spherical Aberration :

Spherical aberration arises due to to spherical nature of lens (or mirror).

The paraxial rays (close to principal axis) get focused at I_P and marginal rays (away from the principal axis) are focused at I_M. Thus image of a point object O is not a point.

The inability of the lens to form a point image of an axial point object is called spherical aberration.



Spherical aberration can never be eliminated but can be minimized by the following methods:

(i) By using stops
(ii) Using two lenses separated by a distance
(iii) Using parabolic mirrors
(iv) Using lens of large focal length
(v) Using plano-convex lens.
(vi) Using crossed lens

SECTION-E
Microscope and Telescope

34. Microscope :

It is an optical instrument used to see very small objects.

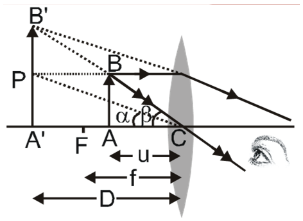
It is of two types :

(1) Simple Microscope

A magnifying glass is a simple microscope.

Principle :

A simple microscope is based upon the fact that if an object is placed between the optical centre and the focus of convex lens, it produces a virtual, erect and magnified image of the object on the same side of the lens.



Magnifying power (or angular magnification):

Magnifying power of a simple microscope is defined as the ratio of the angle subtended by the image at the eye to the angle subtended by the object at the eye when both are placed at the least distance of distinct vision independently.

Magnifying power : $M = \dfrac{\beta}{\alpha}$

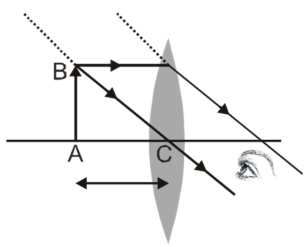
When final image is formed at D :

The magnifying power becomes

$$M_D = \left(1 + \frac{D}{f}\right)$$

When final image is formed at infinity :

The microscope is said to be in normal adjustment



$$M_\infty = \frac{D}{f}$$

Example 100

A man with normal near point 25 cm reads a book with small print using a magnifying glass, a thin convex lens of focal length 5 cm. (a) What is the closest and farthest distance at which he can read the book when viewing through the magnifying glass? (b) What is the maximum and minimum MP possible using the above simple microscope?

Sol. (a) As for normal eye far and near point are ∞ and 25 cm respectively, so for magnifier

$v_{max} = -\infty$ and $v_{min} = -25$ cm.

However, for a lens as

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \text{i.e., } u = \frac{f}{(f/v) - 1}$$

So u will be minimum when

$v_{\ min} = -25$ cm

$$\text{i.e., } (u)_{min} = \frac{5}{-(5/25) - 1} = -\frac{25}{6} = -4.17 \text{ cm}$$

u will be maximum when v = maximum = ∞

$$\text{i.e.} \quad u_{max} = \frac{5}{\left(\frac{5}{\infty} - 1\right)} = -5 \text{ cm}$$

So the closest and farthest distance of the book from the magnifier (or eye) for clear viewing are 4.17 cm and 5 cm respectively.

(b) As in case of simple magnifier MP = (D/u).

So, MP will be minimum when

u = maximum = 5 cm

$$\text{i.e.,} \quad (MP)_{min} = 5\left[= \frac{D}{f}\right] = \frac{-25}{-5}$$

And MP will be maximum when

u = minimum = (25/6) cm

$$\text{i.e.,} \quad (MP)_{max} = 6\left[= 1 + \frac{D}{f}\right] = \frac{-25}{-(25/6)}$$

Example 101

Focal length of convex lens in simple microscope is 2.5 cm, find magnifying power (1) when image is at ∞ (2) when image is at D (3) when image is at 100 cm

Sol. (1) When image is at ∞ (relaxed eye)

$$MP = \frac{D}{f} = \frac{25}{2.5} = 10X$$

(2) When image is at D (strained eye)

$$MP = 1 + \frac{D}{f} = 11X$$

(3) When image is at 100 cm

$v = -100$ cm ; $f = 2.5$ cm

Using lens formula $u = -\dfrac{100}{41}$ cm

Magnifying power is $\dfrac{D}{u} = \dfrac{41}{4} = 10.25$ X

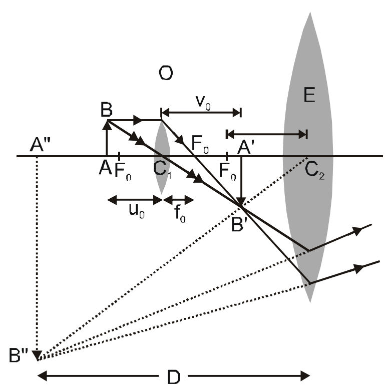
(2) Compound Microscope :

A compound microscope is used to see the minute particles or small objects which are not even seen by the simple microscope.

Principle :

- Compound microscope consists of two convex lenses called objects (O) and the eye piece (E).
- Objective lens is of small aperture and small focal length and faces the object to be seen.
- Eye piece is a convex lens of large aperture and large focal length as compared to objective.
- Both the lenses are placed co-axially at a certain distance apart with a common principal axis.
- The distance between the objective and eyepiece can be adjusted with the help of rack and pinion arrangement.

Theory :



- The object is placed beyond first focus of objective, so that an inverted and real image (intermediate image) is formed by the objective.
- This intermediate image acts as an object for the eye piece and lies between first focus and pole of eye piece. The final magnified virtual image is formed by the eye-piece.

Magnifying Power (or Angular Magnification):

The magnifying power of a compound microscope is defined as the ratio of the angle subtended by the final image at the eye (β) to the angle subtended by the object at the eye(α) when both are at a distance of least distance of distinct vision. Thus,

- Magnification : $M = \dfrac{\beta}{\alpha} = m_0 \times m_E$

  Length of microscope : $L = v_O + u_E$

  Where m_O is magnification produced by objective lens and m_E is magnification produced by the eyepiece

  $m_0 = \dfrac{v_O}{u_O}$ & $m_E = \dfrac{D}{u_E}$

- When the final image is formed at infinity

  Magnifying power : $M_\infty = \dfrac{v_O}{u_O}\left(\dfrac{D}{f_E}\right)$

  Length of microscope : $L_\infty = v_O + f_E$

- When the final image is formed at D

  Magnifying power : $M_D = \dfrac{v_O}{u_O}\left(1 + \dfrac{D}{f_e}\right)$

  Length of microscope : $L_D = v_O + \dfrac{Df_E}{D + f_E}$

- In general, object is placed very near to the principal focus of objective and f_o is also very small, then

  $M_D = -\dfrac{L}{f_O}\left(1 + \dfrac{D}{f_E}\right)$ & $M_\infty = -\dfrac{L}{f_O}\left(\dfrac{D}{f_E}\right)$

Example 102

A compound microscope consists of an objective lens of focal length 2.0 cm and an eye piece of focal length 6.25 cm, separated by a distance of 15 cm. How far from the objective should an object be placed in order to obtain the final image at

(a) The least distance of distinct vision (25 cm)

(b) Infinity ?

Sol. Here, $f_0 = 2.0$ cm; $f_e = 6.25$ cm, $u_0 = ?$

(a) $v_e = -25$ cm $\because \frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e}$

$$\therefore \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} = \frac{1}{-25} - \frac{1}{6.25} = \frac{-1-4}{25} = \frac{-5}{25}$$

$\Rightarrow$ $u_e = -5$ cm

As distance between objective and eye piece = 15 cm.

$v_0 = 15 - 5 = 10$ cm $\because \frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0}$

$$\therefore \frac{1}{u_0} = \frac{1}{v_0} - \frac{1}{f_0} = \frac{1}{10} - \frac{1}{2} = \frac{1-5}{10}$$

$\Rightarrow$ $u_0 = \frac{-10}{4} = -2.5$ cm

Magnifying power =

$$\frac{v_0}{|u_0|}\left[1+\frac{D}{f_e}\right] = \frac{10}{2.5}\left[1+\frac{25}{6.25}\right] = 20$$

(b) $\because$ $v_e = \infty$, $u_e = f_e = 6.25$ cm

$\therefore v_0 = 15 - 6.25 = 8.75$ cm.

$$\because \frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0}$$

$$\therefore \frac{1}{u_0} = \frac{1}{v_0} - \frac{1}{f_0} = \frac{1}{8.75} - \frac{1}{20} = \frac{2-8.75}{17.5}$$

$\Rightarrow$ $u_0 = \frac{-17.5}{6.75} = -2.59$ cm

Magnifying power

$$= \frac{v_0}{|u_0|} \times \left[1+\frac{D}{f_e}\right] = \frac{v_0}{|u_0|} \times \frac{D}{|u_e|}$$

$$= \frac{8.75}{2.59} \times \frac{25}{6.25} = 13.51$$

Example 103

Focal length of objective & eyepiece in compound microscope is 2cm & 5 cm respectively distance of object from objective 2.25 cm. Find M.P. & length of compound microscope

(i) When final image is at ∞

(ii) When final image is at D

Sol. $f_0 = 2$cm $\quad f_e = 5$cm

for objective $\quad u = -2.25$ cm

$$v = \frac{uf}{u+f} = 18\text{cm}\ ; \ m = \frac{v}{u} = -8$$

(i) When image is at ∞ (relaxed eye)

$$\text{M.P.} = m_0\left(\frac{D}{f_e}\right) = -40X$$

$\Rightarrow$ $L = v_O + f_e = 18 + 5 = 23$ cm

(ii) When image is at D (strained eye)

$$\text{M.P.} = m_0\left(1+\frac{D}{f_e}\right) = -48X \quad \Rightarrow$$

$$L = v_O + \frac{Df_e}{D+f_e} = 22.16 \text{ cm}$$

Example 104

The focal length of the objective and eyepiece of a microscope are 2 cm and 5 cm respectively and the distance between them is 20 cm. Find the distance of object from the objective, when the final image seen by the eye is 25 cm from the eyepiece. Also find the magnifying power.

Sol. Given $f_0 = 2$ cm, $f_e = 5$ cm

$|v_o| + |u_e| = 20$ cm $\quad \therefore \quad v_e = -25$ cm

From lens formula

$$\frac{1}{f_e} = \frac{1}{v_o} - \frac{1}{u_e}$$

$$\frac{1}{u} = \frac{1}{v_e} - \frac{1}{f_e} = -\frac{1}{25} - \frac{1}{5} \quad \therefore u_e = -\frac{25}{6} \text{ cm}$$

Distance of real image from objective

$$v_o = 20 - |u_e| = 20 - \frac{25}{6} = \frac{120-25}{6} = \frac{95}{6} \text{ cm}$$

Now $\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$

Given $\frac{1}{u_o} = \frac{1}{v_o} - \frac{1}{f_o} = \frac{1}{(95/6)} - \frac{1}{2}$

i.e., $\frac{1}{u_o} = \frac{6}{95} - \frac{1}{2} = \frac{12-95}{190} = -\frac{83}{190}$

$\therefore \quad u_o = -\frac{190}{83} = -2.3 \text{ cm}$

Magnifying power $M = -\frac{v_o}{u_o}\left(1+\frac{D}{f_e}\right)$

$$= -\frac{95/6}{(190/83)}\left(1+\frac{25}{3}\right) = -41.5$$

35. Telescope :

To look at distant objects , we use telescopes.

There are three types of refracting telescopes :

(1) Astronomical Telescope :

It is used to see the heavenly bodies.

Construction :

It consists of two convex lenses mounted coaxially in two metallic tubes.

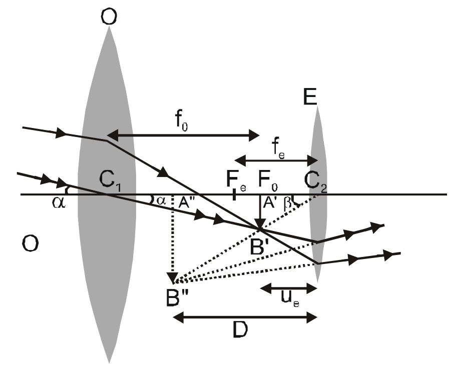
The lens facing the object is called objective lens O. It has large aperture and large focal length f_O.

The other lens through which the image is observed is called eyepiece E. It is of small aperture and has small focal length f_E.

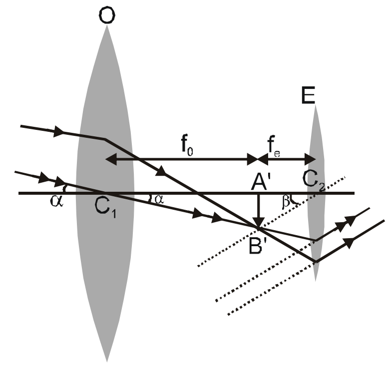
The tube having eyepiece can be moved in and out of the tube holding objective lens with the help of rack and pinion arrangement.

Ray Diagram :

(a) When the final image is at D :



(b) When the final image is at D :



Theory :

- The intermediate image formed by objective is real, inverted and small.
- The final image formed by eye-piece inverted and small.

(B) Magnifying power (angular magnification) :

Magnifying power of an astronomical telescope is defined as the ratio of the angle subtended by the final image at the eye to the angle subtended by the object at the eye.

If α and β be the angle subtended by the object and image at the eye respectively, then

$$M = \frac{\beta}{\alpha} = \frac{f_O}{u_E}$$

- **When the final image is at infinity :**

Magnifying power : $M_\infty = \left(\frac{f_O}{f_E}\right)$

Length of the telescope : $L_\infty = f_O + f_E$

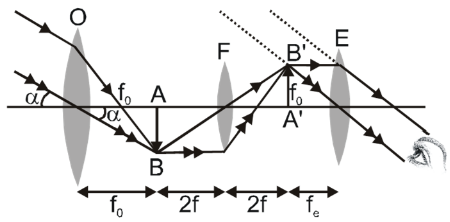
- **When the final image is at D :**

  Magnifying power : $M_D = \left(\frac{f_O}{f_E}\right)\left(1+\frac{f_E}{D}\right)$

  Length of the telescope : $L_D = f_O + \frac{Df_E}{D+f_E}$

(2) Terrestrial Telescope :

- Terrestrial telescope is used to see the objects on the earth, so the image produced should be erect.
- It consists of three converging lenses namely objective, eyepiece and field lens. This field lens is called erecting lens.
- The field lens is placed between the objective and eyepiece.



- The magnifying power or angular magnification of terrestrial telescope is remains same as in the case of astronomical telescope

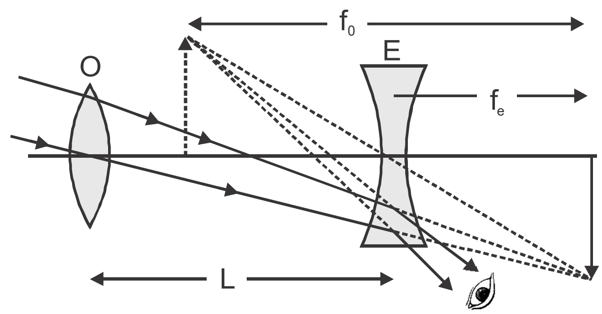
$$M_\infty = \left(\frac{f_O}{f_E}\right) \ \& \ M_D = \left(\frac{f_O}{f_E}\right)\left(1+\frac{f_E}{D}\right)$$

- But length of telescope is

$$L_\infty = f_O + 4f + f_E \ \& \ L_D = f_O + 4f + \frac{Df_E}{D+f_E}$$

(3) Galilean Telescope :

- It is used as a terrestrial telescope but of much smaller field of view.
- In such telescope, a convex lens is used as the objective and a concave lens as an eye piece.
- The objective lens forms a real and inverted image but the divergent lens comes in between.
- This intermediate image acts as virtual object for eye-piece.
- The intermediate image is formed at second focus of objective.
- Final image is erect and magnified as shown in figure.
- This telescope suffers from loss of brightness.



- It has same expressions for magnifying power as in the case of astronomical telescope.

$$M_\infty = \left(\frac{f_O}{f_E}\right) \ \& \ M_D = \left(\frac{f_O}{f_E}\right)\left(1+\frac{f_E}{D}\right)$$

- But length of telescope is

$$L_\infty = f_O - f_E \ \& \ L_D = f_O - \frac{Df_E}{D-f_E}$$

(4) Reflecting type telescope :

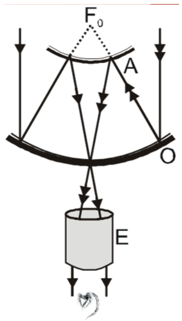
To overcome the spherical and chromatic aberration and light gathering capacity, the objective lens of the telescope is replaced by paraboloidal mirror of large aperture. Such a telescope is known as reflecting type telescope.

There are many types of reflecting type telescopes.

(A) Cassegrain type telescope :

It consists of a concave mirror O of large aperture with a circular hole is its centre and a small convex mirror A placed in front of the objective O of the telescope.

Final image is observed through an eye piece placed in front of the hole of objective.

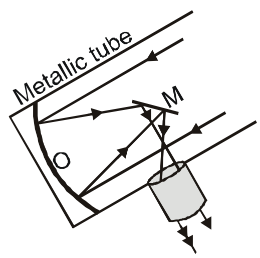


(ii) Newtonian Telescope :

It consists of a concave mirror of large aperture and large focal length known as objective. This mirror is fitted at one end of the metallic tube whose other end is open.

A plane mirror M is placed at an angle of 45° with axis of the tube.

Final image is seen through the eyepiece fitted at one side of the tube as shown in figure. Eye piece acts as a magnifier.



If f_0 = focal length of the concave mirror used as objective and f_e = focal length of the eye piece, then the magnifying power or reflecting telescope is

$$M = \frac{f_O}{f_E} = \frac{R}{2f_E}$$

This shows that larger is the radius of curvature of the concave mirror (objective), larger will be the magnifying power of the reflecting telescope.

(C) Advantages & Disadvantages

Advantages of reflecting type telescope :

- Reflecting type telescopes are free from chromatic and spherical aberrations. Hence sharp image of the object is formed.
- Since the mirrors used in reflecting type telescopes reflect the whole light falling on them, so the image formed by these telescope is quite bright.
- The paraboloidal mirrors of large aperture can be easily manufactured.

Disadvantages of reflecting type telescope :

- These type of telescopes need frequent adjustments and hence inconvenient to use.
- They cannot be used for general purpose.

CHARACTERISTIC OF TELESCOPE

A good telescope should have high magnifying power, high resolving power and large light gathering power.

- **Magnifying power**
- **Resolving power**
- **Light gathering power :** The light gathering power (or brightness) of a telescope is directly proportional to the area of the objective lens $\left(\pi D^2/4\right)$, where D is the diameter of the objective.
- **Brightness ratio.** The brightness ratio of a telescope is defined as the ratio of the light gathered by the telescope to the light gathered by the unaided eye from the distant objects.

Let D is diameter of the objective lens of the telescope and d is the diameter of the eye lens

Since, light gathered by the a lens is proportional to its area, therefore

$$\text{Brightness ratio} = \frac{\pi D^2/4}{\pi d^2/4} = \frac{D^2}{d^2}$$

Example 105

Focal length of objective is 50 cm and that of eye piece is 2 cm. in astronomical telescope. Find MP and its length (i) When final image is at ∞ (ii) When final image is at D

Sol. (i) $\text{M.P.} = -\dfrac{f_O}{f_e} = -\dfrac{50}{2} = -25X$

$L = f_O + f_e = 52 \text{ cm}$

(ii) $\text{M.P.} = \dfrac{f_O}{f_e}\left(1+\dfrac{f_e}{D}\right) = 27X$

$L = f_O + \dfrac{f_e D}{f_e + D} = 51.8 \text{ cm}$

Example 106

The magnifying power of the telescope is found to be 9 and the separation between the lenses is 20 cm for relaxed eye. What are the focal lengths of component lenses?

Sol. Magnification $M = \dfrac{F}{f}$

Separation between lenses

$d = F + f$

Given $\dfrac{F}{f} = 9$ i.e., $F = 9f$ ......(1)

and $F + f = 20$ ......(2)

Putting value of F from (1) in (2), we get

$9f + f = 20 \Rightarrow 10\, f = 20 \qquad \Rightarrow \dfrac{20}{10} = 2\text{cm}$

$\therefore\ F = 9f = 9 \times 2 = 18 \text{ cm} \quad \therefore\ F = 18 \text{ cm}, f = 2 \text{ cm}$

Example 107

A telescope consists of two convex lens of focal length 16 cm and 2 cm. What is angular magnification of telescope for relaxed eye? What is the separation between the lenses?

If object subtends an angle of 0.5º on the eye, what will be angle subtended by its image?

Sol. Angular magnification, $M = \dfrac{\beta}{\alpha} = \dfrac{F}{f} = \dfrac{16}{2} = 8$ cm

Separation between lenses $= F + f = 16 + 2 = 18$ cm

Here $\alpha = 0.5^\circ$

$\therefore$ Angular magnification subtended by image

$\beta = M\alpha = 8 \times 0.5^\circ = 4^\circ$

Example 108

Distance of objective of a telescope is 10 cm and wavelength of light is 5000 Å, 2 object are located at a distance of 1 km from the telescope. Find minimum distance between the objects for which objective of telescope is just able to resolve it.

Sol. $D = 10$ cm ; $\lambda = 5000$ Å

Distance between telescope and object = 1km

$\theta = \dfrac{x}{L}, \dfrac{1.22\lambda}{a} = \dfrac{x}{L}$

$\dfrac{1.22 \times 5 \times 10^{-7}}{10 \times 10^{-2}} = \dfrac{x}{10^3} = 6\text{mm}$

Exercise - 1 Objective Problems (NEET)

Plane Mirror & Spherical Mirror

1. A person is six feet tall. How tall must a vertical mirror be, if he is able to see his entire length ?

(1) 6 ft **(2)** 4.5 ft **(3)** 7.5 ft **(4)** 3 ft

[C. 70.52%, I.C. 26.17%, U.A. 3.31%]

2. An object is initially at a distance of 100 cm from a plane mirror. If the mirror approaches the object at a speed of 5 cm/s. Then after 6 s the distance between the object and its image will be -

(1) 60 cm **(2)** 140 cm **(3)** 170 cm **(4)** 150 cm

[C. 62.61%, I.C. 29.63%, U.A. 7.77%]

3. Which of the following letters do not suffer lateral inversion :-

(1) HGA **(2)** HOX **(3)** VET **(4)** YUL

[C. 62.59%, I.C. 26.36%, U.A. 11.05%]

4. A man 160 cm height stands in front of a plane mirror. His eyes are at a height of 150 cm from the floor. Then the minimum length of the plane mirror for him to see his full length image is-

(1) 85 cm **(2)** 170 cm **(3)** 80 cm **(4)** 340 cm

[C. 58.81%, I.C. 24.73%, U.A. 16.46%]

5. Which of the following can form erect, virtual, diminished image?

(1) plane mirror **(2)** concave mirror

(3) convex mirror **(4)** none of these

[C. 58.56%, I.C. 21.96%, U.A. 19.49%]

6. If an object approaches towards a plane mirror with velocity V, then image approaches the object with velocity-

(1) V **(2)** 1.5 V **(3)** 2 V **(4)** 3 V

[C. 57.62%, I.C. 30.96%, U.A. 11.43%]

7. Five images can be formed, if two plane mirrors are inclined to each other at an angle of :

(i) 60° (ii) 45° (iii) 72° (iv) 90°

(1) (i) and (ii) **(2)** (i), (ii) and (iv)

(3) (i) and (iii) **(4)** (i), (ii) and (iii)

[C. 57.62%, I.C. 30.96%, U.A. 11.43%]

8. A plane mirror is approaching you at a speed of 10 cm/ sec. You can see your image in it. At what speed will your image approach you

(1) 10 cm / sec **(2)** 5 cm / sec

(3) 20 cm / sec **(4)** 15 cm / sec

[C. 57.60%, I.C. 29.30%, U.A. 13.10%]

9. A watch shows the time as 3 : 25. What will be the time that appears when seen through a plane mirror ?

(1) 8 : 35 **(2)** 9 : 35 **(3)** 7 : 35 **(4)** 8 : 25

[C. 56.21%, I.C. 29.19%, U.A. 14.60%]

10. If an object is 30 cm away from a concave mirror of focal length 15 cm, the image will be

(1) errect **(2)** virtual

(3) diminished **(4)** of same size

[C. 55.57%, I.C. 28.04%, U.A. 16.39%]

11. An object is placed between two plane mirrors set at 60° to each other. The maximum number of images seen will be-

(1) 2 **(2)** 3 **(3)** 5 **(4)** 6

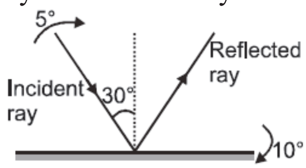
[C. 54.92%, I.C. 36.90%, U.A. 8.18%]

12. The image formed by convex mirror of focal length 30 cm is a quarter of the size of the object. Then the distance of the object from the mirror, is-

(1) 30 cm **(2)** 90 cm **(3)** 120 cm **(4)** 60 cm

[C. 53.46%, I.C. 32.05%, U.A. 14.49%]

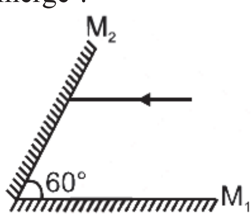
13. Figure shows a plane mirror into which a light ray is incident. If the incident ray is turned by 5^o and the mirror by 10^o, as shown, the angle turned by the reflected ray is :



(1) 15^o, clockwise **(2)** 25^o, clockwise
(3) 30^o, clockwise **(4)** 25^o, anticlockwise

[C. 52.49%, I.C. 30.60%, U.A. 16.91%]

14. Two plane mirrors are inclined at an angle of 60° as shown in figure. A ray of light parallel to M_1 strikes M_2. At what angle with mirror m_1 will the ray finally emerge ?



(1) 30° **(2)** 45° **(3)** 60° **(4)** 90°

[C. 52.29%, I.C. 30.20%, U.A. 16.91%]

15. A plane mirror makes an angle of 30^o with horizontall. If a vertical ray strikes the mirror, find the angle between mirror and reflected ray :

(1) 30° **(2)** 45° **(3)** 60° **(4)** 90°

[C. 51.92%, I.C. 23.80%, U.A. 24.18%]

16. A plane mirror rotating at an angular velocity of $3\ \text{radian}/\text{s}$ reflects a light beam. The angular velocity of the reflected beam is -

(1) 3 rad/s **(2)** 6 rad/s
(3) 9 rad/s **(4)** 12 rad/s

[C. 51.72%, I.C. 24.10%, U.A. 24.18%]

17. When light is reflected from a mirror a change occurs in its :

(1) phase **(2)** frequency
(3) wavelength **(4)** speed

[C. 51.04%, I.C. 32.97%, U.A. 15.99%]

18. If a ray of light is incident on a plane mirror at an angle 60° from the mirror surface then angle of deviation produced by the mirror is

(1) 30° **(2)** 60° **(3)** 90° **(4)** 120°

[C. 50.44%, I.C. 33.16%, U.A. 16.40%]

19. A convex mirror has a focal length f. A real object is placed at a distance f in front of it from the pole, then it produces an image at-

(1) Infinity **(2)** f
(3) f/2 **(4)** 2f

[C. 49.52%, I.C. 37.48%, U.A. 13.00%]

20. A convex mirror has a focal length of 20cm. A real object is placed at a distance of 20 cm in front of the mirror from the pole. The mirror produces an image at :

(1) Infinity **(2)** 20 cm
(3) 40 cm **(4)** 10 cm

[C. 49.27%, I.C. 37.73%, U.A. 13.00%]

21. An object 5 cm tall is placed 10 cm form a convex mirror of radius of curvature 30 cm. What is the nature and size of the image ?

(1) real, 3 cm **(2)** virtual, 7.5 cm
(3) virtual, 3 cm **(4)** real, 7.5 cm

[C. 49.02%, I.C. 37.23%, U.A. 13.00%]

22. An erect image, which is four times the size of a real object, is formed by a spherical mirror. If distance between the object and the image is 90 cm, then :

(1) it is a convex mirror of focal length 36 cm
(2) it is a concave mirror of focal length 36 cm
(3) it is a convex mirror of focal length 24 cm
(4) it is a concave mirror of focal length 24 cm

[C. 49.00%, I.C. 37.25%, U.A. 13.00%]

23. A point object on the principal axis at a distance 15 cm in front of concave mirror of radius of curvature 20 cm has velocity 2m/s perpendicular axis the magnitude of velocity of image at that instant will be

(1) 2 m/s **(2)** 4 m/s **(3)** 8 m/s **(4)** 6 m/s

[C. 48.50%, I.C. 37.25%, U.A. 13.50%]

24. Number of images of an object kept symmetrically between two mirrors inclined at angle 72^{o}, would be

(1) two **(2)** three **(3)** six **(4)** four

[C. 48.60%, I.C. 37.92%, U.A. 13.48%]

25. Radius of curvature of concave mirror is 40cm and the size of image is twice as that of object, then the object distance is

(1) 60cm **(2)** 20cm **(3)** 40cm **(4)** 30cm

[C. 48.60%, I.C. 37.92%, U.A. 13.48%]

26. An object 1 cm tall is placed 4 cm in front of a mirror. In order to produce an upright image of 3 cm height one needs a

(1) Convex mirror of radius of curvature 12 cm.
(2) Concave mirror of radius of curvature 12 cm.
(3) Concave mirror of radius of curvature 4 cm.
(4) Plane mirror of height 12 cm.

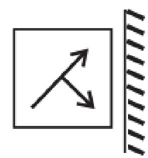
[C. 48.50%, I.C. 37.92%, U.A. 13.58%]

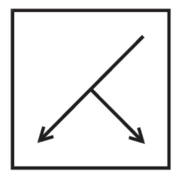
27. Image formed by a concave mirror of focal length 6 cm, is 3 times of the object, then the distance of object from mirror is

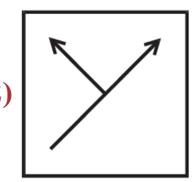
(1) – 4 cm **(2)** 18 cm
(3) 6 cm **(4)** 12 cm

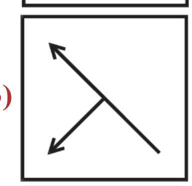
[C. 48.45%, I.C. 37.92%, U.A. 13.43%]

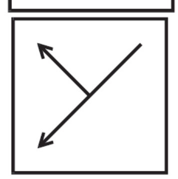
28. Choose the correct mirror image of figure given below –



(1) 

(2) 

(3) 

(4) 

[C. 48.41%, I.C. 36.62%, U.A. 14.97%]

29. The focal length of a concave mirror is 50 cm. Where an object be placed so that its image is two times magnified, real and inverted :-

(1) 75 cm **(2)** 72 cm **(3)** 63 cm **(4)** 50 cm

[C. 47.94%, I.C. 41.40%, U.A. 10.65%]

30. A candle is kept at a distance equal to double the focal length from the pole of a convex mirror, its magnification will be :

(1) $-\frac{1}{3}$ **(2)** $\frac{1}{3}$ **(3)** $\frac{2}{3}$ **(4)** $-\frac{2}{3}$

[C. 47.90%, I.C. 31.88%, U.A. 20.22%]

31. An object of length 5 cm is placed at a distance 1m from a concave mirror. If radius of curvature of mirror is 20 cm. Size of image will be -

(1) 0.11 cm **(2)** 0.50 cm
(3) 0.55 cm **(4)** 0.60 cm

[C. 47.82%, I.C. 38.83%, U.A. 13.36%]

32. An object is placed at a distance of 40 cm in front of a concave mirror of focal length 20 cm. The image produced is -

(1) virtual and inverted
(2) real and erect
(3) real inverted and diminished
(4) real, inverted and of same size as the object

[C. 47.73%, I.C. 34.39%, U.A. 17.88%]

33. A ray of light falls on a plane mirror. When the mirror is turned, about an axis which is at right angle to the plane of the mirror through 20º the angle between the incident ray and new reflected ray is 45º. The angle between the incident ray and original reflected ray was therefore:

(1) 65° **(2)** 25° or 65°
(3) 25° **(4)** 45°

[C. 46.92%, I.C. 43.75%, U.A. 9.33%]

34. Two plane mirrors are inclined at 70°. A ray incident on one mirror at angle θ after reflection falls on the second mirror and is reflected from there parallel to the first mirror, θ is :

(1) 50° **(2)** 45°
(3) 30° **(4)** 55°

[C. 46.03%, I.C. 43.88%, U.A. 10.08%]

35. The focal length of a concave mirror is 12 cm. Where should an object of length 4 cm be placed, so that a real image of 1 cm length is formed ?

(1) 48 cm **(2)** 3 cm
(3) 60 cm **(4)** 15 cm

[C. 45.54%, I.C. 32.24%, U.A. 22.22%]

36. A ray is incident at an angle 38° on a mirror. The angle between normal and reflected ray is

(1) 38° **(2)** 52°
(3) 90° **(4)** 76°

[C. 45.28%, I.C. 41.55%, U.A. 13.17%]

37. An object of height 1.5 cm is situated at a distance of 15 cm from a concave mirror. The concave mirror forms its real image of height 3.0 cm. The focal length of concave mirror will be

(1) -10 cm **(2)** -20 cm
(3) 20 cm **(4)** 30 cm

[C. 45.13%, I.C. 41.12%, U.A. 13.75%]

38. A concave mirror gives an image three times as large as the object placed at a distance of 20 cm from it. For the image to be real, the focal length should be -

(1) -10 cm **(2)** -15 cm
(3) -20 cm **(4)** -30 cm

[C. 45.03%, I.C. 41.22%, U.A. 13.75%]

39. Which of the following could not produce a virtual image.

(1) Plane mirror
(2) Convex mirror
(3) Concave mirror
(4) All the above can produce a virtual image

[C. 44.13%, I.C. 42.12%, U.A. 13.75%]

40. Two vertical plane mirrors are inclined at an angle of 60° with each other. A ray of light travelling horizontally is reflected first from one mirror and then from the other. The resultant deviation is

(1) 60° **(2)** 100°
(3) 180° **(4)** 240°

[C. 43.81%, I.C. 38.57%, U.A. 17.62%]

41. Two plane mirrors are inclined to each other at 70º. A ray of light is incident on one mirror. The ray will undergo a total deviation of :

(1) 180º
(2) 220º
(3) 40º
(4) Cannot be found because angle of incidence is not given.

[C. 43.50%, I.C. 38.88%, U.A. 17.62%]

42. Two plane mirrors are inclined to each other at 90º. A ray of light is incident on one mirror and the reflected light goes to the other mirror. The ray will undergo a total deviation of :

(1) 180º
(2) 90º
(3) 45º
(4) Cannot be found because angle of incidence is not given.

[C. 43.00%, I.C. 38.57%, U.A. 18.43%]

43. An object of height 7.5 cm is placed in front of a convex mirror of radius of curvature 25 cm at a distance of 40 cm. The height of the image should be -

(1) 2.3 cm **(2)** 1.78 cm
(3) 1 cm **(4)** 0.8 cm

[C. 42.94%, I.C. 24.78%, U.A. 32.28%]

44. In case of concave mirror, the minimum distance between a real object and its real image is:

(1) f **(2)** 2f
(3) 4f **(4)** Zero

[C. 41.92%, I.C. 34.74%, U.A. 23.34%]

45. The distance of an object from the focus of a convex mirror of radius of curvature ' a ' is ' b '. Then the distance of the image from the focus is:

(1) $b^2 / 4a$ **(2)** a / b^2
(3) $a^2 / 4b$ **(4)** $4b / a^2$

[C. 40.92%, I.C. 34.74%, U.A. 24.34%]

46. The light reflected by a plane mirror may form a real image

(1) If the ray incident on the mirror are diverging
(2) If the rays incident on the mirror are converging
(3) If the object is placed very close to the mirror
(4) Under no circumstances

[C. 28.09%, I.C. 40.43%, U.A. 31.48%]

47. Two plane mirrors are placed parallel to each other. The distance between the mirrors is 10 cm. An object is placed between the mirrors at a distance of 4 cm from one of them, say M_1. What is the distance between the first image formed at M_1 and the second image formed at M_2?

(1) 14 cm **(2)** 26 cm
(3) 24 cm **(4)** 28 cm

[C. 24.73%, I.C. 22.04%, U.A. 53.23%]

Refraction At Plane Surface, Snell'S Law, Apparent Depth And T.I.R.

48. An object is immersed in a fluid. In order that the object becomes invisible, it should-

(1) Behave as a perfect reflector

(2) Absorb all light falling on it

(3) Have refractive index one

(4) Have refractive index exactly matching with that of the surrounding fluid

[C. 81.58%, I.C. 13.16%, U.A. 5.26%]

49. A ray of light passes from glass having a refractive index of 1.6, to air. The angle of incidence for which the angle of refraction is twice the angle of incidence is :

(1) $\sin^{-1}\left(\frac{4}{5}\right)$ **(2)** $\sin^{-1}\left(\frac{3}{5}\right)$

(3) $\sin^{-1}\left(\frac{5}{8}\right)$ **(4)** $\sin^{-1}\left(\frac{2}{5}\right)$

[C. 80.58%, I.C. 14.16%, U.A. 5.26%]

50. If a ray falls on a plane mirror kept along x-axis of gets reflected along line y = x than the incident ray was travelling along line.

(1) $y - x = 0$

(2) $y + x = 0$

(3) $y - 2x = 0$

(4) $y + 2x = 0$

[C. 72.56%, I.C. 23.35%, U.A. 4.09%]

51. When light travels from one medium to another, there is no change in its :

(1) velocity **(2)** amplitude

(3) frequency **(4)** wavelength

[C. 68.15%, I.C. 24.89%, U.A. 6.95%]

52. How much water should be filled in a container 21 cm in height, so that it appears half filled when viewed from the top of the container (given that ${}_a\mu_\omega = 4/3$)

(1) 8.0 cm **(2)** 10.5 cm

(3) 12.0 cm **(4)** None of the above

[C. 63.17%, I.C. 32.46%, U.A. 4.37%]

53. A glass slab of thickness 3 cm and refractive index 3/2 is placed on ink mark on a piece of paper. For a person looking at the mark at a distance 5.0 cm above it, the distance of the mark will appear to be

(1) 3.0 cm **(2)** 4.0 cm

(3) 4.5 cm **(4)** 5.0 cm

[C. 62.93%, I.C. 32.46%, U.A. 4.37%]

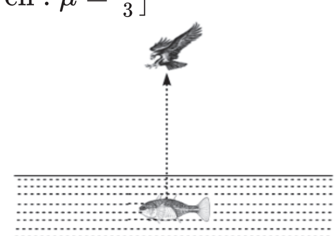
54. A fish at a depth of 12 cm in water is viewed by an observer on the bank of a lake. To what height the image of the fish is raised ?

(1) 9 cm **(2)** 12 cm

(3) 3.8 cm **(4)** 3 cm

[C. 62.67%, I.C. 32.71%, U.A. 4.37%]

55. A fish rising vertically up towards the surface of water with speed 2 m s^{-1} observes a bird diving vertically down towads it with speed 10 m s^{-1}. The actual velocity of bird is : $\left[\text{Given} : \mu = \frac{4}{3}\right]$



(1) 4.5 m s^{-1} **(2)** 6 m s^{-1}

(3) 3.0 m s^{-1} **(4)** 3.4 m s^{-1}

[C. 62.42%, I.C. 32.46%, U.A. 4.87%]

56. Glass has refractive index μ with respect to air and the critical angle for a ray of light going from glass to air is θ. If a ray of light is incident from air on the glass with angle of incidence θ, the corresponding angle of refraction is :

(1) $\sin^{-1}\left(\frac{1}{\mu}\right)$ (2) 90^{o}

(3) $\sin^{-1}\left(\frac{1}{\mu^2}\right)$ (4) $\sin^{-1}\left(\frac{1}{\mu}\right)$

[C. 62.17%, I.C. 33.21%, U.A. 4.37%]

57. An optical fibre (μ = 1.72) is surrounded by a glass coating (μ = 1.50). Find the critical angle for total internal, reflection at the fibre - glass interface

(1) $\cos^{-1}\frac{75}{86}$ (2) $\sin^{-1}\frac{75}{86}$

(3) $\cos^{-1}\frac{55}{65}$ (4) $\sin^{-1}\frac{55}{65}$

[C. 61.92%, I.C. 32.46%, U.A. 5.37%]

58. A ray of light travels through a transparent slab with a speed of 2×10^{10} cms^{-1}. This implies that the refractive index of the slab material is-

(1) 1.5 (2) 0.667 (3) 2.0 (4) 6.0

[C. 60.35%, I.C. 26.43%, U.A. 13.22%]

59. The refractive index of water is (4/3) and that of glass is (3/2) .If the speed of light in glass is 2×10^{8} m/s. The speed of light in water will be -

(1) 1×10^8 m/s (2) $(9/4) \times 10^8$ m/s

(3) $(8/3) \times 10^8$ m/s (4) 4×10^8 m/s

[C. 60.24%, I.C. 28.19%, U.A. 11.56%]

60. The critical angle of light going from medium A to medium B is θ. The speed of light in medium A is v. The speed of light in medium B is:

(1) $\frac{v}{\sin\theta}$ (2) $v \sin \theta$

(3) $v \cot \theta$ (4) $v \tan \theta$

[C. 58.29%, I.C. 29.29%, U.A. 12.42%]

61. Colour of light is determined by its :

(1) velocity in air (2) amplitude

(3) frequency (4) wavelength

[C. 58.27%, I.C. 29.31%, U.A. 12.42%]

62. Velocity of light is maximum in :

(1) diamond (2) water

(3) vacuum (4) hydrogen

[C. 58.25%, I.C. 29.31%, U.A. 12.44%]

63. When a ray of light goes from a rarer medium into a denser medium, then :

(1) speed of light is reduced

(2) frequency of light is increased

(3) wavelength of light is increased

(4) none of the above effects will be observed

[C. 58.23%, I.C. 29.33%, U.A. 12.44%]

64. In glass the velocity of red light :

(1) is same as that of violet light

(2) is more than that of violet light

(3) is lesser than that of violet light

(4) is 3×10^8 m/s

[C. 58.21%, I.C. 29.35%, U.A. 12.44%]

65. A train is approaching towards a stationary person with velocity v. The train emits a light signal. The signal will reach the stationary person with a velocity :

(1) c (2) c + v

(3) c – v (4) $\sqrt{c^2 + v^2}$

[C. 58.19%, I.C. 29.35%, U.A. 12.46%]

66. A monochromatic beam of light passes from a denser medium into a rarer medium. As a result

(1) Its velocity increases
(2) Its velocity decreases
(3) Its frequency decreases
(4) Its wavelength decreases

[C. 58.15%, I.C. 22.87%, U.A. 18.99%]

67. A man runs towards a mirror at a speed 15 m/s. The speed of the image relative to the man is :-

(1) 15 ms^{-1} **(2)** 30 ms^{-1}
(3) 35 ms^{-1} **(4)** 20 ms^{-1}

[C. 57.32%, I.C. 27.19%, U.A. 15.49%]

68. A ray of light is travelling from air into a medium of refractive index 3/2. The speed, wavelength and frequency of light in air are c, λ and f respectively. Which one of the following statements is true ?

(1) The speed in the medium is 3c/2
(2) The frequency in the medium is 2f/3
(3) The wavelength in the medium is $2\lambda/3$
(4) The wavelength in the medium is $3\lambda/2$

[C. 55.82%, I.C. 27.19%, U.A. 16.99%]

69. When light travels from one medium to the other of which the refractive index is different, then which of the following will change

(1) Frequency,wavelenght and velocity
(2) Frequency and wavelength
(3) Frequency and velocity
(4) Wavelength and velocity

[C. 54.70%, I.C. 26.50%, U.A. 18.80%]

70. The refractive index of material varies with wavelength according to the Cauchy's relation is-

(1) $\mu = A\lambda + B$ **(2)** $\mu = A + \frac{B}{\lambda^2}$
(3) $\mu = A \times \frac{B}{\lambda}$ **(4)** $\mu = A^2\lambda + B$

[C. 52.30%, I.C. 33.42%, U.A. 14.29%]

71. Light travels through a glass of thickness t and refractive index n. If c is the velocity of light in vacuum, the time taken by light to travel through the plate is

(1) t/nc **(2)** ntc
(3) nt/c **(4)** tc/n

[C. 52.19%, I.C. 32.13%, U.A. 15.67%]

72. The refractive index of a certain glass is 1.5 for light whose wavelength in vacuum is 6000 Å. The wavelength of this light when it passes through glass is

(1) 4000 Å **(2)** 6000 Å
(3) 9000 Å **(4)** 15000 Å

[C. 50.06%, I.C. 31.14%, U.A. 18.80%]

73. The critical angle for diamond (refractive index = 2) is

(1) About 20° **(2)** 60°
(3) 45° **(4)** 30°

[C. 48.34%, I.C. 37.34%, U.A. 14.32%]

74. The total internal reflection of a beam of light occurs when beam of light enters-
[i_c = critical angle, i = angle of incidence]

(1) Rarer medium from a denser medium and $i < i_c$
(2) Rarer medium from a denser medium $i > i_c$
(3) Denser medium from a rarer medium $i < i_c$
(4) Denser medium from a rarer medium $i > i_c$

[C. 46.69%, I.C. 38.12%, U.A. 15.19%]

75. The refractive index of a piece of transparent quartz is the greatest for

(1) Red light **(2)** Violet light
(3) Green light **(4)** Yellow light

[C. 45.78%, I.C. 34.44%, U.A. 19.78%]

76. The ratio of the refractive index of red light to blue light in air is.

(1) Less than one

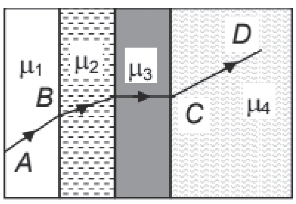
(2) Equal to one

(3) Greater than one

(4) Less as well as greater than one depending upon the experimental arrangement

[C. 41.06%, I.C. 33.54%, U.A. 25.41%]

77. A ray of light passes through four transparent media with refractive indices μ_1, μ_2, μ_3 and μ_4 as shown in the figure. The surfaces of all media are parallel. If the emergent ray CD is parallel to the incident ray AB, we must have



(1) $\mu_1 = \mu_2$ **(2)** $\mu_2 = \mu_3$

(3) $\mu_3 = \mu_4$ **(4)** $\mu_4 = \mu_1$

[C. 40.95%, I.C. 13.33%, U.A. 45.71%]

78. Total internal reflection occurs in waves, when wave enters-

(1) Glass from air

(2) Air from vaccum

(3) Water from air

(4) Air from water

[C. 40.32%, I.C. 40.78%, U.A. 18.89%]

79. A ray of light passes through a plane glass slab of thickness t and refractive index μ = 1.5. The angle between incident ray and emergent ray will be

(1) 0° **(2)** 30°

(3) 45° **(4)** 60°

[C. 39.97%, I.C. 32.46%, U.A. 27.56%]

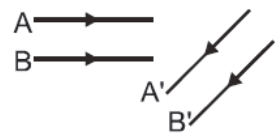
80. Light of frequency 5×10^{14} Hz is travelling in a medium of refractive index 1.5. What is its wavelength ? (c $= 3 \times 10^8$ ms^{-1})

(1) 9000 Å **(2)** 6000 Å

(3) 4500 Å **(4)** 4000 Å

[C. 38.47%, I.C. 32.46%, U.A. 29.06%]

81. Figure shows two rays A and B being reflected by a mirror and going as A' and B'. The mirror



(1) is plane mirror

(2) is convex mirror

(3) is concave mirror

(4) may be any spherical mirror

[C. 32.87%, I.C. 45.63%, U.A. 21.50%]

82. Light appears to travels in a straight line because:

(1) it consists of small particles

(2) the velocity of light is very large

(3) the wavelength of light is very small

(4) light is reflected by surroundings

[C. 4.76%, I.C. 46.03%, U.A. 49.21%]

Prism And Dispersion Of Light

83. Deviation "δ" produced by a prism of refractive index "μ" and small angle "A" is given by-

(1) $\delta = (\mu - 1)A$ **(2)** $\delta = (\mu + 1)A$

(3) $\delta = (A - 1)\mu$ **(4)** $\delta = (A + 1)\mu$

[C. 60.45%, I.C. 8.46%, U.A. 31.09%]

84. The angle of a glass prism is 4.5° and its refractive index is 1.52. The angle of minimum deviation will be –

(1) 1.5° **(2)** 2.3°

(3) 4.5° **(4)** 2°

[C. 59.19%, I.C. 30.72%, U.A. 10.09%]

85. When a ray of light is refracted by a prism such that the angle of deviation is minimum, then -

(1) the angle of emergence is equal to the angle of incidence
(2) the angle of emergence is greater than the angle of incidence
(3) the angle of emergence is smaller than the angle of incidence
(4) the sum of the angle of incidence and the angle of emergence is equal to 90°

[C. 55.66%, I.C. 31.29%, U.A. 13.05%]

86. If the angle of a prism is 60º and angle of minimum deviation is 40º, then the angle of refraction will be

(1) 30º **(2)** 4º
(3) 3º **(4)** 2.6º

[C. 51.99%, I.C. 40.70%, U.A. 7.31%]

87. The wavelength of light in two liquids 'x' and 'y' is 3500 Å and 7000 Å, then the critical angle will be

(1) 60° **(2)** 45°
(3) 30° **(4)** 15°

[C. 51.87%, I.C. 30.97%, U.A. 17.16%]

88. A ray of light passes through equilateral Prism (μ =1.5) such that angle of incidence is equal to angle of emergence and the later is equal to 3/4th of Prism angle. The angle of deviation is

(1) 60° **(2)** 30°
(3) 45° **(4)** 120°

[C. 50.71%, I.C. 41.96%, U.A. 7.33%]

89. White light is passed through a prism whose angle is 5º. If the refractive indices for rays of red and blue colour are respectively 1.64 and1.66, the angle of deviation between the two colours will be

(1) 0.1º **(2)** 0.2º **(3)** 0.3º **(4)** 0.4º

[C. 50.12%, I.C. 40.90%, U.A. 8.98%]

90. Angle of minimum deviation for a prism of refractive index 1.5 is equal to the angle of prism. The angle of prism is (cos 41° = 0.75):-

(1) 62° **(2)** 41°
(3) 82° **(4)** 31°

[C. 48.38%, I.C. 44.07%, U.A. 7.54%]

91. A spectrum is formed by a prism whose dispersive power is ω . If the deviation of the mean ray is δ , the angular dispersion of the spectrum is -

(1) ω / δ **(2)** δ / ω
(3) $1/ \omega \delta$ **(4)** $\omega \delta$

[C. 46.49%, I.C. 43.58%, U.A. 9.93%]

92. The refractive index of flint glass for blue line is 1.6333 and red line is 1.6161, then dispersive power of the glass is -

(1) 0.0276 **(2)** 0.276
(3) 2.76 **(4)** 0.106

[C. 44.79%, I.C. 46.21%, U.A. 9.00%]

93. The refractive indices of violet and red light are 1.54 and 1.52 respectively. If the angle of prism is 10°, then the angular dispersion is

(1) 0.02° **(2)** 0.2°
(3) 3.06° **(4)** 30.6°

[C. 44.13%, I.C. 21.82%, U.A. 34.05%]

94. Indicate the correct statement in the following

(1) The dispersive power depends upon the angle of prism
(2) The angular dispersion depends upon the angle of the prism
(3) The angular dispersion does not depend upon the dispersive power
(4) The dispersive power in vacuum is one.

[C. 43.15%, I.C. 38.58%, U.A. 18.28%]

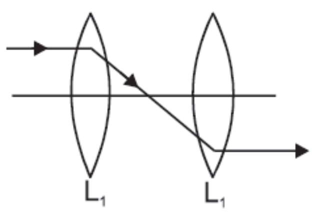
95. An achromatic prism is made by combining two prisms P_1 ($\mu_V = 1.523$, $\mu_R = 1.515$) and P_2($\mu_V = 1.666$, $\mu_R = 1.650$), where μ represents the refractive index. If the angle of the prism P_1 is 6º, then the angle of the prism P_2 will be :

(1) 5º **(2)** 12º
(3) 10.6º **(4)** 3º

[, I.C. 9.62%, U.A. 90.38%]

Refraction From Spherical Surface And Lens

96. In the figure given below, there are two convex lens L_1 and L_2 having focal length of f_1 and f_2 respectively. The distance between L_1 and L_2 will be



(1) f_1 **(2)** f_2
(3) $f_1 + f_2$ **(4)** $f_1 - f_2$

[C. 63.53%, I.C. 25.59%, U.A. 10.88%]

97. In a compound microscope magnification will be large, if the focal length of the eye piece is :

(1) Large
(2) Smaller
(3) Equal to that of objective
(4) Less than that of objective

[C. 58.82%, I.C. 35.29%, U.A. 5.88%]

98. A double convex lens has two surfaces of equal radii R and refractive index $\mu = 1.5$.We have,

(1) f = R/2 **(2)** f = R **(3)** f = –R **(4)** f = 2R

[C. 56.82%, I.C. 35.29%, U.A. 7.88%]

99. If I_1 and I_2 be the sizes of the images respectively for the two positions of the lens in the displacement method, then the size of the object is given by -

(1) $I_1 I_2$ **(2)** $\sqrt{(I_1 I_2)}$
(3) $\sqrt{(I_1/I_2)}$ **(4)** $\sqrt{(I_2/I_1)}$

[C. 55.77%, I.C. 28.85%, U.A. 15.38%]

100 The plane surface of a Plano convex lens of focal length f is silvered. It will behave as :

(1) Plane mirror
(2) Convex mirror of focal lengths 2f
(3) Concave mirror of focal length f/2
(4) None of the above

[C. 55.77%, I.C. 28.85%, U.A. 15.38%]

101 Two convex lens of focal length 20 cm and 25 cm are placed in contact with each other, then power of this combination is –

(1) + 1 D **(2)** + 9 D
(3) − 1 D **(4)** − 9 D

[C. 55.74%, I.C. 34.84%, U.A. 9.43%]

102 A convex lens of glass (μ = 1.5) is immersed in water. Compared to its power in air, its power in water -

(1) increases
(2) decreases
(3) remain same
(4) nothing can be predicted

[C. 55.29%, I.C. 35.29%, U.A. 9.41%]

103 Lenses of powers 3D and -5D are combined to form a compound lens. An object is placed at a distance of 50 cm from this lens. Calculate the position of its image.

(1) -10cm **(2)** +10cm
(3) - 25cm. **(4)** + 25cm

[C. 53.71%, I.C. 35.81%, U.A. 10.48%]

104 When a thin convex lens is put in contact with a thin concave lens of the same focal length, the resultant combination has a focal length equal to -

(1) f/2 **(2)** 2f **(3)** 0 **(4)** ∞

[C. 52.75%, I.C. 33.03%, U.A. 14.22%]

105 Focal length of a convex lens will be maximum for

(1) Blue light **(2)** Yellow light
(3) Green light **(4)** Red light

[C. 52.43%, I.C. 33.51%, U.A. 14.05%]

106 A thin linear object of size 1 mm is kept along the principal axis of a convex lens of focal length 10 cm. The object is at 15 cm from the lens. The length of the image is:

(1) 1 mm **(2)** 4 mm
(3) 2 mm **(4)** 8 mm

[C. 48.84%, I.C. 43.29%, U.A. 7.87%]

107 A thin convex lens of focal length 10 cm and a thin concave lens of focal length 26.2 cm are in contact. The combination acts as -

(1) concave lens of local length 16.4 cm
(2) convex lens of focal length 16.2 cm
(3) concave or convex lens depends upon μ of material of lenses
(4) none of the above

[C. 48.03%, I.C. 38.86%, U.A. 13.10%]

108 The two spherical surfaces of a double concave lens have the same radius of curvature R, and the refractive index of the medium enclosed by the refracting surfaces is μ then the focal length of the lens is

(1) $f = \frac{R}{2}$ **(2)** $f = \frac{R}{2(\mu-1)}$
(3) $f = \frac{R}{2(1-\mu)}$ **(4)** $f = \frac{-(\mu-1)R}{2}$

[C. 47.45%, I.C. 43.63%, U.A. 8.92%]

109 The radii of curvatures of a double convex lens are 15 cm and 30 cm, and its refractive index is 1.5. Then its focal length is -

(1) + 10 cm **(2)** − 10 cm
(3) + 20 cm **(4)** − 20 cm

[C. 46.96%, I.C. 43.77%, U.A. 9.28%]

110 A thin lens is made with a material having refractive index μ = 1.5. Both the sides are convex. It is dipped in water (μ = 1.33). It will behave like -

(1) a convergent lens **(2)** a divergent lens
(3) a rectangular slab **(4)** a prism

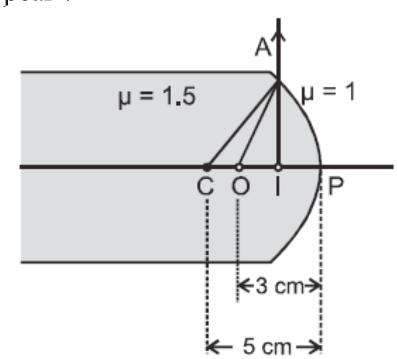
[C. 45.43%, I.C. 46.04%, U.A. 8.54%]

111 The radii of curvature of a lens are + 20 cm and + 30 cm. The material of the lens has a refracting index 1.6. Find the focal length of the lens (a) if it is placed in air, and (b) if it is placed in water (μ = 1.33).

(1) 100 cm & 300 cm **(2)** 200 cm & 450 cm
(3) 300 cm & 450 cm **(4)** 100 cm & 200 cm

[C. 45.41%, I.C. 46.06%, U.A. 8.54%]

112 An air bubble in glass (μ = 1.5) is situated at a distance 3 cm from a convex surface of diameter 10 cm as shown in figure. At what distance from the surface will the bubble appear ?



(1) 2.5 cm **(2)** 2 cm
(3) 3 cm **(4)** 4 cm

[C. 45.39%, I.C. 46.06%, U.A. 8.56%]

113 What is the refractive index of material of a plano-convex lens if the radius of curvature of the convex suface is 10 cm and focal length of the lens is 30 cm?

(1) $\frac{3}{2}$ **(2)** $\frac{4}{3}$ **(3)** $\frac{5}{4}$ **(4)** $\frac{6}{5}$

[C. 45.37%, I.C. 46.08%, U.A. 8.56%]

114 An object is placed at a distance of 75 cm from a screen. Where should a convex lens of focal length 12 cm be placed so as to obtain a real image of the object on the screen ?

(1) 15 cm from screen **(2)** 50 cm from screen
(3) 20 cm from screen **(4)** 45 cm from screen

[C. 45.27%, I.C. 46.18%, U.A. 8.56%]

115 A convex lens makes a real image 12 cm long on a screen. When the lens is shifted to a new position without disturbing the object or the screen, we again get a real image on the screen which is 27 cm long. The length of the object must be :

(1) 2.25 cm **(2)** 18 cm
(3) 6.50 cm **(4)** 36 cm

[C. 45.17%, I.C. 46.18%, U.A. 8.66%]

116 A convex lens of focal length 25 cm and a concave lens of focal length 20 cm are mounted coaxially separated by a distance d cm. If the power of the combination is zero, *d* is equal to

(1) 45 **(2)** 30
(3) 15 **(4)** 5

[C. 45.00%, I.C. 46.01%, U.A. 8.66%]

117 Focal length of convex lens is f. If this lens is cut perpendicular to principal axis in two equal parts then focal length of its half part will be:

(1) f/2 **(2)** f
(3) $\frac{3f}{2}$ **(4)** 2f

[C. 44.86%, I.C. 47.03%, U.A. 8.11%]

118 A convex lens of focal length f will form a magnified real image of an object if the object is placed -

(1) anywhere beyond 2f

(2) anywhere beyond f

(3) between f and 2f

(4) between lens and f

[C. 44.14%, I.C. 42.19%, U.A. 13.67%]

119 A convex lens is made up of three different materials as shown in the figure. For a point object placed on its axis, the number of images formed are

(1) 1 **(2)** 5
(3) 4 **(4)** 3

[C. 44.10%, I.C. 43.37%, U.A. 12.53%]

120 An object placed 10 cm in front of a lens has an image 20 cm behind the lens. What is the power of the lens (in diopters) -

(1) 1.5 **(2)** 3.0
(3) − 15.0 **(4)** + 15.0

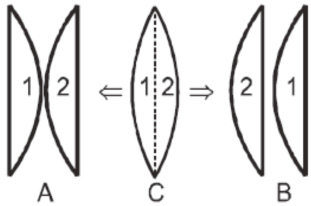
[C. 44.05%, I.C. 43.37%, U.A. 12.58%]

121 A thin glass (refractive index 1.5) lens has optical power of –5D in air. Its optical power in a liquid medium with refractive index 1.2 will be

(1) 25 D **(2)** –25D
(3) 1 D **(4)** None of these

[C. 44.03%, I.C. 43.39%, U.A. 12.58%]

122 A bi-convex lens L is cut into two parts 1 and 2. These parts are kept side by side as shown in figure A and B. The ratio of focal length of the systems A, B and C is

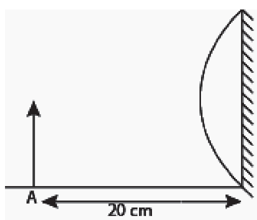


(1) 1 : 1 : 1 **(2)** 1 : 2 : 1

(3) 2 : 1 : 1 **(4)** 1 : 1 : 2

[C. 44.00%, I.C. 43.42%, U.A. 12.58%]

123 Focal length of the plano - convex lens is 15 cm. A small object is placed at A as shown in the figure. The plane surface is silvered. The image will form at



(1) 60 cm to the left of lens

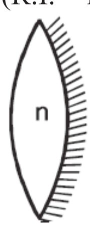
(2) 12 cm to the left of lens

(3) 60 cm to the right of lens

(4) 30 cm to the left of lens

[C. 43.50%, I.C. 43.92%, U.A. 12.58%]

124 An equi-convex lens of focal length f is silvered. The focal length of the combination is (R.I. = n)



(1) $\frac{f}{2}$ **(2)** $\frac{f}{2n-1}$

(3) $\frac{f}{2(n-1)}$ **(4)** $\frac{f(n-1)}{1-2n}$

[C. 43.48%, I.C. 43.94%, U.A. 12.58%]

125 A convex lens of focal length f is placed in contact with a plane mirror. The focal length of the combination is

(1) f **(2)** 2f

(3) $\frac{f}{2}$ **(4)** ∞

[C. 43.40%, I.C. 43.94%, U.A. 12.66%]

126 When the two thin lenses of same nature are put in contact, the focal length of the combination is -

(1) the geometric mean of the two focal lengths

(2) the same as the larger focal length

(3) greater than either focal length

(4) smaller than either focal length

[C. 43.81%, I.C. 42.48%, U.A. 13.72%]

127 A convex lens of focal length 20 cm and a concave lens of focal length f are mounted coaxially 5 cm apart. Parallel beam of light incident on the convex lens emerges from the concave lens as a parallel beam. Then f in cm is-

(1) 35 **(2)** 25

(3) 20 **(4)** 15

[C. 43.70%, I.C. 47.06%, U.A. 9.24%]

128 A convex lens form a real image of a point object placed on its principal axis. If the upper half of the lens is painted black, the image will

(1) Be shifted downwards

(2) Be shifted upwards

(3) Not be shifted

(4) Shift on the principal axis

[C. 42.28%, I.C. 40.94%, U.A. 16.78%]

129 A convex lens of Focal length of 40cm is in contact with a concave lens of focal length 25cm. The power of the combination is.

(1) -1.5 D **(2)** -6.5 D

(3) +6.5 D **(4)** +6.67 D

[C. 40.83%, I.C. 50.00%, U.A. 9.17%]

130 An object is put at a distance of 5 cm from the first focus of a convex lens of focal length 10cm.If a real image is formed.Its distance from the lens will be:

(1) 15cm **(2)** 20 cm **(3)** 25 cm **(4)** 30 cm

[C. 38.87%, I.C. 55.48%, U.A. 5.65%]

131 The image produced by a concave lens is -

(1) always virtual **(2)** always real

(3) always inverted **(4)** always enlarged

[C. 38.77%, I.C. 48.90%, U.A. 12.33%]

132 An object is placed at a distance of 10 cm (in a medium of $\mu = 1$) from the pole of a spherical refracting surface bounding a medium of $\mu = 1.5$. If the image formed is virtual and at a distance of 40 cm,then the spherical surface is -

(1) concave with radius of curvature $= 8$ cm

(2) convex with radius of curvature $= 8$ cm

(3) concave with radius of curvature $= 3.6$ cm

(4) convex with radius of curvature $= 3.6$ cm

[C. 38.48%, I.C. 53.91%, U.A. 7.61%]

133 A convex lens of focal length A and a concave lens of focal length B are placed in contact. The focal length of the combination is

(1) (A+B) **(2)** (A–B)

(3) $\frac{AB}{(A+B)}$ **(4)** $\frac{AB}{(B-A)}$

[C. 37.62%, I.C. 47.03%, U.A. 15.35%]

134 A lens of power + 2 diopters is placed in contact with a lens of power − 1 diopter. The combination will behave like -

(1) a convergent lens of focal length 50 cm

(2) a divergent lens of focal length 100 cm

(3) a convergent lens of focal length 100 cm

(4) a convergent lens of focal length 200 cm.

[C. 36.44%, I.C. 17.78%, U.A. 45.78%]

135 A convex lens of focal length 10 cm is in contact with a concave lens. The focal length of the combination is numerically equal to that of the concave lens. The focal length of the concave lens is -

(1) 10 cm **(2)** 15 cm

(3) 5 cm **(4)** 20 cm

[C. 36.26%, I.C. 51.65%, U.A. 12.09%]

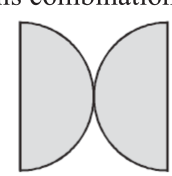
136 Two lenses of power +2.50 D and −3.75 D are combined to form a compound lens. Its focal length in cm will be -

(1) 40 **(2)** −40

(3) −80 **(4)** 160

[C. 35.57%, I.C. 19.24%, U.A. 45.19%]

137 A convex lens of focal length 25 cm is cut into two equal parts to obtain two planoconvex lenses which are then joined as shown in figure. Focal length of this combination is :



(1) 25 cm **(2)** 12.5 cm

(3) 50 cm **(4)** 100 cm

[C. 33.33%, I.C. 13.33%, U.A. 53.33%]

138 A concave mirror and a convex lens are of the same focal length in air. When they are immersed in water

(1) the concave mirror will have its focal length increased
(2) the convex lens will have its focal length increased
(3) they will have equal focal lengths, different from those in air
(4) they will have equal focal lengths, same as those in the air.

[C. 30.93%, I.C. 56.70%, U.A. 12.37%]

139 If the central portion of a convex lens is wrapped in black paper as shown in the figure

(1) No image will be formed by the remaining portion of the lens
(2) The full image will be formed but it will be less bright
(3) The central portion of the image will be missing
(4) There will be two images each produced by one of the exposed portions of the lens

[C. 24.19%, I.C. 30.65%, U.A. 45.16%]

140 A point object is placed in air at a distance of 40 cm from a concave refracting surface of refractive index 1.5. If the radius of curvature of the surface is 20 cm, then the position of the image is -

(1) in air and at 30 cm from pole
(2) in refracting medium and at 30 cm from pole
(3) in air and at infinity
(4) in refracting medium and at infinity

[C. 22.65%, I.C. 30.80%, U.A. 46.55%]

141 The focal length of a plano-concave lens is −10 cm, then its focal length when its plane surface is polished is (n = 3/2):

(1) 20 cm **(2)** –5 cm
(3) 5 cm **(4)** none of these

[C. 18.75%, I.C. 56.25%, U.A. 25.00%]

Microscope And Telescope

142 Magnification produced by objective of a compound microscope is 7. If the magnifying power of the microscope is 35, then the magnification produced by eyepiece will be

(1) 245 **(2)** 5 **(3)** 28 **(4)** 42

[C. 65.28%, I.C. 25.00%, U.A. 9.72%]

143 A microscope is focused on a mark, then a glass slab of refractive index 1.5 and thickness of 6 cm is placed on the mark to get the mark again in focus, the microscope should be moved

(1) 4 cm **(2)** 2 cm **(3)** 6 cm **(4)** 8 cm

[C. 57.95%, I.C. 31.82%, U.A. 10.23%]

144 An astronomical telescope has a magnifying power 10. The focal length of eyepiece is 20 cm. The focal length of objective is

(1) 2 cm **(2)** –200 cm
(3) $\frac{1}{2}$ cm **(4)** $\frac{1}{200}$ cm

[C. 55.30%, I.C. 26.68%, U.A. 18.02%]

145 The magnifying power of an astronomical telescope can be increased, if we -

(1) Increase the focal length of the objective
(2) Increase of the focal length of the eye piece
(3) Decreases the focal length of the objective
(4) Decrease the focal length of the objective and at the same time increase the focal length of the eye piece.

[C. 54.39%, I.C. 35.15%, U.A. 10.46%]

146 If F_0 and F_e are the focal lengths of the objective and eye-piece respectively for a Galilean telescope, its magnifying power is about

(1) $F_0 + F_e$ **(2)** $F_0 \times F_e$
(3) $-F_0/F_e$ **(4)** $1/2\ F_0 + F_e$

[C. 52.39%, I.C. 36.15%, U.A. 11.46%]

147 In a simple microscope, if the final image is located at infinity then its magnifying power-

(1) 25/F **(2)** 25/D
(3) F/25 **(4)** (1 +25/F)

[C. 51.29%, I.C. 38.01%, U.A. 10.70%]

148 An electron microscope gives better resolution that optical microscope because :

(1) electrons are abundant
(2) electrons can be focused nicely
(3) effective wavelength of electron is small
(4) none of these

[C. 48.28%, I.C. 34.48%, U.A. 17.24%]

149 The length of a telescope is 36 cm. The focal lengths of its lenses can be :-

(1) 30 cm, 6 cm **(2)** -30 cm,-6 cm
(3) 30 cm,-6 cm **(4)** -30 cm, 6 cm

[C. 47.71%, I.C. 43.12%, U.A. 9.17%]

150 In a simple microscope, if the final image is located at infinity then its magnifying power-

(1) 25/D **(2)** 25/F
(3) 1/f **(4)** (1+ D/F)

[C. 47.69%, I.C. 25.30%, U.A. 27.01%]

151 When length of a microscope tube increases its magnifying power -

(1) Decreases
(2) Increase
(3) Does not change
(4) May increase or decrease

[C. 44.55%, I.C. 45.87%, U.A. 9.57%]

152 The objective of a small telescope has focal length 120 cm and diameter 5 cm. The focal length of the eye piece is 2 cm. The magnifying power of the telescope for distant object is-

(1) 12 **(2)** 24
(3) 60 **(4)** 300

[C. 44.23%, I.C. 39.10%, U.A. 16.67%]

153 A compound microscope with an objective of 1.0 cm focal length and an eye-piece of 2.0 cm focal length has a tube of length of 20 cm. Calculate the magnifying power of the microscope, if the final image is formed at the near point of the eye.

(1) 350 **(2)** 100 **(3)** 540 **(4)** 270

[C. 44.23%, I.C. 39.10%, U.A. 16.67%]

154 A microscope has an objective of 5 mm focal length and eye-piece of 30 mm focal length and the distance between them is 150 mm. The magnification is

(1) 50 **(2)** 100 **(3)** 200 **(4)** 250

[C. 44.20%, I.C. 39.13%, U.A. 16.67%]

155 In astronomical telescope, the final image is formed at -

(1) The least distant of distinct vision
(2) The focus of objective lens
(3) The focus of the eye lens
(4) Infinity

[C. 44.19%, I.C. 48.84%, U.A. 6.98%]

156 Two convex lenses of focal length 0.3 m and 0.05 m are used to make a telescope. The distance kept between them is equal to -

(1) 0.35 m **(2)** 0.25 m
(3) 0.175 m **(4)** 0.15 m

[C. 44.14%, I.C. 48.89%, U.A. 6.98%]

157. The focal length of the objective of a microscope is-

(1) Greater than the focal length of eye piece
(2) Lesser than the focal length of the eye piece
(3) Equal to the focal length of the eye piece
(4) Any of (1) (2) and (3)

[C. 44.13%, I.C. 43.34%, U.A. 12.53%]

158. The final image produced by a compound microscope is -

(1) real and erect **(2)** virtual and erect
(3) virtual and inverted **(4)** real and inverted

[C. 35.96%, I.C. 49.44%, U.A. 14.61%]

159. An equiconvex lens has a power of 5 diopter. If it is made of glass of refractive index 1.5, then radius of curvature of its each surface will be

(1) 20cm **(2)** 10cm **(3)** 40cm **(4)** ∞

[C. 28.54%, I.C. 20.92%, U.A. 50.54%]

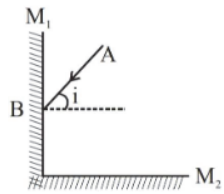
160. In a compound microscope focal length of objective and eyepiece lens is 4 cm and 8 cm respectively. If length of tube is 30 cm then magnifying power for normal adjustment will be :

(1) 20. 3 **(2)** 14. 06 **(3)** 23. 44 **(4)** 15. 3

[C. 11.35%, I.C. 4.37%, U.A. 84.27%]

Exercise - 2 Objective Problems (NEET)

1. The mirrors are perpendicular to each other as shown in the Fig. A light ray AB is incident on the mirror M_1. Then the reflected ray will also suffer a reflection from the mirror M_2. Then the final ray after reflection from M_2 will be parallel to the incident ray, if -



(1) i = 45º
(2) i = 60º
(3) i < 30º
(4) for any i between 0º and 90º

2. A ray of light making an angle 10° with the horizontal is incident on a plane mirror making a angle θ with the horizontal. What should be the value of θ so that the reflected ray goes vertically upwards -

(1) 20° **(2)** 30°
(3) 40° **(4)** 45°

3. A man moves towards a plane mirror with a velocity v in a direction making an angle θ with the normal to the mirror. The magnitude of velocity of the image relative to man normal to mirror will be -

(1) 2v **(2)** 2v cosθ
(3) 2v sinθ **(4)** 2v/cosθ

4. Rays of light strike a horizontal plane mirror at an angle of 45º. A second plane mirror is arranged at an angle θ with it. If the ray after reflection from the second mirror goes horizontally parallel to the first mirror then θ is

(1) 45° **(2)** 60°
(3) 67.5° **(4)** 135°

5. A ray of light makes an angle of 20º with the horizontal and strikes a plane mirror which is inclined at an angle θ to the horizontal. The angle θ for which the reflected ray becomes vertical, is -

(1) 40º **(2)** 80º
(3) 55º & 35º **(4)** 100º

6. Two plane mirrors are inclined to each other at an angle 60°. If a ray of light incident on the first mirror is parallel to the second mirror, it is reflected from the second mirror

(1) Perpendicular to the first mirror
(2) Parallel to the first mirror
(3) Parallel to the second mirror
(4) Perpendicular to the second mirror

7. Real image formed by a concave mirror of radius of curvature 40 cm is half the size of the object. Distance of object and its image from the mirror will respectively be

(1) 30 cm and 60 cm
(2) 60 cm and 120 cm
(3) 60 cm and 30 cm
(4) 120 cm and 60 cm

8. An infinitely long rod lies along the axis of a concave mirror of focal length f. The near end of the rod is at a distance u > f from the mirror. Its image will have a length

(1) $f^2/(u-f)$ **(2)** $uf/(u-f)$
(3) $f^2/(u+f)$ **(4)** $uf/(u+f)$

9. In a concave mirror experiment, an object is placed at a distance x_1 from the focus and the image is formed at a distance x_2 from the focus. The focal length of the mirror would be -

(1) x_1x_2 **(2)** $\sqrt{x_1x_2}$
(3) $\sqrt{x_1/x_2}$ **(4)** $\frac{x_1+x_2}{2}$

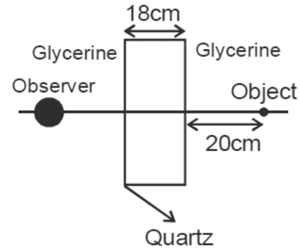
10. A small piece of wire bent into on L shape with upright and horizontal portions of equal lengths, is placed with the horizontal portion along the axis of the concave mirror whose radius of curvature is 10 cm. If the bend is 20 cm from the pole of the mirror, then the ratio of the lengths of the images of the upright and horizontal portions of the wire is -

(1) 1 : 2 **(2)** 3 : 1
(3) 1 : 3 **(4)** 2 : 1

11. A mark at the bottom of a beaker containing liquid appears to rise by 0.1m. The depth of the liquid is 1m. The refractive index of liquid is :

(1) 1.33 **(2)** 9/10
(3) 10/9 **(4)** 1.5

12. Given that, velocity of light in quartz = 1.5×10^8 m/s and velocity of light in glycerine = $\frac{9}{4} \times 10^8$ m/s. Now a slab made of quartz is placed in glycerine as shown. The shift of the object produced by slab is



(1) 6 cm **(2)** 3.55 cm
(3) 9 cm **(4)** 2 cm

13. A ray of light in a liquid of refractive index 1.4, approaches the boundary surface between the liquid and air at an angle of incidence whose sine is 0.8. Which of the following statements is correct about the behavior of the light

(1) It is impossible to predict the behavior of the light ray on the basis of the information supplied.
(2) The sine of the angle of refraction of the emergent ray will less than 0.8.
(3) The ray will be internally reflected
(4) The sine of the angle of refraction of the emergent ray will be greater than 0.8.

14. A ray of light enters a rectangular glass slab of refractive index $\sqrt{3}$ at angle of incidence 60°. It travels a distance of 5 cm inside the slab and emerges out of the slab. The perpendicular distance between the incident and the emergent rays is

(1) $5\sqrt{3}$cm **(2)** $\frac{5}{2}$ cm
(3) $5\sqrt{\frac{3}{2}}$cm **(4)** $\frac{5}{\sqrt{3}}$ cm

15. Light ray is incident on a prism of angle A = 60° and refractive index $\mu = \sqrt{2}$. The angle of incidence at which the emergent ray grazes the surface is given by

(1) $\sin^{-1}\left(\frac{\sqrt{3}-1}{2}\right)$ **(2)** $\sin^{-1}\left(\frac{1-\sqrt{3}}{2}\right)$

(3) $\sin^{-1}\left(\frac{\sqrt{3}}{2}\right)$ **(4)** $\sin^{-1}\left(\frac{2}{\sqrt{3}}\right)$

16. The refractive index of the material of the prism for a monochromatic beam of light is $\sqrt{2}$ and its refracting angle is 60º. The angle of incidence for which the ray of light suffers minimum deviation is

(1) 45º **(2)** 30º

(3) 60º **(4)** 75º

17. R.I. of a prism is $\sqrt{\frac{7}{3}}$ and the angle of prism is 60°. The limiting angle of incidence of a ray that will be transmitted through the prism is :

(1) 30° **(2)** 45°

(3) 15° **(4)** 50°

18. An object is placed at 10 cm from a lens and real image is formed with magnification of 0.5. Then the lens is :

(1) concave with focal length of 10/3 cm

(2) convex with focal length of 10/3 cm

(3) concave with focal length of 10 cm

(4) convex with focal length of 10 cm

19. A thin symmetrical double convex lens of power P is cut into three parts, as shown in the figure. Power of A is:

(1) 2P **(2)** $\frac{P}{2}$ **(3)** $\frac{P}{3}$ **(4)** P

20. A screen is placed 90 cm from an object. The image of an object on the screen is formed by a convex lens at two different locations separated by 20 cm. The focal length of the lens is

(1) 18 cm **(2)** 21.4 cm

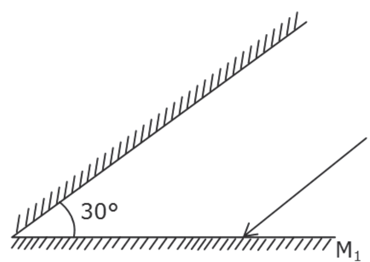
(3) 60 cm **(4)** 85.6 cm

21. An object placed in front of a plane mirror is displaced by 0.4 m along a straight line at an angle of 30° to the mirror plane. The change in the distance between the object and its image is

(1) 0.1 m **(2)** 0.2 m

(3) 0.3 m **(4)** 0.4 m

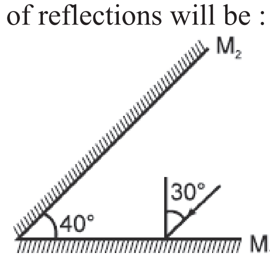
22. Two plane mirrors are inclined to each other at 30°. A ray is incident on M_1 at angle of incidence 40°. Find deviation produced in it by three successive reflections due to mirrors.



(1) 160°CW **(2)** 200°ACW

(3) 200°CW **(4)** 160°ACW

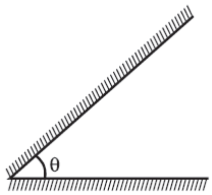
23. In the figure shown, the maximum number of reflections will be :



(1) 2 **(2)** 3

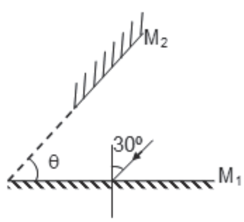
(3) 4 **(4)** 1

24. Two mirrors are inclined at an angle θ as shown in the figure. Light ray is incident parallel to one of the mirrors. Light will start retracing its path after third reflection if :



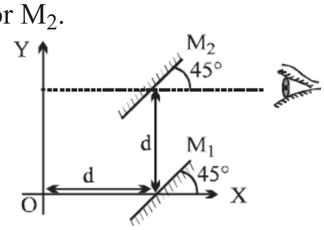
(1) $\theta = 45^0$ **(2)** $\theta = 30^0$
(3) $\theta = 60^0$ **(4)** all three

25. A ray of light is incident at an angle of 30º on a plane mirror M_1. Another plane mirror M_2 is inclined at angle θ to M_1. What is the value of angle θ so that light reflected from M_2 is parallel to M_1.



(1) 60º **(2)** 75º
(3) 67.5º **(4)** none of these

26. Find the coordinates of the image formed that of an object placed at origin, which the eye will observe in mirror M_2.



(1) (d, –d) **(2)** (– 2d, d)
(3) (– d, d) **(4)** (– d, 2d)

27. A point object is moving on the principal axis of a concave mirror of focal length 24 cm towards the mirror. When it is at a distance of 60 cm from the mirror, its velocity is 9 cm/sec. What is the velocity of the image at that instant -

(1) 5 cm/sec. **(2)** 12 cm/sec
(3) 4 cm/sec **(4)** 9 cm/sec

28. A convex mirror of focal length f forms an image which is $\frac{1}{n}$ times the object. The distance of the object from the mirror is

(1) $(n-1)f$ **(2)** $\left(\frac{n-1}{n}\right)f$
(3) $\left(\frac{n+1}{n}\right)f$ **(4)** $(n+1)f$

29. The focal length of a concave mirror is f and the distance from the object to the principle focus is x. The ratio of the size of the image to the size of the object is

(1) $\frac{f+x}{f}$ **(2)** $\frac{f}{x}$ **(3)** $\sqrt{\frac{f}{x}}$ **(4)** $\frac{f^2}{x^2}$

30. A point object is kept in front of a plane mirror. The plane mirror is performing SHM of amplitude 2 cm. The plane mirror moves along the x-axis and x- axis is normal to the mirror. The amplitude of the mirror is such that the object is always in front of the mirror. The amplitude of SHM of the image is

(1) zero **(2)** 2 cm **(3)** 4 cm **(4)** 1 cm

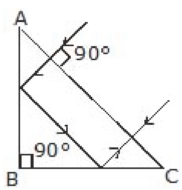
31. When a ray of light enters a medium of refractive index μ, it is observed that the angle of refraction is half the angle of incidence then angle of incidence is

(1) $2\cos^{-1}(\mu/2)$ **(2)** $\cos^{-1}(\mu/2)$
(3) $2\cos^{-1}(\mu)$ **(4)** $2\sin^{-1}(\mu/2)$

32. If μ_r, ε_r are the relative permeability and the dielectric constant of a medium, its refractive index is given by

(1) $1/\sqrt{\mu_r \varepsilon_r}$
(2) $1/(\mu_r \varepsilon_r)$
(3) $\sqrt{\mu_r \varepsilon_r}$
(4) $\mu_r \varepsilon_r$

33. A ray falls on a prism ABC (AB = BC) and travels as shown in figure. The minimum refractive index of the prism material should be-



(1) $\frac{4}{3}$ (2) $\sqrt{2}$
(3) 1.5 (4) $\sqrt{3}$

34. The refracting angle of a prism is 40°. A ray of light is incident at angle 38° and passes in the position of minimum deviation. The angle of minimum deviation is

(1) 40° (2) 38°
(3) 36° (4) 32°

35. The refractive indices of red, violet and yellow light are respectively 1.42, 1.62 and 1.50. The dispersive power of the medium will be -

(1) 0.4 (2) 0.3
(3) 0.2 (4) 0.1

36. A flint glass prism and a crown glass prism of angles A' and A respectively are to be combined in such a manner that there is dispersion without deviation.
For this to occur the ratio of A'/A must be :

(1) $(\mu_y - 1)/(\mu'_y - 1)$
(2) $(\mu'_y - 1)/(\mu_y - 1)$
(3) $(\mu'_y - 1)$
(4) $(\mu_y - 1)$

37. Prism angle of glass prism is 10°. It's refractive index of red and violet colour is 1.51 and 1.52 respectively. Then its dispersive power will be :-.

(1) 0.015 (2) 0.020
(3) 0.011 (4) 0.019

38. Monochromatic light is refracted from air into the glass of refractive index μ . The ratio of the wavelength of incident and refracted waves is

(1) 1 : μ (2) 1 : μ^2
(3) μ : 1 (4) 1 : 1

39. The focal length of a convex lens of glass (μ = 1.5) is 2 cm. The focal length of the lens when immersed in a liquid of refractive index 1.25 will be

(1) 5 cm (2) 2.4 cm
(3) 1 cm (4) 4 cm

40. The focal length of a plano-convex lens is equal to its radius of curvature. The value of the refractive index of its material is

(1) 1.33 (2) 1.6
(3) 1.5 (4) 2

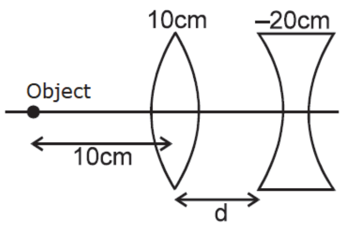
41. A convex lens forms a real image on a screen placed at a distance 60 cm from the object. When the lens is shifted towards the screen by 20 cm, another image of the object is formed on the screen. The focal length of the lens is -

(1) 45 cm **(2)** 40 /3 cm
(3) 30 cm **(4)** 12 cm

42. An object placed at a distance of a 9cm. from the first principal focus of a convex lens produces a real image at a distance of 25cm. from its second principal focus. then the focal length of the lens is :

(1) 9cm **(2)** 25cm
(3) 15cm **(4)** 17cm

43. What should be the value of distance d so that final image is formed on the object itself. (focal lengths of the lenses are written on the lenses).



(1) 10 cm **(2)** 20 cm
(3) 5 cm **(4)** none of these

44. In compound microscope the magnification is 95, and the distance of object from objective lens 1/3.8 cm and focal length of objective is 1/4 cm. What is the angular magnification of eye piece when final image is formed at least distance of distinct vision:-

(1) 5 **(2)** 10
(3) 100 **(4)** None of these

45. A compound microscope having $f_0 = 7$ mm, $f_e = 20$ mm and distance between the lens is 20 cm. If image is formed at least distance of distinct vision, then magnifying power :

(1) 337 **(2)** 400 **(3)** 220 **(4)** 120

46. Least distance of distinct vision is 25 cm, What will be Magnifying power of simple microscope of focal length 5 cm, if final image is formed at minimum distance of distinct vision –

(1) $\frac{1}{5}$ **(2)** 5 **(3)** $\frac{1}{6}$ **(4)** 6

47. The length of the compound microscope is 14 cm. The magnifying power for relaxed eye is 25. If the focal length of eye lens is 5 cm, then the object distance for objective lens will be:

(1) 1.8 cm **(2)** 1.5 cm
(3) 2.1 cm **(4)** 2.4 cm

48. If the focal length of objective and eye lens are 1.2 cm and 3 cm respectively and the object is put 1.25 cm away from the objective lens and the final image is formed at infinity. The magnifying power of the microscope is:

(1) 150 **(2)** 200 **(3)** 250 **(4)** 400

49. A telescope consisting of objective of focal length 60cm and a single lens eye piece of focal length 5cm is focused at a distant object in such a way that parallel rays emerge from the eye piece. If the object subtends an angle of 2° at the objective, then angular width of image will be.

(1) 10° **(2)** 24° **(3)** 50° **(4)** 1/6°

50. An object is placed at distance of 2f from a concave mirror of focal length f. Light reflected from the mirror falls on a plane mirror. The distance of the plane mirror from the concave mirror equals f. The distance of the final image (due to reflection at both concave and plane mirror) from the concave mirror is

(1) f **(2)** f/2
(3) 2f **(4)** zero

51. Two objects A and B when placed in front of a concave mirror of focal length 7.5cm, give image of equal size. If A is three time the size of B and is placed 30 cm from the mirror, what is the distance of B from the mirror ?

(1) 10 cm **(2)** 12.5 cm
(3) 15 cm **(4)** 17.5cm

52. An object is placed infront of a concave mirror of focal length f. A virtual image is formed with a magnification of 2. To obtain a real image of same magnifiaction, the object has to moved by a distance

(1) f **(2)** $\frac{f}{2}$ **(3)** $\frac{3f}{2}$ **(4)** $\frac{2f}{3}$

53. A luminous point object is moving along the principal axis of a concave mirror of focal length 12 cm towards its when its distance from the mirror is 20 cm its velocity is 4 cm/s. The velocity of the image in cm/s to that instant is

(1) 6 cm/s towards the mirror
(2) 6 cm/s away from the mirror
(3) 9 cm/s away from the mirror
(4) 9 cm/s towards the mirror

54. Image of an object approaching a convex mirror of radius of curvature 20 cm along its optical axis is observed to move from 25 / 3 cm to 50 / 7 cm in 25 second. What is the average speed of the object ?

(1) 1 cm/s
(2) 2 cm/s
(3) 3 cm/s
(4) 4 cm/s

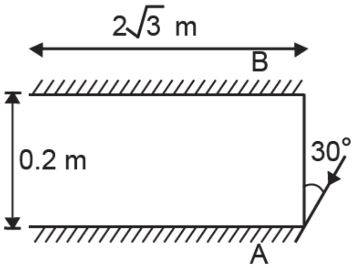
55. A car is fitted with a convex side view mirror of focal lengh 20 cm. A second car 2.8 m behind the first car is overtaking the first car at a relative speed of 15 m/s. The speed of the image of the second car as seen in the mirror of the first one is :

(1) 15 m/s
(2) 1 / 10 m/s
(3) $\frac{1}{15}$ m/s
(4) 10 m/s

56. If $\hat{i}$ is the unit vector along incident ray & $\hat{n}$ is the unit vector along the normal, the unit vector representing reflected ray will be :

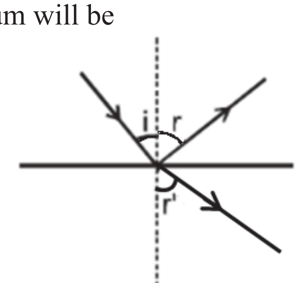
(1) $\hat{i} - (\hat{i} \cdot \hat{n})\hat{n}$
(2) $\hat{i} + (\hat{i} \cdot \hat{n})\hat{n}$
(3) $\hat{i} - 2(\hat{i} \cdot \hat{n})\hat{n}$
(4) $\hat{i} + 2(\hat{i} \cdot \hat{n})\hat{n}$

57. Two plane mirrors A and B are aligned parallel to each other, as shown in figure. A light ray in incident at an angle of 30° at a point just inside one end of A. The plane of incidence coincides with the plane of the figure. The maximum number of times the ray undergoes reflections (including the first one) before it emerges out is :



(1) 28
(2) 30
(3) 32
(4) 34

58. A ray of light is incident at an angle i from denser to rare medium. The reflected and the refracted rays are mutually perpendicular. The angle of reflection and the angle of refraction are respectively r and r', then the ratio of refractive index of denser to rarer medium will be

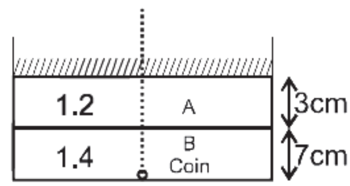


(1) tan r
(2) sin r'
(3) tan i
(4) cot i

59. When a ray of light enters in a medium of refractive index μ_2 from a medium of refractive index μ_1, it is observed that the angle of refraction is double the angle of incidence. Then the angle of incidence is:

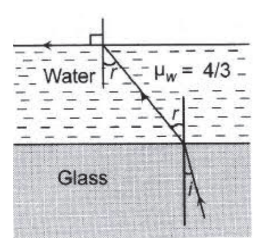
(1) $\cos^{-1}(\mu_1 / 2\mu_2)$
(2) $\cos^{-1}(2\mu_1 / \mu_2)$
(3) $\sin^{-1}(\mu_1 / 2\mu_2)$
(4) $\sin^{-1}(2\mu_1/\mu_2)$

60. A man observes a coin placed at the bottom of a beaker which contains two immiscible liquids of refractive indices 1.2 and 1.4 as shown in figure. A plane mirror is also placed on the surface of liquid. The distance of image (from mirror) of coin in mirror as seen from medium A of refractive index 1.2 by an observer located at the boundary of the two media is :



(1) 18 cm **(2)** 12 cm
(3) 9 cm **(4)** none of these

61. A ray of light is incident at the glass-water interface at an angle i, it emerges finally parallel to the surface of water, then the value of μ_g would be

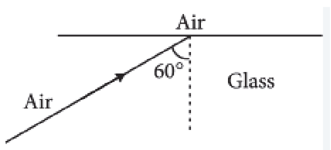


(1) (4/3) i **(2)** 1/sin i
(3) 4/3 **(4)** 1

62. The velocity of light in a medium is half its velocity in air. If ray of light emerges from such a medium into air, the angle of incidence, at which it will be totally internally reflected, is

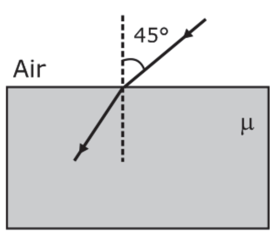
(1) 15° **(2)** 30°
(3) 45° **(4)** 60°

63. A light ray from air is incident (as shown in figure) at one end of a glass fiber making an incidence angle of 60° on the lateral surface, so that it just undergoes a total internal reflection. How much time would it take to traverse the straight fiber of length 1 km ?



(1) 3.33 μs **(2)** 6.67 μs
(3) 5.77 μs **(4)** 3.85 μs

64. In the figure shown, for an angle of incidence 45°, at the top surface, what is the minimum refractive index needed for total internal reflection at vertical face :-

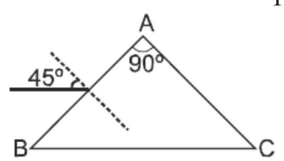


(1) $\frac{\sqrt{2}+1}{2}$ **(2)** $\sqrt{\frac{3}{2}}$
(3) $\sqrt{\frac{1}{2}}$ **(4)** $\sqrt{2}+1$

65. If light travels a distance x in air in t_1 sec air and 10 x distance in t_2 sec in a medium, the critical angle of the medium will be

(1) $\tan^{-1}\left(\frac{t_1}{t_2}\right)$
(2) $\sin^{-1}\left(\frac{t_1}{t_2}\right)$
(3) $\sin^{-1}\left(\frac{10t_1}{t_2}\right)$
(4) $\tan^{-1}\left(\frac{10t_1}{t_2}\right)$

66. Monochromatic light falls on a right-angled prism at an angle of incidence 45°. The emergent light is found to slide along the face AC. Find the refractive index of material of prism.

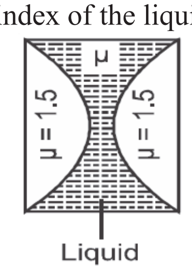


(1) $\frac{2}{\sqrt{3}}$ **(2)** $\sqrt{\frac{2}{3}}$ **(3)** $\sqrt{\frac{3}{2}}$ **(4)** $\frac{\sqrt{3}}{2}$

67. A glass convex lens of refractive index (3/2) has got a focal length equal to 0.3 m. Find the focal length of the lens if it is immersed in water of refractive index (4/3)

(1) 0.3 m **(2)** 0.6 m **(3)** 0.9 m **(4)** 1.2 m

68. Effective focal length of the lens combination shown in figure is 60 cm. The radii of curvature of the curved surface are 12 cm each and the refractive index of the liquid is



(1) 1.33 **(2)** 1.4 **(3)** 1.5 **(4)** 1.60

69. An object is kept at a distance of 16 cm from a thin lens and the image formed is real. If the object is kept at a distance of 6 cm from the same lens the image formed is virtual. If the size of the images formed are equal, the focal length of the lens will be

(1) 15 cm **(2)** 17 cm **(3)** 21 cm **(4)** 11 cm

70. Two point sources S_1 and S_2 are 24 cm apart. Where a convex lens of focal length 9 cm be placed in between then so that the images of both sources are formed at the same place ?

(1) 6 cm from S_1 **(2)** 15 cm from S_1
(3) 10 cm from S_1 **(4)** 12 cm from S_1

71. A thin glass (refractive index 1.5) lens has optical power of –5D in air. Its optical power in a liquid medium with refractive index 1.6 will be :

(1) 1 D **(2)** –1D
(3) 25 D **(4)** –25D

72. A converging lens of focal length 12 cm and a diverging mirror of focal length 7.5 cm are placed 5.0 cm apart with their principal axes coinciding. Where should an object be placed so that its image falls on itself ?

(1) 20 cm **(2)** 30 cm
(3) 60 cm **(4)** 15 cm

73. A microscope is focused on a mark on a piece of paper and then a slab of glass of thickness 3 cm and refractive index 1.5 is placed over the mark. How should the microscope be moved to get the mark in focus again?

(1) 1 cm upward **(2)** 4.5 cm downward
(3) 1 cm downward **(4)** 2 cm upward

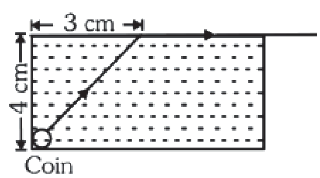
74. A convex lens and a concave lens, each having same focal length of 25 cm, are put in contact to form a combination of lenses. The power in diopters of the combination is :-

(1) 25 **(2)** 50
(3) Infinite **(4)** Zero

75. The frequency of a light wave in a material is 2×10^{14} Hz and wavelength is 5000 Å. The refractive index of material will be :

(1) 1.33 **(2)** 1.40
(3) 1.50 **(4)** 3.00

76. A small coin is resting on the bottom of a beaker filled with a liquid. A ray of light from the coin travels upto the surface of the liquid and moves along its surface how fast light is travelling in liquid. (see figure).



(1) 1.2×10^8 m/s
(2) 1.8×10^8 m/s
(3) 2.4×10^8 m/s
(4) 3.0×10^8 m/s

77. Two thin lenses of focal lengths f_1 and f_2 are in contact and coaxial. The power of the combination is :

(1) $\frac{f_1+f_2}{2}$ **(2)** $\frac{f_1+f_2}{f_1 f_2}$
(3) $\sqrt{\frac{f_1}{f_2}}$ **(4)** $\sqrt{\frac{f_2}{f_1}}$

78. **Assertion:** When an object is placed between two plane parallel mirrors, then all the images found are of equal intensity.

Reason: In case of plane parallel mirrors, only two images are possible.

(1) If both assertion and reason are true and reason is the correct explanation of assertion.
(2) If both assertion and reason are true but reason is not the correct explanation of assertion.
(3) If assertion is true but reason is false.
(4) If assertion and reason both are false.

79. **Assertion:** The size of the mirror affect the nature of the image.

Reason: Small mirrors always forms a virtual image.

(1) If both assertion and reason are true and reason is the correct explanation of assertion.
(2) If both assertion and reason are true but reason is not the correct explanation of assertion.
(3) If assertion is true but reason is false.
(4) If assertion and reason both are false.

80. **Assertion:** Critical angle of light passing from glass to air is minimum for violet colour.

Reason: The wavelength of blue light is greater than the light of other colours.

(1) If both assertion and reason are true and reason is the correct explanation of assertion.
(2) If both assertion and reason are true but reason is not the correct explanation of assertion.
(3) If assertion is true but reason is false.
(4) If assertion and reason both are false.

81. **Assertion:** The images formed by total internal reflections are much brighter than those formed by mirrors or lenses.

Reason: There is no loss of intensity in total internal reflection.

(1) If both assertion and reason are true and reason is the correct explanation of assertion.
(2) If both assertion and reason are true but reason is not the correct explanation of assertion.
(3) If assertion is true but reason is false.
(4) If assertion and reason both are false.

82. **Assertion:** The focal length of lens does not change when red light is replaced by blue light.

Reason: The focal length of lens does not depends on colour of light used.

(1) If both assertion and reason are true and reason is the correct explanation of assertion.
(2) If both assertion and reason are true but reason is not the correct explanation of assertion.
(3) If assertion is true but reason is false.
(4) If assertion and reason both are false.

83. **Assertion:** There is no dispersion of light refracted through a rectangular glass slab.

Reason: Dispersion of light is the phenomenon of splitting of a beam of white light into its constituent colours.

(1) If both assertion and reason are true and reason is the correct explanation of assertion.
(2) If both assertion and reason are true but reason is not the correct explanation of assertion.
(3) If assertion is true but reason is false.
(4) If assertion and reason both are false.

84. **Assertion:** All the materials always have the same colour, whether viewed by reflected light or through transmitted light.
Reason: The colour of material does not depend on nature of light.

(1) If both assertion and reason are true and reason is the correct explanation of assertion.
(2) If both assertion and reason are true but reason is not the correct explanation of assertion.
(3) If assertion is true but reason is false.
(4) If assertion and reason both are false.

85. **Assertion:** If objective and eye lenses of a microscope are interchanged then it can work as telescope.
Reason: The objective of telescope has small focal length.

(1) If both assertion and reason are true and reason is the correct explanation of assertion.
(2) If both assertion and reason are true but reason is not the correct explanation of assertion.
(3) If assertion is true but reason is false.
(4) If assertion and reason both are false.

86. **Assertion:** If the angles of the base of the prism are equal, then in the position of minimum deviation, the refracted ray will pass parallel to the base of prism.
Reason: In the case of minimum deviation, the angle of incidence is equal to the angle of emergence.

(1) If both assertion and reason are true and reason is the correct explanation of assertion.
(2) If both assertion and reason are true but reason is not the correct explanation of assertion.
(3) If assertion is true but reason is false.
(4) If assertion and reason both are false.

87. **Assertion:** Spherical aberration occur in lenses of larger aperture.
Reason: The two rays, paraxial and marginal rays focus at different points.

(1) If both assertion and reason are true and reason is the correct explanation of assertion.
(2) If both assertion and reason are true but reason is not the correct explanation of assertion.
(3) If assertion is true but reason is false.
(4) If assertion and reason both are false.

Exercise - 3 Previous Year Problems (NEET)

1. Which colour of the light has the longest wavelength?

(1) green **(2)** violet **(3)** red **(4)** blue

[C. 74.22%, I.C. 16.32%, U.A. 9.46%] NEET - 2019

2. The angle of a prism is A. One of its refracting surface is silvered. Light rays falling at an angle of incidence 2A on the first surface returns back through the same path after suffering reflection at the silvered surface. The refractive index μ, of the prism is

(1) 2 sin A **(2)** 2 cos A

(3) 1/2 cos A **(4)** tan A

[C. 55.88%, I.C. 33.19%, U.A. 10.92%] CBSE AIPMT 2014

3. A lens of large focal length and large aperture is best suited as an objective of an astronomical telescope since:

(1) a large aperture contributes to the quality and visibility of the images.

(2) a large area of the objective ensures better light gathering power.

(3) a large aperture provides a better resolution.

(4) All the above.

[C. 54.81%, I.C. 18.51%, U.A. 26.68%] NEET - 2021

4. A convex lens has a radius of curvature of magnitude 20 cm. Which one of the following options describe best the image formed of an object of height 2 cm placed 30 cm from the lens ?

(1) Virtual, upright, height = 0.5 cm

(2) Real, inverted, height = 4 cm

(3) Real, inverted, heigh = 1

(4) Virtual, upright, height = 1

[C. 52.43%, I.C. 31.07%, U.A. 16.50%] CBSE AIPMT 2011

5. A rod of length 10 cm lies along the principal axis of a concave mirror of focal length 10 cm in such a way that its end closer to the pole is 20cm away from the mirror. The length of the image is

(1) 10 cm **(2)** 15 cm

(3) 2.5 cm **(4)** 5 cm

[C. 52.40%, I.C. 31.10%, U.A. 16.50%] CBSE AIPMT 2012

6. A ray of light is incident on a 60° prism at the minimum deviation position. The angle of refraction at the first face (i.e., incident face) of the prism is

(1) 30° **(2)** 45°

(3) 60° **(4)** zero

[C. 51.04%, I.C. 36.81%, U.A. 12.15%] AIPMT (MAINS) 2010

7. Which of the following is not due to total internal reflection ?

(1) Working of optical fiber

(2) Difference between apparent and real depth of a pond

(3) Mirage on hot summer days

(4) Brilliance of diamond

[C. 50.42%, I.C. 35.29%, U.A. 14.29%] AIPMT (PRE) 2011

8. A biconvex lens has a radius of curvature of magnitude 20 cm. Which one of the following options describe best the image formed of an object of height 2 cm placed 30 cm from the lens?

(1) Virtual, upright, height = 1 cm

(2) Virtual, upright, height = 0.5 cm

(3) Real, inverted, height = 4 cm

(4) Real, inverted, height = 1 cm

[C. 50.40%, I.C. 35.31%, U.A. 14.29%] AIPMT (MAINS) 2011

9. A thin prism of angle 15° made of glass of refractive index $\mu_1 = 1.5$ is combined with another prism of glass of refractive index $\mu_2 = 1.75$. The combination of the prisms produces dispersion without deviation. The angle of the second prism should be

(1) 5° **(2)** 7°
(3) 10° **(4)** 12°

[C. 50.25%, I.C. 35.46%, U.A. 14.29%] AIPMT (MAINS) 2011

10. The ratio of resolving powers of an optical microscope for two wavelengths $\lambda_1 = 4000$ Å and $\lambda_2 = 6000$ Å is :

(1) 9:4 **(2)** 3:2
(3) 16:81 **(4)** 8:27

[C. 50.00%, I.C. 38.55%, U.A. 11.45%] NEET - 2017

11. A thin prism having refracting angle 10° is made glass of refractive index 1.42. This prism is combination with another thin prism of glass of refractive index 1.7. This combination produces dispersion without deviation. The refracting angle of second prism should be

(1) 6° **(2)** 8°
(3) 10° **(4)** 4°

[C. 45.61%, I.C. 43.27%, U.A. 11.11%] NEET - 2017

12. An object is placed at a distance of 40 cm from a concave mirror of focal length 15 cm. If the object is displaced through a distance of 20 cm towards the mirror, the displacement of the image will be

(1) 30 cm towards the mirror
(2) 36 cm away from the mirror
(3) 30 cm away from the mirror
(4) 36 cm towards the mirror

[C. 44.79%, I.C. 45.31%, U.A. 9.90%] NEET - 2018

13. A beam of light from a source L is incident normally on a plane mirror fixed at a certain distance x from the source. The beam is reflected back as a spot on a scale placed just above the source L. When the mirror is rotated through a small angle θ, the spot of the light is found to move through a distance y on the scale. The angle θ is given by :

(1) $\frac{y}{x}$
(2) $\frac{x}{2y}$
(3) $\frac{x}{y}$
(4) $\frac{y}{2x}$

[C. 43.72%, I.C. 43.72%, U.A. 12.57%] NEET - 2017

14. In total internal reflection when the angle of incidence is equal to the critical angle for the pair of media in contact, what will be angle of refraction ?

(1) equal to angle of incidence
(2) 90^0
(3) 180^0
(4) 0^0

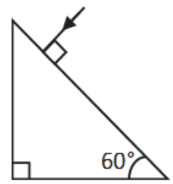
[C. 41.79%, I.C. 22.58%, U.A. 35.63%] NEET - 2019

15. Pick the wrong answer in the context with rainbow.

(1) An observer can see a rainbow when faces the sun
(2) Rainbow is a combined effect of dispersion, refraction and reflection of sunlight.
(3) When the light rays undergo two internal reflections in a water drop, a secondary rainbow is formed.
(4) The order of colours is reversed in the secondary rainbow.

[C. 41.57%, I.C. 22.80%, U.A. 35.63%] NEET - 2019

16. Find the value of angle of emergence from the prism. Refractive index of the glass is $\sqrt{3}$



(1) 90° **(2)** 60° **(3)** 30° **(4)** 45°

[C. 41.79%, I.C. 40.11%, U.A. 18.10%] NEET - 2021

17. For the angle of minimum deviation of a prism to be equal to its refracting angle, the prism must be made of a material whose refractive index –

(1) is less than 1

(2) is greater than 2

(3) lies between $\sqrt{2}$ and 1

(4) lies between 2 and $\sqrt{2}$

[C. 39.58%, I.C. 52.77%, U.A. 7.65%] AIPMT (MAINS)-2012

18. A convex lens 'A' of focal length 20 cm and a concave lens 'B' of focal length 5 cm are kept along the same axis with a distance 'd' between them. If a parallel beam of light falling on 'A' leaves 'B' as a parallel beam, then the distance 'd' in cm will be:

(1) 30 **(2)** 25

(3) 15 **(4)** 50

[C. 38.65%, I.C. 44.33%, U.A. 17.02%] NEET - 2021

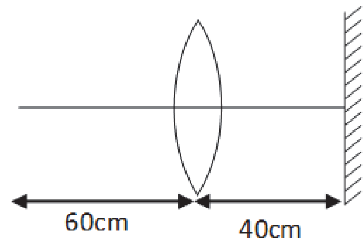
19. A ray of light travelling in transparent medium of refractive index μ falls on a surface separating the medium from air at an angle of incidence of 45°. For which of the following value of μ the ray can undergo total internal reflection ?

(1) $\mu > 1.33$ **(2)** $\mu > 1.4$

(3) $\mu > 1.5$ **(4)** $\mu > 1.25$

[C. 38.51%, I.C. 47.97%, U.A. 13.51%] CBSE AIPMT 2010

20. A point object is placed at a distance of 60 cm from a convex lens of focal length 30 cm. If a plane mirror were put perpendicular to the principal axis of the lens and at a distance of 40 cm from it, the final image would be formed at a distance of –



(1) 20 cm from the plane mirror, it would be a virtual image.

(2) 20 cm from the lens, it would be a real image

(3) 30 cm from the lens, it would be a real image

(4) 30 cm from the plane mirror, it would be a virtual image.

[C. 38.46%, I.C. 39.03%, U.A. 22.51%] NEET - 2021

21. A lens having focal length f and aperture of diameter d forms an image of intensity I. Aperture of diameter $\frac{d}{2}$ in central region of lens is covered by a black paper. Focal length of lens and intensity of image now will be respectively

(1) $\frac{f}{2}$ and $\frac{I}{2}$ **(2)** f and $\frac{I}{4}$

(3) $\frac{3f}{4}$ and $\frac{I}{2}$ **(4)** f and $\frac{3I}{4}$

[C. 37.79%, I.C. 47.71%, U.A. 14.50%] AIPMT (PRE) 2010

22. In an astronomical telescope in normal adjustment a straight black line of length L is drawn on inside part of objective lens. The eye-piece forms a real image of this line. The length of this image is l. The magnification of the telescope is -

(1) $\frac{L}{I}$ **(2)** $\frac{L}{I}+1$ **(3)** $\frac{L}{I}-1$ **(4)** $\frac{L+1}{I-1}$

[C. 35.42%, I.C. 39.48%, U.A. 25.09%] AIPMT - 2015

23. The angle of incidence for a ray of light at a refracting surface of a prism is 45°. The angle of prism is 60°. If the ray suffers minimum deviation through the prism, the angle of minimum deviation and refractive index of the material of the prism respectively, are :

(1) 45° , $\frac{1}{\sqrt{2}}$ **(2)** 30° , $\sqrt{2}$

(3) 45° , $\sqrt{2}$ **(4)** 30° , $\frac{1}{\sqrt{2}}$

[C. 34.92%, I.C. 39.48%, U.A. 25.59%] AIPMT - 2016

24. Match the corresponding entries of column 1 with column 2. [Where 'm' is the magnification produced by the mirror]

Column 1	Column 2
(A) $m = -2$	(a) Convex mirror
(B) $m = -\frac{1}{2}$	(b) Concave mirror
(C) $m = +2$	(c) Real image
(D) $m = +\frac{1}{2}$	(d) Virtual image

(1) A $\rightarrow$ b and c; B $\rightarrow$ b and c; C $\rightarrow$ b and d; D $\rightarrow$ a and d

(2) A $\rightarrow$ a and c ; B $\rightarrow$ a and d; C $\rightarrow$ a and b; D $\rightarrow$ c and d

(3) A $\rightarrow$ a and d ; B $\rightarrow$ b and c; C $\rightarrow$ b and d; D $\rightarrow$ b and c

(4) A $\rightarrow$ c and d ; B $\rightarrow$ b and d; C $\rightarrow$ b and c; D $\rightarrow$ a and d

[C. 34.42%, I.C. 40.02%, U.A. 25.59%] AIPMT - 2016

25. Two similar thin equi-convex lenses, of focal length f each, are kept coaxially in contact with each other such that the focal length of the combination is F_1. When the space between the two lenses is filled with glycerin (which has the same refractive index (μ=1.5) as that of glass) then the equivalent focal length is F_2. The ratio $F_1 : F_2$ will be :

(1) 2:3 **(2)** 3:4 **(3)** 2:1 **(4)** 1:2

[C. 34.03%, I.C. 50.84%, U.A. 15.13%] NEET - 2019

26. The refracting angle of a prism is A and refractive index of the material of the prism is cot (A/2). Then the angle of minimum deviation will be -

(1) $180^\circ - 2A$ **(2)** $90^\circ - A$

(3) $180^\circ + 2A$ **(4)** $180^\circ - 3A$

[C. 32.61%, I.C. 50.00%, U.A. 17.39%] AIPMT - 2015

27. Two identical thin Plano-convex glass lenses (refractive index 1.5) each having radius of curvature of 20 cm are placed with their convex surfaces in contact at the center. The intervening space is filled with oil of refractive index 1.7. The focal length of combination is

(1) –25 cm **(2)** –50 cm

(3) 50 cm **(4)** – 20 cm

[C. 32.36%, I.C. 50.50%, U.A. 17.39%] AIPMT - 2015

28. A ray is incident at an angle of incidence i on one surface of a small angle prism (with angle of prism A) and emerges normally from the opposite surface. If the refractive index of the material of the prism is μ, then the angle of incidence is nearly equal to:

(1) μA **(2)** $\frac{\mu A}{2}$

(3) $\frac{A}{2\mu}$ **(4)** $\frac{2A}{\mu}$

[C. 32.04%, I.C. 56.91%, U.A. 11.05%] NEET - 2020

29. The speed of light in media M_1 and M_2 are 1.5×10^8 m/s and 2.0×10^8 m/s respectively. A ray of light enters from medium M_1 to M_2 at an incidence angle i. If the ray suffers total internal reflection, the value of i is :-

(1) Equal to or less than $\sin^{-1}\left(\frac{3}{5}\right)$

(2) Equal to or greater than $\sin^{-1}\left(\frac{3}{4}\right)$

(3) Less than $\sin^{-1}\left(\frac{2}{3}\right)$

(4) Equal to $\sin^{-1}\left(\frac{2}{3}\right)$

[C. 31.03%, I.C. 51.72%, U.A. 17.24%] AIPMT (MAINS) 2010

30. If the focal length of objective lens is increased then magnifying power of

(1) microscope will increase but that of telescope decrease
(2) microscope and telescope both will increase
(3) microscope and telescope both will decrease
(4) microscope will decrease but that of telescope increase.

[C. 30.82%, I.C. 32.30%, U.A. 36.88%] AIPMT - 2014

31. A biconvex lens has radii of curvature, 20 cm each. If the refractive index of the material of the lens is 1.5, the power of the lens is :

(1) + 20 D **(2)** + 5 D
(3) infinity **(4)** + 2 D

[C. 28.39%, I.C. 29.66%, U.A. 41.95%] NEET - 2022

32. Two thin lenses are of same focal lengths (f), but one is convex and the other one is concave. When they are placed in contact with each other, the equivalent focal length of the combination will be :

(1) f/4 **(2)** f/2
(3) Infinite **(4)** Zero

[C. 26.53%, I.C. 49.06%, U.A. 24.41%] NEET - 2023

33. Light travels a distance x in time t_1 in air and 10x in time t_2 in another denser medium. What is the critical angle for this medium ?

(1) $\sin^{-1}\left(\frac{10t_2}{t_1}\right)$ **(2)** $\sin^{-1}\left(\frac{t_1}{10t_2}\right)$
(3) $\sin^{-1}\left(\frac{10t_1}{t_2}\right)$ **(4)** $\sin^{-1}\left(\frac{t_2}{t_1}\right)$

[C. 25.48%, I.C. 47.32%, U.A. 27.19%] NEET - 2023

34. Two transparent media A and B are separated by a plane boundary. The speed of light in those media are 1.5×10^8 m/s and 2.0×10^8 m/s, respectively. The critical angle for a ray of light for these two media is :

(1) $\sin^{-1}(0.750)$ **(2)** $\tan^{-1}(0.500)$
(3) $\tan^{-1}(0.750)$ **(4)** $\sin^{-1}(0.500)$

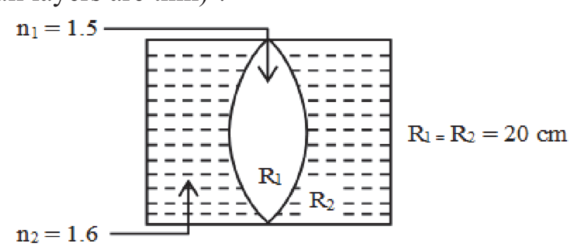
[C. 25.41%, I.C. 54.70%, U.A. 19.89%] NEET - 2022

35. A light ray falls on a glass surface of refractive index $\sqrt{3}$, at an angle 60°. The angle between the refracted and reflected rays would be :

(1) 60° **(2)** 90°
(3) 120° **(4)** 30°

[C. 23.00%, I.C. 51.66%, U.A. 25.34%] NEET - 2022

36. In the figure shown here, what is the equivalent focal length of the combination of lenses (Assume that all layers are thin) ?



(1) – 40 cm **(2)** – 100 cm
(3) – 50 cm **(4)** 40 cm

[C. 19.76%, I.C. 49.52%, U.A. 30.71%] NEET - 2023

Answer Key

Exercise - 1 **Objective Problems (NEET)**

1. 4	**2.** 2	**3.** 2	**4.** 3	**5.** 3	**6.** 3	**7.** 3	**8.** 3
9. 1	**10.** 4	**11.** 3	**12.** 2	**13.** 1	**14.** 2	**15.** 3	**16.** 2
17. 1	**18.** 4	**19.** 3	**20.** 4	**21.** 3	**22.** 4	**23.** 2	**24.** 4
25. 4	**26.** 2	**27.** 1	**28.** 3	**29.** 1	**30.** 2	**31.** 3	**32.** 4
33. 4	**34.** 1	**35.** 3	**36.** 1	**37.** 1	**38.** 2	**39.** 4	**40.** 4
41. 2	**42.** 1	**43.** 2	**44.** 4	**45.** 3	**46.** 2	**47.** 3	**48.** 4
49. 2	**50.** 2	**51.** 3	**52.** 3	**53.** 2	**54.** 4	**55.** 2	**56.** 3
57. 2	**58.** 1	**59.** 2	**60.** 1	**61.** 3	**62.** 3	**63.** 1	**64.** 2
65. 3	**66.** 1	**67.** 1	**68.** 3	**69.** 4	**70.** 2	**71.** 3	**72.** 1
73. 4	**74.** 2	**75.** 2	**76.** 1	**77.** 4	**78.** 4	**79.** 1	**80.** 4
81. 1	**82.** 3	**83.** 1	**84.** 2	**85.** 1	**86.** 1	**87.** 3	**88.** 2
89. 1	**90.** 3	**91.** 4	**92.** 1	**93.** 2	**94.** 2	**95.** 4	**96.** 3
97. 4	**98.** 2	**99.** 2	**100.**3	**101.**2	**102.**2	**103.**3	**104.**4
105.4	**106.**2	**107.**2	**108.**3	**109.**3	**110.**2	**111.**1	**112.**1
113.2	**114.**1	**115.**2	**116.**4	**117.**4	**118.**3	**119.**4	**120.**4
121.4	**122.**1	**123.**2	**124.**4	**125.**3	**126.**4	**127.**2	**128.**3
129.1	**130.**4	**131.**1	**132.**4	**133.**4	**134.**3	**135.**2	**136.**3
137.1	**138.**4	**139.**2	**140.**1	**141.**3	**142.**2	**143.**2	**144.**2
145.1	**146.**3	**147.**1	**148.**3	**149.**1	**150.**2	**151.**1	**152.**3
153.4	**154.**4	**155.**4	**156.**1	**157.**2	**158.**3	**159.**1	**160.**3

Exercise - 2 Objective Problems (NEET)

1. 4	**2.** 3	**3.** 2	**4.** 3	**5.** 3	**6.** 2	**7.** 3	**8.** 1
9. 2	**10.** 2	**11.** 3	**12.** 1	**13.** 3	**14.** 2	**15.** 1	**16.** 1
17. 1	**18.** 2	**19.** 4	**20.** 2	**21.** 4	**22.** 1	**23.** 2	**24.** 2
25. 1	**26.** 3	**27.** 3	**28.** 1	**29.** 2	**30.** 3	**31.** 1	**32.** 3
33. 2	**34.** 3	**35.** 1	**36.** 1	**37.** 4	**38.** 3	**39.** 1	**40.** 4
41. 2	**42.** 3	**43.** 1	**44.** 1	**45.** 1	**46.** 4	**47.** 1	**48.** 2
49. 2	**50.** 4	**51.** 3	**52.** 1	**53.** 3	**54.** 1	**55.** 3	**56.** 3
57. 2	**58.** 4	**59.** 1	**60.** 3	**61.** 2	**62.** 2	**63.** 4	**64.** 2
65. 3	**66.** 3	**67.** 4	**68.** 4	**69.** 4	**70.** 1	**71.** 1	**72.** 2
73. 1	**74.** 4	**75.** 4	**76.** 2	**77.** 2	**78.** 4	**79.** 4	**80.** 3
81. 1	**82.** 4	**83.** 2	**84.** 4	**85.** 4	**86.** 1	**87.** 1	

Exercise - 3 Previous Year Problems (NEET)

1. 3	**2.** 2	**3.** 4	**4.** 2	**5.** 4	**6.** 1	**7.** 2	**8.** 3
9. 3	**10.** 2	**11.** 1	**12.** 2	**13.** 4	**14.** 2	**15.** 1	**16.** 2
17. 4	**18.** 3	**19.** 2	**20.** 1	**21.** 4	**22.** 1	**23.** 2	**24.** 1
25. 4	**26.** 1	**27.** 2	**28.** 1	**29.** 2	**30.** 4	**31.** 2	**32.** 3
33. 3	**34.** 1	**35.** 2	**36.** 2				

POINTS TO REMEMBER

POINTS TO REMEMBER