CHAPTER 1

Geometrical Optics

SECTION A - PLANE MIRROR

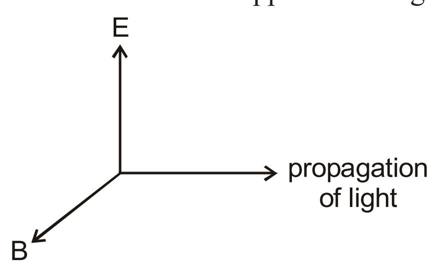
1. Properties of light

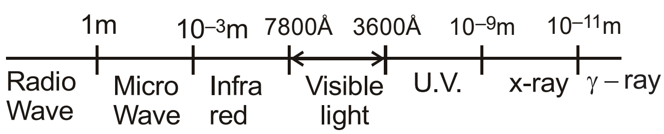
(I) Speed of light in vaccum, denoted by c, is equal to 3×10^8 m/s approximately

(ii) Light is an electromagnetic wave (proposed by Maxwell). It consists of varying electric field and magnetic field.

(iii) Light carries energy and momentum.

(iv) The formula $v = f\lambda$ is applicable to light.





Electromagnetic spectrum

2. Ray optics

Ray optics treats propagation of light in terms of rays and is valid only if the size of the obstacle is much greater than the wavelength of light. It concerns with the image formation and deals with the study of the simply facts such as rectilinear propagation, laws of reflection and refraction by geometrical methods.

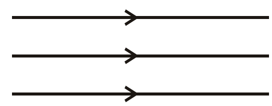
2.1 Ray

A ray can be defined as an imaginary line drawn in the direction in which light is travelling. Light behaves as a stream of energy propagated along the direction of rays. The rays are directed outward from the source of light in straight lines.

2.2 Beam of Light

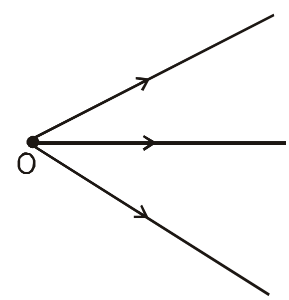
A beam of light is a collection of these rays. There are mainly three types of beams.

(i) Parallel beam of light



A search light and the headlight of a vehicle emit a parallel beam of light. The source of light at a very large distance like sun effectively gives a parallel beam.

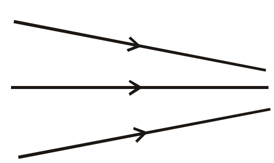
(ii) Divergent beam of light



The rays going out from a point source generally form a divergent beam.

(iii) Convergent beam of light

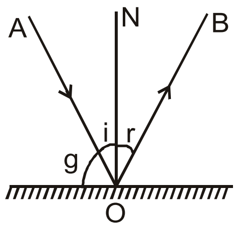
A beam of light that is going to meet (or converge) at a point is known as a convergent beam. A parallel beam of light after passing through a convex lens becomes a convergent beam.



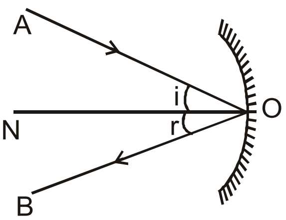
3. Reflection

When a ray of light is incident at a point on the surface, the surface throws partly or wholly the incident energy back into the medium of incidence. This phenomenon is called reflection.

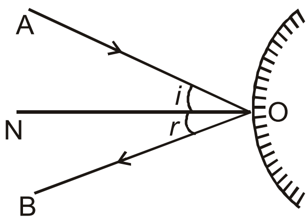
Surfaces that cause reflection are known as mirrors or reflectors. Mirrors can be plane or curved.



Plane mirror



Concave mirror



Convex mirror

In the figure 1.5,

O is the point of incidence, AO is the incident ray, OB is the reflected ray, ON is the normal at the incidence.

Angle of incidence

The angle which the incident ray makes with the normal at the point of incidence is called the angle of incidence. It is generally denoted by 'i'.

Angle of reflection

The angle which the reflected ray makes with the normal at the point of incidence is called the angle of reflection. It is generally denoted by 'r'.

Glancing angle

The angle which the incident ray makes with the plane reflecting surface is called glancing angle. It is generally denoted by 'g'.

$g = 90° - i$ (1)

3.1 Law of reflection

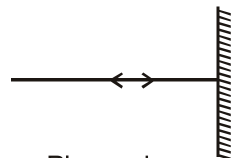
(i) The incident ray, the reflected ray and the normal to the reflecting surface at the point of incidence, all lie in the same plane.

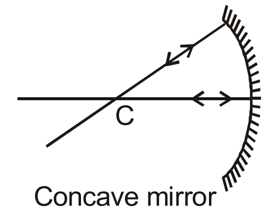
(ii) The angle of incidence is equal to the angle of reflection, i.e., $\angle i = \angle r$

These laws hold good for all reflecting surfaces either plane or curved.

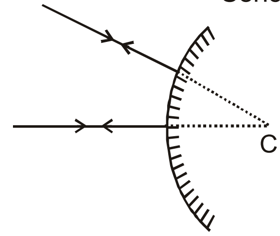
Some important points

(i) If $\angle i = 0$, $\angle r = 0$, i.e., if a ray is incident normally on a boundary, after reflection it retraces its path.


Plane mirror

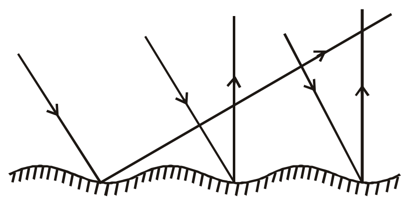


Concave mirror



Convex mirror

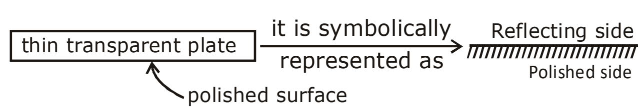
(ii) None of the frequency, wavelength and speed change due to reflection. However, intensity and hence amplitude ($I \propto A^2$) usually decrease as there is loss of energy.



(iii) If the surface is irregular, the reflected rays on an incident beam of parallel light rays will be in random direction. Such an irregular reflection is called diffused reflection.

4. PLANE MIRROR

Plane mirror is formed by polishing one surface of a plane thin glass plate. It is also said to be silvered on one side.



PLANE MIRROR

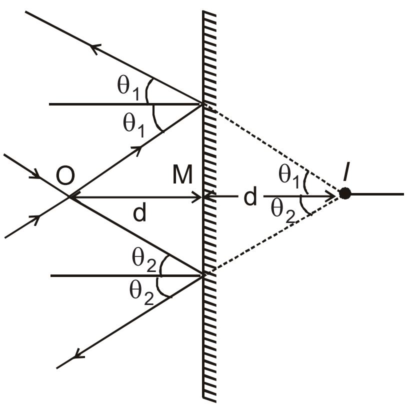
A beam of parallel rays of light, incident on a plane mirror will get reflected as a beam of parallel reflected rays.

Formation of image by a plane mirror.

From the argument of similar triangles

$$OM = IM$$

i.e., perpendicular distance of the object from the mirror = perpendicular distance of the image from the mirror



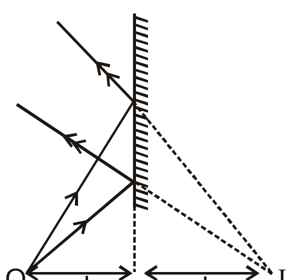
Steps to draw the image :

(i) Drop a perpendicular on the mirror and extend it on the back side of the mirror.

(ii) Image always lie on this extended line

(iii) To exactly locate the image, use the concept:

Perpendicular distance of the object from the mirror is equal to the perpendicular distance from the mirror of the image.



Example 1

A mirror is inclined at an angle of 45° with the horizontal and one end of the mirror is at the origin, an object is kept at x = – 2 cm. Locate its image

Sol.

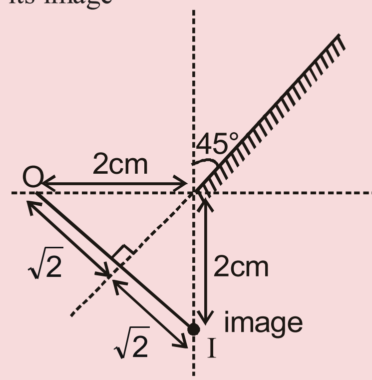
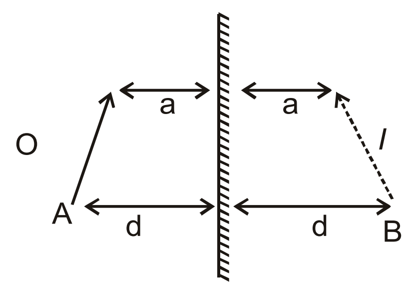


Image is at y = -2 cm.

4.1 Image of an extended linear object

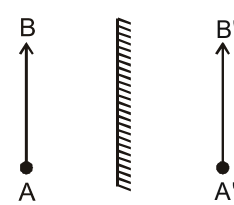
Draw the images of the extreme points and joined them with a straight line



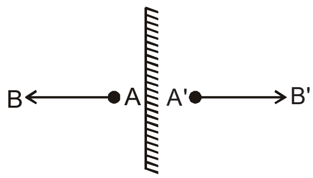
Properties of image of an extended object, formed by a plane mirror

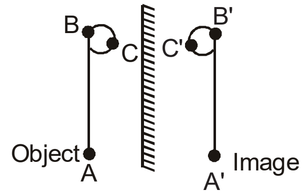
1. Size of extended object = size of extended image.

2. The image is erect, if the extended object is placed parallel to the mirror.

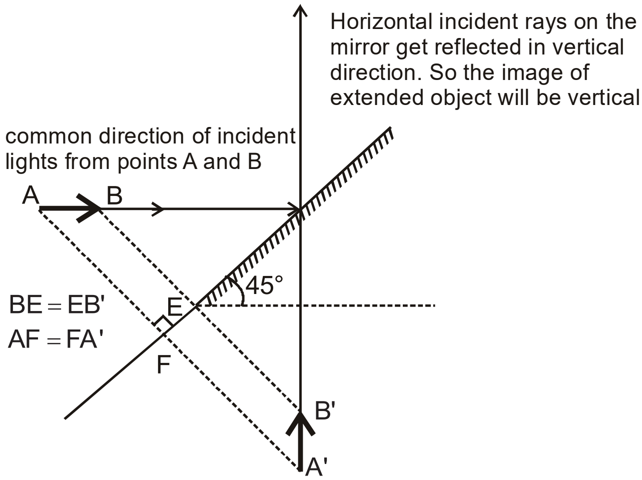


3. The image is inverted if the extended object lies perpendicular to the plane mirror.

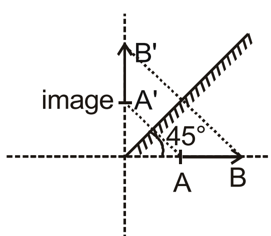




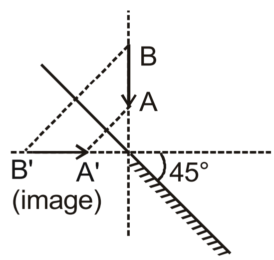
4. If an extended horizontal object is placed infront of a mirror inclined 45° with the horizontal, the image formed will be vertical. See figure.



(i)



(ii)



Example 2

An unnumbered wall clock shows a time of 8 : 12 where 1st term represents hours, 2nd represents minutes. What time will its image in plane mirror show.

Sol.

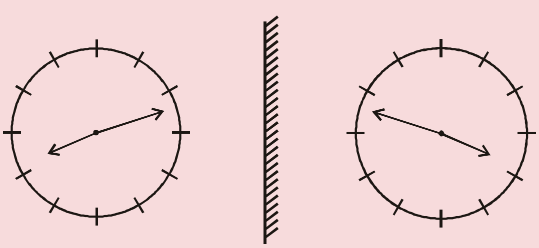


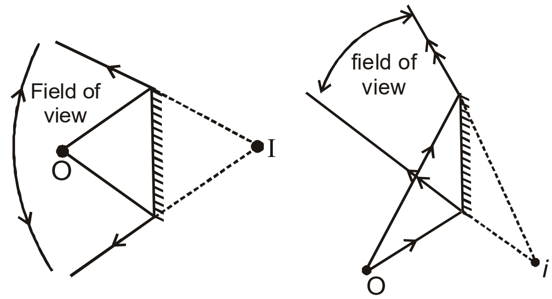
Image shows 3 : 48

Short trick

Draw watch on paper and then see it from reverse side.

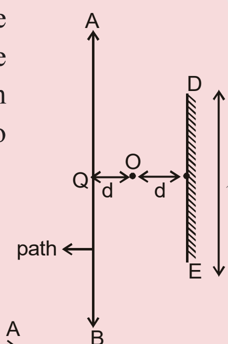
4.2 Field of view

Area in which reflected rays exists is called field of view. It is the area from which an observer can see the image of an object. If the observer is outside this area, he will not be able to see the image although the image will be there.



Example 3

A man is travelling on the road along AB. Find the length of the road for which the image will be visible to him.



(A) ℓ (B) 3ℓ

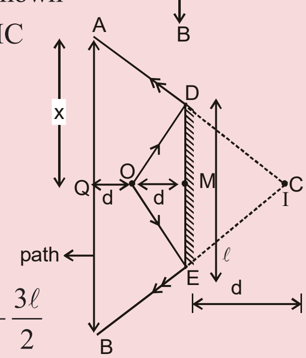
(C) $1.5\,\ell$ (D) 2ℓ

Sol. In the ray diagram shown

Δ AQC ~ Δ DMC

$$\frac{x}{\ell/2} = \frac{3d}{d}$$

$$\Rightarrow x = \frac{3\ell}{2}$$



$\therefore$ Total length$= \frac{3\ell}{2} + \frac{3\ell}{2}$

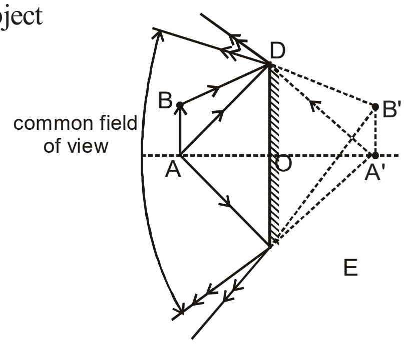
$= 3\ell$ (option = B)

Note

Most of the problems in optics invoving geometry can be solved by using similar triangles.

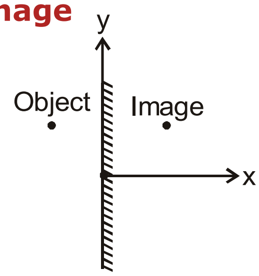
4.3 Field of view of extended linear object

Common field of view of extreme points of the object will be the field of view of extended linear object



Sign Convention:- Direction of incident liht (along principal axis) is taken to be positive and distances are measured from the mirror (along principal axis).

4.4 Relation between velocity of object and image



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

$v_{iG} - v_{mG} = - (v_{oG} - v_{mG})$

$$\Rightarrow v_{mG} = \frac{v_{iG} + v_{oG}}{2}$$

Here,

v_{iG} = velocity of image with respect to ground

v_{OG} = velocity of object with respect to ground.

v_{mg} = velocity of mirror with respect to ground.

There will be no change along y and z directions.

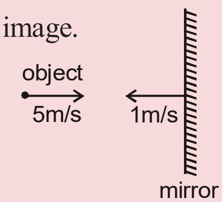
If the plane mirror is in y - z plane.

Note

Valid only for perpendicular component of velocity to the mirror.

Example 4

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



Sol. Take $\rightarrow$ as + direction.

$v_i - v_m = v_m - v_0$

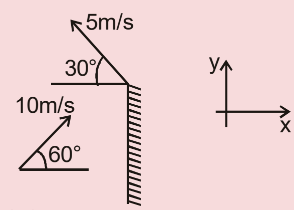
$\Rightarrow v_i - (-1) = (-1) - 5$

$\therefore v_i = - 7 m/s$

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

Example 5

In the situation shown in figure, find the velocity of image.



Sol. Along x direction, applying

$v_i - v_m = - (v_0 - v_m)$

$v_i - (- 5 \cos 30°) = - (10 \cos 60° - (-5 \cos 30°))$ $\quad \therefore \quad v_1 = - 5 (1 + \sqrt{3})$ m/s

Along y direction

$v_0 = v_i$

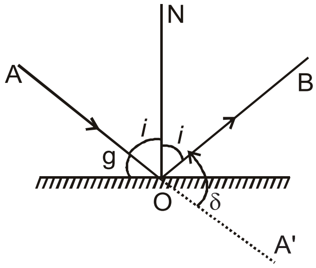
$v_i = 10 \sin 60° = 5\sqrt{3}$ m/s

$\therefore$ Velocity of the image

$$= -5(1+\sqrt{3})\hat{i} + 5\sqrt{3}\hat{j} \text{ m/s}$$

4.5 Deviation produced by a Plane mirror

Deviation is defined as the angle between directions of the incident ray and the reflected ray (or, the emergent ray). It is generally denoted by δ.



Here, $\angle A'OB = \delta$

$= \angle AOA' - \angle AOB$

$= 180° - 2i$ or, $\delta = 180° - 2i$.

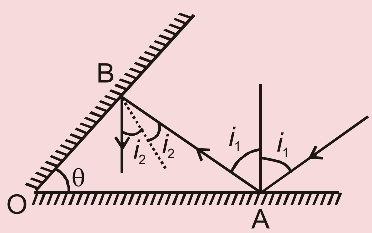
Example 6

Two plane mirrors are inclined at an angle θ with each other. A ray of light strikes one of them. Find its deviation after it has been reflected twice-once from each mirror.

Sol. **Case I :**

δ_1 = clockwise deviation at A = $180° - 2\,i_1$

δ_2 = anticlockwise deviation at B = $180° - 2i_2$



Now, from Δ OAB, we have

$\angle BOA + \angle OAB + \angle ABO = 180°$

$\theta + (90° - i_1) + (90° + i_2) = 180°$

$\Rightarrow\ i_1 - i_2 = \theta$

As $i_1 > i_2$, $\delta_1 < \delta_2$

Hence, the net angle anticlockwise deviation $= \delta_2 - \delta_1$

$= (180° - 2i_2) - (180° - 2i_1)$

$= 2(i_1 - i_2) = 2\theta$

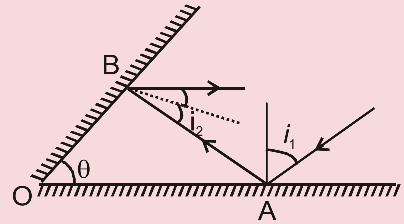
OR

Total angle of deviation

$= \delta_1 + \delta_2 = (180 - 2i_1) - (180 - 2i_2)\,CW$

$= 2(i_1 - i_2)\,CW$

Case II :



δ_1 = clockwise deviation at A = $180° - 2\,i_1$

δ_2 = clockwise deviation at B = $180° - 2\,i_2$

Now, from Δ OAB, we have

or $\theta + (90° - i_1) + (90° - i_2) = 180°$

$\Rightarrow\ i_1 + i_2 = \theta$

Hence, net clockwise deviation $= \delta_2 + \delta_1$

$= (180° - 2i_2) + (180° - 2i_1)$

$= 360° - 2(i_1 + i_2)$

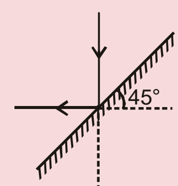
$= 360° - 2\theta$

$\Rightarrow$ Net anticlockwise deviation

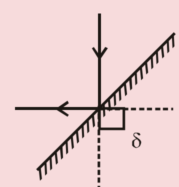
$= 360° - (360° - 2\theta) = 2\theta$

Example 7

Find the angle of deviation

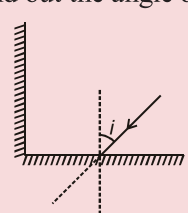


Sol. Angle of deviation = 90°

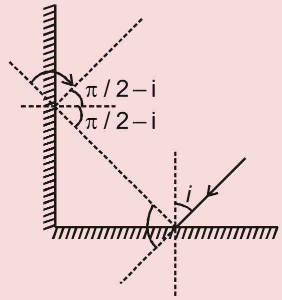


Example 8

Find out the angle of deviation



Sol.



δ_1 = For I[st] reflection

$= \pi - 2i$ (clockwise)

δ_2 = For 2[nd] reflection

$= \pi - 2\left(\frac{\pi}{2} - i\right)$ (clockwise)

$= 2i$

$\delta_{net} = \delta_1 + \delta_2$

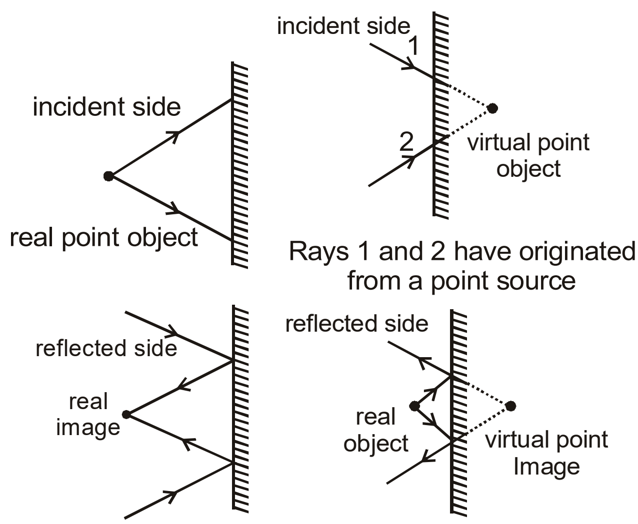
$= \pi - 2i + 2i$

$= \pi$

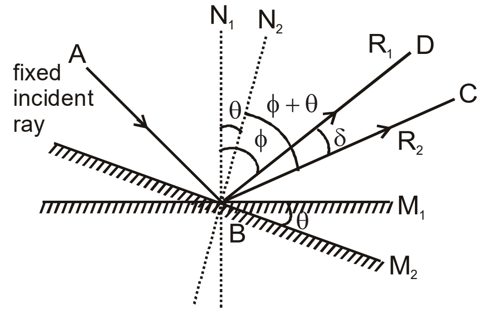
4.6 Real or virtual image/Object

Object and Image

Object is defined as point of intersection of incident rays. Image is defined as point of intersection of reflected rays (in case of reflection) or refracted rays (in case of refraction).



5. ROTATION OF MIRROR



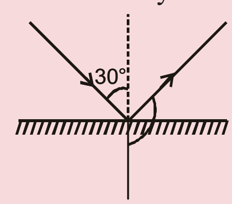
For a fixed incident light ray, if the mirror be rotated through an angle θ (about an axis which lies in the plane of mirror and perpendicular to the plane of incidence), the reflected ray turns through an angle 2θ in same sense.

See figure M_1, N_1 and R_1 indicate the initial position of mirror, initial normal and initial direction of reflected light ray respectively. M_2, N_2 and R_2 indicate the final position of mirror, final normal and final direction of reflected light ray respectively. From figure it is clear that $\angle ABC = 2\phi + \delta = 2(\phi + \theta)$ or $\delta = 2\theta$.

Example 9

By what angle the mirror must be rotated such that the reflected ray becomes vertical.

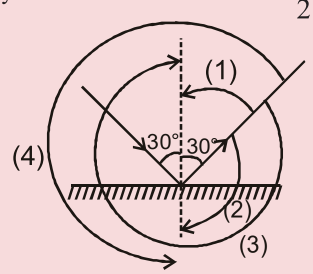
Sol. The diagram below shows the four ways in which the reflected ray can become vertical.



For case 1 :

Angle by which the Reflected rayn should rotate = 30° (CCW)

Angle by which the mirror rotates = $\frac{30°}{2}$ = 15°(CCW)



For case 2 :

Angle by which the Reflected ray should rotate $= 150°$ (CW)

Angle by which the mirror rotates $= 75°$(CW)

For case 3 :

Angle by which the Reflected ray rotates $= 300°$(CW)

Angle by which the mirror rotates $= 150°$(CW)

For case 4 :

Angle by which the Reflected ray rotates $= 210°$(CCW)

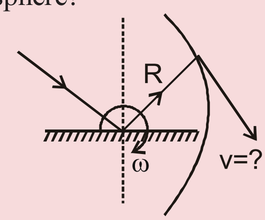
Angle by which the mirror rotates $= 105°$(CCW)

But case (2) & case (3) are not possible as the I.R. falls on the polished part of mirror after rotation of mirror.

$\therefore$ Answer is 15° (CCW)and 105°(CCW)

Example 10

A mirror is placed at the centre of a sphere and it is rotating with an angular speed ω. Incident light falls on the mirror at the centre of the sphere. Find the linear speed of the light spot on the sphere?



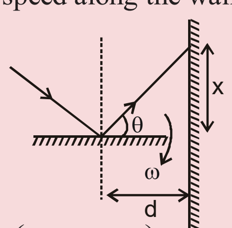
Sol. Angular speed of mirror $= \omega$

Angular speed of Reflected Ray $= 2\omega$

Speed of light spot on the mirror : $2\omega(R)$

Example 11

In the previous question instead of spherical wall there is a vertical wall at a perpendicular distance d from the point where the light is incident. Find the linear speed along the wall.



Sol. $\tan\theta = \dfrac{x}{d}$

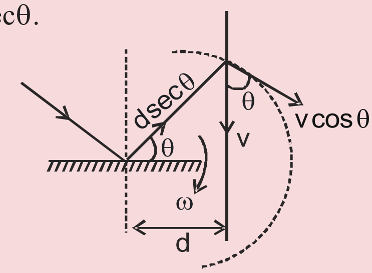
$\Rightarrow x = d\tan\theta$

$$\frac{dx}{dt} = d\sec^2\theta\frac{d\theta}{dt}$$

$$= 2\,\omega\, d\sec^2\theta \qquad \left(\because \frac{d\theta}{dt} = 2\omega\right)$$

OR

Considering an instantaneous circle of radius $d\sec\theta$.



$v_t = 2\omega d\sec\theta$

($2\omega d\cos\theta$ is a component of v.)

$v\cos\theta = 2\omega d\sec\theta$

$$\Rightarrow v = \frac{2\omega d\sec\theta}{\cos\theta} = 2\omega d\sec^2\theta$$

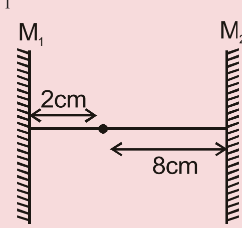
6. IMAGES FORMED BY TWO PLANE MIRRORS

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.

6.1 Images due to parallel plane mirrors

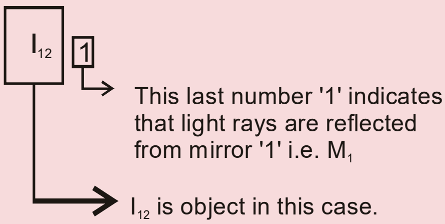
Example 12

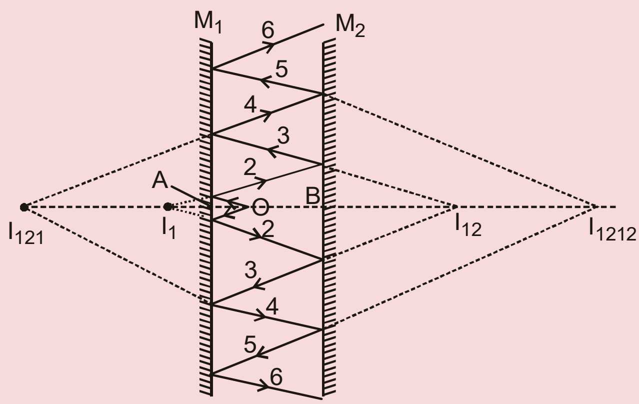
Figure shows a point object placed between two parallel mirrors. Its distance from M_1 is 2 cm and that from M_2 is 8 cm. Find the distance of images from the two mirrors considering reflection on mirror M_1 first.



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.



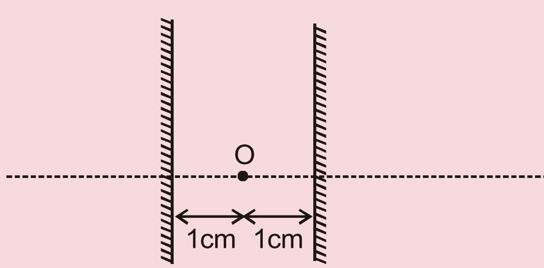


Incident rays	Ref. by	Ref. rays	Object	Image	Object distance	Image distance
Rays 1	M_1	Rays 2	O	I1	AO=2cm	AI_1=2cm
Rays 2	M_2	Rays 3	I1	I_{12}	BI_1=12cm	BI_{12}=12cm
Rays 3	M_1	Rays 4	I_{12}	I_{121}	AI_{12}=22cm	AI_{121}=22cm
Rays 4	M_2	Rays 5	I_{121}	I_{1212}	BI_{121}=32cm	BI_{1212}=32cm

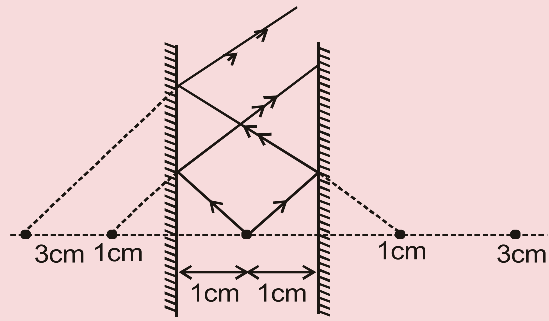
Similarly images will be formed by the rays striking mirror M_2 first. Total number of images $= \infty$.

Example 13

Two plane mirrors are kept parallel to each other at a distance of 2 cm. An object is kept at the midpoint of the line joining them. Locate the images by drawing appropriate Ray diagram.



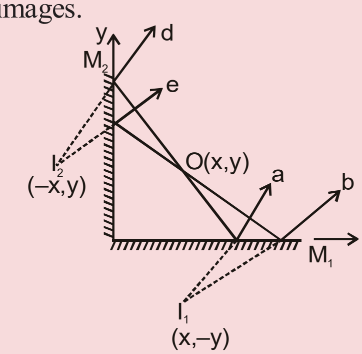
Sol.



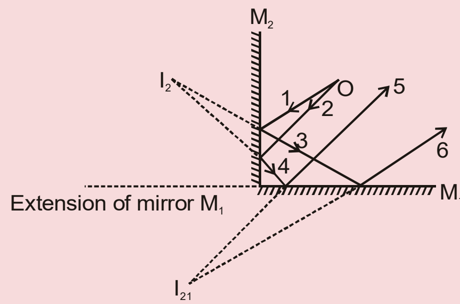
Thus, it forms an A.P.

Example 14

Consider two perpendicular mirrors. M_1 and M_2 and an object O. Taking origin at the point of intersection of the mirrors and the coordinate of object as (x, y), find the position and number of images.



Sol.

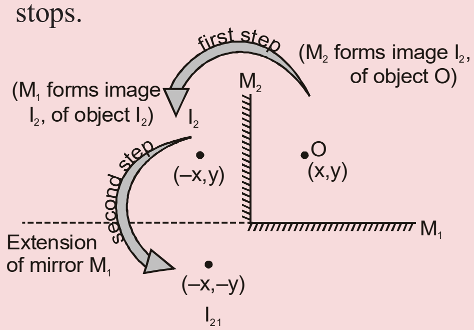


Rays 'a' and 'b' strike mirror M_1 only and these rays will form image I_1 at (x, –y), such that O and I_1 are equidistant from mirror M_1. These rays do not form further image because they do not strike any mirror again. Similarly rays 'd' and 'e' strike mirror M_2 only and these rays will form image I_2 at (–x, y), such that O and I_2 are equidistant from mirror M_2.

Now consider those rays which strike mirror M_2 first and then the mirror M_1.

For incident ray 1,2 object is O, and reflected rays 3, 4 from image I_2.

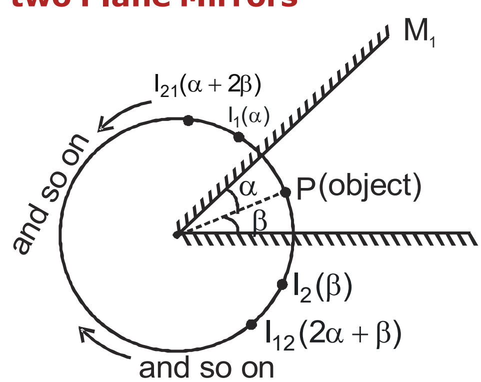
Now rays 3, 4 incident on M_1 (object is I_2) which reflect as rays 5, 6 and form image I_{21}. Rays 5, 6 do not strike any mirror, so image formation stops.



I_2 and I_{21}, are equidistant from M_1. To summarize see the following figure Now rays 3,4 incident on M_1 (object is I_2) which reflect as rays 5, 6 and form image I_{21}. Rays 5, 6 do not strike any mirror, so image formation stops. For rays reflecting first from M_1 and from M_2, first image I_1 at (x, –y)) will be formed and this will function as object for mirror M_2 and then its image I_{12} (at (–x, –y)) will be formed. I_{12} and I_{21} coincide.

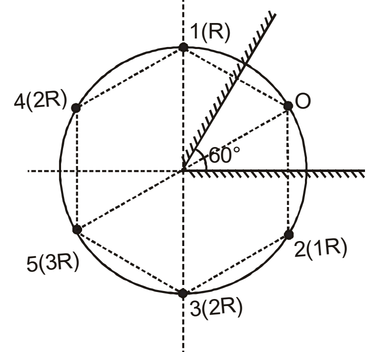
$\therefore$ Three images are formed

6.2 Locating all the Images formed by two Plane Mirrors



Consider two plane mirrors M_1 and M_2 inclined at an angle $\theta = \alpha + \beta$ as shown in figure. Point P is an object kept such that it makes angle α with mirror M_1 and angle β with mirror M_2. Image of object P formed by M_1, denoted by I_1, will be inclined by angle α on the other side of mirror M_1. This angle is written in bracket in the figure besides I_1. Similarly image of object P formed by M_2, denoted by I_2, will be inclined by angle β on the other side of mirror M_2. This angle is written in bracket in the figure besides I_2. Now I_2 will act as an object for M_1 which is at an angle $(\alpha + 2\beta)$ on the opposite side of M_1. This image will be denoted as I_{21}, and so on. Think when this process stop [Hint : The virtual image formed by a plane mirror must not be in front of the mirror of its extension.]

6.3 Circle concept



All the images formed will lie on a circle whose centre is the intersection point of the mirror and radius equal to distance of object from the intersection point

7. NUMBER OF IMAGES FORMED BY TWO INCLINED MIRRORS.

1. if $\dfrac{360°}{\theta}$ = even number.; number of image

$$= \frac{360°}{\theta} - 1$$

2. If $\dfrac{360°}{\theta}$ = odd number ; number of image

$$= \frac{360°}{\theta} - 1,$$

If the object is placed on the angle bisector.

3. If $\dfrac{360°}{\theta}$ = odd number ; number of images

$$= \frac{360°}{\theta},$$

If the object is not placed on the angle bisector.

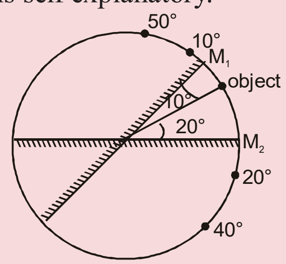
4. If $\dfrac{360°}{\theta} \neq$ integer , then the number of images

= nearest even integer.

Example 15

Two mirrors are inclined by an angle 30°. An object is placed making 10° with the mirror M_1. Find the positions of first two images formed by each mirror. Find the total number of images using (i) direct formula and (ii) counting the images.

Sol. Figure is self explanatory.



Number of images

(i) Using direct formula

$$\frac{360°}{30°} = 12 \text{(even number)}$$

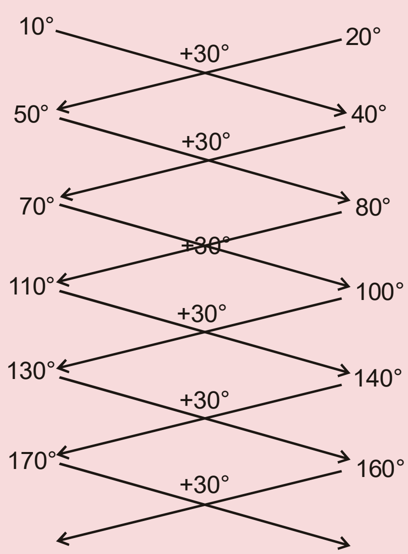
$\therefore$ number of images = 12 – 1 = 11

(ii) By counting

Consider Fig. 1.25

Image formed by Mirror M_1 (angles are measured from the mirror M_1)

Image formed by Mirror M_2 (angles are measured from the mirror M_2)



Stop because next angle will be more than 180°

Stop because next angle will be more than 180°

To check whether the final images made by the two mirrors coincide or not : add the last angles and the angle between the mirrors. If it comes out to be exactly 360°, it implies that the final images formed by the two mirrors coincide. Here last angles made by the mirrors + the angle between the mirrors = 160° + 170° + 30° = 360°.

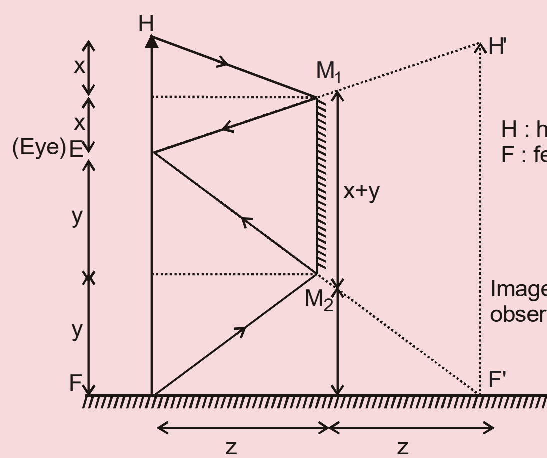
Therefore in this case the last images coincide. Therefore the number of images = number of images formed by mirror M_1 + number of images formed by mirror M_2 – 1 (as the last images coincide) = 6 + 6 – 1 = 11.

8. MINIMUM LENGTH OF THE MIRROR TO SEE FULL IMAGE.

Example 16

Show that the minimum size of a plane mirror required to see the full image of an observer is half the size of the observer.

Sol. See the following figure. It is self explanatory if you consider lengths 'x' and 'y' as shown in figure.



Aliter :

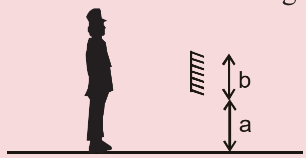
$\Delta E\ M_1, M_2$ and $\Delta E\ H'\ F'$ are similar

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

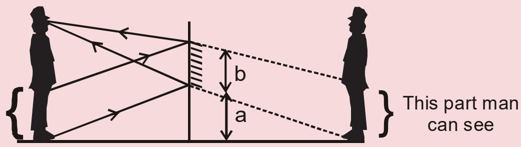
or $M_1\ M_2 = H'\ F' / 2 = HF / 2$

Example 17

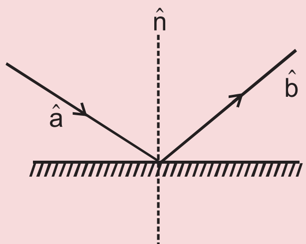
Show the Part of the image which man can see in the mirror as shown in the figure.



Sol.



Vector – form



$\hat{a}$ = Unit vector along the incident ray

$\hat{n}$ = Unit normal vector

$\hat{b}$ = Unit vector along the reflected Ray

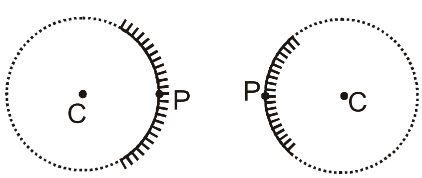
$$\hat{b} = \hat{a} - 2(\hat{a}.\hat{n})\hat{n}$$

Section B - Mirror formula and Magnification.

9. SPHERICAL MIRROR

9.1 Some Important Definitions

(i) Spherical Mirrors



Concave mirror Convex mirror

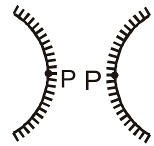
(ii) Paraxial Rays

The ray which have very small angle of incidence are known as paraxial rays.

(iii) Pole or Vertex

It is a point on the mirror from where it is easy to measure object and image distance.

In Fig. 1.27, the point P is the pole.

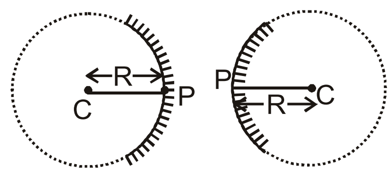


(iv) Centre of curvature

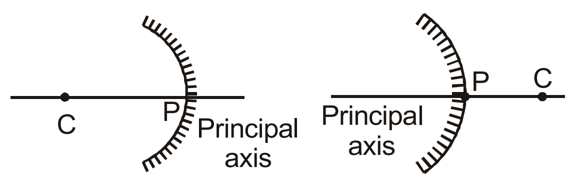
The centre C of the sphere of which the spherical mirror is a part, is the centre of curvature of the mirror.

(v) Radius of curvature (R)

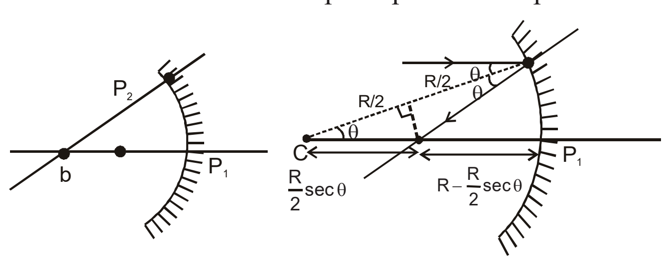
Radius of curvature is the radius R of the sphere of which the mirror forms a part.



(vi) Principal axis



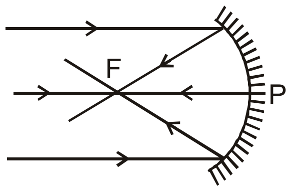
Line joining pole and centre of curvature of the mirror is known as principal axis or optical axis.



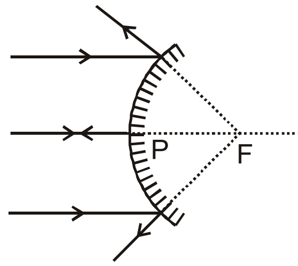
If θ is very small : $R - \frac{R}{2}\sec\theta \simeq \frac{R}{2}$

(vii) Focus (F)

If the rays are parallel to principal axis and paraxial, then the point at which they appear to converge is known as focus. Distance of focus from pole is R/2



Concave Mirror



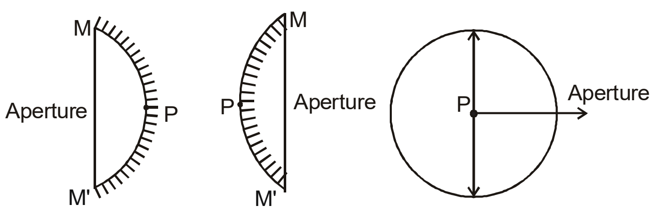
Convex mirror

(viii) Focal Length (f)

Focal length is the distance PF between the pole P and focus F along the principal axis.

(ix) Aperture

The line joining the end points of a spherical mirror is called the aperture or linear aperture.

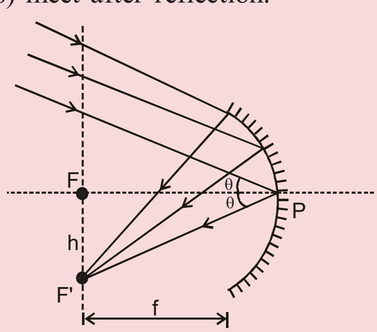


(x) Focal plane

Plane passing through focus and perpendicular to the optical axis called focal plane.

Example 18

Find distance of focal plane where parallel and paraxial rays (which are not parallel to optic axis) meet after reflection.



Sol. In $\Delta FF'P$

$$\tan\theta = \frac{h}{f}$$

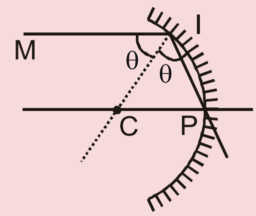
$h = f\,\theta$ (θ is small).

Note

If the rays are parallel and paraxial but not parallel to optic axis then they will meet at focal plane.

Example 19

Find the angle of incidence of a ray for which reflected ray passes through the pole. Given MI || CP.



Sol. $\angle MIC = \angle CIP = \theta$

MI || CP $\angle MIC = \angle ICP = \theta$

$CI = CP = R$

$\angle CIP = \angle CPI = \theta$

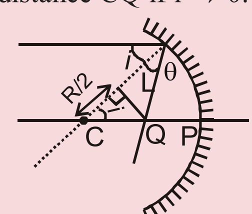
$\therefore$ In ΔCIP all angles are equal

$3\theta = 180°$

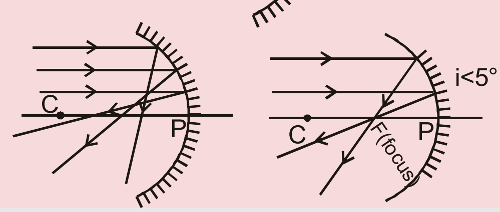
$\Rightarrow$ $\theta = 60°$

Example 20

Find the distance CQ if incident light ray parallel to principal axis is incident at an angle i. Also find the distance CQ if $i \to 0$.



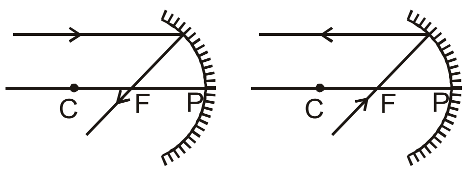
Sol.



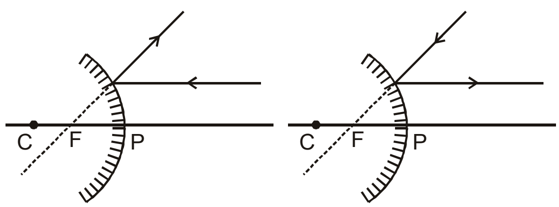
$$\cos i = \frac{R}{2CQ}$$

$$\Rightarrow \quad CQ = \frac{R}{2\cos i}$$

As i increases cos i decreases.
Hence CQ increases
So, paraxial rays meet at a distance equal to R/2 from centre of curvature, which is called focus,
Principal focus (F) is the point of intersection of all the reflected rays for which the incident rays strike the mirror (with small aperture) parallel to the principal axis. In concave mirror, it is real and in the convex mirror it is virtual. The distance from pole to focus is called focal length. Aperture (related to the size of mirror) is the diameter of the mirror.



Concave mirror

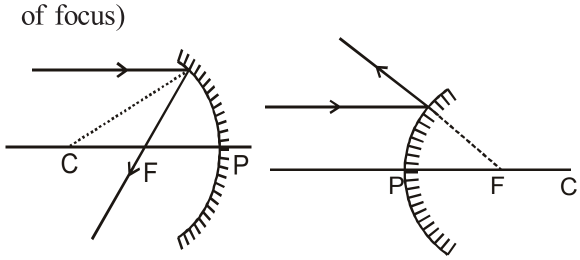


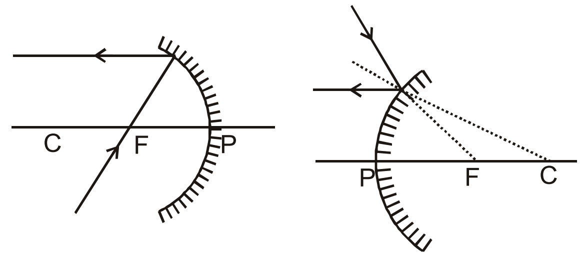
Convex mirror

9.2 Rules for Image Formation

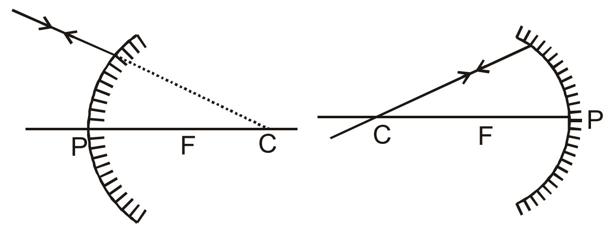
The reflection of light rays and formation of images are shown with the help of ray diagrams. Some typical incident rays and the corresponding reflected rays are shown below.

1. A ray passing parallel to the principal axis, after reflection from the spherical mirror passes or appears to pass through its focus (by the definition of focus)

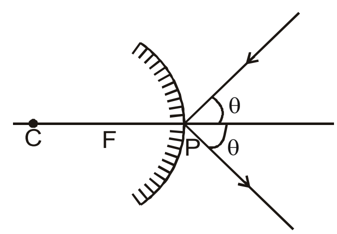




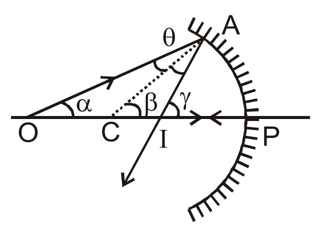
3. A ray passing through or directed towards the centre of curvature, after reflection from the spherical mirror, retraces its path (as for it $\angle i = 0$ and so $\angle r = 0$)



4. It is easy to make the ray tracing of a ray incident at the pole as shown in below.



9.3 Relation Between u,v and R for Spherical Mirrors



Consider the situation shown in figure. A point object is placed at the point O of the principal axis of a concave mirror. A ray OA is incident on the mirror at A. It is reflected in the direction AI. Another ray OP travels along the principal axis. As PO is normal to the mirror at P, the ray is reflected back along PO. The reflected rays PO and AI interesect at I where the image is formed.

Let C be the centre of curvature. The line CA is the normal at A. Thus, by the laws of reflection, $\angle OAC = \angle CAI$. Let α, β, γ and θ denote the angles AOP, ACP, AIP and OAC respectively. As the exterior angle in a triangle equals the sum of the two opposite interior angles, we have,

from triangle OAC

$$\beta = \alpha + \theta \qquad (1)$$

and from triangle OAI

$$\gamma = \alpha + 2\theta. \qquad (2)$$

Eliminating θ from (i) and (ii),

$$2\beta = \alpha + \gamma. \qquad (3)$$

If the point A is close to P, the angles α, β and γ are small and we can write

$$\alpha = \frac{AP}{PO} \qquad \beta = \frac{AP}{PC}$$

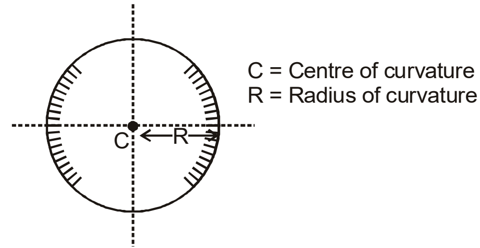
$$\text{and } \gamma \approx \frac{AP}{PI}. \quad \text{or} \quad \frac{1}{PO} + \frac{1}{PI} = \frac{2}{PC} \qquad (4)$$

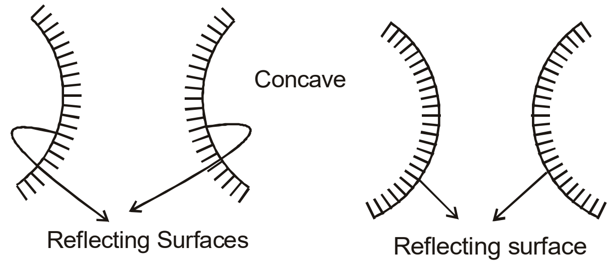
The pole P is taken as the origin and the principal axis as the X-axis. The rays are incident from left to right. We take the direction from left to right as the positive X-direction. The points O, I and C are situated to the left of the origin P in the figure. The quantities u, v and R are, therefore, negative. As the distances PO, PI and PC are positives, PO = – u, PI = – v and PC = – R. Putting in (4),

$$\frac{1}{-u} + \frac{1}{-v} = \frac{2}{-R}$$

$$\text{or} \quad \frac{1}{u} + \frac{1}{v} = \frac{2}{R} \qquad (5)$$

Although equation (vii) is derived for a special situation shown in figure, it is also valid in all other situations with a spherical mirror. This is because we have taken proper care of the signs of u, v and R appearing in figure shown.





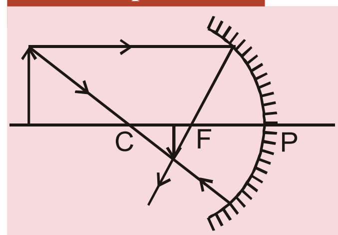
9.4 Sign Convention

1. All distances are measured from the pole of the spherical mirror along the principal axis. (Pole is considered as origin)

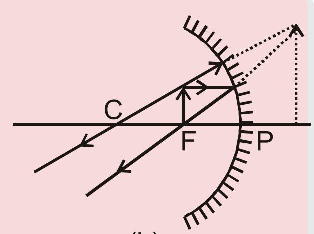
2. Distances measured along the principal axis in the direction of the incident ray are taken to be positive while the distance measured along the principal axis against the direction of the incident ray are taken to be negative.

3. Distances measured above the principal axis are taken to be positive while distances measured below the principal axis are taken to be negative.

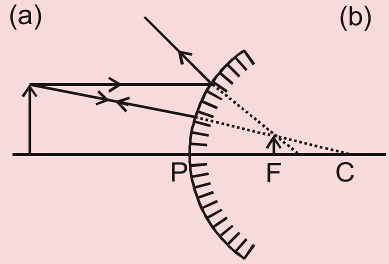
Example 21



(a)



(b)



(c)

Figure	u	v	R	f
(a)	–Ve	–Ve	–Ve	–Ve
(b)	–Ve	+Ve	–Ve	–Ve
(c)	–Ve	+Ve	+Ve	+Ve

Important Points Regarding Sign Convention

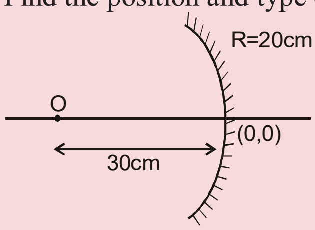
(i) Convention concides with right hand co-ordinate (or new Cartesian co-ordinate system).

(ii) In this sign convention, focal length of a concave mirror is always negative while the focal length of a convex mirror is always positive.

Assume the pole to be (0, 0).

Example 22

Find the position and type of image formed.



Sol. $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$

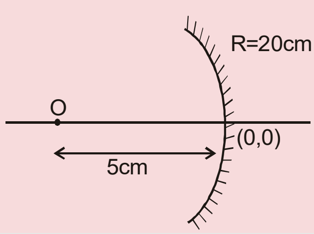
$\Rightarrow \frac{-1}{10}=\frac{-1}{30}+\frac{1}{v}$

$\Rightarrow \frac{1}{v}=\frac{1}{30}+\frac{-1}{10}=\frac{1-3}{30}=\frac{-2}{30}=\frac{-1}{15}$ cm

V = – 15cm (Real image)

Example 23

Find the position and nature of image formed.

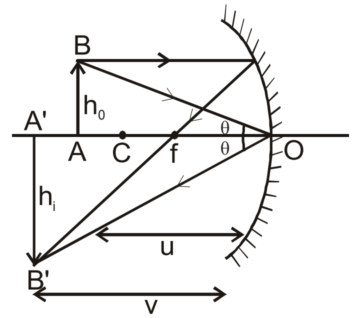


Sol. $\frac{1}{f}=\frac{1}{u}+\frac{1}{v} \Rightarrow \frac{-1}{10}=\frac{-1}{5}+\frac{1}{v}$

$\Rightarrow \frac{1}{v}=\frac{1}{5}-\frac{1}{10}=\frac{2-1}{10}=\frac{1}{10}$

$\therefore$ v = + 10 (Virtual image)

9.5 Magnification



9.5.1 Transverse Magnification

Δ ABO ~ Δ A'B'O

$$x=\frac{h_i}{v}=\frac{h_0}{u} \Rightarrow m=\frac{h_i}{h_0}=-\frac{v}{u}$$

- The above formula is valid for both concave and convex mirrors.
- Above the optical axis is considered positive and below to be negative
- h_i, h_0, v and u should be put with sign.

9.5.2 In case of successive reflections from mirrors, the overall lateral magnification is given by $\mathbf{m_1 \times m_2 \times m_3 ....}$, where m_1, m_2 etc. are lateral magnifications produced by individual mirrors.

Note

Using above relation, following conclusion can be made (check yourself).

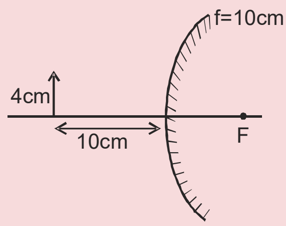
Nature of Object	Nature of Image	Nature of Erect
Real	Real	Inverted
Real	Virtual	Erect
Virtual	Real	Erect
Virtual	Virtual	Inverted

9.5.3 From previous formula we get

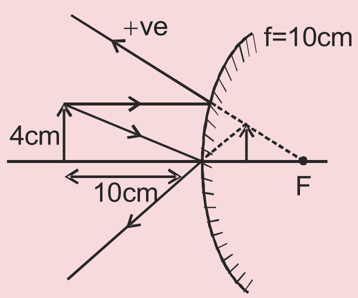
$$m = \frac{f}{f-u} = \frac{f-v}{f} \quad \text{(just a time saving formula)}$$

Example 24

Find the position, height and type of image.



Sol.



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

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

$$\Rightarrow \frac{1}{v} = \frac{+1}{10} + \frac{1}{10}$$

$$\Rightarrow V = +5\text{cm}$$

$$\frac{h_i}{4} = \frac{-5}{-10}$$

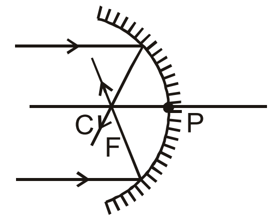
$$\Rightarrow h = +2\text{cm}$$

Hence image is virtual, erect & diminished.

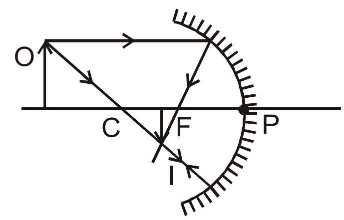
9.6 Cases for image formation by concave mirror

(i) When the object is at infinity

The image is formed at F. It is real, inverted and highly diminished.

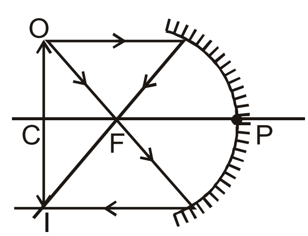


(ii) When the object lies beyond C (i.e., between infinity and C)



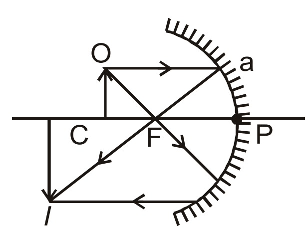
The image is formed between F and C. It is real, inverted and diminished.

(iii) When the object lies at C



The image is formed at C it is real, inverted and of same size.

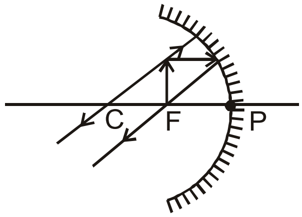
(iv) When the object lies between F and C



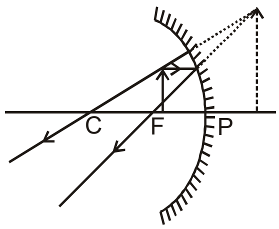
The image is formed beyond C (i.e., between C and infinity). It is real, inverted and enlarged.

(v) When the object is at F

The image is formed at infinity. It is real, inverted and highly enlarged.



(vi) When the object lies between P and F



The image is formed behind the concave mirror. It is virtual, erect and enlarged (magnified).

9.7 Longitudinal Magnification

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

By differentiating

$$\Rightarrow \quad -\frac{dv}{v^2}-\frac{du}{u^2}=0$$

$$\Rightarrow \quad \frac{dv}{du}=-\frac{v^2}{u^2}$$

Longitudinal magnification when the size of object is quite less with respect to its distance from the pole.

Above formula is valid only when the length of object is very small as compared to the distance of object from the pole.

$dv \rightarrow$ length of image

$du \rightarrow$ length of object

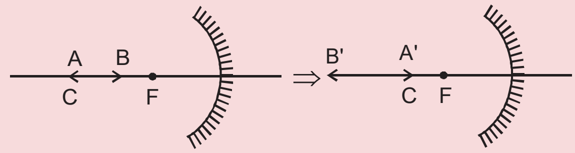
$u \rightarrow$ object distance from the pole.

$v \rightarrow$ Image distance from the pole.

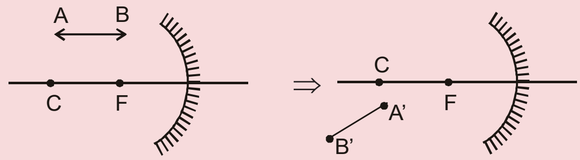
Example 25

Show the approximate image of AB in following cases.

(i)

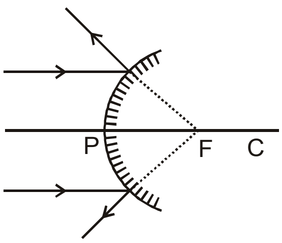


(ii)



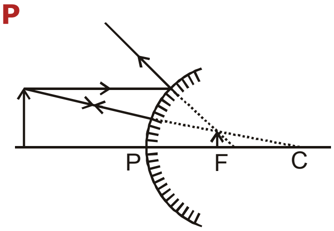
9.8 Cases for image formation by convex mirror

(i) When the object is at infinity



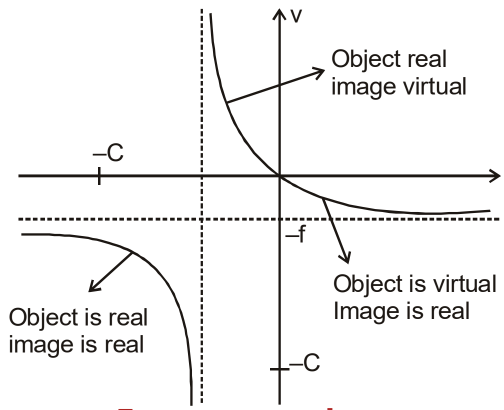
The image is formed at F. It is virtual, erect and highly diminished.

(ii) When the object lies in between infinity and P

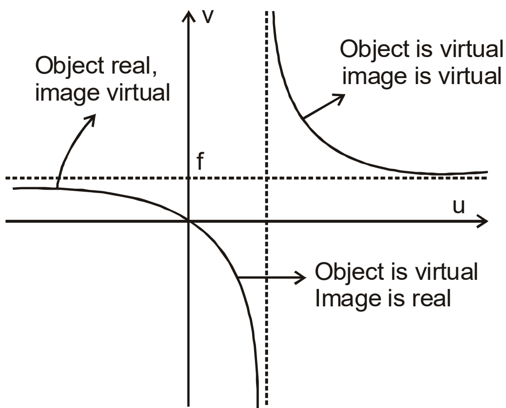


The image is formed between P and F. It is virtual, erect and diminished.

In case of image formation, unless stated otherwise, object is taken to be real and we consider only rays that are close to the principal axis and that make small angles with it. Such rays are called paraxial rays. In practice, this condition may be achieved by using a mirror whose size is much smaller than the radius of curvature of the surface. Otherwise the image will be distorted.



For concave mirror



For convex mirror

Section C - Velocity in Spherical Mirror

9.9 Velocity in Spherical Mirror : Velocity of image

(a) Object moving along principal axis :

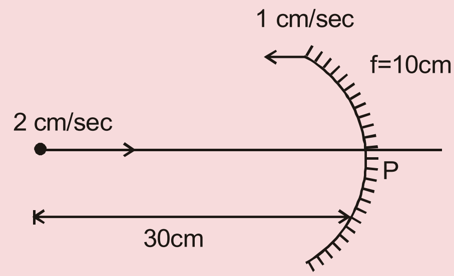
On differentiating the mirror formula with respect to time we get $\frac{dv}{dt} = -\frac{v^2}{u^2}\frac{du}{dt}$ where $\frac{dv}{dt}$ is the velocity of image along Principal axis and $\frac{du}{dt}$ is the velocity of the object along Principal axis. Negative sign implies that the image, in case of mirror, always moves in the direction opposite to that of object. This discussion is for velocity with respect to mirror and along the x axis.

Hence above equation can be written as

$$V_{IM} = -\frac{v^2}{u^2}(V_{OM})$$

Example 28

Find velocity of image in the given figure.



Sol. Here $u = -30$ cm

$f = -10$ cm

From using mirror formula,

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

$$v = -15 \text{ cm}$$

$$V_{IM} = -\frac{v^2}{u^2}(V_{OM})$$

$$V_I - (-1) = -\left(\frac{15}{30}\right)^2 (2-(-1))$$

$$\Rightarrow V_I = -\frac{7}{4} \text{ cm/sec.}$$

(b) Object moving perpendicular to principal axis

From the magnification formula we have,

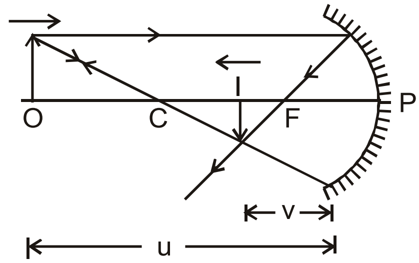
$$\frac{h_i}{h_o} = -\frac{v}{u} \quad \text{or} \quad h_i = -\frac{v}{u}h_o$$

If a point object moves perpendicular to the principal axis, x coordinate of both the object & the image becomes constant. On differentiating the above relation w.r.t time, we get,

$$\frac{dh_i}{dt} = -\frac{v}{u}\frac{dh_o}{dt}$$

Here, $\frac{dh_o}{dt} = v_0$ denotes velocity of object perpendicular to the principal axis and $\frac{dh_i}{dt} = v_y$ denotes velocity of image perpendicular to the principal axis.

(c) Object moving parallel to Principal axis



$$v_x = \frac{dv}{dt} = \frac{-v^2}{u^2}\frac{du}{dt}$$

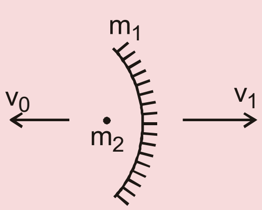
On differentiating equation

$$h_i = -\frac{v}{u}h_0$$

$$v_y = \frac{dh_i}{dt} = -h_0\left[\frac{dv}{dt}.\frac{1}{u} - \frac{v}{u^2}\frac{du}{dt}\right]$$

Example 27

A gun of mass m_1 fires a bullet of mass m_2 with a horizontal speed v_0. The gun is fitted with a concave mirror of focal length (f) facing towards a receding bullet. Find the speed of separation of the bullet and the image just after the gun was fired.



Sol. Let v_1 be the speed of gun (or mirror) just after the firing of bullet.

From conservation of linear momentum.

$$m_2v_0 = m_1v_1$$

or $$v_1 = \frac{m_2v_0}{m_1} \quad \text{...(i)}$$

Now, $\frac{du}{dt}$ = rate at which distance between mirror and bullet is increasing

$$= v_1 + v_0 \quad \text{...(ii)}$$

$$\therefore \quad \frac{dv}{dt} = \left(\frac{v^2}{u^2}\right)\frac{du}{dt}$$

Here $\frac{v^2}{u^2} = m^2 = 1$

(as at the time of firing bullet is at pole)

$$\because \quad \frac{dv}{dt} = \frac{du}{dt} = v_1 + v_0 \quad \text{...(iii)}$$

Here $\frac{dv}{dt}$ is the rate at which distance between image (of bullet) and mirror is increasing. So if v_2 is the absolute velocity of image (towards right) then,

$$v_2 - v_1 = \frac{dv}{dt} = v_1 + v_0$$

or $v_2 = 2v_1 + v_0$ ...(iv)

Therefore, speed of separation of bullet and image will be,

$$v_r = v_2 + v_0$$
$$= 2v_1 + v_0 + v_0$$

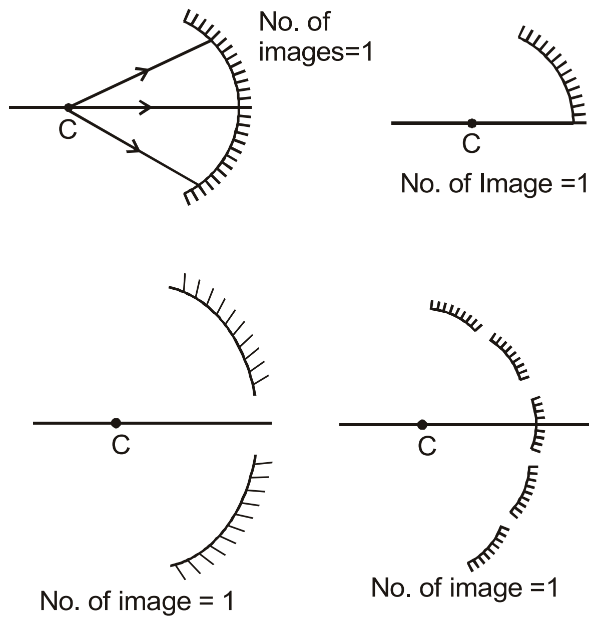
or $v_r = 2(v_1 + v_0)$

Substituting value of v_1 from equation (i) we have,

$$v_r = 2\left(1 + \frac{m_2}{m_1}\right)v_0 \qquad \textbf{Ans.}$$

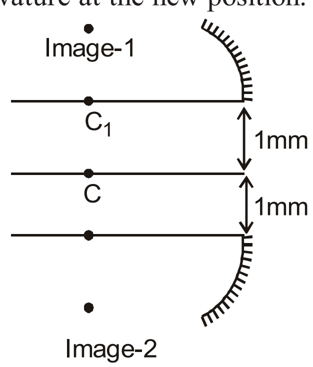
Section D - Cutting of Mirrors

10. CUTTING OF MIRRORS



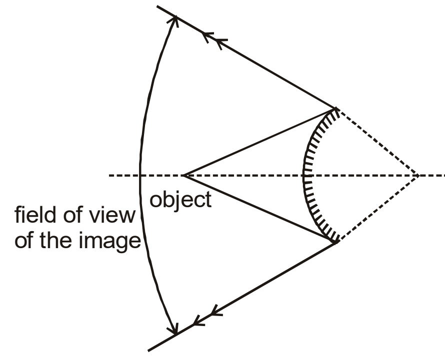
Both the parts of mirror have same hollow sphere so its radius of curvature is same. Therefore number of images formed is 1.

If we cut the mirror and shift it, the centre of curvature changes. For example in the figure shown below, a concave mirror is cut and each part is shifted by 1mm. Then centre of curvature of each part shifts by 1mm and each part behaves as 2 independent concave mirrors with its centre of curvature at the new position.



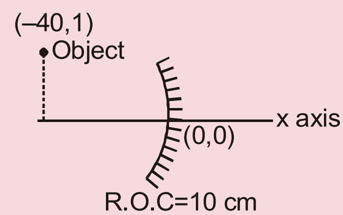
Therefore two images are found.

10.1 Field of View



Example 28

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



Sol. According to sing convention,

$u = -40$ cm

$h_1 = +1$ cm

$f = -5$ cm

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

$$v=\frac{-40}{7}\text{cm}$$

$$\frac{h_2}{h_1}=\frac{-v}{u}$$

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

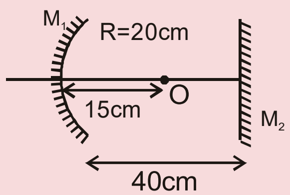
$\therefore$ The position of image is $\left(\frac{-40}{7}\text{cm}, -\frac{1}{7}\text{cm}\right)$

Section E - Combination of Mirrors, Intensity of light

11. COMBINATION OF MIRRORS

Example 29

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 :

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f} \quad \Rightarrow \quad v = -30 \text{ cm}$$

(i.e. it forms the image in front of the concave mirror)

For II reflection on plane mirror :

u = – 10 cm

$\therefore$ v = 10 cm (Behind the mirror)

For III reflection on curved mirror again :

u = – 50 cm (= 40 + 10) from concave mirror

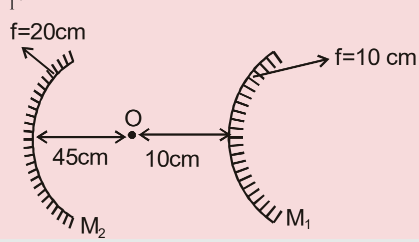
f = – 10 cm

Applying mirror formula :

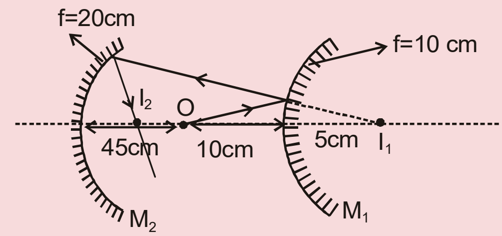
$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f} \quad \Rightarrow \quad v = -12.5 \text{ cm}$$

Example 30

Find out the position of the final image formed by two reflections. Take the first reflection from M_1.



Sol.



For M_1

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

$$\Rightarrow \frac{1}{10}=\frac{1}{v}-\frac{1}{10}$$

$$\Rightarrow \frac{1}{v}=\frac{2}{10}$$

$\Rightarrow$ v = + 5 cm (Image will be behind M_1)

For M_2 : u = –60cm, f = – 20cm

[Hence u = (45+10+5)]

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

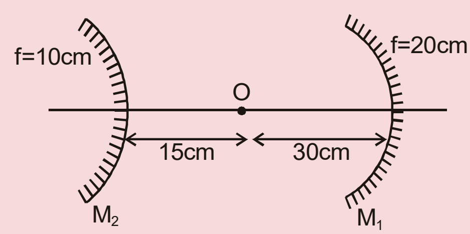
$$\Rightarrow -\frac{1}{20}=\frac{1}{v}-\frac{1}{60}$$

$$\Rightarrow \frac{1}{v}=-\left(\frac{1}{20}-\frac{1}{60}\right)$$

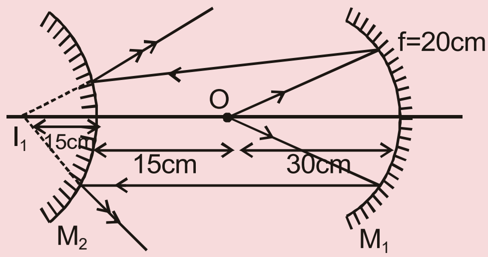
$\Rightarrow$ v = – 30 cm

Example 31

Find the position of the final image formed by two reflections. Take the first reflection from M_1.



Sol.



For M_1 :

u = – 30cm, f = – 20cm

$$\frac{1}{f}=\frac{1}{u}+\frac{1}{v} \Rightarrow v = -60 \text{ cm (In front of } M_1)$$

For M_2 :

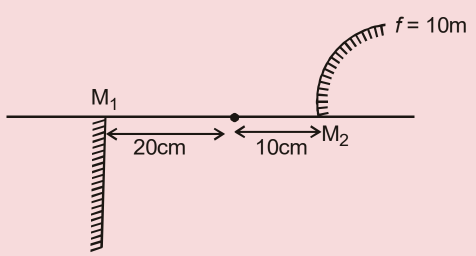
u = (60 - 15 - 30 = 15) (behind M_2)

u = + 15 f = + 10 v = + 30

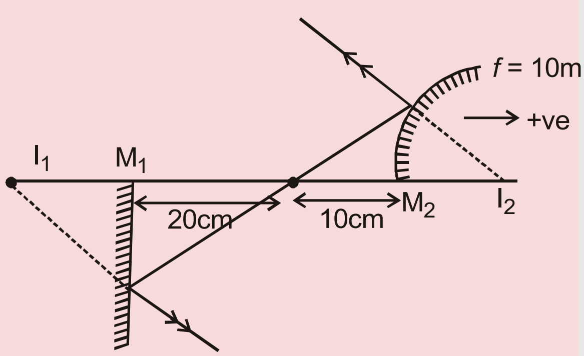
Reversibility of rays

Example 32

Find the number and positions of all the images formed in the figure shown below.



Sol.



For M_2 :

u = – 10 cm, f = + 10 cm,

$$\frac{1}{-10}+\frac{1}{v}=\frac{1}{10} \Rightarrow \frac{1}{v}=\frac{1}{5} \Rightarrow v = 5\text{cm}$$

Hence, two images are formed one by convex mirror at 5 cm behind it & the other by plane mirror at 20 cm behind it.

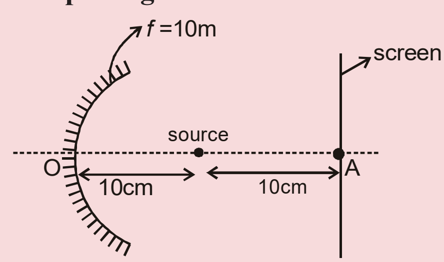
Note

In the above case only one ray will go on the optic axis and the one ray is not responsible for image formation.

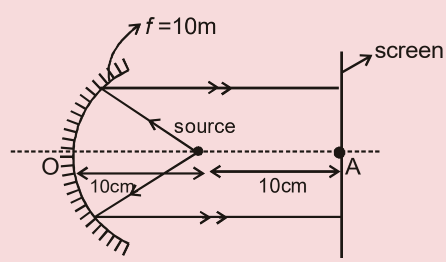
12. INTENSITY OF LIGHT

Example 33

Intensity at A due to source is I without concave mirror, then find the intensity of A after placing concave mirror.



Sol.



$$I = \frac{P}{4\pi(10)^2}$$

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

$$\Rightarrow \quad \frac{-1}{10}=\frac{1}{v}-\frac{1}{10}$$

$$\Rightarrow \quad v = \infty.$$

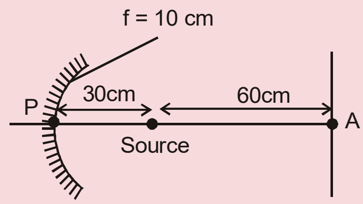
Intensity at A due to reflection = I.

Total intensity = I + I = 2I

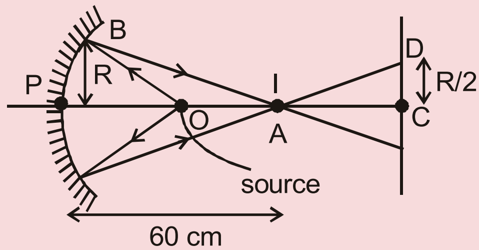
Example 34

Intensity at A due to source is I without concave mirror, then find the intensity of A after placing concave mirror.

(I)



Sol.



$P = I \times A$, where P is the power of source.

$= I \times 4\pi(60)^2$

Intensity at point P (I') $= \dfrac{P}{\text{Area}}$

$$= \frac{4\pi(60)^2 I}{4\pi(30)^2} = 4I$$

Now Δ PAB ~ ΔOBP

$$\Rightarrow \frac{AP}{PB} = \frac{AC}{CD}$$

$$\Rightarrow CD = \frac{30}{60} \times R = \frac{R}{2}.$$

The area spread in the region near point A

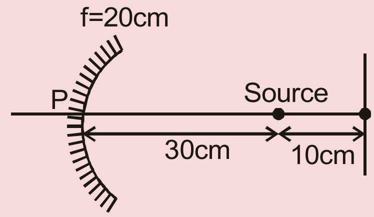
$[A'] = \pi(R/2)^2$

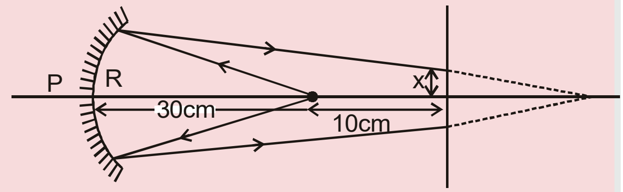
Power at Area of R radius $= 4\,I \times \pi R^2$

So intensity from mirror $= \dfrac{4 I \times \pi R^2}{\pi(R/2)^2} = 16\,I$

Total Intensity $= 16\,I + I = 17\,I$

(ii)





Sol. P = Power of source

$P = I \times 4\pi(10)^2$

Intensity at P (I') $= \dfrac{P}{\text{Area}}$

$$= \frac{P}{4\pi(30)^2} = \frac{I}{9}$$

Now $\dfrac{R}{60} = \dfrac{x}{20}$

$$x = \frac{R}{3}$$

Power incident on mirror

$$P_P = \frac{I}{9} \times \pi R^2$$

This power will be incident on πx^2 area

So Intensity from mirror $= \dfrac{I \times \pi R^2}{9\pi(R/3)^2} = I$

So total, $I = I + I = 2I$

Section F - Snell's Law, Apparent depth and Normal shift, Refraction through a Glass slab, Lateral shift

13. REFRACTION OF LIGHT

Deviation or bending of light rays from their original path while passing from one medium to another is called refraction. It is due to change in speed of light as light passes from one medium to another medium. If the light is incident normally then it goes to the second medium without bending, but still it is called refraction.

Refractive index of a medium is defined as the factor by which speed of light reduces as compared to the speed of light in vacuum.

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

More (less) refractive index implies less (more) speed of light in that medium, which therefore is called denser(rarer) medium.

Note

- Higher the value of Refractive index denser (optically) is the medium.
- Frequency of light does not change during refraction
- Refractive index of the medium relative to vacuum

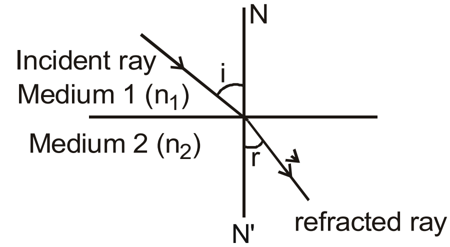
$$= \sqrt{\mu_r \in_r}$$

$$n_{vacuum} = 1;$$
$$n_{air} \geq 1;$$
$$n_{water} \text{ (average value)} = 4/3;$$
$$n_{glass} \text{ (average value)} = 3/2$$

13.1 Laws of Refraction

(a) The incident ray, the normal to any refracting surface at the point of incidence and the refracted ray all lie in the same plane (called the plane of incidence or plane of refraction).

(b) $\frac{\sin i}{\sin r}$ = Constant for any pair of media and for light of a given wavelength.



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

Also, $\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$

For applying in problems:-

$$\mathbf{n_1 \sin i = n_2 \sin r}$$

$\frac{n_2}{n_1} = {}_1n_2$ = Refractive Index of the second medium with respect to the first medium.

C = speed of light in air (or vacuum)

$= 3 \times 10^8$ m/s.

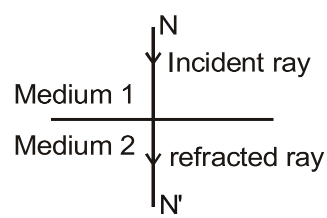
i & r should be taken from normal.

Special cases :

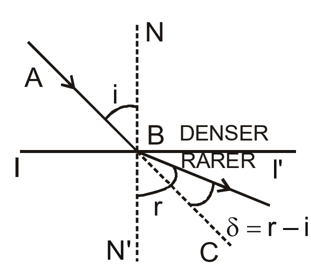
- Normal incidence :

$$i = 0$$

From snell's law, r = 0

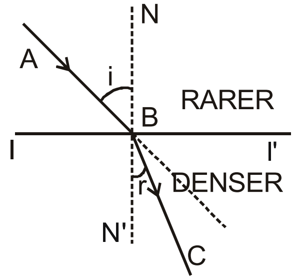


- When light moves from denser to rarer medium it bends away from normal.



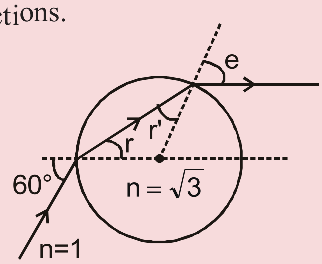
r>i

- When light moves from rarer to denser medium it bends towards the normal.



Example 35

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



Sol. Applying Snell's law 1 sin 60° = $\sqrt{3}\sin r$

$\Rightarrow$ r = 30°

From geometry r' = r = 30°

Again applying snell's law at second surface

1 sin e = $\sqrt{3}\sin r$

$\Rightarrow$ e = 60°

Deviation at first surface = i – r

= 60° – 30° = 30° (CW)

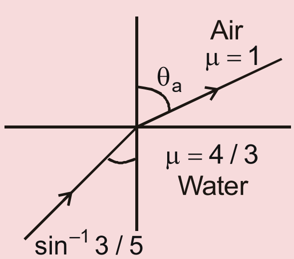
Deviation at second surface = e – r′

= 60° – 30° = 30°(CW)

Therefore total deviation = 60°(CW)

Example 36

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



Sol. From Snell's Law

$$\mu_w \sin\theta_w = \mu_a \sin\theta_a$$

$$\Rightarrow \frac{4}{3}\times\frac{3}{5} = 1\sin\theta_a$$

$$\sin\theta_a = \frac{4}{5}$$

$$\Rightarrow \theta_a = \sin^{-1}\frac{4}{5}$$

Example 37

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 45° and 60° respectively with the normal.

Sol. From Snell's Law

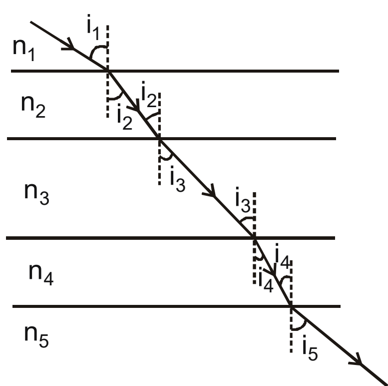
$$\mu_a \sin\theta_a = \mu_b \sin\theta_b$$

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

$$\frac{c}{v_a}\sin 45° = \frac{c}{c/3}\sin 60°$$

$$\Rightarrow v_a = \frac{\sqrt{2}c}{3\sqrt{3}}$$

13.2 Plane Refraction

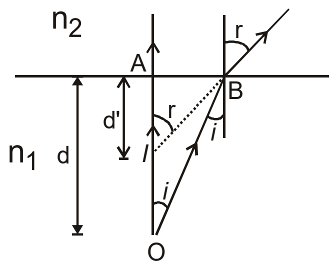


Prove that $n_1 \sin i_1 = n_2 \sin i_2 = n_3 \sin i_3 = n_4 \sin i_4$

Also Prove that if $n_1 = n_4$ then light rays in medium n_1 and in medium n_4 are parallel.

14. APPARENT DEPTH AND NORMAL SHIFT

Case I : When the object is in denser medium and the observer is in rarer medium (near normal incidence)



When an object O is in denser medium of depth 'd' and absolute refractive index n_1 and is viewed almost normally to the surface from the outside rarer medium (R.I. = n_2), its image is seen at I. Which is at a distance d′ from surface AO is the real depth of the object. AI is the apparent depth of the object. O*I* is called apparent shift.

According to Snell's law,

$$\frac{n_2}{n_1} = \frac{\sin i}{\sin r}$$

or, $$\frac{n_2}{n_1} = \frac{\tan i}{\tan r} \quad (\because \text{ i and r are small angles})$$

$$\frac{n_2}{n_1} = \frac{AB}{AO} \times \frac{AI}{AB}$$

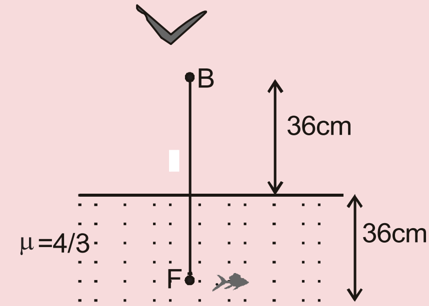
$$\mathbf{\frac{n_2}{n_1} = \frac{d'}{d} = \frac{apparent\ depth}{Real\ depth}}$$

Note

1. The above formula is valid only for paraxial rays.
2. Distances should be taken from the surface.
3. n_2 is the reflective index of the medium from where ray is going and n_1 is the reflective index of the medium from where ray is coming

Example 38

Find the following in the figure shown below :



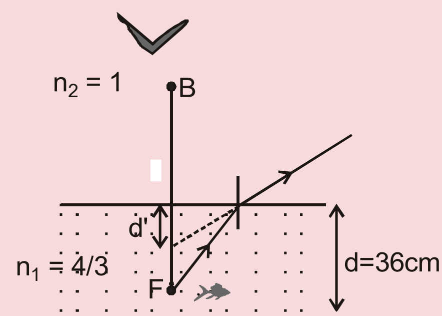
(a) The apparent distance of the fish from the surface as observed by the bird

(b) The apparent distance of the bird from the surface as observed by the fish

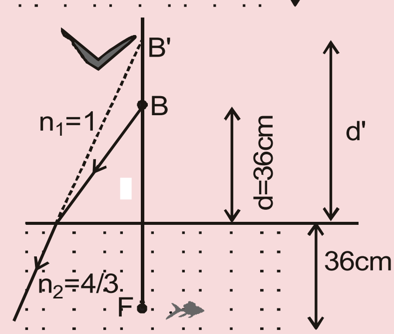
Sol. **(a)** $$\frac{\text{apparent depth}}{\text{Real depth}} = \frac{n_2}{n_1} = \frac{d'}{d}$$

$$\frac{1}{4/3} = \frac{d'}{36}$$

$\Rightarrow$ d′ = 27 cm



(b)

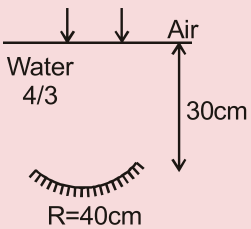


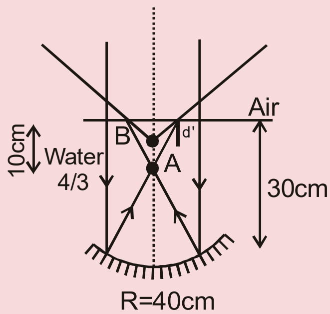
$$\frac{4/3}{1} = \frac{d'}{36}$$

$\Rightarrow$ d′ = 48 cm

Example 39

A concave mirror is placed inside water with its shining surface upwards and principal axis vertical as shown. Rays are incident parallel to the principal axis of concave mirror. Find the position of final image.



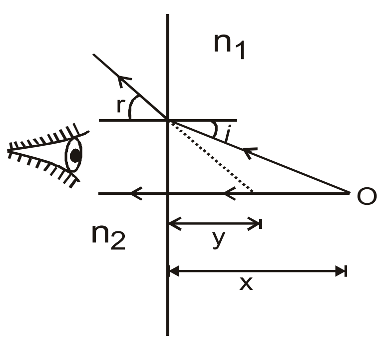


Sol. The incident rays will pass undeviated through the water surface and strike the mirror parallel to its principal axis. Therefore for the mirror, object is at ∞. Its image A (in figure) will be formed at focus which is 20 cm from the mirror. Now for the interface between water and air, d = 10 cm

$$\frac{d}{d'} = \frac{n_w}{n_a}$$

$$\therefore\ d' = \frac{d}{\left(\frac{n_w}{n_a}\right)} = \frac{10}{\left(\frac{4/3}{1}\right)} = 7.5\,\text{cm}$$

14.1 Velocity of the image in case of plane refraction



$$\frac{n_2}{n_1} = \frac{y}{x} \quad \Rightarrow \quad y = \frac{n_2}{n_1}.x$$

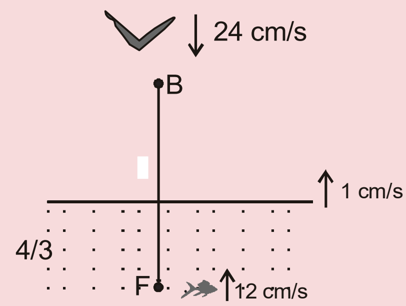
$$\frac{dy}{dt} = \frac{n_2}{n_1}\frac{dx}{dt} \quad \Rightarrow \quad V_{IS} = \frac{n_2}{n_1}V_{OS}$$

Example 40

Find the following in the figure shown below :

(a) The apparent speed of the fish as observed by the bird

(b) The apparent speed of the bird as observed by the fish



Sol. **(a)** $V_{IS} = \dfrac{n_2}{n_1}V_{OS}$

$$\Rightarrow\ V_I - 1 = \frac{3}{4}(12-1)$$

$$V_I = \frac{33}{4} + 1 = \frac{37}{4}$$

$$V_{IB} = V_I - V_B = \frac{37}{4} + 24 = \frac{133}{4}\,\text{cm/sec}$$

(b) $n_2 = 4/3$,

$n_1 = 1$

$$V_{IS} = \frac{n_2}{n_1}V_{OS}$$

$$V_0 = -24,\ \ V_s = +1$$

$$\Rightarrow\ V_I - 1 = \frac{4}{3}\ [-24-1]$$

$$V_I = -\frac{97}{3}$$

$$\Rightarrow\ V_{If} = \frac{97}{3} + 12$$

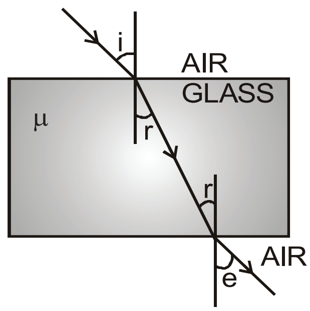
$$= \frac{133}{3}\ \text{cm/sec.}$$

15. REFRACTION THROUGH A GLASS SLAB

When a light ray passes through a glass slab having parallel faces, it gets refracted twice before finally emerging out of it.

First refraction takes place from air to glass.

So, $\mu = \dfrac{\sin i}{\sin r}$ ...(i)



The second refraction takes place from glass to air.

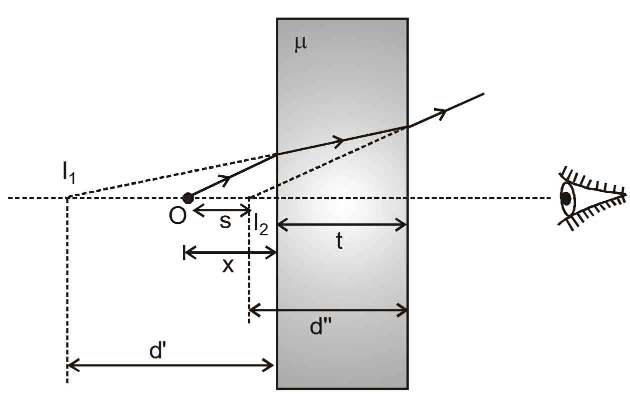
So, $\dfrac{1}{\mu} = \dfrac{\sin r}{\sin e}$ ...(ii)

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

$$\frac{\sin i}{\sin r} = \frac{\sin e}{\sin r} \quad \Rightarrow \ i = e$$

Thus, the emergent ray is parallel to the incident ray.

15.1 Apparent shift due to slab when object is seen normally through the slab



Ist Refraction

Because of the refraction at the first surface, the image of O is formed at I_1. For this refraction, the real depth is x and the apparent depth is d'. Also, the first medium is air and the second is the slab. Thus,

$$\frac{\mu}{1} = \frac{d'}{x} \qquad \Rightarrow \ \mu x$$

IInd Refraction

The point I_1 acts as the object for the refraction at the second surface. Due to this refraction, the image of I_1 is formed at I_2. Thus.

$$\frac{1}{\mu} = \frac{d''}{\mu x + t} \quad \Rightarrow \ d'' = x + \frac{t}{\mu}$$

Shift $\qquad S = x + t - x - \dfrac{t}{\mu}$

$$\mathbf{S} = t\left[1 - \frac{1}{\mu}\right]$$

If medium is not air, outside the slab

$$\mathbf{S} = t\left[1 - \frac{\mu_{surrounding}}{\mu_{slab}}\right]$$

Important points

1. Rays should be paraxial
2. Shift is measured from the object.
3. Shift is independent of the distance of the object from the slab.
4. If shift comes out +ve then it is towards the direction of incident rays and vice versa.

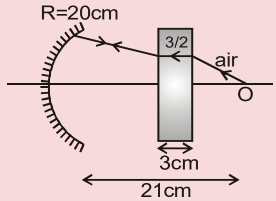
Example 41

Calculate the shift produced by the slab having thickness 15cm and refractive index 1.5 which is kept in air.

Sol. shift $\mathbf{S} = t\left[1 - \dfrac{1}{\mu}\right] = 15\left[1 - \dfrac{2}{3}\right] = 5$ cm

Example 42

See the figure. Find the distance of final image formed by mirror



Sol. Shift = $3\left(1-\frac{1}{3/2}\right)$ =1 cm

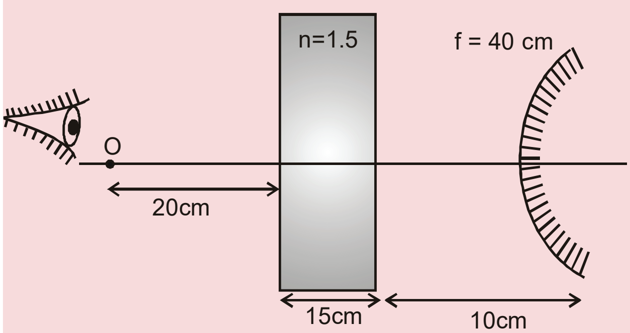
For mirror object is at a distance

= (21cm – 1cm)= 20 cm

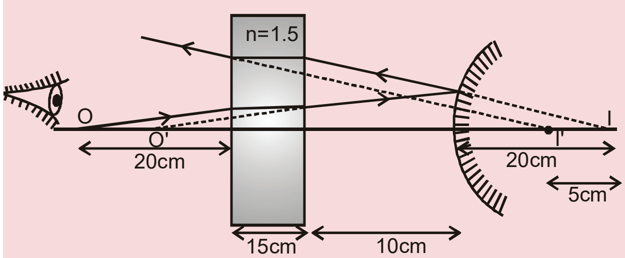
∴ Object is at the centre of curvature of mirror. Hence the light ray will retrace and image will formed on the object itself.

Example 43

Find the distance between image and the mirror as observed by observer in the figure shown below



Sol.



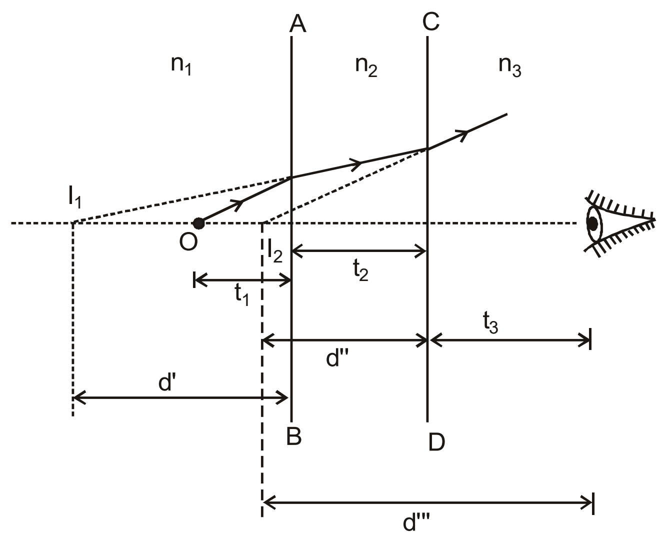
$$\text{shift} = t\left(1-\frac{1}{\mu}\right) = 15\left(1-\frac{2}{3}\right) = 5\text{cm}$$

$$u = -40\text{cm}, \quad f = +40\text{cm} \Rightarrow v = +20\text{cm}$$

$$\left[\text{Use } \frac{1}{u}+\frac{1}{v}=\frac{1}{f}\right]$$

the distance between mirror and the image as observed by observer = 20 – shift = 15 cm

15.2 Apparent distance between object and observer when both are in different medium.



Ist Refraction :

$$\frac{n_2}{n_1} = \frac{\text{apparent distance of object from interface AB}}{\text{Real distance of object from interface AB}} = \frac{d'}{t_1}$$

$$d' = \frac{n_2 t_1}{n_1}$$

IInd Refraction :

$$\frac{n_3}{n_2} = \frac{\text{apparent distance of } I_1 \text{ from interface CD}}{\text{Real distance of } I_1 \text{ from interface CD}}$$

$$= \frac{d''}{\frac{n_2 t_1}{n_1} + t_2}$$

$$d'' = \frac{n_3}{n_2}\left[\frac{n_2}{n_1}t_1 + t_2\right]$$

$$= n_3\left[\frac{t_1}{n_1}+\frac{t_2}{n_2}\right]$$

Final distance of image from observer (d''')

$$= d''+t_3$$

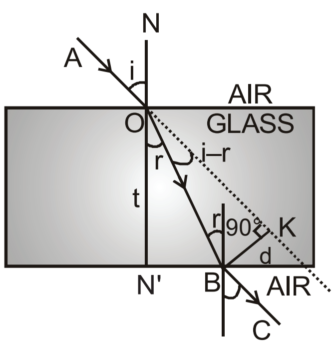
$$d''' = n_3\left[\frac{t_1}{n_1}+\frac{t_2}{n_2}+\frac{t_3}{n_3}\right]$$

Note

If object and observer are in same medium then shift formula should be used and if both are in different medium then the above formula of apparent distance should be used.

15.3 Lateral Shift

The perpendicular distance between the incident ray and the emergent ray, when a light ray is incident obliquely on a parallel sided refracting glass slab is called 'lateral shift'.



In right - angled triangle OBK, we have

$\angle$ BOK = i – r

$$\therefore \quad \sin(i-r) = \frac{d}{OB}$$

or, $d = OB\sin(i-r)$ ...(i)

In right angled triangle ON′ B, we have

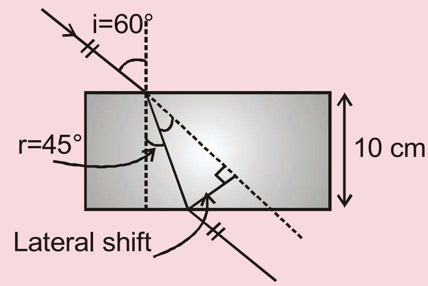
$$\cos r = \frac{ON'}{OB} \quad \text{or, } OB = \frac{t}{\cos r}$$

Substituting the above value of OB in equation (i), we get

$$d = \frac{t}{\cos r}\sin(i-r) \quad ...(13)$$

Example 44

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 60° and the angle of refraction in glass is 45°.



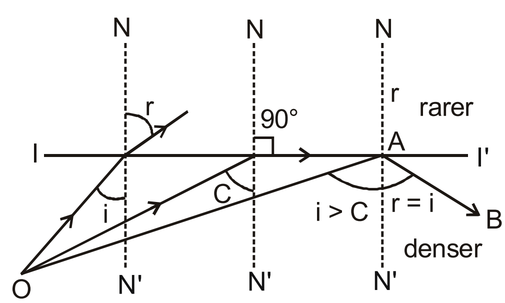
Sol.
$$d = \frac{t\sin(i-r)}{\cos r} = \frac{10\sin(60°-45°)}{\cos 45°}$$

$$= \frac{10\sin 15°}{\cos 45°} = 10\sqrt{5}\sin 15°$$

Section G - Critical Angle and Total Internal Reflection (T.I.R.)

16. CRITICAL ANGLE AND TOTAL INTERNAL REFLECTION (T.I.R.)

Critical angle is the angle made in denser medium for which the angle of refraction in rarer medium is 90°. When angle in denser medium is more than critical angle, the light ray reflects back in denser medium following the laws of reflection and the interface behaves like a perfectly reflecting mirror. In the figure.



O = object

NN′ = Normal to the interface

II′ = Interface

C = Critical angle :

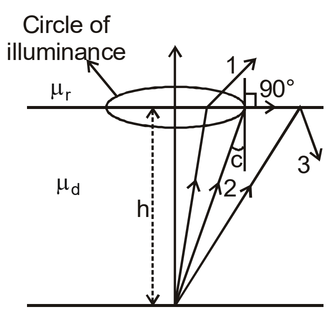
AB = reflected ray due to T.I.R.

When $i = C$

then $r = 90°$

$\therefore \quad C = \sin^{-1}\frac{n_r}{n_d}$

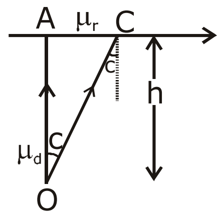
16.1 Conditions of TIR



(a) Light is incident on the interface from denser medium.

(b) Angle of incidence should be greater than the critical angle ($i > c$). Figure shows a luminous object placed in denser medium at a distance h from an interface separating two media of refractive indices μ_r and μ_d. Subscript r & d stand for rarer and denser medium respectively.

In the figure ray 1 strikes the surface at an angle less than critical angle C and gets refracted in rarer medium. Ray 2 strikes the surface at critical angle and grazes the interface. Ray 3 strikes the surface making an angle more than critical angle and gets internally reflected. The locus of points where ray strikes at critical angle is a circle, called **circle of illuminance**. All light rays striking inside the circle of illuminance get refracted in rarer medium. If an observer is in rarer medium, he/she will see light coming out only from within the circle of illuminance. If a circular opaque plate covers the circle of illuminance, no light will get refracted in rarer medium and then the object can not be seen from the rarer medium. Radius of C.O.I



$i = c,\ r = 90°$

$\tan c = \frac{r}{h}$ ... (i)

from Snell's law

$\mu_d \sin c = \mu_r \sin 90°$

$\Rightarrow \sin c = \frac{\mu_r}{\mu_d}$

$\Rightarrow \tan c = \frac{\mu_r}{\sqrt{\mu_d^2 - \mu_r^2}}$.

Hence $r = \frac{h\mu_r}{\sqrt{\mu_d^2 - \mu_r^2}}$

If $\mu_r = 1$

$r = \frac{h}{\sqrt{\mu^2 - 1}}$

Example 45

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. $1.5 \sin C = 1 \sin 90°$, where C = critical angle.

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

Example 46

Find the angle of refraction in a medium ($n = 2$) 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.

$C = \sin^{-1}\frac{1}{\mu} = 30°$

$\Rightarrow \quad \therefore \ i = 2C = 60°$

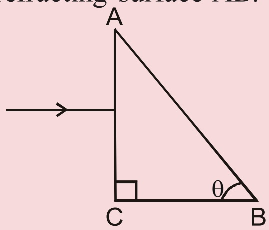
Applying Snell's Law. $1 \sin 60° = 2 \sin r$

$\sin r = \frac{\sqrt{3}}{4}$

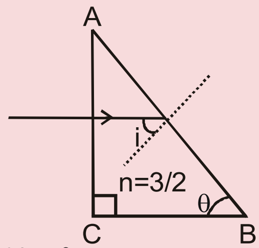
$\Rightarrow \quad r = \sin^{-1}\left(\frac{\sqrt{3}}{4}\right)$

Example 47

What should be the value of angle θ so that light entering normally through the surface AC of a prism (n = 3/2) does not emerge from the second refracting surface AB.



Sol. Light ray will pass the surface AC without bending since it is incident normally. Suppose it strikes the surface AB at an angle of incidence i.



$i = 90° - \theta$

For the required condition :

$90° - \theta > C$

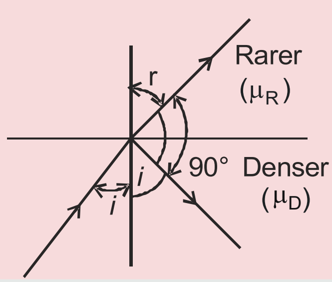
or $\sin(90° - \theta) > \sin C$

or $\cos\theta \geq \sin C$ & $\cos\theta \geq \frac{1}{\frac{3}{2}}$

or $\cos\theta > \frac{2}{3}$ or $\theta > \cos^{-1}\frac{2}{3}$

Example 48

A ray of light from a denser medium strikes a rarer medium at an angle of incidence i. If the reflected and the refracted rays are mutually perpendicular to each other, what is the value of the critical angle ?



Sol. From Snell's law, we have

$$\frac{\sin i}{\sin r} = \frac{\mu_R}{\mu_D} \qquad \text{But,} \qquad \mu = \frac{\mu_D}{\mu_R} \qquad \ldots\text{(i)}$$

$$\therefore \mu = \frac{\sin r}{\sin i}$$

According to the given problem,

$i + r + 90° = 180°$

or, $r = 90° - i$

Substituting the above values of 'r' in equation (i), we get

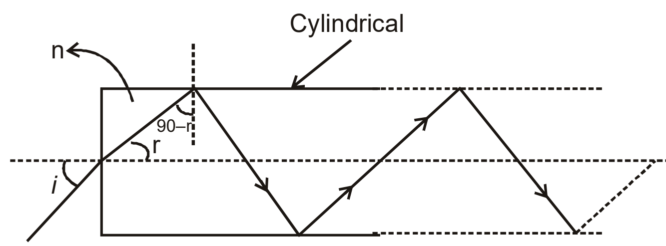
$$\mu = \frac{\sin(90° - i)}{\sin i} \quad \text{or,} \quad \mu = \cot i \qquad \ldots(ii)$$

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

or, $C = \sin^{-1}\left(\frac{1}{\cot i}\right)$ (using equation (ii)

or, $C = \sin^{-1}(\tan i)$

16.2 Optical Fibre Cable



Find out the range of n for which ray will show T.I.R through curved surface.

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 (Why ?). Therefore the minimum value of r' is 90° – C.

For T.I.R. :-

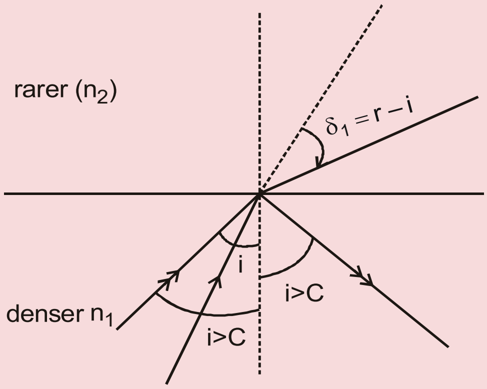
For r_{max}

$\Rightarrow i_{max} = 90°$

when $i = 90°$, $r = C$

$90° - C > C \Rightarrow C < 45° \Rightarrow \sin C < \sin 45°$

$$\Rightarrow \frac{1}{n} < \frac{1}{\sqrt{2}} \Rightarrow n > \sqrt{2}$$



Graph between d and i :

when $i \le C$

$\delta = r - i$

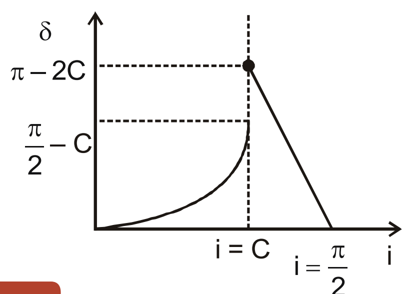
and $n_1 \sin i = n_2 \sin r$

$$r = \sin^{-1}\left(\frac{n_1}{n_2}\sin i\right)$$

so $$\delta = \sin^{-1}\left(\frac{n_1}{n_2}\sin i\right) - i \qquad ...(1)$$

when $i > C$:

then $\delta = \pi - 2i \qquad ...(2)$



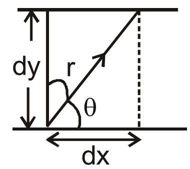
Note

If the angle δ is between $\left(0, \frac{\pi}{2} - C\right)$, then there are two possible values of i..

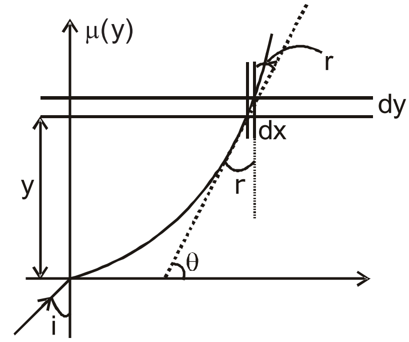
VARIABLE REFRACTIVE INDEX

If R.I. is a function of y :

Taking a small element of y of width dy



Here



a) Now 1 sin i = μ (y). sin r

$$\Rightarrow \sin r = \frac{\sin i}{\mu(y)}$$

b) $\tan\theta = \frac{dy}{dx} = \tan(90° - r)$

or $\cot r = \frac{dy}{dx}$

$$\Rightarrow \frac{dy}{dx} = \frac{\sqrt{\mu^2(y) - \sin^2 i}}{\sin i} \quad \text{[from (a) and (b)]}$$

$$\int_0^y \frac{dy}{\sqrt{\mu^2(y) - \sin^2 i}}$$

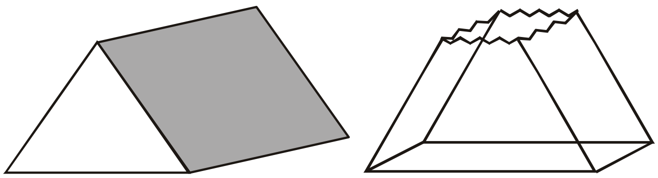
$$= \int_0^x \frac{dx}{\sin i}$$

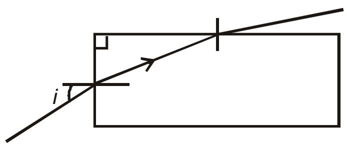
Section H - Prism

17. PRISM

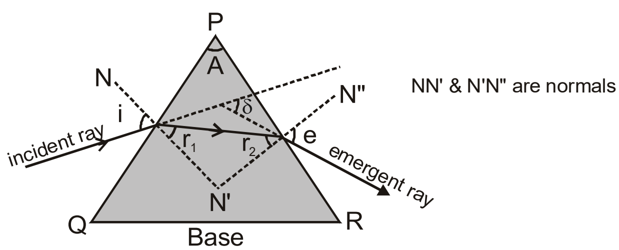
A homogeneous solid transparent and refracting medium bounded by two plane surfaces inclined at an angle is called a prism :

3-D View





Refraction through a prism



(a) PQ and PR are refracting surfaces.

(b) $\angle QPR = A$ is called refracting angle or the angle of prism (also called Apex angle.)

(c) δ = angle of deviation

(d) For refraction of a monochromatic (single wave length) ray of light through a prism;

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

and $\quad r_1 + r_2 = A$

$\therefore \quad \delta = i + e - A.$

Note

I. If ray crosses two surface which are inclined to each other then we use the concept of prism

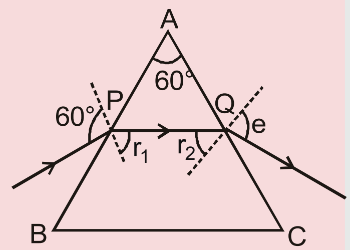
II. If ray crosses two plain parallel surfaces then we use concept of slab.

Example 49

A ray of light is incident on one face of a prism (μ = 1.5) at an angle of 60°. The refracting angle of the prism is also 60°. Find the angle of emergence and the angle of deviation. Is there any other angle of incidence, which will produce the same deviation?

Sol. Angle of incidence = i = 60°

At point P,



$$\frac{\sin 60^\circ}{\sin r_1} = \frac{1.5}{1}$$

$$\Rightarrow \sin r_1 = \frac{1}{\sqrt{3}}$$

or, $r_1 \approx 35°6'$

Using $\quad r_1 + r_2 = A$,

we get $\quad r_2 = A - r_1 = 60° - 35°6' = 24°44'$

At point Q, $\dfrac{\sin r_2}{\sin e} = \dfrac{1}{1.5}$

$\Rightarrow \sin e = 1.5 \sin 24°\, 44'$

$\Rightarrow \sin e = 0.63$

$\Rightarrow e = 39°$

$\therefore$ deviation $= \delta = (i + e) - A = 60° + 39° - 60°$
$= 39°$

If i and e are interchanged, deviation remains the same. Hence same deviation is obtained for angles of incidence of 60° and 39°.

Example 50

A ray of light makes an angle of 60° on one of the face of a prism and suffers a total deviation of 30° on emergence from the other face. If the angle of the prism is 30°, show that the emergent ray is perpendicular to the other face. Also calculate the refractive index of the material of the prism.

Sol. The angle of deviation

$$\delta = (i_1 + e) - A$$

Here, $\delta = 30°$,

$i_1 = 60°$;

$A = 30°$

Hence $30° = 60° + e - 30° = 30° + e$

$\Rightarrow \quad e = 0$

The angle of emergence is zero. This means that the emergent ray is perpendicular to the second face. Since e = 0, the angle of incidence at the second face is zero.

$\therefore \quad r_2 = 0$

Now, $\quad r_1 + r_2 = A$

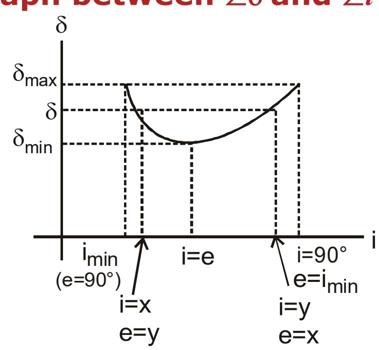
or, $\quad r_1 = A = 30°$

We know,

$$\mu = \frac{\sin i_1}{\sin r_1} = \frac{\sin 60°}{\sin 30°} = \frac{\sqrt{3}/2}{1/2}$$

$$\sqrt{3} = 1.732$$

17.1 Graph between ∠δ and ∠*i*



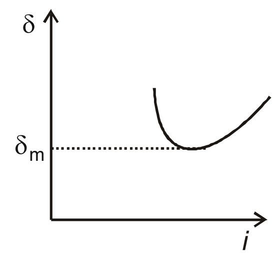
(1) Variation of δ versus i (shown in Figure).
For one δ (except δ min) there are two values of angle of incidence. If i and e are interchanged then we get the same value of δ because of reversibility principle of light

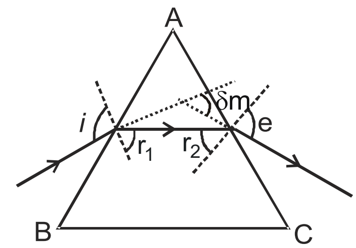
(2) There is one and only one angle of incidence for which the angle of deviation is minimum.

(3) Right hand side part of the graph is more tilted than the left hand side.

17.2 Minimum Deviation and Condition for Minimum Deviation

The angle of deviation depends on the anlge of incidence in a particular way. When the angle of incidence is small, the deviation is large. As i increase, δ decreases rapidly and attains a minimum value and then increases slowly with increase of i. The minimum value of δ so attained is called the minimum deviation (δ_m).





Condition

Theory and experiment shows that δ will be minimum when the path of the light ray through the prism is symmetrical.

i.e., angle of incidence = angle of emergence

or, $\quad \angle i = \angle e$

For the refraction at the face AB, we have

$$\frac{\sin i}{\sin r_1} = \mu (\text{Snell's law})$$

or, $\quad \sin i = \mu \sin r_1$,

and, $$\frac{\sin e}{\sin r_2} = \mu$$

or, $\quad \sin e = \mu \sin r_2$

$\therefore \quad \mu \sin r_1 = \mu \sin r_2$

or, $\quad r_1 = r_2$

Hence, the condition for minimum deviation is

$$i = e \text{ and } r_1 = r_2 \qquad ....(19)$$

17.3 Relation Between Refractive Index and the Angle of Minimum Deviation

When $\delta = \delta_m$, we have

$e = i$

and $r_1 = r_2 = r$ (say)

We know

$$A = r_1 + r_2 = r + r = 2r$$

or, $r = \dfrac{A}{2}$

Also, $A + \delta = i + e$

or, $A + \delta_m = i + i$

or, $i = \dfrac{A+\delta_m}{2}$

The refractive index of the material of the prism is given by

$$\mu = \frac{\sin i}{\sin r} \text{(Snell's law)}$$

$$\text{or,} \quad \mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}} \quad \ldots(20)$$

If surrounding medium has refractive index $= n_s$

$$\text{then} \quad \frac{n_p}{n_s} = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$$

Example 51

A ray of light incident at 49° on the face of an equilateral prism passes symmetrically Calculate the refractive index of the material of the prism.

Sol. As the prism is an equilateral one, A = 60°. As the ray of light passes symmetrically, the prism is in the position of minimum deviation.

So, $r = \dfrac{A}{2} = \dfrac{60°}{2} = 30°$

also, $i = 49°$

$$\therefore \quad \mu = \frac{\sin i}{\sin r} = \frac{\sin 49°}{\sin 30°} = \frac{0.7547}{0.5} = 1.5$$

Example 52

The refracting angle of the prism is 60° and the refractive index of the material of the prism is 1.632. Calculate the angle of minimum deviation.

Sol. Here, $A = 60°$; $\mu = 1.632$

$$\text{Now,} \quad \mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$$\text{or,} \quad 1.632 = \frac{\sin\left(\frac{60°+\delta_m}{2}\right)}{\sin\left(\frac{60°}{2}\right)} = \frac{\sin\left(\frac{60°+\delta_m}{2}\right)}{\sin 30°}$$

$$\text{or,} \quad \sin\left(\frac{60°+\delta_m}{2}\right) = 1.632 \times \sin 30°$$

$$= 1.632 \times 0.5$$

$$\text{or,} \quad \sin\left(\frac{60°+\delta_m}{2}\right) = 0.816$$

$$\text{or,} \quad \frac{60°+\delta_m}{2} = 54°42'$$

$$\delta_m = 49°\ 27'$$

17.4 Condition for Prism

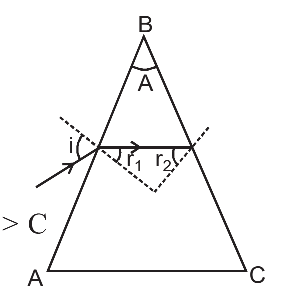
(a) Relation between prism angle A & critical angle C such that ray will always show T I R at BC :

For this $(r_2)_{min} > C$ ...(i)

For $(r_2)_{min}$, r_1 should be maximum and

for $(r_1)_{max}$

$\Rightarrow$ $i_{max} = 90°$



& $(r_1)_{max} = C$ if $i = 90°$

$(r_2)_{max} = A - C$

Now from eq. (i) $A - C > C$

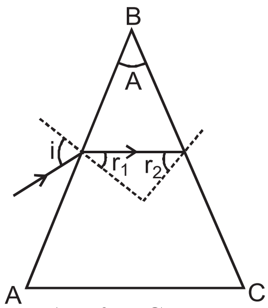
$A > 2C$

i.e. A > 2C, all rays are reflected back from the second surface.

(b) The relation between A & C such that ray will always refract form prenormal incidence surface BC.

For this $(r_2)_{max} < C$

$(A - r_1)_{max} < C$ ..(ii)



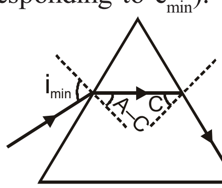
from eq. (2) $A - 0 < C$

$A < C$

i.e. If $A \le C$, no rays are reflected back from the second surface i.e. all rays are refracted from second surface.

(c) If $2C \ge A > C$, some rays are reflected back from the second surface and some rays are refracted from second surface, depending on the angle of incidence. δ is maximum for two values of i

$\Rightarrow$ i_{min} (corresponding to e = 90º) and i = 90º (corresponding to e_{min}).

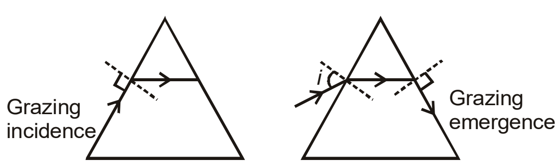


For $i_{min} : n_s \sin i_{min} = n_p \sin (A - C)$

If $i < i_{min}$ then T.I.R. takes place at second refracting surface PR.

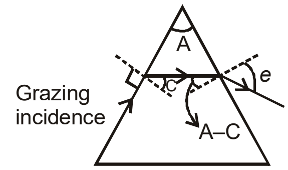
Condition for δ_{max} :

$i = 90°$ or $e = 90°$



$n \sin (A - C) = \sin e$

$$e = \sin^{-1}[n \sin(A - C)]$$



$$\delta_{max} = i + e - A$$

$$\delta_{max} = 90 + \sin^{-1}[n \sin(A - C)] - A$$

Example 53

Find the minimum and maximum angle of deviation for a prism with angles A = 60° and μ = 1.5

Sol. **Minimum deviation**

The angle of minimum deviation occurs when i = e and $r_1 = r_2$ and is given by

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

$$\Rightarrow \delta_m = 2\sin^{-1}\left(\mu \sin\frac{A}{2}\right) - A$$

Substituting μ = 1.5 and A = 60°, we get

$\delta_m = 2 \sin^{-1} (0.75) - 60° = 37°$

Maximum deviation (Grazing incidence or Grazing emergence) :

The deviation is maximum when *i = 90°* or e = 90° that is at grazing incidence or grazing emergence.

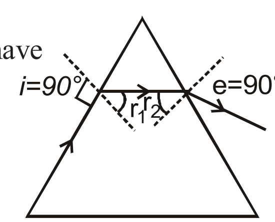
Let i = 90°

$$\Rightarrow r_1 = C = \sin^{-1}\left(\frac{1}{\mu}\right)$$

$$\Rightarrow r_1 = \sin^{-1}\left(\frac{2}{3}\right) = 42°$$

$$\Rightarrow r_2 = A - r_1 = 60° - 42° = 18°$$

Using $\frac{\sin r_2}{\sin e} = \frac{1}{\mu}$, we have



$\sin e = \mu \sin r_2$

$= 1.5 \times \sin 18°$

$\Rightarrow \sin e = 0.463$

$\Rightarrow$ e = 28°

$\therefore$ Deviation = δ_{max}

= (i + e) – A

= 90° + 28° – 60° = 58°

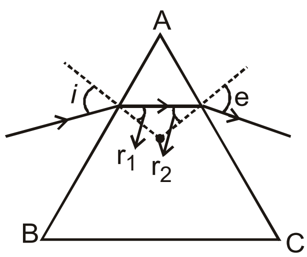
17.5 Deviation Through a Prism of Small Angle

If the angle of the prism A is small, r_1 and r_2 (as $r_1 + r_2 = A$) and i and e will be small.

For the refraction at the face AB, we have

$$\mu = \frac{\sin i}{\sin r_1}$$

or, $\mu = \frac{i}{r_1}$ (since i and r_1 are small angles, $\sin i_1 \approx i_1$ and $\sin r_1 \approx r_1$)



$\Rightarrow$ For refraction at the face AC, we have

$$\mu = \frac{\sin e}{\sin r_2}$$

or, $\mu = \frac{e}{r_2}$ ($\because$ e and r_2 are small angles, so sin e $\simeq$ e and sin $r_2 \simeq r_2$)

$\Rightarrow$ e = μr_2

Now, deviation produced by a prism

$\delta = (i + e) - A$

or, $\delta = (\mu r_1 + \mu r_2) - A$

or, $\delta = \mu(r_1 + r_2) - A$

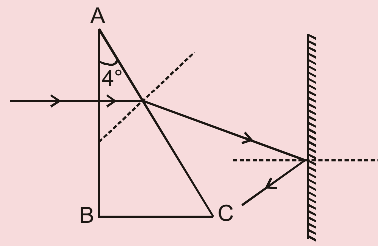
or, $\delta = \mu A - A$ [$\because$ $r_1 + r_2 = A$]

or, $\delta = (\mu - 1) A$ ...(20)

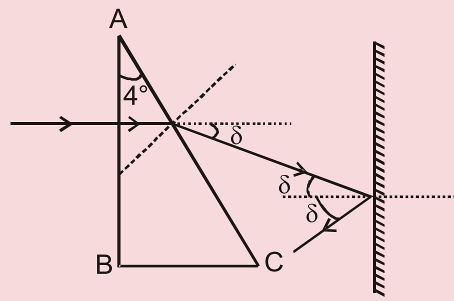
The above formula is valid for all positions of the prism provided the angle of the prism A is small (say $\leq$ 10°).

Example 54

A prism having a refracting angle 4° and refractive index 1.5 is located in front of a vertical plane mirror as shown. A horizontal ray of light is incident on the prism. What is the angle of incidence at the mirror ?



Sol.



The deviation suffered by refraction through the small angled prism is given by

$$\delta = (\mu - 1)A = (1.5 - 1) \times 4° = 2°$$

This gives the angle of incidence 2° at the mirror.

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,

$$r_1 = r_2 = \frac{A}{2} = 30º$$

Applying snell's law at I surface

$$1 \times \sin i = \frac{3}{2} \sin 30º$$

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

$$\delta_{min} = 2i - A$$

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

Example 56

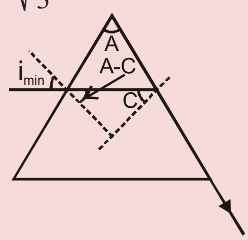
For a prism, $A = 60^\circ$, $n = \sqrt{\frac{7}{3}}$. Find the minimum possible angle of incidence, so that the light ray is refracted from the second surface. Also find δ_{max}.

Sol. In minimum incidence case the angles will be as shown in figure

Applying snell's law :

$$1 \times \sin i_{min} = \sqrt{\frac{7}{3}} \sin (A - C)$$

$$= \sqrt{\frac{7}{3}} (\sin A \cos C - \cos A \sin C)$$



$$= \sqrt{\frac{7}{3}} \left(\sin 60 \sqrt{1 - \frac{3}{7}} - \cos 60 \sqrt{\frac{3}{7}} \right) = \frac{1}{2}$$

$\therefore\ i_{min} = 30^\circ$

$\therefore\ \delta_{max} = i_{min} + 90^\circ - A \quad = 30^\circ + 90^\circ - 60^\circ = 60^\circ.$

Section I - Dispersion of Light

18. DISPERSION OF LIGHT

The angular splitting of a ray of white light into a number of components and spreading in different directions is called Dispersion of Light. [It is for whole Electro Magnetic Wave in totality]. This phenomenon takes place because waves of different wavelength move with same speed in vacuum but with different speeds in a medium. Therefore, the refractive index of a medium depends slightly on wavelength also. This variation of refractive index with wavelength is given by Cauchy's formula.

Cauchy's formula

$$n(\lambda) = a + \frac{b}{\lambda^2}$$

where a and b are positive constants of a medium.

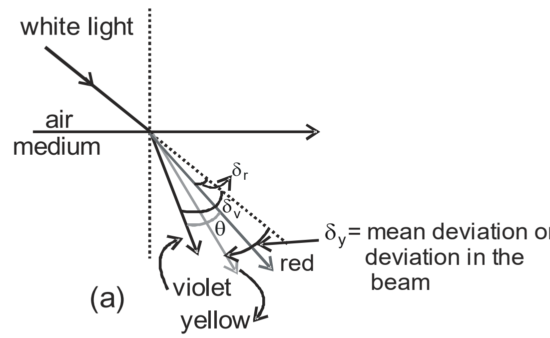
$$\xrightarrow[\lambda \uparrow \; f_{req.} \downarrow]{\text{VIBGYOR}}$$

Note

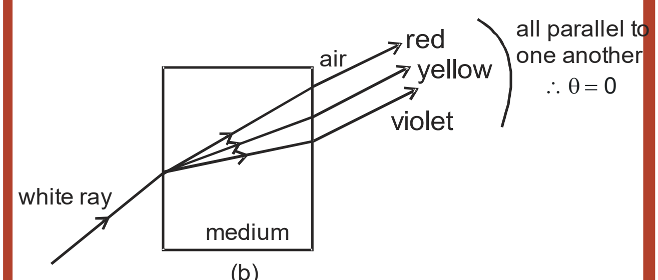
* Such phenomenon is not exhibited by sound waves. Angle between the rays of the extreme colour in the refracted (dispersed) light is called angle of dispersion.

$\theta = \delta_1 - \delta_1 \qquad$ (Fig. (a))

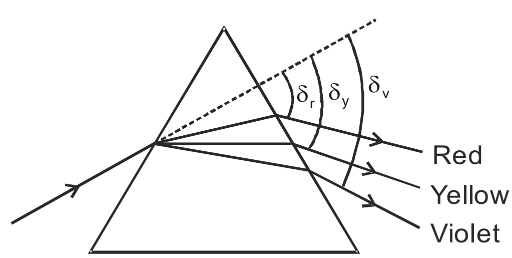
Fig. (a) and (c) represents dispersion, whereas in fig. (b) there is no dispersion.



(a)



(b)



For prism of small A and with small i,

$\theta = \delta_v - \delta_r = (n_v - n_r) A$

Example 57

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 $= \delta_v - \delta_r$

$= (\mu_v - \mu_r)A$

$= (1.632 - 1.613) \times 5°$

$= 0.095°$

Note

Deviation of beam (also called mean deviation)

$$\delta = \delta_y = (n_y - 1)A = m$$

n_v, n_r and n_y are R.I. of material for violet, red and yellow colours respectively.

Numerical data reveals that if the average value of m is small $\mu_v - \mu_r$ is also small and if the average value of m is large $\mu_v - \mu_r$ is also large. Thus, larger the mean deviation, larger will be the angular dispersion.

18.1 Dispersive power (ω)

Dispersive power of the medium of the material of prism is given by :

$$\omega = \frac{n_v - n_r}{n_y - 1}$$

- ω is the property of a medium.

For small angled prism ($A \le 10°$) with light incident at small angle i :

$$\frac{n_v - n_r}{n_y - 1} = \frac{\delta_v - \delta_r}{\delta_y} = \frac{\theta}{\delta_y}$$

$$= \frac{\text{angular dispersion}}{\text{deviation of mean ray (yellow)}}$$

[$n_y = \dfrac{n_v + n_r}{2}$ if n_y is not given in the problem]

- $n - 1$ = refractivity of the medium for the corresponding colour.

Example 58

Refractive index of glass for red and violet colours are 1.50 and 1.60 respectively. Find

(a) The refractive index for yellow colour, approximately

(b) Dispersive power of the medium.

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

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

Example 59

Calculate the dispersive power of crown and flint glass-prism from the following data. For crown glass

$\mu_v = 1.522$ $\mu_R = 1.514$

For flint glass

$\mu_v = 1.662$ $\mu_R = 1.644$

Sol. For crown glass

$\mu_v = 1.522$ $\mu_R : 1.514$

$\therefore \mu_Y = \dfrac{\mu_V + \mu_R}{2} = \dfrac{1.522 + 1.514}{2} = 1.518$

Hence, the dispersive power of crown glass

$\omega = \dfrac{\mu_v - \mu_R}{\mu_Y - 1} = \dfrac{1.522 - 1.514}{(1.518 - 1)} = 0.01544$

$\therefore \omega = 0.01544$

For flint glass :

$\mu'_v = 1.662$ $\mu'_R = 1.644$

$\therefore \mu' = \dfrac{\mu'_v + \mu'_R}{2} = \dfrac{1.662 + 1.644}{2} = 1.653$

$\therefore \omega' = \dfrac{\mu'_v - \mu'_R}{\mu' - 1} = \dfrac{1.662 - 1.644}{(1.653 - 1)} = 0.0276$

18.2 Dispersion without average deviation and average deviation without dispersion

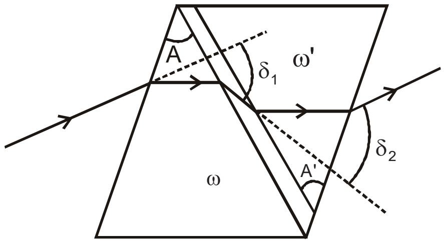


Figure shows two thin prisms placed in contact in such a way that the two refracting angles are reversed with respect to each other. Suppose, the refracting angles of the two prisms are A and A′ and their dispersive power are ω and ω′ respectively.

Consider a ray of light for which the refractive indices of the materials of the two prisms are μ and μ′. Assuming that the ray passes through the prisms in symmetrical situation, the deviations produced by the two prisms are

$$\delta_1 = (\mu - 1)A$$

and $\delta_2 = (\mu' - 1)A'$

As the two deviations are opposite to each other, the net deviation is

$$\delta = \delta_1 - \delta_2$$

$$= (\mu - 1)A - (\mu' - 1)A' \quad ...(1)$$

If white light passes through the combination, the net deviation of the violet ray is

$$\delta_v = (\mu_v - 1)A - (\mu'_v - 1)A'$$

and that of the red ray is

$$\delta_r = (\mu_r - 1)A - (\mu'_v - 1)A'$$

The angular dispersion produced by the combination is

$$\delta_v - \delta_r = (\mu_v - \mu_r)A - (\mu'_v - \mu'_r)A' \quad ...(2)$$

The dispersive power are given by

$$\omega = \frac{\mu_v - \mu_r}{\mu_y - 1}$$

and $\omega' = \dfrac{\mu'_v - \mu'_r}{\mu'_y - 1}$

Thus, by (2), the net angular dispersion is

$$\delta_v - \delta_r = (\mu_y - 1)\omega A - (\mu'_y - 1)\omega' A' \quad ...(3)$$

The net deviation of the yellow ray i.e., the average deviation, is, by (1)

$$\delta_y = (\mu_y - 1)A - (\mu'_y - 1)A' \quad ...(4)$$

Dispersion without Average Deviation

If the combination is not to produce a net average deviation in the beam, δ_y should by 0. By (4), the required condition is

$$(\mu_y - 1)A = (\mu'_y - 1)A' \quad ...(5)$$

Using this in (3), the net angular dispersion produced is

$$\delta_v - \delta_r = (\mu_y - 1)A(\omega - \omega') \quad ...(6)$$

By choosing ω and ω′ different and the refracting angles to satisfy (5), one can get dispersion without average deviation.

Average Deviation without Dispersion.

If the combination is not to produe a net dispersion,

$\delta_v - \delta_r = 0$, By (iii)

$$(\mu_y - 1)\omega A = (\mu'_y - 1)\omega' A' \quad ....(7)$$

By (2), this condition may also be written as

$$(\mu_v - \mu_r)A = (\mu'_v - \mu'_r)A' \quad ....(8)$$

The net average deviation produced is, by (1),

$$\delta = (\mu_y - 1)A - (\mu'_y - 1)A'$$

$$= (\mu_y - 1)A\left[1 - \frac{\mu'_y - 1}{\mu_y - 1}\frac{A'}{A}\right]$$

By (7)

$$\frac{(\mu'_y - 1)}{(\mu_y - 1)}\frac{A'}{A} = \frac{\omega}{\omega'}$$

So that the net average deviation produced by the combination is

$$\delta = (\mu_y - 1)A\left(1 - \frac{\omega}{\omega'}\right) \quad ...(9)$$

Example 60

Find the angle of the flint glass prism which should be combined with a crown glass prism of 5° so as to give dispersion but no deviation.

For crown glass : $\mu_v = 1.523$; $\mu_R = 1.515$

For flint glass : $\mu_v' = 1.688$; $\mu_R' = 1.650$

Sol. For no deviation

$$\frac{A'}{A} = \left(\frac{\mu - 1}{\mu' - 1}\right)$$

or, $$A' = \left(\frac{\mu - 1}{\mu' - 1}\right) A$$

Now, $$\mu = \frac{\mu_v + \mu_R}{2}$$

$$= \frac{1.523 + 1.515}{2}$$

$$= 1.519$$

$$\mu' = \frac{\mu_v' + \mu_R'}{2} = \frac{1.668 + 1.650}{2} = 1.659$$

$$\therefore \quad A' = \left(\frac{1.519 - 1}{1.659 - 1}\right) 5° \quad = 3.94°$$

Example 61

Find the angle of a prims of dispersive power 0.021 and refractive index 1.53 to form an achromatic combination with the prism of angle 4.2° and dispersive power 0.045 having refractive index 1.65. Also calculate the resultant deviation.

Sol. $\omega = 0.021$ $\qquad \mu = 1.53$

$\omega' = 0.045$ $\qquad \mu' = 1.65$

$A' = 4.2°$

For no dispersion

$$\omega\delta + \omega'\delta' = 0$$

or, $$\omega(\mu - 1)A + \omega'(\mu' - 1)A' = 0$$

or, $$A = \frac{\omega' A'(\mu' - 1)}{\omega(\mu - 1)} = \frac{0.045 \times 4.2° \times (1.65 - 1)}{0.021 \times (1.53 - 1)}$$

Net deviation

$$\delta + \delta' = (\mu - 1) A + (\mu' - 1) A'$$

$$= -11.04° (1.53 - 1) + 4.2° (1.65 - 1)$$

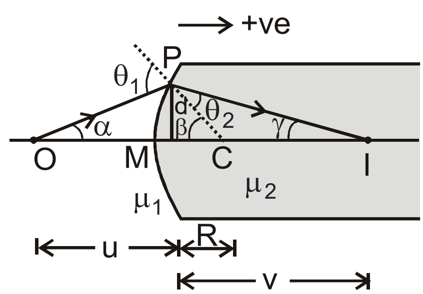
$$= -3.12°$$

Section J - Refraction from a Spherical Surface

19. REFRACTION FROM A SPHERICAL SURFACE

Consider two transparent media having indices of refraction μ_1 and μ_2, where the boundary between the two media is a spherical surface of radius R. We assume that $\mu_1 < \mu_2$. Let us consider a single ray leaving point O and focussing at point I. Snell's law applied to this refracted ray gives,

$$\mu_1 \sin \theta_1 = \mu_2 \sin \theta_2$$



Because θ_1 and θ_2 are assumed to be small, we can use the small angle approximation

$$\sin \theta \approx \theta$$

(angles in radians) and say that

$$\mu_1 \theta_1 = \mu_2 \theta_2 \qquad ...(1)$$

From the geometry shown in the figure.

$$\theta_1 = \alpha + \beta \qquad ...(2)$$

and $$\beta = \theta_2 + \gamma \qquad ...(3)$$

Eqs. (1) and (3) can be combined to express θ_2 in terms of α and β. Substituting the resulting expression into Eq. (2) then yields.

$$\beta = \frac{\mu_1}{\mu_2}(\alpha+\beta)+\gamma$$

So $$\mu_1\alpha + \mu_2\gamma = (\mu_2-\mu_1)\beta \qquad ...(4)$$

Since, the arc PM (of length S) subtends an angle β at the centre of curvature

$$\beta = \frac{S}{R}$$

Also in the paraxial approxiamation

$$\alpha = \frac{S}{R} \quad \text{and } \gamma = \frac{S}{v}$$

Using these expressions in Eq. (4) with proper signs, we are left with,

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

or $$\boxed{\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2-\mu_1}{R}} \qquad ...(5)$$

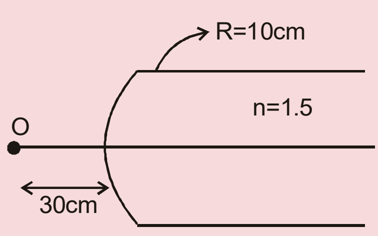
Although the formula (5) is derived for a particular situation, it is valid for all other situations of refraction at a single spherical surface.

Important point for above formula

- Above formula is valid only for paraxial rays.
- u,v,R should be put along with sign
- μ_2 is R.I. of medium in which rays is going (refracting) and μ_1 is the R.I. of medium from which rays are coming (incident).

Example 62

Find the position of the image formed and draw the appropriate ray diagram



u = – 30 cm R = + 10 cm

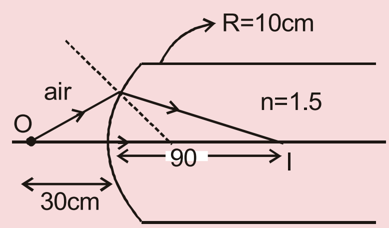
Sol. $$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2-n_1}{R}$$

$$\Rightarrow \frac{1.5}{v} + \frac{1}{30} = \frac{0.5}{10}$$

$$\Rightarrow \frac{1.5}{v} = \frac{0.5}{10} - \frac{1}{30}$$

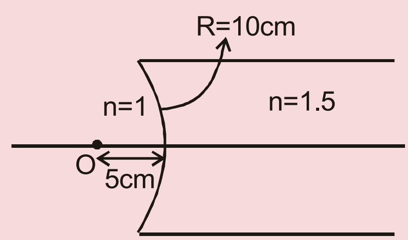
$$\Rightarrow \frac{1.5}{v} = \frac{0.5}{30}$$

$$\Rightarrow v = \frac{30\times 1.5}{0.5} = 90 \text{ cm (Real)}$$



Example 63

Find the position of the image formed and draw the appropriate ray diagram



Sol. $n_2 = 1.5$

$n_1 = 1$

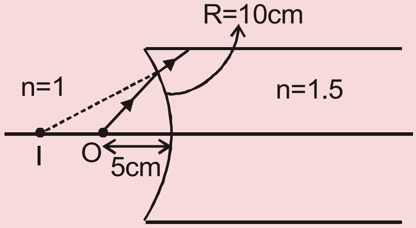
$u = -5$cm

$R = -10$ cm

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

$$\Rightarrow \frac{1.5}{v} + \frac{1}{5} = -\frac{0.5}{10}$$

$$\Rightarrow \frac{1.5}{v} = \frac{-0.5}{10} - \frac{1}{5}$$

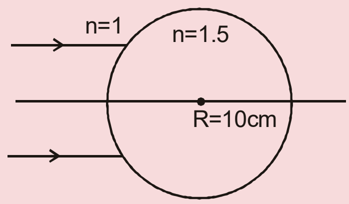


$$\Rightarrow \frac{1.5}{v} = \frac{-2.5}{10}$$

$$\Rightarrow v = -6 \text{ cm}$$

Example 64

Find the position where parallel rays will meet after coming out of the sphere and draw the appropriate ray diagram



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

$$\Rightarrow \frac{1.5}{v} - \frac{1}{\infty} = \frac{0.5}{10}$$

$$\Rightarrow \frac{1.5}{v} = \frac{0.5}{10}$$

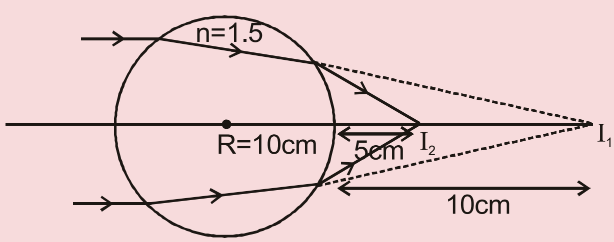
$$\Rightarrow v = \frac{15}{0.5} = 30 \text{ cm (from the first surface)}$$

For IInd

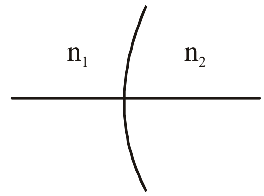
$\because u = -\ 30 - 20 = -10\text{cm}$ (from 2nd surface)

$$\frac{1}{v} - \frac{1.5}{10} = \frac{1-1.5}{-10}$$

$$\Rightarrow v = +5 \text{ cm}$$



19.1 Velocity of Spherical Refraction



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

differentiate with respect to time

$$-\frac{n_2}{v^2}\frac{dv}{dt} + \frac{n_1}{u^2}\frac{du}{dt} = 0$$

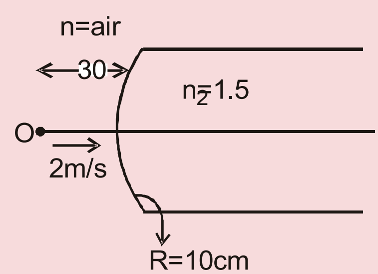
$$\frac{dv}{dt} = +\left(\frac{n_1}{n_2}\right)\left(\frac{v^2}{u^2}\right)\frac{du}{dt}$$

$$V_{IS} = \frac{n_1}{n_2}\frac{v^2}{u^2}V_{OS}$$

$$V_I - V_s = \frac{n_1}{n_2}.\frac{v^2}{u^2}(v_O - v_s)$$

Example 65

Find the velocity of image in the figure shown



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

$$\frac{1.5}{v} + \frac{1}{30} = \frac{0.5}{10}$$

$$\Rightarrow \frac{1.5}{v} = \frac{1}{20} - \frac{1}{30} = \frac{1}{60}$$

$$\Rightarrow v = 90 \text{ cm}$$

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

By differentiating :

$$-\frac{n_2}{v^2}\cdot\frac{dv}{dt}+\frac{\mu_1}{u^2}\cdot\frac{du}{dt}=0$$

$$\Rightarrow \frac{dv}{dt}=\frac{\mu_1}{\mu_2}\cdot\frac{v^2}{u^2}\cdot\frac{du}{dt}$$

$$\Rightarrow \frac{dv}{dt}=\frac{1}{1.5}\frac{v^2}{u^2}\times 2=\frac{2}{3}\left(\frac{90}{30}\right)^2\times 2$$

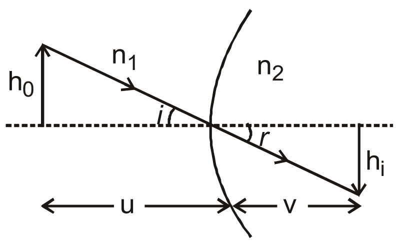
= 12 m/sec

19.2 Transverse Magnification

If i and r are very small

$\tan i \approx \sin i \approx i$

$\tan r \approx \sin r \approx r$



$$\Rightarrow \tan r = \frac{h_i}{v}$$

$$\Rightarrow r \approx \frac{h_i}{v} \qquad ...(1)$$

$$\tan i = \frac{h_0}{u}$$

$$\Rightarrow i \approx \frac{h_0}{u} \qquad ...(2)$$

Again, by applying snells law :

$n_1 \sin i = n_2 \sin r$

$\Rightarrow n_1 i \approx n_2 r \qquad ...(3)$

$\Rightarrow$ From (1), (2), (3)

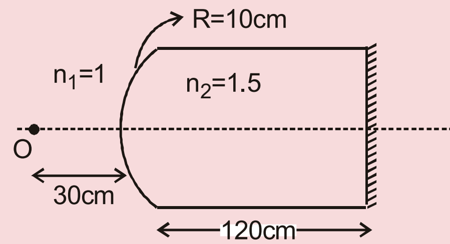
$$m=\frac{h_i}{h_0}=\frac{n_1}{n_2}\left(\frac{v}{u}\right)$$

Example 66

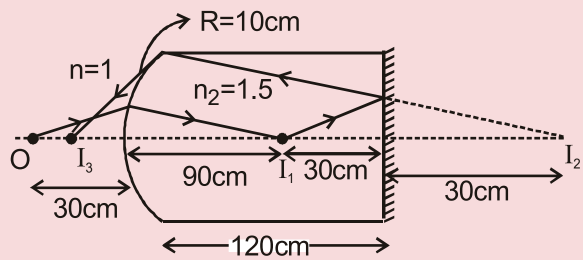
Find the position of the image formed and draw the appropriate ray diagram.

u = –30 cm

R = + 10 cm



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



$$\Rightarrow \frac{1.5}{v}+\frac{1}{30}=\frac{0.5}{10}$$

$$\Rightarrow \frac{1.5}{v}=\frac{0.5}{10}-\frac{1}{30}$$

$$\Rightarrow \frac{1.5}{v}=\frac{0.5}{30}$$

$\Rightarrow$ v = + 90cm

Distacne of this image from plane mirror = 30 cm Mirror will form the image of I_1 30 cm behind it as shown in the figure.

For the second refraction :

u = – 150 cm [= 30+120 = 150 cm]

R = – 10 cm

n_1 = 1.5

n_2 = 1

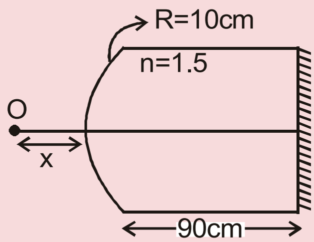
$$\frac{1}{v}+\frac{1.5}{150}=\frac{-0.5}{-10}$$

$$\Rightarrow \frac{1}{v}=\frac{0.5}{10}-\frac{1}{100}$$

$$\Rightarrow \frac{1}{v}=\frac{4}{100} \Rightarrow v = 25 \text{ cm (Real)}$$

Example 67

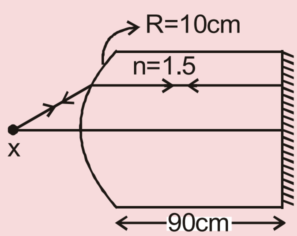
Find the value of x for which the image is formed on the object itself.



Sol. **For object and image to coincide the rays of light have to hit the surface normally or at the pole of the mirror**

Case I : for first Refraction

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



$$\Rightarrow \frac{1.5}{v}+\frac{1}{x}=\frac{0.5}{10}$$

$$\Rightarrow \frac{1.5}{v}=\frac{0.5}{10}-\frac{1}{x}$$

$$\Rightarrow \frac{1.5}{v}=\frac{0.5x-10}{10x}$$

$$\Rightarrow v=\frac{15x}{0.5x-10}$$

for $v = \infty$; $0.5x - 10 = 0$

$\Rightarrow$ x = 20 cm

Case II :

$n_2 = 1.5$

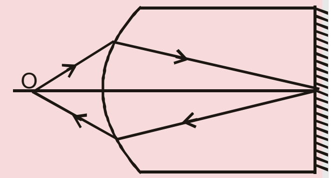
$n_1 = 1$

$R = +10$

$u = -x$

$v = 90$ cm

$x = 30$ cm



Section K - Lens Maker formula and Magnification, Image formation by convex and concave lens, Combination of lens, Cutting of lens

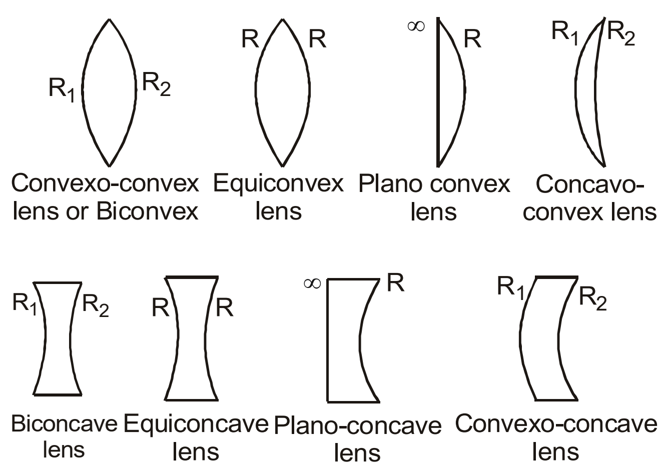
20. REFRACTION THROUGH THIN LENSES

Lens

A lens is a transparent medium bounded by two refracting surfaces such that at least one of the refracting surfaces is curved. (or spherical)

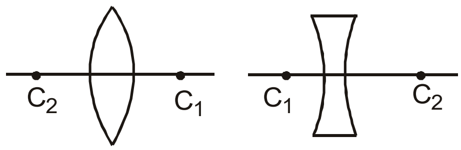
Types of lenses

Broadly, lenses are of the following types :



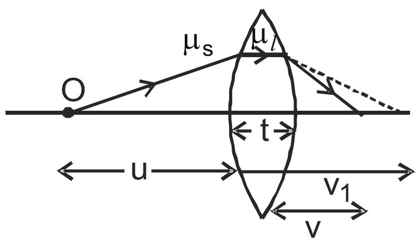
Principal axis

The line joining the centres of curvature of the two bounding surfaces is called the principal axis.



20.1 Lens Maker formula

For first refraction :



$$\frac{\mu_\ell}{v_1} - \frac{\mu_s}{u} = \frac{(\mu_\ell - \mu_s)}{R_1} \qquad ...(1)$$

thickness of lens t is negligible

For second refraction :

$$\frac{\mu_s}{v} - \frac{\mu_\ell}{v_1} = \frac{\mu_s - \mu_\ell}{R_2} \qquad ...(2)$$

Adding (1) and (2) equation we get

$$\frac{1}{v} - \frac{1}{u} = \left(\frac{\mu_\ell}{\mu_s} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \qquad ...(3)$$

Important points for the above formula :

(1) Rays should be paraxial

(2) v, u, R_1 and R_2 should used with the proper sign.

(3) R_1 is the radius of curvature of that surface on which the ray strikes first.

(4) Lens should be thin.

(5) Medium on both sides of the lens should be same.

20.2 Sign Convention (consider pole as origin)

(i) Whenever and wherever possible, rays of light are taken to travel from left to right.

(ii) Distances are measured along the principal axis from the optical centre of the lens.

(iii) Distances measured along the principal axis in the direction of the incident rays are taken as positive while those measured against the direction of the incident rays are taken negative.

(iv) Distances measured above the principal axis are taken as positive and those measured below the principal axis are taken as negative.

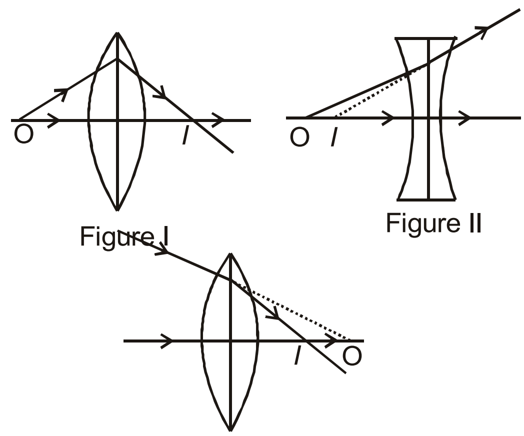


Figure I

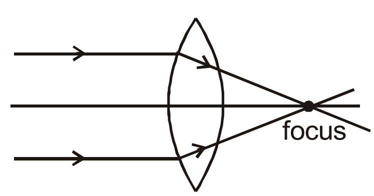
Figure II

Figure III

Figure	u	v	t	R_1	R_2
(i)	–ve	+ve	+ve	+ve	–ve
(ii)	–ve	–ve	–ve	–ve	+ve
(iii)	+ve	+ve	+ve	+ve	–ve

20.3 Focus

If the rays are parallel to optical axis and paraxial then the point where they meet or appears to meet is known as focus of the system.



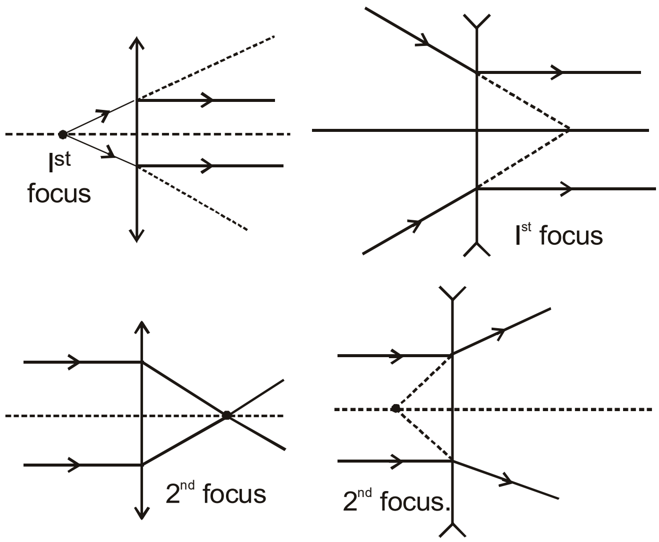
In the lens maker formula if $u \to \infty$, $v = f$.

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

Substituting in the lens maker formula :

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \text{(lens formula)}$$

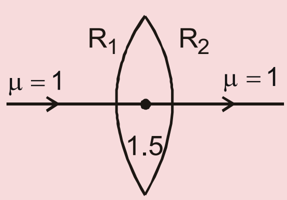
Lenses have two focii called first and second focus



Example 68

Calculate the focal length of a biconvex lens in air if the radii of its surfaces are 60 cm and 15 cm. Refractive index of glass = 1.5

Sol. Consider a light ray going through the lens as shown. it strikes the convex side of 60 cm radius and concave side of 15 cm radius while coming out.



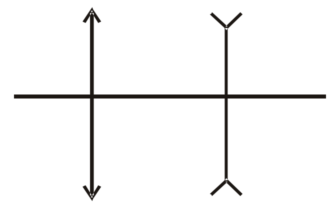
$R_1 = +60$ cm, $R_2 = -15$ cm

$$\therefore \frac{1}{f} = \left[\frac{\mu_\ell}{\mu_s} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\text{or, } \frac{1}{f} = \left[\frac{1.5}{1} - 1\right]\left[\frac{1}{60} + \frac{1}{15}\right]$$

$\Rightarrow$ $f = +24$ cm

Note

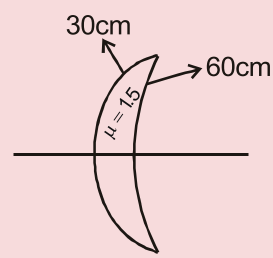


converging lens   Diverging lens.

- Signs for converging and diverging lenses
- Focal length of lens depends on surrounding medium
- If f = + ve implies converging and if f = – ve implies diverging lens.

Example 69

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

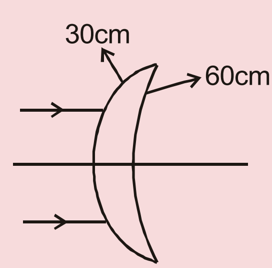


Sol.

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

$$\Rightarrow \frac{1}{f} = (1.5 - 1)\left(+\frac{1}{30} - \left(+\frac{1}{60}\right)\right)$$

$\Rightarrow$ $f = 120$ cm



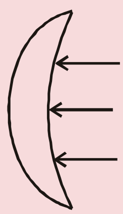
If in the above case direction of rays is reversed.

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

$$\Rightarrow \frac{1}{f}=(1.5-1)\left(-\frac{1}{60}-\left(-\frac{1}{30}\right)\right)$$

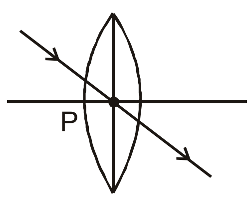
$$f=+\,120 \text{ cm}$$

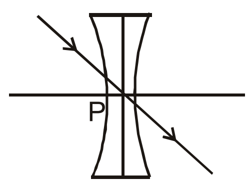
This Illustration shows that focal length does not depends on the direction of incident ray.



20.4 Rules For Image Formation

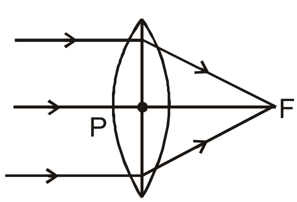
(i) A ray passing through the optical centre of the lens proceeds undeviated through the lens. (By definition of optical centre)

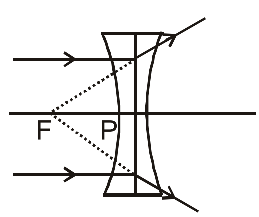




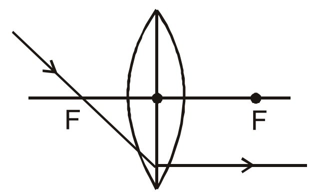
Pole is the intersection of the ray which goes undeviated through the lens and the optical axis.

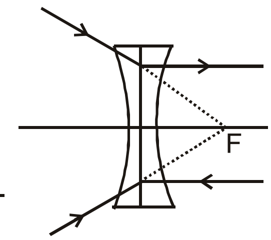
(ii) A ray passing parallel to the principal axis after refraction through the lens passes or appear to pass through the focus. (By the definition of the focus)





(iii) A ray through the focus or directed towards the focus, after refraction from the lens, becomes parallel to the principal axis. (Principle of reversibility of light)





Only two rays from the same point of an object are needed for image formation and the point where the rays after refraction through the lens intersect or appear to intersect, is the image of the object. If they actually intersect each other, the image is real and if they appear to intersect the image is said to be virtual.

Example 70

Find the position of the image formed.

$u=+\,30$ cm, $f=+\,10$ cm

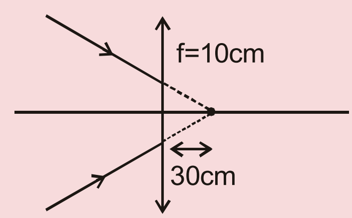
Sol.

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

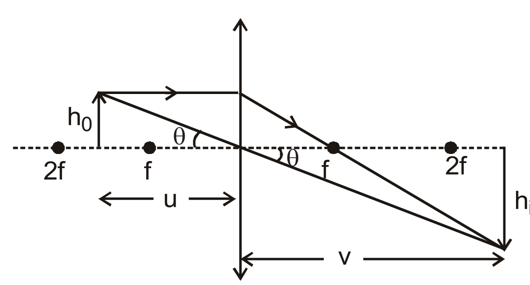
$$\Rightarrow \frac{1}{10}=\frac{1}{v}-\frac{1}{30}$$

$$\Rightarrow \frac{1}{v}=\frac{1}{10}+\frac{1}{30}$$

$$\Rightarrow v=\frac{300}{40}=7.5 \text{ cm}$$



20.5 Transverse Magnification Converging lens.



$$\tan\theta = \frac{h_0}{u} \qquad ...(1),$$

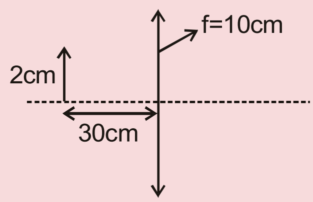
$$\tan\theta = \frac{h_i}{v} \qquad ...(2)$$

from eq. (2) / (1)

$$\mathbf{m} = \frac{h_i}{h_0} = \frac{v}{u}$$

Example 71

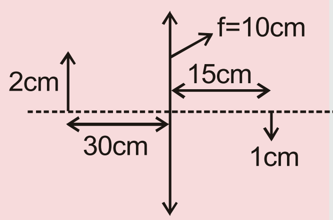
Find the position, height and nature of the image formed.



Sol. $u = -30$ cm

$f = +10$ cm

$h_0 = +2$ cm



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

$$\Rightarrow \quad \frac{1}{10} = \frac{1}{v} + \frac{1}{30}$$

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{15}$$

$$\Rightarrow \quad v = +15\text{cm}$$

$$\frac{h_i}{h_0} = \frac{v}{u}$$

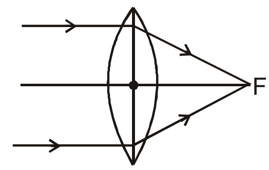
$$\Rightarrow \quad \frac{h_i}{2} = \frac{15}{-30}$$

$$\Rightarrow \quad h_i = -1 \text{ cm}$$

$\therefore$ Real, inverted, diminished

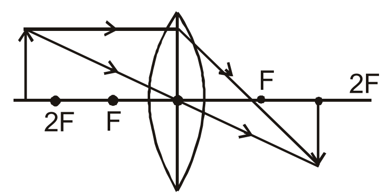
21. IMAGE FORMATION BY A CONVEX LENS OF THE LINEAR OBJECT

(i) When the object is at infinity :



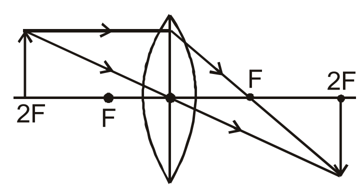
The image is formed at F. It is real, inverted and highly diminished.

(ii) When the object is beyond 2F :



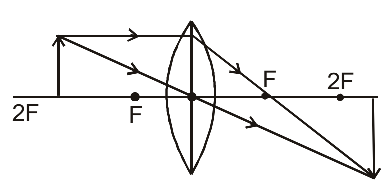
The image is formed between F and 2F. It is real, inverted and diminished

(iii) When the object is at 2F :



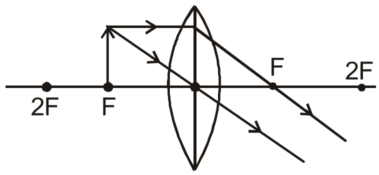
The image is formed at 2F. It is real, inverted and the same size as the object.

(iv) When the object is between F and 2F :



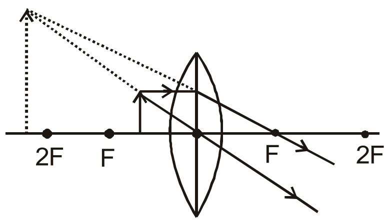
The image is formed beyond 2F (i.e., between 2F and ∞). It is real, inverted and enlarged.

(v) When the object is at F :



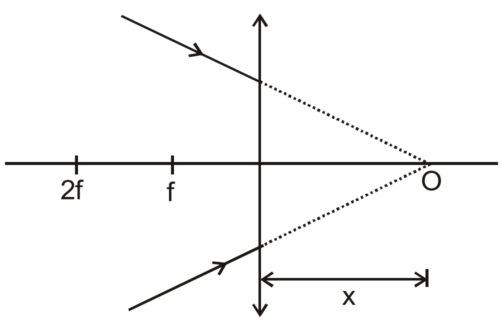
The image is formed at infinity. It is real, inverted and highly magnified.

(vi) When the object is between F and O :



The image is on the same side as the object. It is virtual, erect and magnified.

(vii) Virtual object case for converging lens :



$u = + x$

$f = + f$

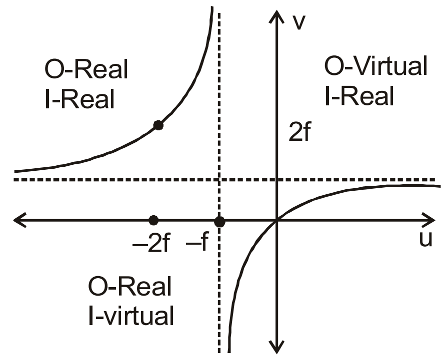
from lens formula $\frac{1}{v} - \frac{1}{x} = \frac{1}{f}$

$\frac{1}{v} = \frac{1}{f} + \frac{1}{x}$

if $x = 0, \; v \to \infty$

if $x = \infty, \; v \to f$

Graphs for converging lens



21.1 Image Formation by a Concave Lens of a Linear Object

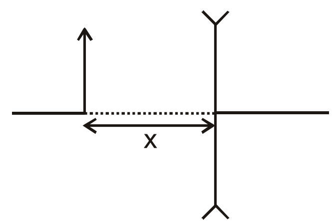
(a) Real object case

$u = - x\,, \;\; f = - f$

from lens formula

$\frac{1}{v} + \frac{1}{x} = -\frac{1}{f}$

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



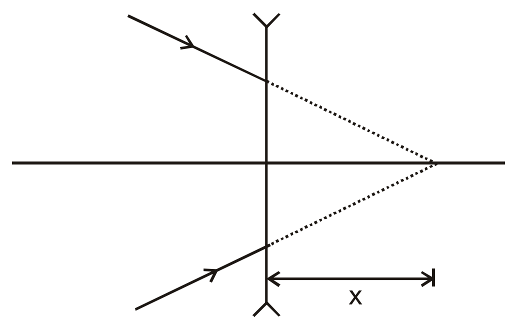
If $x \to \infty$

$v \to - f$

If $x \to 0$

$v \to 0'$

(b) Virtual object case :



$u = +x, \; f = - f$

from lens formula

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

If $x = 0 \rightarrow v = 0$

If $x < f$; $v = +u$

If x is just smaller than f

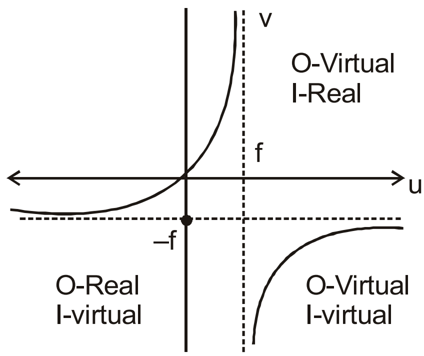
$v \rightarrow +\infty$

If x is just greater than f , then $v \rightarrow -\infty$

If $x \rightarrow \infty$

$v \rightarrow -f$

Graphs for diverging lenses.



Example 71

An object is placed in front of a converging lens of focal length 10 cm and image formed is double the size of object. Then find the position of object.

Case I : If the image formed is real

$$-\frac{h_i}{h_0} = 2$$

$$\Rightarrow \frac{v}{u} = -2 \Rightarrow v = -2u$$

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

$$\Rightarrow \frac{1}{10} = -\frac{1}{2v} - \frac{1}{u}$$

$$\Rightarrow \frac{1}{10} = -\frac{3}{2u}$$

$$\Rightarrow u = -15 \text{ cm}$$

Case II : If the image formed is virtual

$$\frac{h_i}{h_0} = 2$$

$$\Rightarrow v = 2u$$

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

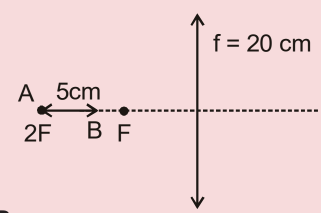
$$\Rightarrow \frac{1}{10} = \frac{1}{2u} - \frac{1}{u}$$

$$\Rightarrow \frac{1}{10} = -\frac{1}{2u}$$

$$\Rightarrow u = -5 \text{ cm}$$

Example 73

Find the linear length of the image of the object AB shown in figure.

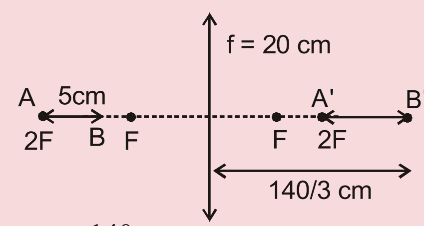


Sol. **For B :**

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

$$\Rightarrow \frac{1}{20} = \frac{1}{v} + \frac{1}{35}$$

$$\Rightarrow \frac{1}{v} = \frac{1}{20} - \frac{1}{35}$$



$$\Rightarrow v = \frac{140}{3} \text{ cm}$$

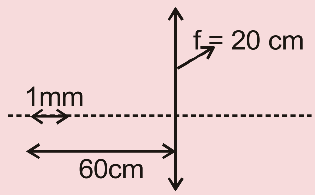
$$A' B' = (v_B - v_A)$$

$$= \frac{140}{3} - 40$$

$$= \frac{20}{3} \text{ cm}$$

Example 74

Findout the linear length of the image of the object shown in figure.



Sol. Here the length of the object is very small then

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

By differentiating

$$\frac{dv}{du}=\frac{v^2}{u^2}$$

$$u=-60 \text{ cm}$$

$$f=+20 \text{ cm}$$

$$\frac{1}{f}=\frac{1}{v}+\frac{1}{60}$$

$$\Rightarrow v=30$$

$$\frac{dv}{du}=\frac{v^2}{u^2}$$

$$\Rightarrow \frac{dv}{1}=\frac{(30)^2}{(60)^2}$$

$$\Rightarrow dv=\frac{1}{4}\text{mm}$$

= length of the image

Note

Differentiating in solving 73 & 74 (Trick)

21.2 Velocity of the image formed by a lens

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

differentiate the above eq.

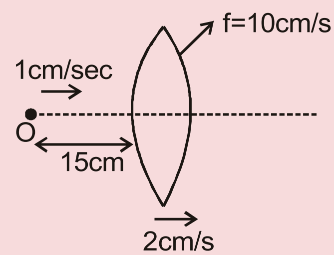
$$-\frac{1}{v^2}\frac{dv}{dt}+\frac{1}{u^2}\frac{du}{dt}=0$$

$$\Rightarrow \frac{dv}{dt}=\frac{v^2}{u^2}\frac{du}{dt}$$

$$v_{IL}=\frac{v^2}{u^2}V_{OL}$$

Example 75

Find the velocity of the image of the object shown in the figure.



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

$$\Rightarrow \frac{1}{10}=\frac{1}{v}+\frac{1}{15}$$

$$\Rightarrow \frac{1}{v}=\frac{1}{10}-\frac{1}{15}$$

$$\Rightarrow v=\frac{150}{5}=30 \text{ cm}$$

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

By differentating :

$$0=\frac{dv}{v^2dt}-\frac{du}{dt\,u^2}$$

$$\Rightarrow 0=-\frac{dv}{v^2}+\frac{du}{u^2}$$

$$\Rightarrow \frac{du}{u^2} = \frac{dv}{v^2} \Rightarrow \frac{dv}{du} = \frac{v^2}{u^2}$$

$$\Rightarrow dv = \frac{(30)^2}{(15)^2} \times (1-2) = -4\ (1)$$

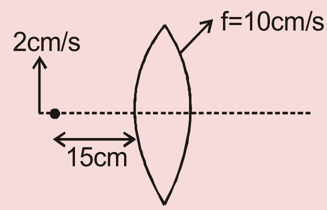
$$\Rightarrow (v_I - v_L) = -4$$

$$\Rightarrow (v_I - 2) = -4$$

$$\Rightarrow v_I = -2 \text{ cm/s}$$

Example 76

Find the velocity of the image of the object shown in the figure.



Sol.

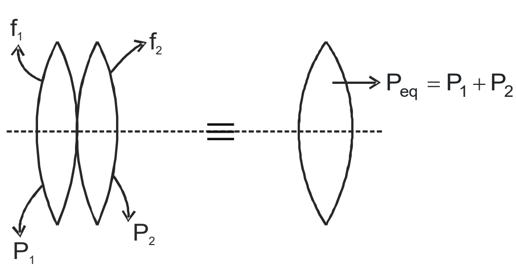
$$\frac{h_i}{h_0} = \frac{v}{u}$$

$$\Rightarrow \frac{h_i}{h_0} = \frac{v}{u}$$

$$\Rightarrow \frac{dh_i}{dt} = \frac{v}{u}\frac{dh_0}{dt}$$

$$v_I = \frac{30}{-15} \times 2 = -4 \text{ cm/sec (downwards)}$$

21.3 COMBINATION OF LENS.



$$P_{eq} = P_1 + P_2$$

$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2}$$

Important points :

(1) Rays should be paraxial

(2) Lens should be thin

(3) Lenses should be kept in contact

(4) f_1, f_2, f_3, ... should be put with sign.

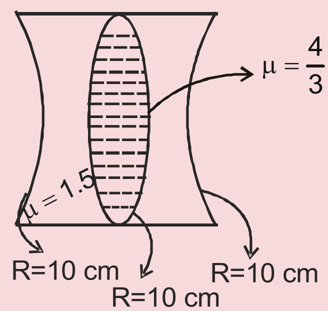
(5) f_1, f_2, f_3 .... are the focal length of lenses in the surrounding medium.

(6) If f_{eq} = + ve then system will behave as converging system.

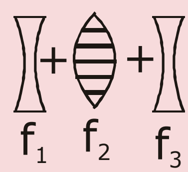
If f_{eq} = – ve then system will behave as diverging system.

Example 77

Find the equivalent focal length of the combination of lenses shown in the figure. Surrounding medium is air.



Sol. This is a combination of



$$\frac{1}{f_1} = \left(\frac{\mu_\ell}{\mu_s} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$= (1.5-1)\left(-\frac{1}{10} - \frac{1}{10}\right)$$

$$= 0.5 \times \frac{-2}{10}$$

$$\Rightarrow f_1 = \frac{10}{0.5 \times -2} = -10\text{cm}$$

$$\frac{1}{f_2} = \left(\frac{\mu_\ell}{\mu_s} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$= \left(\frac{4}{3} - 1\right)\left(\frac{1}{10} + \frac{1}{10}\right)$$

$$\Rightarrow \frac{1}{f_2} = \frac{1}{3}\left(\frac{2}{10}\right)$$

$$\Rightarrow f_2 = \left(\frac{30}{2}\right) = 15\text{cm}$$

$f_3 = -10$ cm

$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3}$$

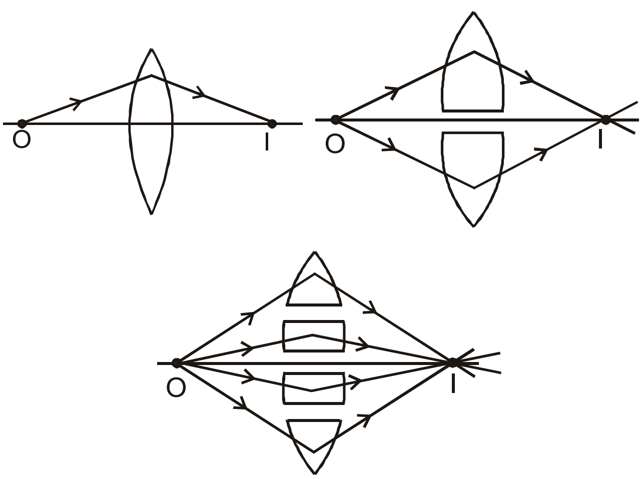
$$= \frac{1}{15} - \frac{2}{10}$$

$$\Rightarrow f_{eq} = \frac{150}{-20} = -7.5 \text{ cm}$$

i.e. the combination will behave like a concae lens.

22. CUTTING OF LENS.

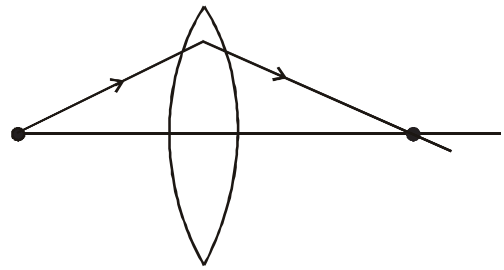
22.1 Parallel Cutting



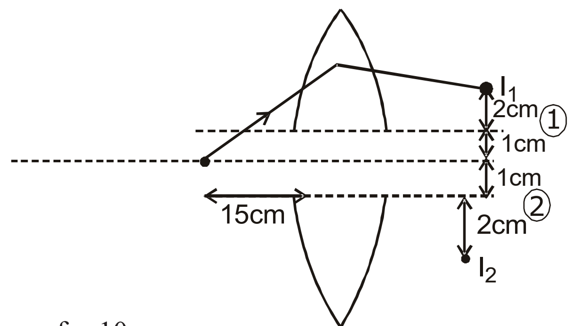
No. of images in all the cases = 1

$\because$ Principle axis does not shift

(ii)



Que. In the figure shown, if the lens is cut into two equal parts and separated as shown, find the distance between the images formed



Sol. f = 10 cm

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

$\Rightarrow \quad \frac{1}{10} = \frac{1}{v} + \frac{1}{15}$

$\Rightarrow \quad \frac{1}{v} = \frac{1}{10} - \frac{1}{15}$

$\Rightarrow \quad v = \frac{150}{5} = 30$ cm

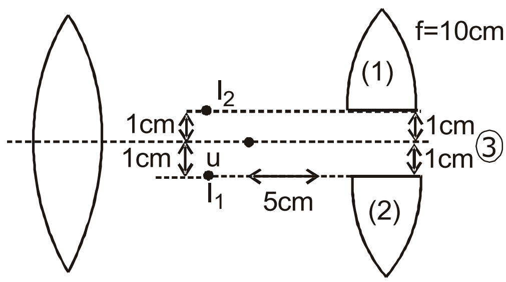
b) $\frac{h_i}{h_0} = \frac{v}{u}$

$\Rightarrow \quad \frac{h_i}{-1} = \frac{30}{-15}$

$\Rightarrow \quad h = +2$ (upwards)

Total distance = 2 + 2 + 2 = 6 cm

(iii)



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

$$\Rightarrow \quad \frac{1}{10} = \frac{1}{v} + \frac{1}{5}$$

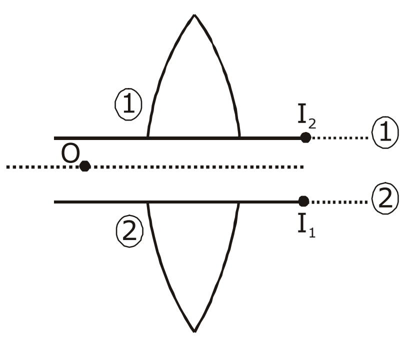
$$\Rightarrow \quad \frac{1}{v} = \frac{1}{10} - \frac{1}{5}$$

$$\Rightarrow \quad v = -\frac{50}{5} = -10\,cm$$

$$\frac{h_i}{h_0} = \frac{v}{u}$$

$$\Rightarrow \quad \frac{h_i}{-1} = \frac{-10}{-5}$$

$$\Rightarrow \quad h_i = -2 \text{ cm}$$



Distance = 1 + 1 = 2 cm

Section L - Power of lens and Mirror, Silverging of lens, Displacement Method

22.2 Power of a Lens

$$\text{Power} = \frac{1}{f}$$

Unit : Diopters

where f is in meter

and f should be put with sign

power of converging lens. = + ve

Power of diverging lens. = – ve

22.3 Power of Mirror

$$\text{Power} = -\frac{1}{f} \text{ (diopter)}$$

where $f \to$ meter

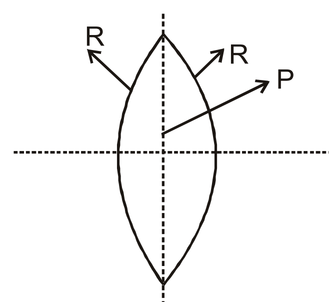
and f should be put with sign.

Power of converging mirror = + ve

Power of diverging mirror = – ve

22.4 Perpendicular Cutting

(1)

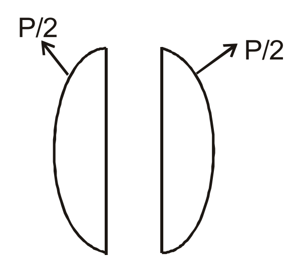


$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R} - \left(-\frac{1}{R}\right)\right)$$

$$\Rightarrow \quad \frac{1}{f} = (\mu - 1)\frac{2}{R}$$

$$\frac{1}{f_1} = (\mu - 1)\left(\frac{1}{R} - 0\right)$$

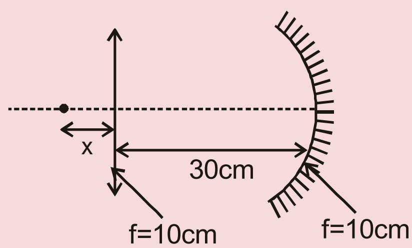
$$= \frac{(\mu - 1)}{R}$$



$f' = 2f$

Example 78

Find the value of x so that the image is formed on the object itself.



Sol.

Case I : When the lens forms the image at the pole of the mirror

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

$\Rightarrow$ $$\frac{1}{10}=\frac{1}{30}-\frac{1}{-x}$$

$\Rightarrow$ $$\frac{1}{x}=\frac{1}{10}-\frac{1}{30}$$

$\Rightarrow$ x = 15 cm

Case II : When the lens forms the image at the centre of curvature of the mirror v = 20cm, u = -x cm, f = 10 cm.

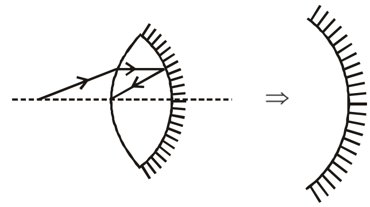
$\Rightarrow$ $$\frac{1}{20}+\frac{1}{x}=\frac{1}{10}$$

$\Rightarrow$ $$\frac{1}{x}=\frac{1}{10}-\frac{1}{20}$$

$\therefore$ x = 20 cm

Note: - For the object to coincide with its image, the rays of light have to hit the mirror normally.

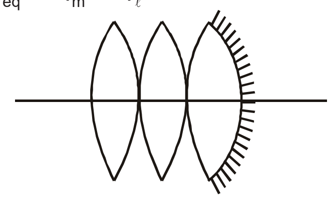
23. SILVERVING OF LENS.



$$\mathbf{P_{eq} = 2P_{\ell} + P_m}$$

$\Rightarrow$ $$-\frac{1}{f_{eq}}=\frac{2}{f_{\ell}}-\frac{1}{f_m}$$

$\Rightarrow$ $$\frac{1}{f_{eq}}=\frac{1}{f_m}-\frac{2}{f_{\ell}}$$



$$\mathbf{\frac{1}{f_{eq}}=\frac{1}{f_m}-2\left[\frac{1}{f_{\ell_1}}+\frac{1}{f_{\ell_2}}+.....\right]}$$

Important points :

(1) Rays should be paraxial

(2) Lenses should be thin

(3) All the lenses should be in contact.

(4) f_{ℓ}, f_m should be put along with the sign.

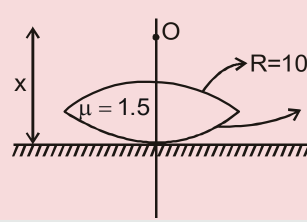
(5) If f_{eq} = – ve $\Rightarrow$ concave,

f_{eq} = + ve $\Rightarrow$ convex,

If $f_{eq} = \infty$ $\Rightarrow$ plane mirror

Example 79

Find the value of x so that the image will form on object itself.



Sol. $$\frac{1}{f_{eq}}=\frac{1}{f_m}-2\left\{(0.5)\left(\frac{1}{10}+\frac{1}{10}\right)\right\}$$

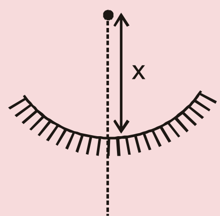
$$\Rightarrow \frac{1}{f_{eq}}=\frac{1}{\infty}-\frac{2}{10}$$

$$\Rightarrow f_{eq}=-5\text{cm}$$

The system is equivalent to a concave mirror of focal length 5 cm

Object must be at the centre of curvature

$\therefore\ x = 2(5) = 10$ cm



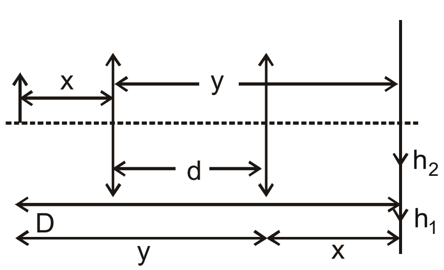
OR

For the object and image to coincide, the rays of light have to hit the plane mirror normally i.e. they should emerged parallely from the lens.

Hence $v=\infty \Rightarrow u=f=\dfrac{R}{2(\mu-1)}=10\text{cm}$

24. DISPLACEMENT METHOD

For the formation of the real image by convex lens minimum distance between object and image is 4f, f being the focal length of the lens. If the distance between object and screen (D) is greater than 4f then there are two positions of the lens for which the image of object on the screen is distinct and clear. In these two positions the distance of object and image from lens are interchange.



For first refraction :

$u = -x \qquad h_0 = h_0$

$v = +y \qquad h_i = -h_i$

$$\frac{-h_1}{h_0}=\frac{-y}{x} \qquad ...(1)$$

For second refraction :

$u = -y \qquad v = +x$

$h_i = -h_2 \qquad h_0 = h_0$

$$-\frac{h_2}{h_0}=\frac{-x}{y} \qquad ...(2)$$

(1) × (2)

$$h_0^2 = h_1h_2 \Rightarrow h_0=\sqrt{h_1h_2}$$

Now $D = x + y,$ ...(3)

$d = y - x$ ...(4)

After solving eq. (3) & (4)

$$y=\frac{D+d}{2} \qquad x=\frac{D-d}{2}$$

from $\dfrac{1}{y}+\dfrac{1}{x}=\dfrac{1}{f}$

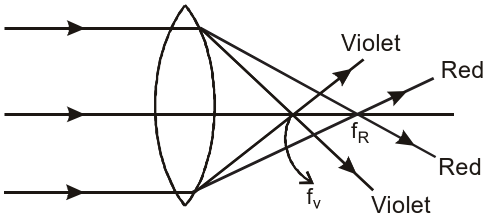
$$\frac{2}{D+d}+\frac{2}{D-d}=\frac{1}{f}$$

$$\Rightarrow f=\frac{D^2-d^2}{4D}$$

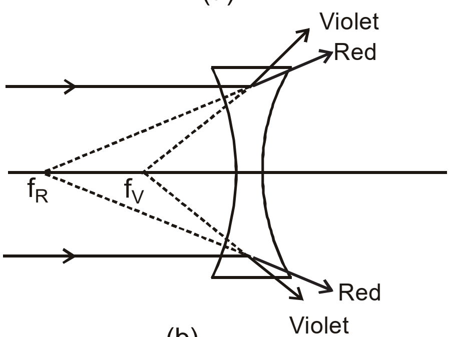
Section M - Chromatic Aberration and Achromatism, Optical Instrument + Eye + Luminous Intensity

25. CHROMATIC ABERRATION AND ACHROMATISM

The refractive index of the material of a lens varies slightly with the wavelength and hence, the focal length is also different for different wavelengths. In the visible region, the focal length is maximum for red and minimum for violet. Thus, if white light is used, each colour forms a separate image of the object.

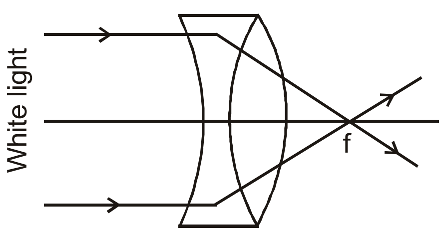


(a)



(b)

The violet rays are deviated more and hence, they form an image closer to the lens as compared to the image formed by the red rays. If light is incident on the lens from left to right, the violet image is to the left of the red image for convex lens and it is to the right of the red image for the concave lens. In the first case, the chromatic aberration is called positive and in the second case, it is negative. Thus, a proper combination for a convex and a concave lens may result in no chromatic aberration. Such a combination is called an achromatic combination for the pair of wavelenghts.



$$\frac{1}{f_v} = (\mu_v - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \qquad ...(1)$$

$$\frac{1}{f_R} = (\mu_R - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \qquad ...(2)$$

Eq. (1) – eq. (2)

$$\frac{1}{f_v} - \frac{1}{f_R} = (\mu_v - \mu_R)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{f_R - f_v}{f_R . f_v} = \frac{(\mu_v - \mu_R)}{(\mu_y - 1)}(\mu_y - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$f_R . f_v = f_1^{\,2}$$

$$\Rightarrow \text{ and } \quad f_R - f_v = df$$

$$\frac{df}{f_y^{\,2}} = \frac{\omega}{f_y}$$

$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\Rightarrow \quad -\frac{df_{eq}}{f^2} = -\frac{df_1}{f_1^2} - \frac{df_2}{f_2^{\,2}}$$

for achromatism $df_{eq} = 0$

$$\Rightarrow \quad \frac{df_1}{f_1^2} + \frac{df_2}{f_2^2} = 0$$

$$\frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} = 0$$

EXTRA PORTION OF JEE MAIN

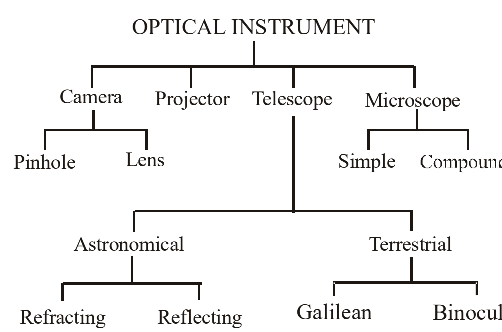
26. OPTICAL INSTRUMENTS

26.1 Definition

Optical instruments are used primarily to assist the eye in viewing an object.

26.2 Types of Instruments

Depending upon the use, optical instruments can be categorised in the following way :

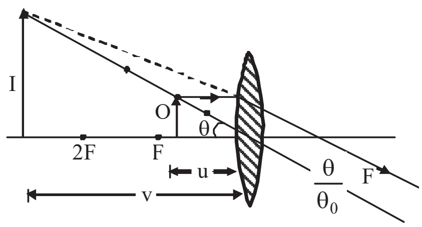


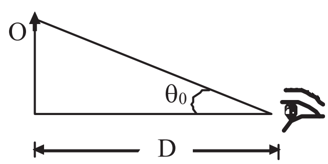
27. MICROSCOPE

It is an optical instrument used to increase the visual angle of near objects which are too small to be seen by naked eye. Microscopes are of two types viz. simple microscope and compound microscope.

27.1 Simple Microscope

It is also known as magnifying glass or **magnifier** and consists of a convergent lens with object between its focus and optical centre and eye close to it. The image formed by it is erect, virtual, enlarged and on same side of lens between object and infinity.





Here, Magnifying power

$$= \frac{\text{Visual angle with instrument}}{\text{Maximum visual angle for unaided eye}} = \frac{\theta}{\theta_0}$$

Now, $\theta = \frac{h_i}{v} = \frac{h_0}{u}$

with, $\theta_0 = h_0/D$

$$\text{M.P.} = \frac{\theta}{\theta_0} = \frac{h_0}{u} \times \frac{D}{h_0} = \frac{D}{u}$$

Now, two possibilities are there :

(A) Image is at infinity (far point)

If $v = \infty$ $u = f$ (from lens formula)

So, $\text{M.P.} = \frac{D}{u} = \frac{D}{f}$

Note

Here parallel beam of light enters the eye i.e., eye is least strained.

(B) Image is at D (Near point)

In this situation, $v = -D$, so that,

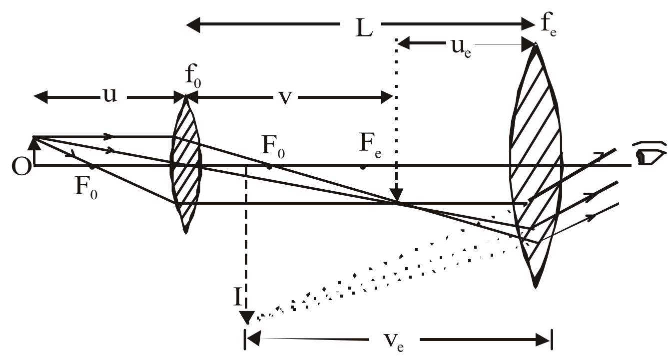
$$\frac{1}{-D} - \frac{1}{-u} = \frac{1}{f} \text{ or } \frac{D}{u} = 1 + \frac{D}{f}$$

So, $\text{M.P.} = 1 + \frac{D}{f}$

Note

Here final image is closest to eye i.e., eye is under maximum strain.

27.2 Compound Microscope



It consists of two converging lenses of short focal lengths and apertures arranged co-axially.

Lens f_0 is the **objective** or **field lens** and f_e is the **eye-piece** or **ocular**. Objective has smaller aperture and focal length than eye-piece. The separation between objective and eye-piece can be varied.

Magnifying Power

$$= \frac{\theta}{\theta_0} = \frac{h_i}{u_e} \times \frac{D}{h_0} = \frac{h_i}{h_0} \times \frac{D}{u_e}$$

But for objective,

$$m = \frac{v}{u} \text{ i.e., } \frac{h_i}{h_0} = -\frac{v}{u}$$

So, $\text{M.P.} = -\frac{v}{u}\left[\frac{D}{u_e}\right]$ where, $\mu_e + \mu = L$

Now two possibilities are there :

(A) Final image is at infinity (far point)

$\mu_e = f_e$

$$\Rightarrow \text{M.P} = -\frac{v}{u}\left[\frac{D}{f_e}\right]$$

where $L = u + f_e$

L is the length of microscope it is the distance between the two lenses

Note

A microscope is usually considered to operate in this mode unless stated otherwise.

(B) Final image is at D (near point)

For eye - piece . $v_e = D$,

$$\Rightarrow \frac{1}{-D} - \frac{1}{-u_e} = \frac{1}{f_e}$$

$$\Rightarrow \frac{1}{u_e} = \frac{1}{D}\left(1+\frac{D}{f_e}\right)$$

$$\text{M.P} .= -\frac{v}{u}\left(1+\frac{D}{f_e}\right)$$

$$\text{with } L = v + \frac{f_e D}{f_e + D}$$

Note

In case, $u \cong f_0$

and $L = v + u_e \cong v$,

so that $|\text{M.P}| \cong \frac{L}{f_0} \times \frac{D}{f_e}$

IMPORTANT POINTS

1. **As magnifying power** is negative, the image seen in a microscope is always truly inverted, i.e., left is turned right with upside down simultaneously.

2. **Resolving Power** : The minimum distance between two lines at which they are just distinct is called limit of resolution and reciprocal of limit of resolution is called resolving power.

$$\text{R.P.} = \frac{1}{\Delta x} \propto \frac{1}{\lambda} = 2\mu\sin\theta/\lambda$$

28. TELESCOPE

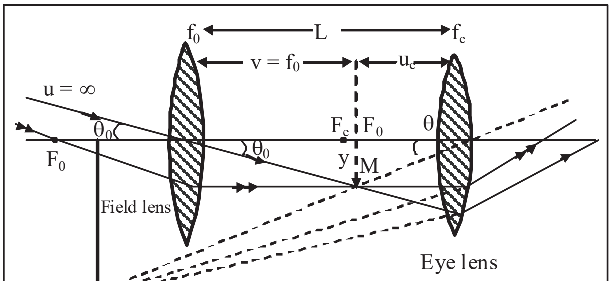
It is an optical instrument used to increase the visual angle of distant large objects. Telescopes mainly are of two types viz. astronomical and terrestrial.

28.1 Astronomical Telescope :

It consists of two converging lenses placed coaxially with objective having large aperture and a large focal length while the eye- piece is having smaller aperture and focal length. The separation between eye- piece and objective can be varied.

Magnifying power

$$= \frac{\text{visual angle with instrument}}{\text{visual angle for unaided eye}} = \frac{\theta}{\theta_0}$$



Astronomical Telescope

$$\theta_0 = \frac{h}{f_0} \quad \& \quad \theta = h/(-u_e)$$

$$\Rightarrow \text{M.P.} = -\left[\frac{f_0}{u_e}\right] \quad \text{with } L = f_0 + u_e$$

Now two possibilities are there

(A) Final image is at infinity (far point)

It is called normal adjustment.

Here, $v = \infty \Rightarrow u_e = f_e$

So, M.P. $= -(f_0/f_e)$ with, $L = f_0 + f_e$

Note

Usually, a telescope operates in this mode unless stated otherwise.

(B) Final image is at D (near point)

Here, $v = D$

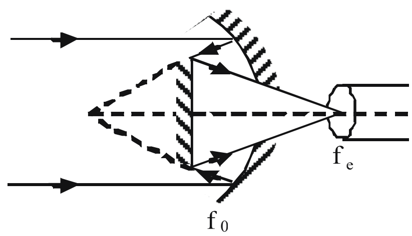
$$\Rightarrow \frac{1}{-D} - \frac{1}{-u_e} = \frac{1}{f_e} = \frac{1}{u_e} = \frac{1}{f_e}\left[1 + \frac{f_e}{D}\right]$$

$$\text{So, M.P.} = -\frac{f_0}{f_e}\left[1 + \frac{f_e}{D}\right]$$

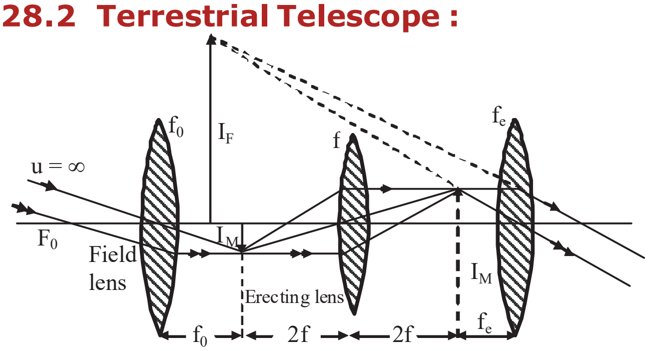
$$\text{with } L = f_0 + \frac{f_e D}{f_e + D}$$

Note

1. The above discussion is that of the refracting telescope
2. **Reflecting Telescope :** If the field lens of refracting telescope is replaced by a converging mirror, then the telescope becomes a reflecting one, where M.P. = f/f



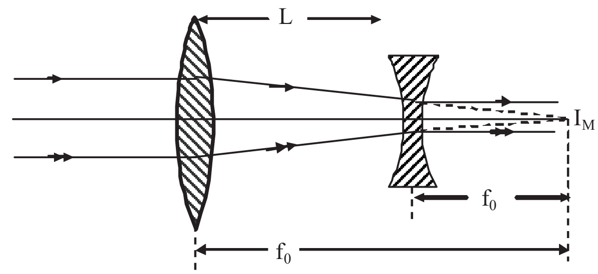
28.2 Terrestrial Telescope :



If a lens of short focal length f is placed at 2f from the intermediate image. It forms an image at a distance 2f on the other side of it and this image will act as an object for eye- lens which will produce erect image with respect to the object. This lens is called **erecting lens** and as for it magnification = – 1, the MP and length of telescope for relaxed eye will be

$$\text{M.P.} = -\frac{f_0}{f_e}(-1) = \frac{f_0}{f_e}, \; L = f_0 + f_e + 4f$$

(A) Galilean Telescope



Here the convergent eye- piece of astronomical telescope is replaced by a divergent lens.

Here M.P. = f_0 / f_e with , $L = f_0 - f_e$

Note

In this telescope as the intermediate image is outside the tube, the telescope cannot be used for measurements. This was not the case for all previous telescopes.

$$\text{Resolving power of Telescope} = \frac{D}{1.22\lambda}$$

Exercise 1 (Level-A) JEE Main Level

Plane Mirror

1. A point source of light is placed in front of a plane mirror.

(A) Only the reflected rays close to the normal meet at a point when produced backward.
(B) All the reflected rays meet at a point when produced backward.
(C) Only the reflected rays making a small angle with the mirror, meet at a point when produced backward.
(D)
Light of different colours make different images.

[C. 65.79%, I.C. 26.67%, U.A. 7.54%]

2. Two mirrors are placed perpendicular to each other. A ray strikes the first mirror and after reflection from the first mirror it falls on the second mirror. The ray after reflection from second mirror will emerge -

(A) Perpendicular to the origial ray
(B) Parallel to the original ray
(C) At 45° to the original ray
(D) At 60° to the original ray

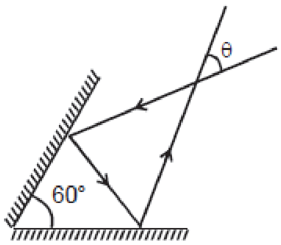
[C. 63.49%, I.C. 28.07%, U.A. 8.44%]

3. 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 -

(A) 60 cm **(B)** 140 cm
(C) 170 cm **(D)** 150 cm

[C. 62.61%, I.C. 29.62%, U.A. 7.77%]

4. A light ray is incident on a plane mirror, which after getting reflected strikes another plane mirror, as shown in figure. The angle between the two mirrors is 60°. Find the angle 'θ' shown in figure.



(A) 60° **(B)** 30°
(C) 45° **(D)** 90°

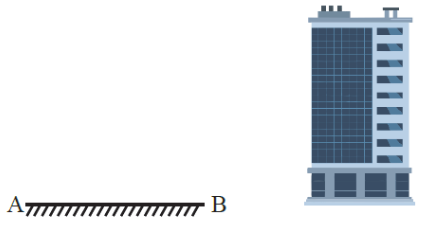
[C. 54.36%, I.C. 35.20%, U.A. 10.44%]

5. A clock shows the time as 3 : 25. What will be the time that appears when seen through a plane mirror ?

(A) 8 : 35 **(B)** 9 : 35 **(C)** 7 : 35 **(D)** 8 : 25

[C. 52.89%, I.C. 37.42%, U.A. 9.69%]

6. When a plane mirror AB is placed horizontally on level ground at a distance of 60 meters from the foot of a tower, the top of the tower and its image in the mirror subtends, an angle of 90° at B. The height of the tower is :



(A) 30 meter **(B)** 60 meter
(C) 90 meter **(D)** 120 meter.

[C. 52.35%, I.C. 39.35%, U.A. 8.30%]

7. If a ray of light is incident on a plane mirror at an angle 60° from the mirror surface, then deviation produced by mirror is:

(A) 30° **(B)** 60° **(C)** 90° **(D)** 120°

[C. 50.28%, I.C. 41.58%, U.A. 8.14%]

8. Two plane mirrors are placed parallel to each other at a distance L apart. A point object O is placed between them, at a distance L/3 from one mirror. Both mirrors form multiple images. The distance between any two images cannot be

(A) 3L/2 **(B)** 2L/3 **(C)** 2L **(D)** L

[C. 46.74%, I.C. 43.64%, U.A. 9.62%]

9. If an object is placed unsymmetrically between two plane mirrors, inclined at the angle of 72°, then the total number of images formed is-

(A) 5 **(B)** 4

(C) 2 **(D)** infinite

[C. 46.30%, I.C. 31.81%, U.A. 21.89%]

10. A plane mirror is moving with velocity $4\hat{i}+5\hat{j}+8\hat{k}$. A point object in front of the mirror moves with a velocity $3\hat{i}+4\hat{j}+5\hat{k}$. Here, $\hat{k}$ is along the normal to the plane mirror and facing toward the object. The velocity of the image is-

(A) $-3\hat{i}+4\hat{j}+5\hat{k}$

(B) $3\bar{i}+4\bar{j}+11\hat{k}$

(C) $-3\hat{i}+4\hat{j}+11\hat{k}$

(D) $7\bar{i}+9\bar{j}+11\hat{k}$

[C. 33.02%, I.C. 22.65%, U.A. 44.33%]

11. A rays is incident at an angle 38º on a mirror. The angle between normal and reflected ray is

(A) 38° **(B)** 52º **(C)** 90º **(D)** 76º

[C. 29.25%, I.C. 27.46%, U.A. 43.29%]

12. A man 2m tall stands 5m in front of a large vertical plane mirror. Then the angle subtended at his eye by his image in the plane mirror is nearly :

(A) 0.4 rad **(B)** 0.2rad

(C) 0.2° **(D)** 0.4°

[C. 26.37%, I.C. 31.28%, U.A. 42.35%]

Mirror Formula And Magnification, Velocity In Spherical Mirror, Cutting Of Mirrors, Combination Of Mirrors, Intensity Of Light

13. A convex mirror has a focal length f. A real object, placed at a distance f in front of it from the pole, produces an image at

(A) 2 *f* **(B)** *f*/2

(C) *f* **(D)** ∞

[C. 58.58%, I.C. 26.42%, U.A. 15.00%]

14. If an object is 30 cm away from a concave mirror of focal length 15 cm, the image will be

(A) errect **(B)** virtual

(C) diminished **(D)** of same size

[C. 55.57%, I.C. 28.04%, U.A. 16.39%]

15. A candle is kept at a distance equal to double the focal length from the pole of a convex mirror, its magnification will be :

(A) $-\frac{1}{3}$ **(B)** $\frac{1}{3}$

(C) $\frac{2}{3}$ **(D)** $-\frac{2}{3}$

[C. 47.90%, I.C. 31.88%, U.A. 20.22%]

16. A concave mirror cannot form

(A) virtual image of virtual object

(B) virtual image of a real object

(C) real image of a real object

(D) real image of a virtual object.

[C. 47.51%, I.C. 35.71%, U.A. 16.78%]

17. The focal length of spherical mirror is -

(A) Maximum for red light

(B) Maximum for blue light

(C) Maximum for white light

(D) Same for all lights

[C. 45.72%, I.C. 41.84%, U.A. 12.44%]

18. A concave mirror of radius of curvature 20 cm forms image of the sun. The diameter of the sun subtends an angle 1° on the earth. Then the diameter of the image is (in cm) :

(A) $2\pi/9$ **(B)** $\pi/9$

(C) 20 **(D)** $\pi/18$

[C. 43.83%, I.C. 43.96%, U.A. 12.21%]

19. In image formation from spherical mirrors, only paraxial rays are considered because they :

(A) are easy to handle geometrically

(B) contain most of the intensity of the incident light

(C) form nearly a point image of a point source

(D) show minimum dispersion effect.

[C. 42.95%, I.C. 47.32%, U.A. 9.73%]

20. A convex mirror has a focal length is 20 cm. A convergent beam tending to converge to a point 20 cm behind convex mirror on principal axis falls on it. The image is formed at

(A) infinity **(B)** 40 cm

(C) 20 cm **(D)** 10 cm

[C. 37.83%, I.C. 30.41%, U.A. 31.76%]

21. The largest distance of the image of a real object from a convex mirror of focal length 20 cm can be :

(A) 20 cm

(B) infinite

(C) 10 cm

(D) depends on the position of the object.

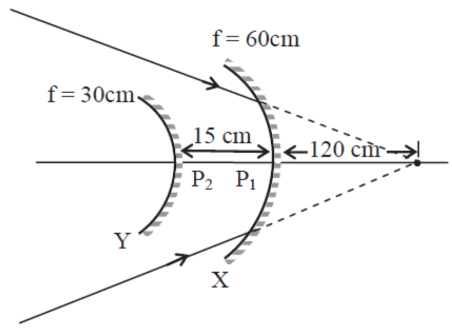
[C. 36.50%, I.C. 53.51%, U.A. 9.99%]

22. 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 :

(A) 10 cm **(B)** 15 cm **(C)** 20 cm **(D)** 30 cm

[C. 35.76%, I.C. 35.72%, U.A. 28.52%]

23. In figure, the image formed after two reflections (first at X then at Y) will be:



(A) erect and enlarged 2 times

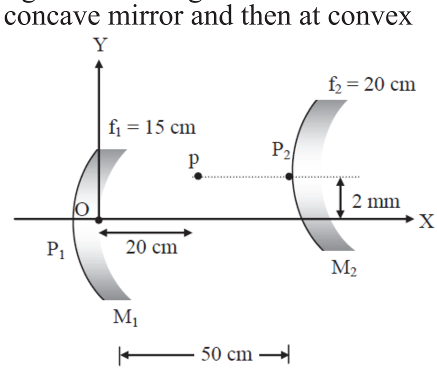
(B) inverted and enlarged 2 times

(C) erect and diminished 2 times

(D) inverted and diminished 4 times

[C. 26.22%, I.C. 30.49%, U.A. 43.29%]

24. The co-ordinates of image of point object P formed after two successive reflection in situation as shown in fig. considering first reflection at concave mirror and then at convex



(A) (30 cm, –14 mm)

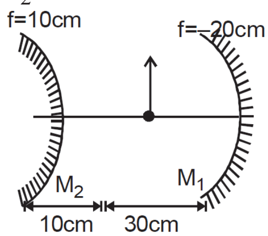
(B) (–30 cm, 14 mm)

(C) (– 30 cm, – 14 mm)

(D) (30 cm, 14 mm)

[C. 19.32%, I.C. 36.87%, U.A. 43.81%]

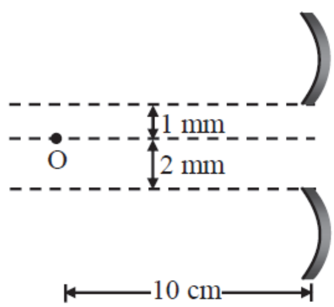
25. In the figure shown find the total magnification after two successive reflections first on M_1 and then on M_2.



(A) 2 **(B)** -2 **(C)** 3 **(D)** -3

[C. 9.25%, I.C. 33.14%, U.A. 57.61%]

26. A mirror of focal length 15 m is cut into two halves and placed before an object at a distance of 10 cm as shown in figure. The separation between images formed by two halves of mirror is :



(A) 3 mm **(B)** 4 mm **(C)** 5 mm **(D)** 6 mm

[C. 7.21%, I.C. 37.15%, U.A. 55.64%]

Snell'S Law, Apparent Depth And Normal Shift, Refraction Through A Glass Slab, Lateral Shift

27. A ray of light is incident on one face of a transparent slab of thickness 15 cm. The angle of incidence is 60°. If the lateral displacement of the ray on emerging from the parallel plane is 5 $\sqrt{3}$ cm, the refractive index of the material of the slab is

(A) 1.414 **(B)** 1.532

(C) 1.732 **(D)** 2

[C. 43.16%, I.C. 47.49%, U.A. 9.35%]

28. A ray of light passes through a plane glass slab of thickness t and refractive index $\mu = 1.5$. The angle between incident ray and emergent ray will be

(A) 0° **(B)** 30° **(C)** 45° **(D)** 60°

[C. 41.52%, I.C. 44.11%, U.A. 14.37%]

29. 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 :

(A) 1.33 **(B)** 9/10 **(C)** 10/9 **(D)** 1.5

[C. 39.81%, I.C. 34.31%, U.A. 25.88%]

30. A bird is flying 3 m above the surface of water. If the bird is diving vertically down with speed = 6 m/s, his apparent velocity as seen by a stationary fish underwater is $\left(\mu_{\text{water}} = \frac{4}{3}\right)$

(A) 8 m/s **(B)** 6 m/s **(C)** 12 m/s **(D)** 4 m/s

[C. 19.17%, I.C. 24.28%, U.A. 56.55%]

31. A ray incident at a point at an angle of incidence of 60° enters a glass sphere of $\mu = \sqrt{3}$ and it is reflected and refracted at the farther surface of the sphere. The angle between reflected and refracted rays at this surface is

(A) 50° **(B)** 90° **(C)** 60° **(D)** 40°

[C. 16.48%, I.C. 27.78%, U.A. 55.74%]

Critical Angle And Total Internal Reflection (T.I.R.)

32. 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:

(A) $\frac{v}{\sin\theta}$ **(B)** v $\sin\theta$

(C) v $\cot\theta$ **(D)** v $\tan\theta$

[C. 58.29%, I.C. 29.29%, U.A. 12.42%]

33. Two transparent media A and B are separated by a plane boundary. The speed of light in medium A is 2.0×10^8 m s^{-1} and in medium B is 2.5×10^8 ms^{-1}. The critical angle for which a ray of light going from A to B is totally internally reflected is

(A) $\sin^{-1}\left(\frac{1}{2}\right)$ **(B)** $\sin^{-1}\left(\frac{2}{5}\right)$

(C) $\sin^{-1}\left(\frac{4}{5}\right)$ **(D)** $\sin^{-1}\left(\frac{1}{3}\right)$

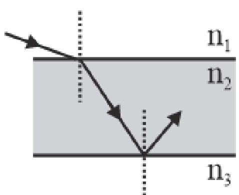
[C. 48.68%, I.C. 37.89%, U.A. 13.43%]

34. A light ray is incident on a transparent sphere of index = $\sqrt{2}$, at an angle of incidence = 45°. What is the deviation of a tiny fraction of the ray, which enters the sphere, undergoes two internal reflections, and then refracts out into air?

(A) 270° **(B)** 240° **(C)** 120° **(D)** 180°

[C. 45.44%, I.C. 44.94%, U.A. 9.62%]

35. Light travelling through three transparent substances follows the path shown in figure. Arrange the indices of refraction in order from smallest to largest. Note that total internal reflection does occur on the bottom surface of medium 2.



(A) $n_1 < n_2 < n_3$ **(B)** $n_2 < n_1 < n_3$

(C) $n_1 < n_3 < n_2$ **(D)** $n_3 < n_1 < n_2$

[C. 43.73%, I.C. 45.45%, U.A. 10.82%]

36. A ray of light traveling in glass (μ_g = 3/2) is incident on a glass air surface at the critical angle. If a thin layer of water (μ_w= 4/3) is now poured on the glass air surface, at what angle will the ray of light emerge into air at the water air surface?

(A) 60° **(B)** 30° **(C)** 45° **(D)** 90°

[C. 16.63%, I.C. 28.26%, U.A. 55.11%]

37. A ray of light travelling in water is incident on its surface open to air. The angle of incidence is θ, which is less than the critical angle. Then there will be

(A) only a reflected ray and no refracted ray

(B) only a refracted ray and no reflected ray

(C) a reflected ray and a refracted ray and the angle between them would be less than $180^\circ - 2\theta$

(D) a reflected ray and a refracted ray and the angle between them would be greater than $180^\circ - 2\theta$

[C. 15.44%, I.C. 39.35%, U.A. 45.21%]

Prism

38. A ray of light is incident at angle i on a surface of a prism of small angle A & emerges normally from the opposite surface. If the refractive index of the material of the prism is μ, the angle of incidence i is nearly equal to :

(A) $\frac{A}{\mu}$ **(B)** $\frac{A}{(2\mu)}$

(C) μA **(D)** $\mu\frac{A}{2}$

[C. 51.24%, I.C. 31.62%, U.A. 17.14%]

39. A beam of monochromatic light is incident at i = 50° on one face of an equilateral prism, the angle of emergence is 40°, then the angle of minimum deviation is :

(A) 30° **(B)** < 30°

(C) ≤ 30° **(D)** ≥ 30°

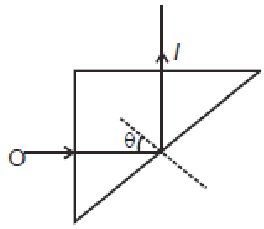
[C. 47.11%, I.C. 37.64%, U.A. 15.25%]

40. A prism having refractive index $\sqrt{2}$ and refracting angle 30°, has one of the refracting surface polished. A beam of light incident on the other refracting surface will retrace its path if the angle of incidence is :

(A) 0° **(B)** 30° **(C)** 45° **(D)** 60°

[C. 42.71%, I.C. 40.21%, U.A. 17.08%]

41. A triangular prism of glass is shown in figure. A ray incident normally on one face is totally reflected. If θ is 45°, the index of refraction of glass is :



(A) Less than $\sqrt{2}$ **(B)** Equal to $\sqrt{2}$
(C) Greater than $\sqrt{2}$ **(D)** 2

[C. 40.69%, I.C. 46.23%, U.A. 13.08%]

42. An equilateral prism deviates a ray through 23° for two angles of incidence differing by 23°. Find μ of the prism ?

(A) $\frac{\sqrt{33}}{5}$ **(B)** $\frac{\sqrt{43}}{3}$ **(C)** $\frac{\sqrt{43}}{5}$ **(D)** $\frac{\sqrt{62}}{2}$

[C. 39.81%, I.C. 53.37%, U.A. 6.82%]

43. A certain prism is found to produce a minimum deviation of 38°. It produces a deviation of 44° when the angle of incidence is either 42° or 62°. What is the angle of incidence when it is undergoing minimum deviation?

(A) 45° **(B)** 49° **(C)** 40° **(D)** 55°

[C. 37.79%, I.C. 55.47%, U.A. 6.74%]

Dispersion Of Light

44. Indicate the correct statement in the following

(A) The dispersive power depends upon the angle of prism
(B) The angular dispersion depends upon the angle of the prism
(C) The angular dispersion does not depend upon the dispersive power
(D) The dispersive power in vacuum is one.

[C. 43.15%, I.C. 38.58%, U.A. 18.27%]

45. The dispersion of light in a medium implies that :

(A) lights of different wavelengths travel with different speeds in the medium
(B) lights of different frequencies travel with different speeds in the medium
(C) the refractive index of medium is different for different wavelengths
(D) all of the above.

[C. 41.16%, I.C. 40.65%, U.A. 18.19%]

46. A medium has $n_V = 1.56$, $n_R = 1.44$. Then its dispersive power is :

(A) $\frac{3}{50}$ **(B)** $\frac{6}{25}$
(C) 0.03 **(D)** $\frac{3}{25}$

[C. 32.88%, I.C. 32.15%, U.A. 34.97%]

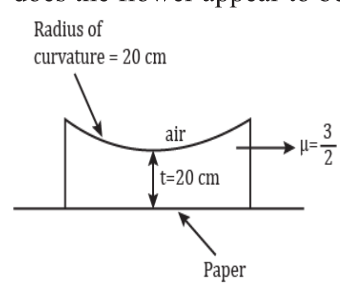
47. Critical angle of light passing from glass to air is minimum for

(A) Red **(B)** Green
(C) Yellow **(D)** Violet

[C. 30.41%, I.C. 33.88%, U.A. 35.71%]

Refraction From A Spherical Surface

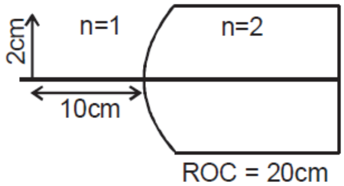
48. A planoconcave lens is placed on a paper on which a flower is drawn. How far above its actual position does the flower appear to be-



(A) 10 cm **(B)** 15 cm
(C) 50 cm **(D)** 40 cm

[C. 47.78%, I.C. 41.65%, U.A. 10.57%]

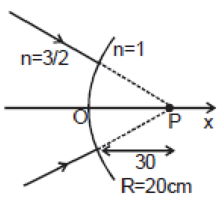
49. An extended object of size 2 cm is placed at a distance of 10 cm in air (n = 1) from pole, on the principal axis of a spherical curved surface. The medium on the other side of refracting surface has refractive index n = 2. Find the position, nature and size of image formed after single refraction through the curved surface.



(A) 30 cm from pole in the medium of refractive index 1, virtual, erect and 4 cm in size.
(B) 40 cm from pole in the medium of refractive index 1, virtual, erect and 4 cm in size.
(C) 40 cm from pole in the medium of refractive index 1, real, inverted and 4 cm in size.
(D) 30 cm from pole in the medium of refractive index 1, virtual, erect and 6 cm in size.

[C. 46.84%, I.C. 42.55%, U.A. 10.61%]

50. The image for the converging beam after refraction through the curved surface is formed at:



(A) $x = 40$ cm **(B)** $x = \frac{40}{3}$ cm
(C) $x = -\frac{40}{3}$ cm **(D)** $x = \frac{180}{7}$ cm

[C. 44.83%, I.C. 44.20%, U.A. 10.97%]

51. A fish is near the centre of a spherical water filled fish bowl. A child stands in air at a distance 2R (R is radius of curvature of the sphere) from the centre of the bowl. At what distance from the centre would the child's nose appear to the fish situated at the centre (R.I of water $\mu = 4/3$)

(A) 4R **(B)** 2R **(C)** 3R **(D)** R

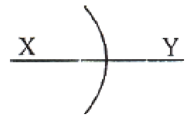
[C. 43.11%, I.C. 46.44%, U.A. 10.45%]

52. A narrow parallel beam of light is incident on a transparent sphere of refractive index 'n'.If the beam finally gets focused at a point situated at a distance = 2× (radius of sphere) from the centre of the sphere, then find n ?

(A) 4/3 **(B)** 3/2 **(C)** 5/4 **(D)** 5/3

[C. 43.11%, I.C. 49.73%, U.A. 7.16%]

53. A concave spherical surface of radius of curvature 10 cm separates two mediums X and Y of refractive index 4/3 and 3/2 respectively. If the object is placed along principal axis in medium X then



(A) Image is always real
(B) Image is real if the object distance is greater than 90 cm.
(C) Image is always virtual
(D) Image is virtual only if the object distance is less than 90 cm.

[C. 37.12%, I.C. 51.01%, U.A. 11.87%]

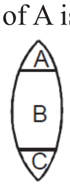
Lens Maker Formula And Magnification, Image Formation By Convex And Concave Lens, Combination Of Lens, Cutting Of Lens

54. A plano convex lens has a curved surface of radius 100 cm. If $\mu = 1.5$, then the focal length of the lens is :

(A) 50 cm **(B)** 100 cm
(C) 200 cm **(D)** 500 cm

[C. 58.55%, I.C. 29.00%, U.A. 12.45%]

55. A thin symmetrical double convex lens of power P is cut into three parts, as shown in the figure. Power of A is:



(A) 2P **(B)** $\frac{P}{2}$ **(C)** $\frac{P}{3}$ **(D)** P

[C. 58.14%, I.C. 29.60%, U.A. 12.26%]

56. When the object is at distances u_1 and u_2 the images formed by the same lens are real and virtual respectively and of the same size. Then focal length of the lens is ;

(A) $\frac{1}{2}\sqrt{u_1u_2}$ **(B)** $\frac{1}{2}(u_1+u_2)$

(C) $\sqrt{u_1u_2}$ **(D)** $2(u_1+u_2)$

[C. 54.39%, I.C. 36.30%, U.A. 9.31%]

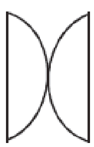
57. Which of the following cannot form real image of a real object ?

(A) concave mirror **(B)** convex mirror

(C) both mirror **(D)** Plane mirror

[C. 51.24%, I.C. 36.90%, U.A. 11.86%]

58. A biconvex lens has a focal length of 10 cm. It is cut in half and two pieces are placed as shown. The focal length of the final combination is



(A) 10 **(B)** 20

(C) 40 **(D)** Not a lens

[C. 51.08%, I.C. 37.94%, U.A. 10.98%]

59. 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:

(A) 1 mm **(B)** 4 mm **(C)** 2 mm **(D)** 8 mm

[C. 48.84%, I.C. 43.29%, U.A. 7.87%]

60. A double convex lens has focal length 50 cm. The radius of curvature of one of the surfaces is double of the other. Find the radii, if the refractive index of the material of the lens is 2.

(A) 150 cm, 75 cm **(B)** 125 cm, 150 cm

(C) 75 cm, 150 cm **(D)** 25 cm, 75 cm

[C. 48.67%, I.C. 40.66%, U.A. 10.67%]

61. An object is placed at 10 cm from a lens and real image is formed with magnification of 0.5. Then the lens is :

(A) concave with focal length of 10/3 cm

(B) convex with focal length of 10/3 cm

(C) concave with focal length of 10 cm

(D) convex with focal length of 10 cm

[C. 28.49%, I.C. 62.91%, U.A. 8.60%]

62. Two symmetric double convex lenses A and B have same focal length, but the radii of curvature differ so that $R_A = 0.9\,R_B$. If $n_A = 1.63$, find n_B.

(A) 1.7 **(B)** 1.6 **(C)** 1.5 **(D)** 4/3

[C. 26.21%, I.C. 17.94%, U.A. 55.85%]

63. A double convex lens forms a real image of an object on a screen which is fixed. Now the lens is given a constant velocity $v = 1\,ms^{-1}$ along its axis and away from the screen. For the purpose of forming the image always on the screen, the object is also required to be given an appropriate velocity. Find the velocity of the object at the instant its size is double the size of the image.

(A) 3 m/s away from screen

(B) 3 m/s towards screen

(C) 5 m/s towards screen

(D) 5 m/s away from screen

[C. 26.67%, I.C. 46.66%, U.A. 26.67%]

Power Of Lens And Mirror, Silverging Of Lens, Displacement Method

64. A lens of power + 2.0 D is placed in contact with another lens of power – 1.0 D. The combination will behave like

(A) a converging lens of focal length 100 cm

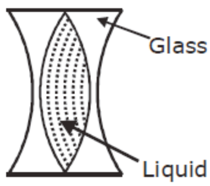
(B) a diverging lens of focal length 100 cm

(C) a converging lens of focal length 50 cm

(D) a diverging lens of focal length 50 cm.

[C. 46.88%, I.C. 40.07%, U.A. 13.05%]

65. A liquid of refractive index 1.6 is contained in the cavity of a glass specimen of refractive index 1.5 as shown in figure. If each of the curved surfaces has a radius of curvature of 0.20 m, the arrangement behaves as a



(A) converging lens of focal length 0.25 m
(B) diverging lens of focal length 0.25 m
(C) diverging lens of focal length 0.17 m
(D) converging lens of focal length 0.72 m

[C. 45.58%, I.C. 42.47%, U.A. 11.95%]

66. The source is placed 30 cm from a convex lens which has a focal length of 20 cm. The source is initially located on the axis of the lens. The lens is then cut into two halves in a plane along the principal axis. The two halves are separated by a distance of 4 mm. What will be the locations of the image of the source?

(A) 7 cm **(B)** 3 cm
(C) 4 cm **(D)** 6 cm

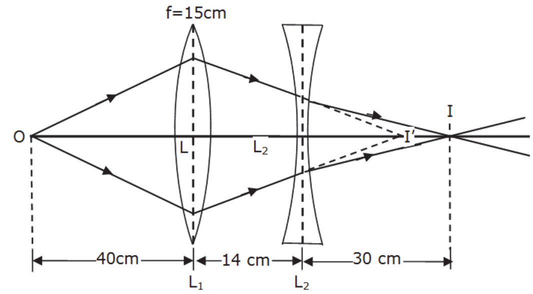
[C. 45.27%, I.C. 43.42%, U.A. 11.31%]

67. A telephoto combination consists of convex lens of focal length 30 cm and a concave lens of focal length 15 cm, the separation between two lens is 27.5 cm. Where should be the photographic plate placed in order to photograph an object 10 m in front of the first lens?

(A) 5 cm **(B)** 3 cm
(C) 4 cm **(D)** 6 cm

[C. 41.84%, I.C. 49.27%, U.A. 8.89%]

68. In the adjoining ray-diagram are given the positions of an object O, image I and two lenses L_1 and L_2. The focal length of L_1 is also given. Find the focal length of the lens L_2.



(A) 30cm **(B)** -30cm
(C) -15cm **(D)** +15 cm

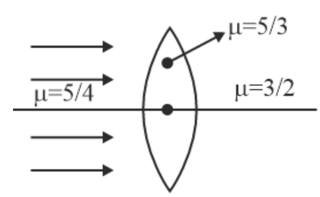
[C. 39.85%, I.C. 37.86%, U.A. 22.29%]

69. A concave mirror of focal length 30 cm is placed on the flat horizontal surface with its concave side up. Water with refractive index 1.33 is poured into the lens. Where should an object be placed if its image is to be captured on a screen with a magnification of 2?

(A) 44.25 cm **(B)** 40.60 cm
(C) 33.75 cm **(D)** 38.50 cm

[C. 39.21%, I.C. 52.57%, U.A. 8.22%]

70. A thin equi-convex lens having radius of curvature 10 cm is placed as shown in figure. Calculate focal length of the lens, if parallel rays are incident as shown.



(A) $\frac{120}{7}$ cm **(B)** $\frac{160}{7}$ cm
(C) $\frac{180}{7}$ cm **(D)** $\frac{7}{180}$

[C. 38.41%, I.C. 53.47%, U.A. 8.12%]

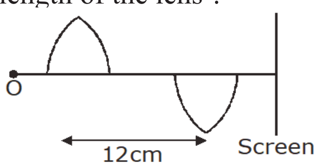
71. A convex lens of focal length 10 cm is placed 30 cm in front of a second convex lens also of the same focal length. A plane mirror is placed after the two lenses. Where should a point object be placed in front of the first lens so that it images on to itself ?

(A) 20 cm **(B)** 15 cm

(C) 30 cm **(D)** 25 cm

[C. 36.26%, I.C. 54.97%, U.A. 8.77%]

72. A convex lens is cut in half along its principal axis and the two halves are separated by a distance of 12 cm. An object is placed in front of the lens as shown in Figure. Two sharp images are formed on the screen placed 80 cm from the object. What is the focal length of the lens ?



(A) 12.50 cm **(B)** 23.45 cm

(C) 17.30 cm **(D)** 19.55 cm

[C. 28.52%, I.C. 59.18%, U.A. 12.30%]

Chromatic Aberration And Achromatism, Optical Instrument + Eye + Luminous Intensity

73. 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

(A) $F_0 + F_e$ **(B)** $F_0 \times F_e$

(C) F_0/F_e **(D)** $\frac{1}{2}F_0 + F_e$

[C. 55.70%, I.C. 34.49%, U.A. 9.81%]

74. An astronomical telescope has a magnifying power 10. The focal length of eyepiece is 20 cm. The focal length of objective is

(A) 2 cm **(B)** –200 cm

(C) $\frac{1}{2}$ cm **(D)** $\frac{1}{200}$ cm

[C. 55.30%, I.C. 26.68%, U.A. 18.02%]

75. A compound microscope has a magnification power of 100 when the image is formed at infinity. The objective has a focal length of 0.5 cm and the tube length is 6.5 cm. Find the focal length of eyepiece.

(A) 1 cm **(B)** 2 cm

(C) 20 cm **(D)** 40 cm

[C. 46.98%, I.C. 41.63%, U.A. 11.39%]

76. The focal length of the objective of a microscope is-

(A) Greater than the focal length of eye piece

(B) Lesser than the focal length of the eye piece

(C) Equal to the focal length of the eye piece

(D) Any of (1) (2) and (3)

[C. 44.13%, I.C. 43.34%, U.A. 12.53%]

77. In a simple microscope, if the final image is located at infinity then its magnifying power-

(A) 25/F **(B)** 25/D

(C) F/25 **(D)** (1+ 25/F)

[C. 44.00%, I.C. 35.00%, U.A. 21.00%]

78. The focal lengths of the objective and the eyepiece of a compound microscope are 2.0 cm and 3.0 cm, respectively. The distance between the objective and the eyepiece is 15.0 cm,. The final image formed by the eyepiece is at infinity. The two lenses are thin. The distance, in cm, of the object and the image produced by the objective, measured from the objective lens, are respectively

(A) 2.4 and 12.0

(B) 2.4 and 15.0

(C) 2.0 and 12.0

(D) 2.0 and 3.0

[C. 43.65%, I.C. 36.74%, U.A. 19.61%]

79. An eye specialist prescribes spectacles having combination of convex lens of focal length 40 cm in contact with a concave lens of focal length 25 cm. The power of this lens combination in diopters is

(A) $+1.5$ **(B)** -1.5

(C) $+6.67$ **(D)** -6.67

[C. 43.05%, I.C. 42.05%, U.A. 14.90%]

80. A myopic person can not see objects lying beyond 2 m. The focal length and power of the lens required to remove this defect will be -

(A) 1 m & 0.5 D

(B) − 2m & − 0.5 D

(C) 0.5 m & 0.5 D

(D) - 0.5m & 0.5 D

[C. 30.30%, I.C. 31.42%, U.A. 38.28%]

81. A telescope has an objective of focal length 30 cm and an eyepiece of focal length 3.0 cm. It is focused on an object of distance 2.0 meter. For seeing with relaxed eye, calculate the separation between the objective and the eyepiece.

(A) 33 cm **(B)** 27 cm

(C) 38.3 cm **(D)** 22 cm

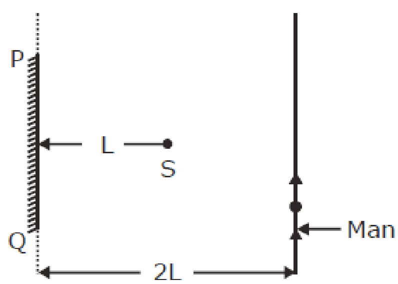
[C. 27.87%, I.C. 42.33%, U.A. 29.80%]

Exercise 1 (Level-B) — Basic Learning

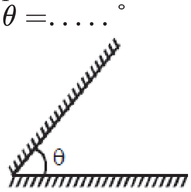
Plane Mirror

1. 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 "Parallel to which mirror".

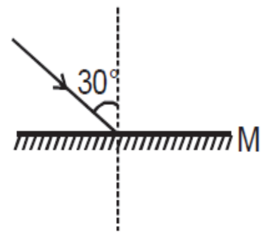
2. A point source of light S is placed at a distance L in front of the centre of a plane mirror PQ of width d hung vertically on a wall as shown in Figure. A man walks in front of the mirror along a line parallel to the mirror at a distance 2L from it as shown. The greatest distance over which he can see the image of the light source in the mirror is



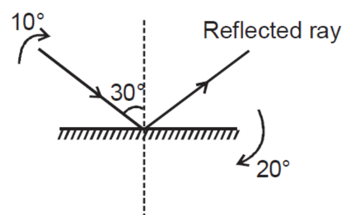
3. Two mirrors are inclined at an angle θ as shown in the figure. Light ray is incident parallel to one of the mirrors. Light will start retracing its path after third reflection if : $\theta = ...^{\circ}$



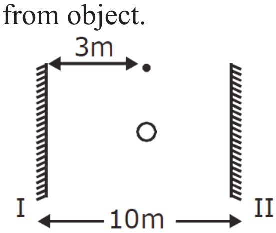
4. Find the angle of deviation (both clockwise and anticlockwise) suffered by a ray incident on a plane mirror, at an angle of incidence 30°.



5. Figure shows a plane mirror onto which a light ray is incident. If the incident light ray is turned by 10° and the mirror by 20°, as shown, find the angle turned by the reflected ray.



6. A straight line joining the object point and image point is always perpendicular to the mirror, find distance of 2nd image in II mirror from object.



Mirror Formula And Magnification, Velocity In Spherical Mirror, Cutting Of Mirrors, Combination Of Mirrors, Intensity Of Light

7. 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-

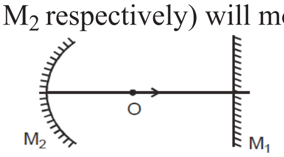
8. A car is fitted with a convex side-view mirror of focal length 20 cm. A second car 2.8 m behind the first car is overtaking the first car at a relative speed of 15m/s. The speed of the image of the second car as seen in the mirror of the first one is

9. A driver stops his car at a red light. The car is fitted with side view mirror of focal length 10 m. An ambulance is approaching the car at a constant speed of 16 ms^{-1}. The speed of image of the ambulance, as seen by the driver in the side view mirror, when it is at distance of 50 m from the mirror will be

10. In case of concave mirror, the minimum distance between a real object and its real image is-

11. An observer whose least distance of distinct vision is 'd', views his own face in a convex mirror of radius of curvature 'r'. Prove that magnification produced can not exceed $\frac{r}{d+\sqrt{d^2+r^2}}$

12. In the figure shown if the object 'O' moves towards the plane mirror, then the image I (which is formed after successive reflections from M_1 & M_2 respectively) will move:



13. A short linear object of length l lies along the axis of a concave mirror of focal length f at a distance u from the pole of the mirror. The size of the image is approximately equal to :

(A) $l\left(\frac{u-f}{f}\right)^{1/2}$

(B) $l\left(\frac{u-f}{f}\right)^{2}$

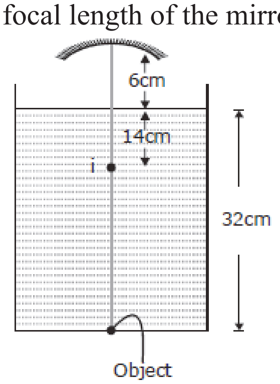
(C) $l\left(\frac{f}{u-f}\right)^{1/2}$

(D) $l\left(\frac{f}{u-f}\right)^{2}$

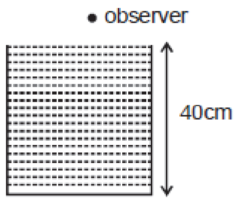
14. If a and b denote the distances of the object and image from the pole of a spherical mirror respectively the line y = 4x cuts the a – b graph at a point whose abscise a is 20 cm. The value of radius of curvature (in cm) of mirror is

Snell's Law, Apparent Depth And Normal Shift, Refraction Through A Glass Slab, Lateral Shift

15. A beaker contains water (μ=4/3) filled to a height of 32 cm. A concave mirror is fixed 6 cm above the surface of water as shown in figure. An object is placed at the bottom of the beaker and its image is formed 14 cm below the surface of water. The focal length of the mirror (in cm) is



16. An observer in air (n = 1) sees the bottom of a beaker filled with water (n = 4/3) upto a height of 40 cm. What will be the depth (in cm) felt by this observer.

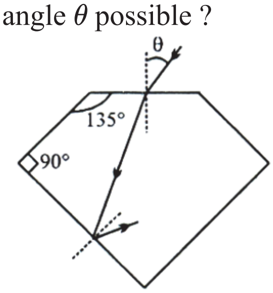


17. A light ray falling at an angle of 60° with the surface of a clean slab of ice of thickness 1.00 m is refracted into it at an angle of 15°. Calculate the time taken by the light rays to cross the slab. Speed of light in vacuum = 3×10^8 m/s.

Critical Angle And Total Internal Reflection (T.I.R.)

18. A small source of light is 4m below the surface of a liquid of refractive index 5/3. In order to cut off all the light coming out of liquid surface, minimum diameter of the disc placed on the surface of liquid is

19. A ray of light enters a diamond (n = 2) from air and is being internally reflected near the bottom as shown in the figure. Find maximum value of angle θ possible ?



20. A long solid cylindrical glass rod of refractive index 3/2 is immersed in a liquid of refractive index $3\sqrt{3}/4$. The end of the rod are perpendicular to the central axis of the rod. a light enters one end of the rod at the central axis as shown in the figure. Find the maximum value of angle θ for which internal reflection occurs inside the rod?

21. Light from a luminous point on the lower face of a 2 cm thick glass slab, strikes the upper face and the totally reflected rays outline a circle of radius 3.2 cm on the lower face. What is the refractive index of the glass.

Prism

22. A prism (n = 2) of apex angle 90° is placed in air (n = 1). What should be the angle of incidence (in degree) so that light ray strikes the second surface at an angle of incidence of 60°

23. R.I. of a prism is $\sqrt{\frac{7}{3}}$ and the angle of prism is 60°. The limiting angle of incidence (in degree) of a ray that will be transmitted through the prism is :

Question No. 24 & 25

Paragraph:

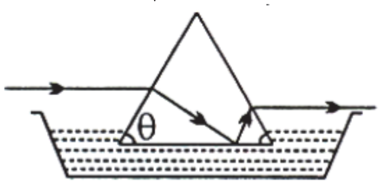
A person's far point is 2 m and his near point is 50 cm. Find the nature, focal length and power of the lenses, he must use to

24. see distant objects and

25. read a book clearly, The least distance of distinct vision is 25 cm.

26. Calculate the maximum angular magnification produced by a magnifying glass of 5 cm focal length. Distance of distinct vision = 25 cm.

27. An isosceles triangular glass prism stands with its base in water as shown. The angles that its two equal sides make with the base are θ each. An incident ray of light parallel to the water surface internally reflects at the glass-water interface and subsequently re-emerges into the air. Taking the refractive indices of glass and water to be 3/2 and 4/3 respectively, show that θ must be at least $\tan^{-1}\frac{2}{\sqrt{17}}$ or 25.9º.



Dispersion Of Light

28. A certain material has refractive indices 1.56, 1.60 and 1.68 for red, yellow and violet light respectively.
(a) Calculate the dispersive power.
(B) Find the angular dispersion produced by a thin prism of angle 6° made of this material.

29. A flint glass prism and a crown glass prism are to be combined in such a way that the deviation of the mean ray is zero. The refractive index of flint and crown glasses for the mean ray are 1.620 and 1.518 respectively. If the refracting angle of the flint prism is 6.0°, what would be the refracting angle of crown prism?

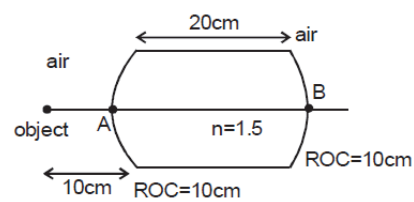
30. A plane glass slab is placed over various coloured letters. The letter which appears to be raised the least is :

Refraction From A Spherical Surface

31. A spherical surface of radius 30 cm separates two transparent media A and B with refractive indices 4/3 and 3/2 respectively. The medium A is on the convex side of the surface. Where should a point object be placed in medium A so that the paraxial rays becomes parallel after refraction at the surface?

32. An objects is placed 21 cm in front of a concave mirror of radius of curvature 10 cm. A glass slab of thickness 3 cm and μ = 1.5 is then placed close to the mirror in the space between the object and the mirror. The position of final image formed is

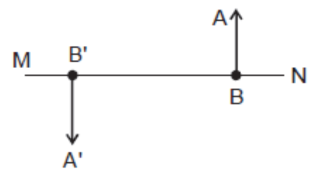
33. An object is placed 10 cm away from a glass piece (n = 1.5) of length 20 cm bound by spherical surfaces of radii of curvature 10 cm. Find the position of final image formed after twice refractions.



Lens Maker Formula And Magnification, Image Formation By Convex And Concave Lens, Combination Of Lens, Cutting Of Lens

34. A thin lens made of a material of refractive index μ_2 has a medium of refractive index μ_1 on one side and a medium of refractive index μ_3 on the other side. The lens is biconvex and the two radii of curvature has equal magnitude R. A beam of light travelling parallel to the principal axis is incident on the lens. Where will the image be formed if the beam is incident from (a) the medium μ_1 and (B) from the medium μ_3 ?

35. Given an optical axis MN & the positions of a real object A B and its image A' B', determine diagrammatically the position of the lens (its optical centre O) and its foci. Is it a converging or diverging lens? Is the image real or virtual?



36. Lenses are constructed by a material of refractive index 1.50. The magnitude of the radii of curvature are 20 cm and 30 cm. Find the focal lengths of the possible lenses with the above specifications.

37. A converging lens and a diverging mirror are placed at a separation of 15 cm. The focal length of the lens is 25 cm and that of the mirror is 40 cm. Where should a point source be placed between the lens and the mirror (in cm) so that the light, after getting reflected by the mirror and then getting transmitted by the lens, comes out parallel to the principal axis?

38. The aperture diameter of a plano-convex lens is 6 cm and the thickness at the centre is 3 mm. If the speed of light in the material of the lens is 2×10^8 m/s, the focal length of the lens is

39. The power of a lens having refractive index 1.25 is +3 diopters. When placed in a liquid its power is −2 diopters. The refractive index of the liquid is 6/x.Find x.

Power Of Lens And Mirror, Silverging Of Lens, Displacement Method

40. 2 identical thin converging lenses brought in contact so that their axes coincide are placed 12.5 cm from an object. What is the optical power of each lens, if the real image formed by the system of lenses is four times as large as the object?

41. A point source of light is kept at a distance of 15 cm from a converging lens, on its optical axis. The focal length of the lens is 10 cm and its diameter is 3 cm. A screen is placed on the other side of the lens, perpendicular to the axis of lens, at a distance 20 cm from it. Then find the area of the illuminated part of the screen ?

42. A thin plano-convex lens acts like a concave mirror of focal length 0.2 m when silvered from its plane surface. The refractive index of the material of the lens is 1.5. The radius of curvature of the convex surface of the lens will be

43. A plano-convex lens, when silvered on the plane side, behaves like a concave mirror of focal length 30 cm. When it is silvered on the convex side, it behaves like a concave mirror of focal length 10 cm. Find the refractive index of the material of the lens.

Chromatic Aberration And Achromatism, Optical Instrument + Eye + Luminous Intensity

44. An astronomical telescope has a magnifying power 10. The focal length of the eye piece is 20 cm. the focal length of the objective is -

45. A person can not see the objects clearly placed at a distance more than 40 cm. He is advised to use a lense of power

46. To remove myopia (short sightedness) a lens of power 0.66D is required. The distant point of the eye is approximately

47. 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.

Exercise 2 — JEE Advanced Level

Plane Mirror (Single Correct)

1. There are two plane mirror with reflecting surface facing each other. Both the mirrors are moving with speed v away from each other. A point object is placed between the mirrors. The velocity of the image formed due to n-th reflection will be

(A) nv **(B)** 2nv **(C)** 3nv **(D)** 4nv

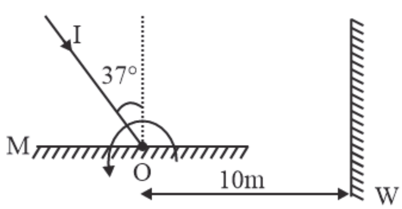
[C. 57.35%, I.C. 33.33%, U.A. 9.32%]

2. A person's eye is at a height of 1.5 m. He stands in-front of a 0.3m long plane mirror which is 0.8 m above the ground. The length of the image he sees of himself is:

(A) 1.5 m **(B)** 1.0 m
(C) 0.8 m **(D)** 0.6 m

[C. 55.03%, I.C. 36.03%, U.A. 8.94%]

3. A light ray I is incident on a plane mirror M. The mirror is rotated in the direction as shown in the figure by an arrow at frequency $9/\pi$ rev/sec. The light reflected the mirror is received on the wall W at a distance 10m from the axis of rotation. When the angle of incidence becomes 37° find the speed of the spot (a point) on the wall?



(A) 960 m/s **(B)** 840 m/s
(C) 1000 m/s **(D)** 900 m/s

[C. 44.30%, I.C. 46.13%, U.A. 9.57%]

4. A plane mirror of circular shape with radius r = 20 cm is fixed to the ceiling. A bulb is to be placed on the axis of the mirror. A circular area of radius R = 1 m on the floor is to be illuminated after reflection of light from the mirror. The height of the room is 3m. What is the maximum distance from the centre of the mirror and the bulb so that the required area is illuminated ?

(A) 75 cm
(B) 60 cm
(C) 65 cm
(D) 90 cm

[C. 40.46%, I.C. 51.49%, U.A. 8.05%]

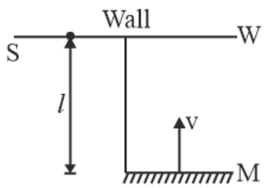
(Multiple Correct)

5. A man of height 170 cm wants to see his complete image in a plane mirror (while standing). His eyes are at a height of 160 cm from the ground.

(A) Minimum length of the mirror = 80 cm
(B) Minimum length of the mirror = 85 cm
(C) Bottom of the mirror should be at a height 80 cm or less
(D) Bottom of the mirror should be at a height 85 cm

[C. 59.14%, I.C. 28.73%, U.A. 12.13%]

6. A flat mirror M is arranged parallel to a wall W at a distance l from it. The light produced by a point source S kept on the wall is reflected by the mirror and produces a light spot on the wall. The mirror moves with velocity v towards the wall.



(A) The spot of light will move with the speed v on the wall
(B) The spot of light will not move on the wall
(C) As the mirror comes closer the spot of light will become larger and shift away from the wall with speed larger then v
(D) The size of the light on the wall remains the same

[C. 57.11%, I.C. 29.88%, U.A. 13.01%]

Mirror Formula And Magnification, Velocity In Spherical Mirror, Cutting Of Mirrors, Combination Of Mirrors, Intensity Of Light -(Single Correct)

7. A rod of length 30 cm lies along the principal axis ofa concave mirror of focal length 10 cm in such a way that its end closer to the pole is 20 cm away from the mirror. The length of the image is

(A) 10 cm **(B)** 15 cm **(C)** 2.5 cm **(D)** 7.5 cm

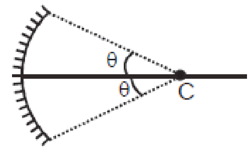
[C. 57.32%, I.C. 27.55%, U.A. 15.13%]

8. A candle flame of 3 cm is placed at 300 cm from a wall. A concave mirror is kept at distance x from the wall in such a way that image of the flame on the wall is 9 cm. Then x is :

(A) 339 cm **(B)** 900 cm **(C)** 450 cm **(D)** 423 cm

[C. 50.56%, I.C. 43.69%, U.A. 5.75%]

9. The circular boundary of the concave mirror subtends a cone of half angle θ at its centre of curvature. The minimum value of θ for which ray incident on this mirror parallel to the principal axis suffers reflection more than one is



(A) 30° **(B)** 45° **(C)** 60° **(D)** 75°

[C. 49.44%, I.C. 35.18%, U.A. 15.38%]

10. A convex mirror has a focal length f. An object of height h is placed in front of it. If an erect image of height h/n is formed. The distance of the object from the mirror is :

(A) nf **(B)** f/n **(C)** (n+1)f **(D)** (n-1)f

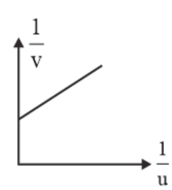
[C. 44.66%, I.C. 45.50%, U.A. 9.84%]

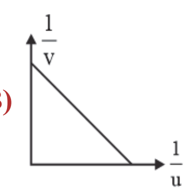
11. The distance of an object from a spherical mirror is equal to focal length of the mirror. Then the image :

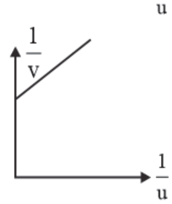
(A) must be at infinity
(B) may be at infinity
(C) may be at the focus
(D) must be at focus

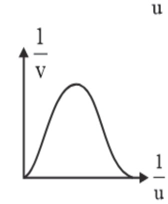
[C. 35.34%, I.C. 49.48%, U.A. 15.18%]

12. An object is placed at a distance u from a concave mirror and its real image is received on a screen placed at a distance of v from the mirror. If f is the focal length of the mirror, then the graph between 1/v versus 1/u is

(A)


(B)


(C)


(D)


[C. 31.36%, I.C. 51.78%, U.A. 16.86%]

(Multiple Correct)

13. The image (of a real object) formed by a concave mirror is twice the size of the object. The focal length of the mirror is 20 cm. The distance of the object from the mirror is (are)

(A) 10 cm **(B)** 30cm

(C) 25 cm **(D)** 15 cm

[C. 69.05%, I.C. 22.62%, U.A. 8.33%]

14. 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

(A) 6 cm/s towards the mirror

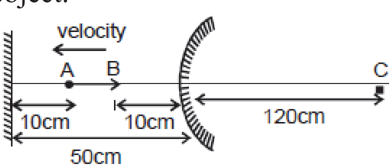
(B) 6 cm/s away from the mirror

(C) 9 cm/s away from the mirror

(D) 9 cm/s towards the mirror

[C. 68.05%, I.C. 21.89%, U.A. 10.06%]

15. In the figure shown consider the first reflection at the plane mirror and second at the convex mirror. AB is object.



(A) the second image is real , inverted of 1/5 th magnification w.r.t AB

(B) the second image is virtual and erect with magnification1/5 w.r.t AB

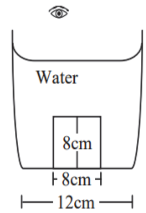
(C) the second image moves towards the convex mirror

(D) the second image moves away from the convex mirror

[C. 55.29%, I.C. 15.77%, U.A. 28.94%]

Snell'S Law, Apparent Depth And Normal Shift, Refraction Through A Glass Slab, Lateral Shift-(Single Correct)

16. A cylindrical vessel of diameter 12 cm contains 800π cm^3 of water. A cylindrical glass piece of diameter 8.0 cm and height 8.0 cm is placed in the vessel. If the bottom of the vessel under the glass piece is seen by the paraxial rays (see figure), locate its image from the bottom. The index of refraction of glass is 1.50 and that of water is 1.33.



(A) 2.1 cm **(B)** 7.1 cm

(C) 9.1 cm **(D)** 11.1 cm

[C. 18.64%, I.C. 13.56%, U.A. 67.80%]

17. A bird in air looks at a fish vertically below it and inside water in a tank. If the distances of the fish as estimated by the bird is S_1 and that of bird as estimated by the fish is S_2 then the refractive index of liquid μ is

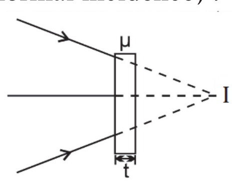
(A) $\frac{S_1}{S_2}$ **(B)** $\frac{S_1+S_2}{S_1-S_2}$

(C) $\frac{S_2}{S_1}$ **(D)** $\frac{S_1+S_2}{S_1}$

[C. 17.02%, I.C. 12.43%, U.A. 70.55%]

(Multiple Correct)

18. A beam of light is converging towards a point L. A plane parallel plate of glass of thickness t, refractive index μ is introduced in the path of the beam. The convergent point is shifted by (assume near-normal incidence) :



(A) $t\left(1-\frac{1}{\mu}\right)$ **(B)** $t\left(1+\frac{1}{\mu}\right)$

(C) nearer **(D)** away

[C. 61.32%, I.C. 27.79%, U.A. 10.89%]

19. A concave mirror is placed on a horizontal table, with its axis directed vertically upwards. Let O be the pole of the mirror and C its centre of curvature. A point object is placed at C. Its has a real image, also located at C (a condition called auto-collimation). If the mirror is now filled with water, then choose the wrong statements about image :

(A) real, and will remain at C

(B) real, and located at a point between C and ∞

(C) virtual, and located at a point between C and O

(D) real, and located at a point between C and O

[C. 53.11%, I.C. 21.76%, U.A. 25.13%]

Critical Angle And Total Internal Reflection (T.I.R.) (Single Correct)

20. The refractive index of water is 4/3 and that of glass is 5/3. Then the critical angle for a ray of light entering water from glass will be:

(A) $\sin^{-1}(4/5)$ **(B)** $\sin^{-1}(5/4)$

(C) $\sin^{-1}(20/9)$ **(D)** $\sin^{-1}(9/20)$

[C. 39.81%, I.C. 34.16%, U.A. 26.03%]

21. 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

(A) It is impossible to predict the behavior of the light ray on the basis of the information supplied.

(B) The sine of the angle of refraction of the emergent ray will less than 0.8.

(C) The ray will be internally reflected

(D) The sine of the angle of refraction of the emergent ray will be greater than 0.8.

[C. 36.69%, I.C. 37.27%, U.A. 26.04%]

22. Light passes from air into flint glass with index of refraction n. What angle of incidence must the light have so that the component of its velocity perpendicular to the interface remains same in both medium?

(A) $\tan^{-1}\left(\frac{1}{n}\right)$ **(B)** $\sin^{-1}\left(\frac{1}{n}\right)$

(C) $\cos^{-1}\left(\frac{1}{n}\right)$ **(D)** $\tan^{-1} n$

[C. 18.42%, I.C. 59.21%, U.A. 22.37%]

23. Which of the following statements is/are correct about the refraction of light from a plane surface when light ray is incident in denser medium. [C is critical angle]

(A) The maximum angle of deviation during refraction is $\frac{\pi}{2} - C$, it will be at angle of incidence is greater than C.

(B) The maximum angle of deviation for all angle of incidences is $\pi - 2C$, when angle of incidence is slightly less than C.

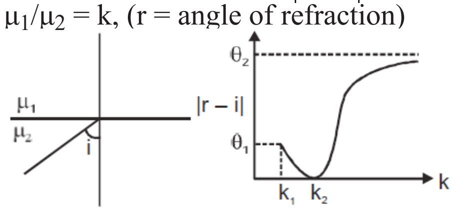
(C) If angle of incidence is less than C then deviation increases if angle of incidence is also decreased.

(D) If angle of incidence is greater than C then angle of deviation decreases if angle of incidence is increased.

[C. 16.00%, I.C. 60.21%, U.A. 23.79%]

Critical Angle And Total Internal Reflection (T.I.R.) (Multiple Correct)

24. The figure shows ray incident at an angle $i = \pi/3$. If the plot drawn shown the variation of $|r - i|$ versus $\mu_1/\mu_2 = k$, (r = angle of refraction)



(A) the value of k_1 is $\frac{2}{\sqrt{3}}$

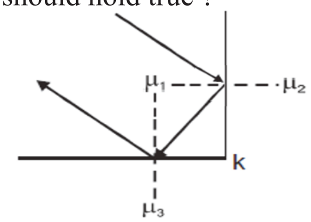
(B) the value of $\theta_1 = \pi/6$

(C) the value of $\theta_2 = \pi/3$

(D) the value of k_2 is 1

[C. 75.48%, I.C. 14.42%, U.A. 10.10%]

25. In the diagram shown, a ray of light is incident on the interface between 1 and 2 at angle slightly greater than critical angle. The light surffers total internal reflection at this interface. After that the light ray falls at the interface of 1 and 3, and again it suffers total internal reflection. Which of the following relations should hold true ?



(A) $\mu_1 > \mu_2 < \mu_3$ **(B)** $\mu_1^2 - \mu_2^2 > \mu_3^2$
(C) $\mu_1^2 - \mu_3^2 > \mu_2^2$ **(D)** $\mu_1^2 + \mu_2^2 > \mu_3^2$

[C. 63.71%, I.C. 26.16%, U.A. 10.13%]

Prism (Single Correct)

26. A ray of monochromatic light is incident on one refracting face of a prism of angle 75˚. It passes through the prism and is incident on the other face at the critical angle. If the refractive index of the material of the prism is $\sqrt{2}$, the angle of incidence on the first face of the prism is

(A) 30^0 **(B)** 45^0 **(C)** 60^0 **(D)** 0^0

[C. 54.23%, I.C. 31.12%, U.A. 14.65%]

27. A prism is made up of material of refractive index $\sqrt{3}$. The angle of prism is A. If the angle of minimum deviation is equal to the angle of the prism, then the value of A is :

(A) 30˚ **(B)** 45˚ **(C)** 60˚ **(D)** 75˚

[C. 53.62%, I.C. 33.71%, U.A. 12.67%]

28. A prism has a refractive index $\sqrt{\frac{3}{2}}$ and refracting angle 90°. The minimum deviation produced by prism is 15n°. Find n.

(A) 40° **(B)** 45° **(C)** 30° **(D)** 49°

[C. 48.90%, I.C. 32.53%, U.A. 18.57%]

Prism (Multiple Correct)

29. For the refraction of light through a prism

(A) For every angle of deviation there are two angles of incidence.
(B) The light traveling inside an equilateral prism is necessarily parallel to the base when prism is set for minimum deviation.
(C) There are two angles of incidence for maximum deviation.
(D) Angle of minimum deviation will increase if refractive index of prism is increased keeping the outside medium unchanged if $\mu_p > \mu_s$.

[C. 69.37%, I.C. 17.12%, U.A. 13.51%]

30. For refraction through a small angled prism, the angle of deviation :

(A) increases with the increase in R.I. of prism.
(B) will decrease with the increase in R.I. of prism.
(C) is directly proportional to the angle of prism.
(D) will be 2D for a ray of R.I. = 2.4 if it is D for a ray of R.I = 1.2

[C. 65.55%, I.C. 21.01%, U.A. 13.44%]

31. A ray of light is incident normally on one face of 30° − 60° − 90° prism of refractive index 5/3 immersed in water of refractive index 4/3 as shown in figure.

(A) The exit angle θ_2 of the ray is $\sin^{-1}(5/8)$
(B) The exit angle θ_2 of the ray is $\sin^{-1}(5/4\sqrt{3})$
(C) Total internal reflection at point P ceases if the refractive index of water is increased to $5/2\sqrt{3}$ by dissolving some substance.
(D) Total internal reflection at point P ceases if the refractive index of water is increased to 5/6 by dissolving some substance.

[C. 61.39%, I.C. 19.62%, U.A. 18.99%]

Dispersion Of Light (Single Correct)

32. A thin prism P_1 with angle 4° made of glass of refractive index 1.54 is combined with another thin prism P_2 made of glass of refractive index 1.72 to produce dispersion without deviation. The angle of the prism P_2 is :

(A) 3°

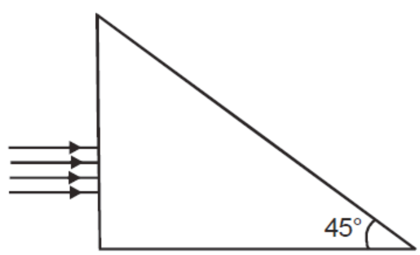
(B) 2.6°

(C) 4°

(D) 5.33°

[C. 42.69%, I.C. 41.27%, U.A. 16.04%]

33. A beam of light consisting of red, green and blue colours is incident on a right angled prism. The refractive index of the material of the prism for the above red, green and blue colours wavelengths are 1.39, 1.44 and 1.47 respectively. The prism will:



(A) separate part of the red colors from the green and blue colors.

(B) separate part of the blue colors from red and green colors.

(C) separate all the three colors from the other two colors.

(D) not separate even partially any color from the other two colors.

[C. 41.07%, I.C. 34.87%, U.A. 24.06%]

34. Light of wavelength 4000 Å is incident at small angle on a prism of apex angle 4° (i.e A = 4°). The prism has $n_v = 1.5$ & $n_r = 1.48$. The angle of dispersion produced by the prism in this light is :

(A) 0.2°

(B) 0.08°

(C) 0.192°

(D) Dispersion not possible

[C. 2.33%, I.C. 30.00%, U.A. 67.67%]

Dispersion Of Light (Multiple Correct)

35. By properly combining two prisms made of different materials, it is possible to

(A) have dispersion without average deviation

(B) have deviation without dispersion

(C) have both dispersion and average deviation

(D) have neither dispersion nor average deviation

[C. 67.23%, I.C. 15.96%, U.A. 16.81%]

Refraction From A Spherical Surface (Single Correct)

36. A spherical surface of radius of curvature 10 cm separates two media X and Y of refractive Indices 3/2 and 4/3 respectively. Centre of the spherical surface lies in denser medium. An object is placed in medium X. For image to be real, the object distance must be

(A) greater than 90 cm

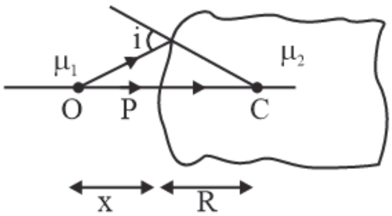
(B) less than 90 cm

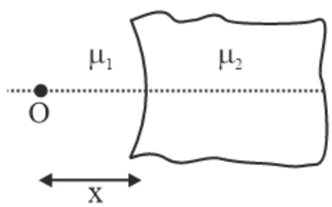
(C) greater than 80 cm

(D) less than 80 cm

[C. 38.90%, I.C. 48.72%, U.A. 12.38%]

37. A curved surface of radius R separates two medium of refractive indices μ_1 and μ_2 as shown in figures A and B





Choose the correct statement(s) related to the real image formed by the object O placed at a distance x, as shown in figure A

(A) Real image is always formed irrespective of the position of object if $\mu_2 > \mu_1$

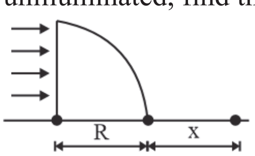
(B) Real image is formed only when x > R

(C) Real image is formed due to the convex nature of the interface irrespective of μ_1 and μ_2

(D) None of these

[C. 32.45%, I.C. 51.98%, U.A. 15.57%]

38. A uniform, horizontal beam of light is incident upon a quarter cylinder of radius R = 5 cm, and has a refractive index $\frac{2}{\sqrt{3}}$. A patch on the table for a distance 'x' from the cylinder is unilluminated, find the value of 'x' ?

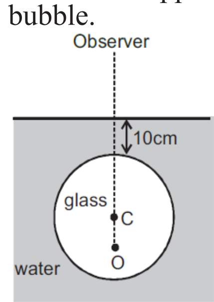


(A) 7. 2 cm **(B)** 12. 5 cm

(C) 5 cm **(D)** 10 cm

[C. 28.12%, I.C. 59.64%, U.A. 12.24%]

39. There is a small air bubble inside a glass sphere (m = 1.5) of radius 5 cm. The bubble is 7.5 cm below the surface of the glass. The sphere is placed inside water (m = $\frac{4}{3}$) such that the top surface of glass is 10 cm below the surface of water. The bubble is viewed normally from air. Find the apparent depth on the bubble.



(A) 15 cm below the surface of water

(B) 10.5 cm below the surface of water

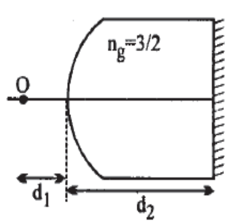
(C) 16.66 cm below the surface of water

(D) 13.5 cm below the surface of water

[C. 26.23%, I.C. 61.78%, U.A. 11.99%]

Refraction From A Spherical Surface (Multiple Correct)

40. In the figure shown a point object O is placed in air on the principal axis. The radius of curvature of the spherical is 60 cm. I_f is the final image formed after all the refractions and reflections.



(A) If d_1 = 120 cm, then the `$I_f$' is formed on `O' for any value of d_2.

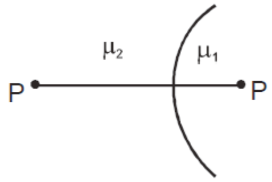
(B) If d_1 = 240 cm, then the `$I_f$' is formed on `O' only if d_2 = 360 cm.

(C) If d_1 = 240 cm, then the `$I_f$' is formed on `O' for all value of d_2.

(D) If d_1 = 240 cm, then the `$I_f$' cannot be formed on `O'.

[C. 60.69%, I.C. 24.83%, U.A. 14.48%]

41. Two refracting media are separated by a spherical interface as shown in the figure. PP′ is the principal axis, μ_1,and μ_2 are the refractive Indices of medium of incidence and medium of refraction respectively. Then:



(A) if $\mu_2 > \mu_1$, then there cannot be a real image of real object.
(B) if $\mu_2 > \mu_1$, then there cannot be a real image of virtual object.
(C) if $\mu_1 > \mu_2$, then there cannot be a virtual image of virtual object.
(D) if $\mu_1 > \mu_2$, then there cannot be a real image of real object.

[C. 56.30%, I.C. 30.25%, U.A. 13.45%]

Lens Maker Formula And Magnification, Image Formation By Convex And Concave Lens, Combination Of Lens, Cutting Of Lens (Single Correct)

42. An object is placed at a distance of 15 cm from a convex lens of focal length 10 cm. On the other side of the lens, a convex mirror is placed at its focus such that the image formed by the combination coincides with the object itself. The focal length of the convex mirror is

(A) 20 cm **(B)** 10 cm **(C)** 15 cm **(D)** 30 cm

[C. 46.36%, I.C. 46.36%, U.A. 7.28%]

43. When a lens of power P (in air) made of material of refractive index μ is immersed in liquid of refractive index μ_0. Then the power of lens is:

(A) $\left(\frac{\mu-1}{\mu-\mu_0}\right)$p **(B)** $\left(\frac{\mu-\mu_0}{\mu-1}\right)$P

(C) $\left(\frac{\mu-\mu_0}{\mu-1}\right)\frac{P}{\mu_0}$ **(D)** $\left(\frac{\mu-\mu_0}{\mu-1}\right)\frac{\mu_0}{P}$

[C. 40.93%, I.C. 45.88%, U.A. 13.19%]

44. An object is placed at a distance of 10 cm from a coaxial combination of two lenses A and B in contact. The combination forms a real image three times the size of the object. If lens B is concave with a focal length of 30 cm, what is the nature and focal length of lens A ?

(A) Convex, 12 cm **(B)** Concave, 12 cm
(C) Convex, 6 cm **(D)** Convex, 18 cm

[C. 39.86%, I.C. 46.71%, U.A. 13.43%]

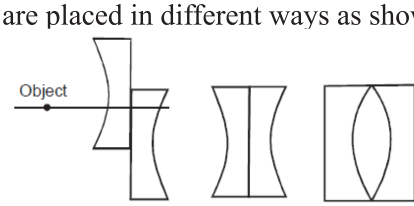
Lens Maker Formula And Magnification, Image Formation By Convex And Concave Lens, Combination Of Lens, Cutting Of Lens (Multiple Correct)

45. A convex lens forms an image of an object on screen. The height of the image is 9 cm. The lens is now displaced until an image is again obtained on the screen. The height of this image is 4 cm. The distance between the object and the screen is 90 cm.

(A) The distance between the two positions of the lens is 30 cm.
(B) The distance of the object from the lens is its first position is 36cm.
(C) The height of the object is 6cm.
(D) The focal length of the lens is 21.6 cm.

[C. 81.63%, I.C. 9.18%, U.A. 9.19%]

46. If a symmetrical biconcave thin lens is cut into two identical halves. They are placed in different ways as shown

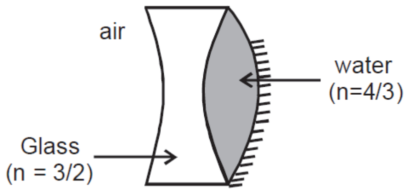


Fig(i) Fig(ii) Fig(iii)

(A) three images will be formed in case (i)
(B) two images will be formed in the case (i)
(C) the ratio of focal lengths in (ii) & (iii) is 1
(D) the ratio of focal lengths (in) (ii) & (iii) is 2

[C. 68.54%, I.C. 20.22%, U.A. 11.24%]

47. The radius of curvature of the left and right surface of the concave lens are 10 cm and 15 cm respectively. The radius of curvature of the mirror is 15 cm



(A) equivalent focal length of the combination is -18 cm
(B) equivalent focal length of the combination is +36 cm
(C) the system behaves like a concave mirror
(D) the system behaves like a convex mirror

[C. 62.36%, I.C. 31.18%, U.A. 6.46%]

Power Of Lens And Mirror, Silverging Of Lens, Displacement Method (Single Correct)

48. A luminous object and a screen are at a fixed distance D apart. A converging lens of focal length f is placed between the object and screen. A real image of the object in formed on the screen for two lens positions if they are separated by a distance d equal to

(A) $\sqrt{D(D+4f)}$ **(B)** $\sqrt{D(D-4f)}$
(C) $\sqrt{2D(D-4f)}$ **(D)** $\sqrt{D^2+4f}$

[C. 53.30%, I.C. 32.55%, U.A. 14.15%]

49. In a compound microscope, the intermediate image is -

(A) virtual, errect and magnified
(B) real, errect and magnified
(C) real, inverted and magnified
(D) virtual, errect and reduced

[C. 49.75%, I.C. 35.47%, U.A. 14.78%]

50. A telescope has an objective of focal length 50 cm and eyepiece of focal length 5 cm. The least distance of distinct vision is 25 cm. The telescope is focused for distinct vision on a scale 200 cm away from the objective. Calculate the magnification produced.

(A) -2 **(B)** 3 **(C)** 2 **(D)** -4

[C. 38.36%, I.C. 53.88%, U.A. 7.76%]

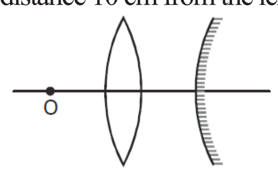
Power Of Lens And Mirror, Silverging Of Lens, Displacement Method (Multiple Correct)

51. In displacement method, the distance between object and screen is 96cm. The ratio of length of two images formed by a converging lens placed between them is 4.

(A) Ratio of the length of object to the length of shorter image is 2.
(B) Distance between the two positions of the lens is 32 cm.
(C) Focal length of the lens is $\frac{64}{3}$ cm.
(D) When the shorter image is formed on screen, distance of the lens from the screen is 32 cm.

[C. 84.95%, I.C. 5.37%, U.A. 9.68%]

52. A biconvex lens $f_1 = 20$ cm, is placed 5 cm in front of a convex mirror, $f_2 = 15$ cm. An object of length 2 cm is placed at a distance 10 cm from the lens.

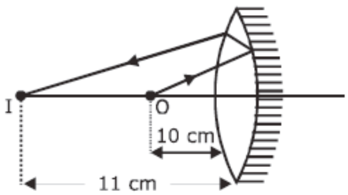


Choose the correct statement(s) about the location and nature of the final image after the leftward traveling rays once again pass through the lens.

(A) 51.1 cm right of lens, real, erect and magnified
(B) overall magnification = $\frac{8}{3}$
(C) 62.7 cm from lens, real, inverted and magnified
(D) overall magnification = 3

[C. 75.32%, I.C. 20.78%, U.A. 3.90%]

53. A pin is placed 10 cm in front of a convex lens of focal length 20 cm, made of a material having refractive index 1.5. The surface of the lens farther away from the pin is silvered and has a radius of curvature 22 cm. Choose the wrong statement(s) about the position and nature of the final image.



(A) image will be 2.1 cm behind of silvered lens and real.

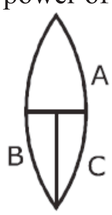
(B) image will be 11 cm infront of silvered lens and real.

(C) image will be 1.7 cm infront of silvered lens and real.

(D) image will be 1.4 cm behind of silvered lens and real.

[C. 68.42%, I.C. 25.00%, U.A. 6.58%]

54. A thin, symmetric double convex lens of power P is cut into three parts A, B, and C as shown in Figure. The power of



(A) A is P

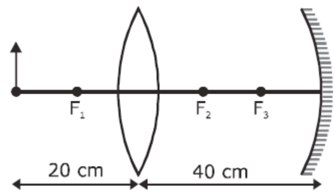
(B) A is 2P

(C) B is P/2

(D) C is P/4

[C. 63.08%, I.C. 29.23%, U.A. 7.69%]

55. An equiconvex lens, $f_1 = 10$ cm, is placed 40 cm in front of a concave mirror, $f_2 = 7.50$ cm, as shown in figure. An object 2 cm high is placed 20 cm to the left of the lens. Choose the correct statement(s) about the position of the final image formed when leftward traveling rays once again pass through the lens.



(A) Final image real inverted and lies 16.5 cm to left of lens.

(B) Final image real inverted and lies 15.6 cm to left of lens.

(C) overall magnification = –0.333

(D) overall magnification = –0.467

[C. 62.50%, I.C. 33.33%, U.A. 4.17%]

Chromatic Aberration And Achromatism, Optical Instrument + Eye + Luminous Intensity -(Single Correct)

56. 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.

(A) 10° **(B)** 24° **(C)** 50° **(D)** 1/6°

[C. 56.35%, I.C. 34.92%, U.A. 8.73%]

57. When length of a microscope tube increases its magnifying power -

(A) Decreases

(B) Increase

(C) Does not change

(D) May increase or decrease

[C. 44.55%, I.C. 45.87%, U.A. 9.58%]

58. It is desired to make an achromatic combination of two lenses (L_1 & L_2) made of materials having dispersive powers ω_1 and ω_2 ($<\omega_1$). If the combination of lenses is converging then -

(A) L_1 is converging

(B) L_2 is converging

(C) Power of L_1 is greater than the power of L_2

(D) L_1 is diverging

[C. 39.78%, I.C. 50.83%, U.A. 9.39%]

Chromatic Aberration And Achromatism, Optical Instrument + Eye + Luminous Intensity-(Single Correct)

59. In an astronomical telescope, the distance between the objective and the eyepiece is 36 cm and the final image is formed at infinity with a magnification 5. The focal length f_0 of the objective and the focal length f_e of the eyepiece are

(A) $f_0 = 45$ cm and $f_e = -9$ cm

(B) $f_0 = 50$ cm and $f_e = 10$ cm

(C) $f_0 = 7.2$ cm and $f_e = 5$ cm

(D) $f_0 = 30$ cm and $f_e = 6$ cm

[C. 45.16%, I.C. 46.78%, U.A. 8.06%]

Chromatic Aberration And Achromatism, Optical Instrument + Eye + Luminous Intensity--(Multiple Correct)

60. A planet is observed by an astronomical refracting telescope having an objective of focal length 16 m and an eyepiece of focal length 2 cm. Then,

(A) the distance between the objective and the eyepiece is 16.02 m.

(B) the angular magnification of the planet is -800

(C) the image of the planet is inverted

(D) the objective is larger than the eyepiece

[C. 91.67%, I.C. 1.67%, U.A. 6.66%]

(Multiple Correct)

61. Which of the following statements is/are correct-

(A) The inability of a lens to bring the light of different colours to focus at a single point is called chromatic aberration.

(B) The difference between focal lengths of the lens for red and violet light i.e. $f_r - f_v$ gives the measure of axial (or longitudinal) chromatic aberration. Mathematically : $f_r - f_v = \omega \times f$

(C) The chromatic aberration in a lens is because of the fact that it has different focal lengths for light of different colours.

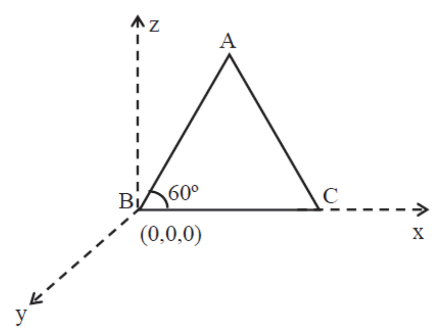
(D) Spectrometer is an optical instrument to obtain and study the pure spectrum.

[C. 31.67%, I.C. 36.78%, U.A. 31.55%]

Question No. 62-64

Paragraph:

An equilateral prism ABC is placed in air with its base side BC lying horizontally along x-axis as shown in figure. A ray given by $\sqrt{3}z + x = 10$ is incident at a point P on face AB of prism.



62. Find the value of μ for which the ray grazes the face AC -

(A) $\frac{3}{2}$ **(B)** $\frac{4}{3}$

(C) $\frac{2}{\sqrt{3}}$ **(D)** $\frac{\sqrt{5}}{2}$

[C. 42.57%, I.C. 31.83%, U.A. 25.60%]

63. Find direction of the finally refracted ray if $\mu = \frac{3}{2}$

(A) Parallel to x axis **(B)** Parallel to z axis

(C) Parallel to y axis **(D)** Parallel to face AB

[C. 41.82%, I.C. 34.23%, U.A. 23.95%]

64. Find the equation of ray coming out of prism if bottom BC is silvered ($\mu = \frac{3}{2}$) -

(A) $z + \sqrt{3}x = 10$ **(B)** $\sqrt{3}z + x = 10$

(C) $z + \sqrt{3}x = 20$ **(D)** $x + z = 10\sqrt{3}$

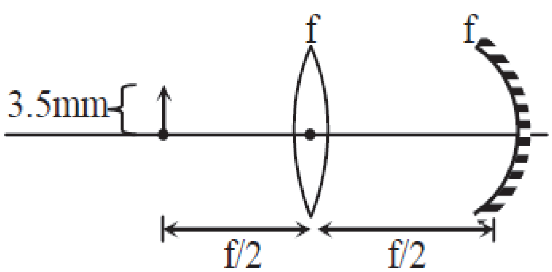
[C. 39.91%, I.C. 28.67%, U.A. 31.42%]

Question No. 65-67

Paragraph:

In the figure one converging lens and a concave mirror of focal length f each are arranged coaxially at a separation of f/2. An object of height 3.5 mm is placed at a distance f/2 from lens away from mirror. Consider refraction with lens, reflection from mirror and then refraction from lens again and corresponding images as I_1, I_2 and I_3 respectively.

Answer the following questions.



65. Which of the following is correct regarding nature of images -

(A) I_1 : Real, I_2 : Real, I_3 : Real

(B) I_1 : Virtual, I_2 : Real, I_3 : Real

(C) I_1 : Virtual , I_2 : Virtual, I_3 : Real

(D) None of the above

[C. 41.43%, I.C. 24.12%, U.A. 34.45%]

66. Net magnification in three consecutive optical events is -

(A) $-\frac{8}{7}$

(B) $+\frac{2}{7}$

(C) $+\frac{8}{7}$

(D) None

[C. 40.00%, I.C. 23.54%, U.A. 36.46%]

67. Find the distance of tip of final image from optical center of lens (if f = 7 cm) is -

(A) 5 cm

(B) $\sqrt{29}$ cm

(C) $\sqrt{2516}$ cm

(D) 12 cm

[C. 39.65%, I.C. 29.35%, U.A. 31.00%]

(Column Match)

68. Column I indicate the nature of image formed column II indicate the location of the object, then match column I with column II:

Column-I (Nature image)		Column-II (Position of object)	
(A)	Real	(P)	object is between pole & focus of a convex mirror
(B)	Virtual	(Q)	object is between pole & focus of a concave mirror
(C)	Magnified	(R)	object is between pole & centre of curvature of a convex mirror
(D)	Erect	(S)	object is between pole & centre of curvature of a

(A) A–P,S ; B–R,Q; C–P,Q,R,S; D–P,Q

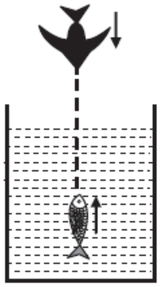
(B) A–R,Q ; B–P,R; C–P,Q,R,S; D–P,Q

(C) A–P,S ; B–R,Q; C–R,S; D–P,Q

(D) A–P,S ; B–R,Q; C–P,Q; D–P,Q,R,S

[C. 32.19%, I.C. 27.31%, U.A. 40.50%]

69. A bird in air is diving vertically over a tank with speed 6cm/sec. Base of tank is silvered. A fish in the tank is rising upward along the same line with 4cm/sec.



Column-I		Column-II	
(A)	Speed of image of fish as seen by the bird directly	(P)	12
(B)	Speed of image of fish after reflection from mirror as seen by bird	(Q)	4
(C)	Speed of image of bird relative to the fish looking upwards	(R)	9
(D)	Speed of image of bird relative to the fish looking downwards in the mirror	(S)	3

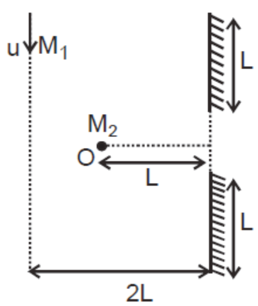
(A) A – R ; B – S ; C – Q ; D – P
(B) A – R ; B – P ; C – S ; D – Q
(C) A – S ; B – R ; C – P ; D – Q
(D) A – R ; B – S ; C – P ; D – Q

[C. 29.73%, I.C. 31.54%, U.A. 38.73%]

Exercise 3 — Numerical Type

1. The focal length of the objective of an astronomical telescope is 75 cm and that of the eye-piece is 5 cm. If the final image is formed at the least distance of distinct vision from the eye, calculate the magnifying power of the telescope.

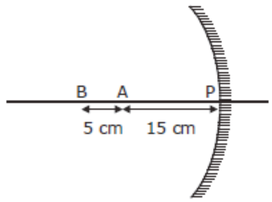
2. Two plane mirrors of length L are separated by distance L and a man M_2 is standing at distance L from the connecting line of mirrors as shown in figure. A man M_1 is walking in a straight line at distance 2 L parallel to mirrors at speed u=3 unit per sec, then man M_2 at O will be able to see image of M_1 for total time .....(take L= 6 units)



3. A transparent cube of 15 cm edge contains a small air bubble . Its apparent depth when viewed through one face is 6 cm and when viewed through the opposite face is 4 cm. Then the refractive index of the material of the cube is

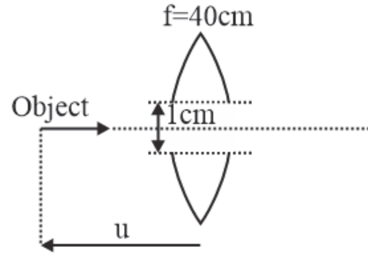
4. A person is in a room whose ceiling and two adjacent walls are mirrors. How many images are formed ?

5. A rod AB of length 5 cm is placed in front of a concave mirror of focal length 10 cm as shown in figure. The length of the image of AB formed by the mirror (in cm) is

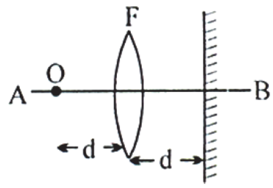


6. A concave mirror has the form of a hemisphere with a radius of R = 60 cm. A thin layer of an unknown transparent liquid is poured into the mirror. The mirror-liquid system forms one real image and another real image is formed by mirror alone, with the source in a certain position. One of them coincides with the source and the other is at a distance of $l = 30$ cm from source. Find the possible value(s) refractive index μ of the liquid.

7. In the figure shown, find the relative speed of approach/separation of the two final images formed after the light rays pass through the lens, at the moment when u = 30 cm. The speed object = 4 cm/s. The two lens halves are placed symmetrically w.r.t. the moving object in cm/s



8. In the figure shown 'O' is point object. AB is principal axis of the converging lens of focal length F. Find the distance (in units) of the final image from the lens.....(take F= 5 unit and d=3 unit)



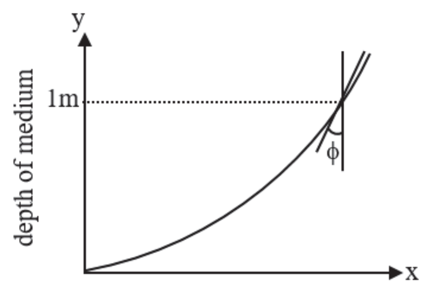
9. A ray of light from a denser medium strike a rarer medium. The angle of reflection is r and that of refraction is r'. The reflected and refracted rays make an angle of 90º with each other. The critical angle will be.......(in degree) ,(take $r = 45^\circ$)

10. The apparent depth of water in cylindrical water tank of diameter 2R cm (where R= 10 cm is reducing at the rate of x=2 cm min^{-1} when water is being drained out at a constant rate. The amount of water drained in cc per minute is (n_1 = refractive index of air $= 1$, n_2 = refractive index of water $= 1.33$)

11. A thief is running away in a car with velocity of 20 m/s. A police jeep is following him, which is sighted by thief in his rear view mirror which is a convex mirror of focal length 10 m. He observes that the image of jeep is moving towards him with a velocity of 1cm/s. If the magnification of the mirror for the jeep at that time is 1/10 , then rate at which magnification is changing in $-x \times 10^{-3}$, find x
Assume that police jeep is on axis of the mirror.

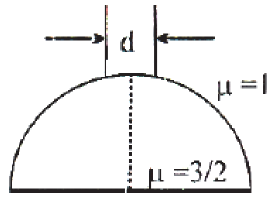
12. A surveyor on one bank of canal observed the image of the 4 inch and 17 ft marks on a vertical staff, which is partially immersed in the water and held against the bank directly opposite to him, coincides. If the 17 ft mark and the surveyor's eye are both 6ft above the water level, estimate the width of the canal (in feet) , assuming that the refractive index of the water is 4/3.

13. A ray of light travelling in air is incident at grazing angle (incidence angle = 90º) on a medium whose refractive index depends on the depth of the medium. The trajectory of the light in the medium is a parabola, $y = 2x^2$. Find the refractive index of the medium at a depth of 1 m in the medium.



14. A equilateral prism provides the least deflection angle 46° in air. the refracting index of an unknown liquid in which same prism gives least deflection angle of 30° is

15. A beam of diameter 'd' is incident on a glass hemisphere as shown. If the radius of curvature of the hemisphere is very large in comparison to d, then the diameter of the beam at the base of the hemisphere will be (take d=3)



16. A parallel beam of light falls normally on the first face of a prism of small angle. At the second face it is partly transmitted and partly reflected, the reflected beam striking at the first face again, and emerging from it in a direction making an angle 6º30' with the reversed direction of the incident beam. The refracted beam is found to have undergone a deviation of 1º15' from the original direction. Find the refractive index of the glass and the angle of the prism.

Question No. 17 & 18

Paragraph:

A detective uses a converging lens of focal length 12 cm to examine the fine details of some cloth fibers found at the scene of a crime.

17. What is the maximum magnification given by the lens?

18. What is the magnification for relaxed eye viewing

Exercise 4 (Level-A) JEE Main (Previous Year Questions)

1. The focal length f is related to the radius of curvature r of the spherical convex mirror by -

(A) $f = r$ **(B)** $f = -\frac{1}{2}r$

(C) $f = +\frac{1}{2}r$ **(D)** $f = -r$

[C. 66.50%, I.C. 17.63%, U.A. 15.87%] (JEE Main 2021)

2. Consider a light ray travelling in air is incident into a medium of refractive index $\sqrt{2n}$. The incident angle is twice that of refracting angle. Then, the angle of incidence will be:

(A) $\sin^{-1}\left(\sqrt{n}\right)$ **(B)** $\cos^{-1}\left(\sqrt{\frac{n}{2}}\right)$

(C) $\sin^{-1}\left(\sqrt{2n}\right)$ **(D)** $2\cos^{-1}\left(\sqrt{\frac{n}{2}}\right)$

[C. 32.76%, I.C. 53.45%, U.A. 13.79%] (JEE Main 2022)

3. 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 -

(A) $180^\circ - 2A$

(B) $90^\circ - A$

(C) $180^\circ + 2A$

(D) $180^\circ - 3A$

[C. 32.61%, I.C. 50.00%, U.A. 17.39%] (JEE Main 2022)

4. Which of the following statements is correct ?

(A) In primary rainbow, observer sees red colour on the top and violet on the bottom

(B) In primary rainbow, observer sees violet colour on the top and red on the bottom

(C) In primary rainbow, light wave suffers total internal reflection twice before coming out of water drops.

(D) primary rainbow is less bright than secondary rainbow.

[C. 31.03%, I.C. 40.23%, U.A. 28.74%] (JEE Main 2022)

5. The aperture diameter of a telescope is 5 m. The separation between the moon and the earth is 4×10^5 km. With light of wavelength of 5500 Å, the minimum separation between objects on the surface of moon, so that they are just resolved, is close to :

(A) 600 m **(B)** 60 m

(C) 20 m **(D)** 200 m

[C. 30.72%, I.C. 30.72%, U.A. 38.56%] (JEE Main 2020)

6. A vessel of depth 2h is half filled with a liquid of refractive index $2\sqrt{2}$ and the upper half with another liquid of refractive index $\sqrt{2}$. The liquids are immiscible. The apparent depth of the inner surface of the bottom of vessel will be :

(A) $\frac{h}{\sqrt{2}}$

(B) $\frac{h}{3\sqrt{2}}$

(C) $\frac{3}{4}h\sqrt{2}$

(D) $\frac{h}{2\left(\sqrt{2}+1\right)}$

[C. 27.70%, I.C. 18.65%, U.A. 53.65%] (JEE Main 2020)

7. Car B overtakes another car A at a relative speed of 40 ms^{-1}. How fast will the image of car B appear to move in the mirror of focal length 10 cm fitted in car A, when the car B is 1.9 m away from the car A?

(A) 0.1 ms^{-1}

(B) 0.2 ms^{-1}

(C) 4 ms^{-1}

(D) 40 ms^{-1}

[C. 27.15%, I.C. 17.17%, U.A. 55.68%] (JEE Main 2021)

8. A short straight object of height 100 cm lies before the central axis of a spherical mirror whose focal length has absolute value $|f| = 40$ cm. The image of object produced by the mirror is of height 25 cm and has the same orientation of the object. One may conclude from the information :

(A) Image is real, same side of concave mirror.
(B) Image is virtual, opposite side of convex mirror.
(C) Image is virtual, opposite side of concave mirror.
(D) Image is real, same side of convex mirror.

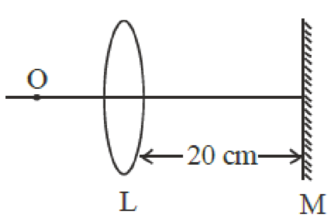
[C. 25.43%, I.C. 56.90%, U.A. 17.67%] (JEE Main 2021)

9. A prism of refractive index μ and angle of prism A is placed in the position of minimum angle of deviation. If minimum angle of deviation is also A, then in terms of refractive index value of A is

(A) $\sin^{-1}\left(\frac{\mu}{2}\right)$
(B) $2\cos^{-1}\left(\frac{\mu}{2}\right)$
(C) $\sin^{-1}\left(\sqrt{\frac{\mu-1}{2}}\right)$
(D) $\cos^{-1}\left(\frac{\mu}{2}\right)$

[C. 23.26%, I.C. 55.81%, U.A. 20.93%] (JEE Main 2021)

10. An object is placed on the principal axis of convex lens of focal length 10 cm as shown. A plane mirror is placed on the other side of lens at a distance of 20 cm. The image produced by the plane mirror is 5 cm inside the mirror. The distance of the object from the lens is _______cm.



[C. 22.76%, I.C. 35.45%, U.A. 41.79%] (JEE Main 2023)

11. A ray of light is incident at an angle of incidence 60° on the glass slab of refractive index $\sqrt{3}$. After refraction, the light ray emerges out from other parallel faces and lateral shift between incident ray and emergent ray is $4\sqrt{3}$cm. The thickness of the glass slab is ________ cm.

[C. 22.29%, I.C. 22.87%, U.A. 54.84%] (JEE Main 2022)

12. Two objects A and B are placed at 15 cm and 25 cm from the pole in front of a concave mirror having radius of curvature 40 cm. The distance between images formed by the mirror is

(A) 100 cm **(B)** 60 cm **(C)** 160 cm **(D)** 40 cm

[C. 22.08%, I.C. 37.38%, U.A. 40.54%] (JEE Main 2023)

13. A point object in air is in front of the curved surface of a plano-convex lens. The radius of curvature of the curved surface is 30 cm. and the refractive index of the lens material is 1.5, then the focal length of the lens (in cm) is................

[C. 20.08%, I.C. 12.01%, U.A. 67.91%] (JEE Main 2020)

14. If we need a magnification of 375 from a compound microscope of tube length 150 mm and an objective of focal length 5 mm, the focal length of the eye-piece, should be close to:

(A) 22 mm **(B)** 12 mm **(C)** 2 mm **(D)** 33 mm

[C. 19.80%, I.C. 48.52%, U.A. 31.68%] (JEE Main 2020)

15. In a medium the speed of light wave decreases to 0.2 times to its speed in free space The ratio of relative permittivity to the refractive index of the medium is x : 1. The value of x is _____.

(Given speed of light in free space $= 3 \times 10^8$ m/s and for the given medium $\mu_r = 1$)

[C. 19.58%, I.C. 26.81%, U.A. 53.61%] (JEE Main 2023)

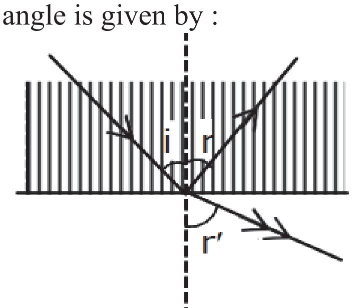
16. When an object is kept at a distance of 30 cm from a concave mirror, the image is formed at a distance of 10 cm from the mirror. If the object is moved with a speed of 9 cms^{-1} along the principal axis, the speed (in cms^{-1}) with which image moves at that instant is ____.

[C. 19.49%, I.C. 11.78%, U.A. 68.73%] (JEE Main 2020)

17. A light ray enters a solid glass sphere of refractive index $\mu = \sqrt{3}$ at an angle of incidence 60°. The ray is both reflected and refracted at the farther surface of the sphere. The angle (in degrees) between the reflected and refracted rays at this surface is ________.

[C. 19.30%, I.C. 49.12%, U.A. 31.58%] (JEE Main 2020)

18. A ray of light passes from a denser medium to a rarer medium at an angle of incidence i. The reflected and refracted rays make an angle of 90° with each other. The angle of reflection and refraction are resepectively r and r'. The critical angle is given by :



(A) $\sin^{-1}$ (tanr)
(B) $\sin^{-1}$ (tanr)
(C) $\sin^{-1}$(cotr)
(D) $\tan^{-1}$(sini)

[C. 18.75%, I.C. 68.75%, U.A. 12.50%] (JEE Main 2021)

19. A small bulb is placed at the bottom of a tank containing water to a depth of $\sqrt{7}$ m. The refractive index of water is $\frac{4}{3}$. The area of the surface of water through which light from the bulb can emerge out is $x\pi m^2$. The value of x is ____________.

[C. 18.10%, I.C. 12.76%, U.A. 69.14%] (JEE Main 2022)

20. In a compound microscope, the magnified virtual image is formed at a distance of 25 cm from the eye-piece. The focal length of its objective lens is 1 cm. If the magnification is 100 and the tube length of the microscope is 20 cm, then the focal length of the eye-piece lens (in cm) is __________.

[C. 17.78%, I.C. 55.56%, U.A. 26.66%] (JEE Main 2020)

21. A thin lens made of glass (refractive index = 1.5) of focal length f = 16 cm is immersed in a liquid of refractive index 1.42. If its focal length in liquid is f_1, then the ratio f_1 / f is closest to the integer :

(A) 17 **(B)** 1 **(C)** 9 **(D)** 5

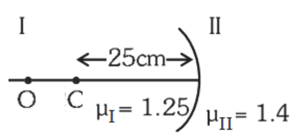
[C. 17.24%, I.C. 52.87%, U.A. 29.89%] (JEE Main 2020)

22. The magnifying power of a telescope with tube length 60 cm is 5. What is the focal length of its eye piece

(A) 10 cm **(B)** 20 cm **(C)** 40 cm **(D)** 30 cm

[C. 16.98%, I.C. 57.55%, U.A. 25.47%] (JEE Main 2020)

23. Region I and II are separated by a spherical surface of radius 25 cm. An object is kept in region I at a distance of 40 cm from the surface. The distance of the image from the surface is :



(A) 55.44 cm **(B)** 9.52 cm
(C) 37.58 cm **(D)** 18.23 cm

[C. 15.79%, I.C. 26.32%, U.A. 57.89%] (JEE Main 2021)

24. The distance between an object and a screen is 100 cm. A lens can produce real image of the object on the screen for two different positions between the screen and the object. The distance between these two positions is 40 cm. If the power of the lens is close to $\left(\frac{N}{100}\right)$ D where N is an integer, the value of N is _________.

[C. 15.39%, I.C. 71.79%, U.A. 12.82%] (JEE Main 2020)

25. Given below are two statements: One is labeled as Assertion A and the other is labeled as Reason R.

Assertion A : For a simple microscope, the angular size of the object equals the angular size of the image.

Reason R : Magnification is achieved as the small object can be kept much closer to the eye than 25 cm and hence it subtends a large angle.

In the light of the above statements, choose the most appropriate answer from the options given below:

(A) Both A and R are true but R is not the correct explanationof A

(B) Both A and R are true and R is the correct explanation of A

(C) A is true but R is false

(D) A is false but R is true

[C. 15.26%, I.C. 75.42%, U.A. 9.32%] (JEE Main 2021)

26. A ray of light passing through a prism ($\mu = \sqrt{3}$) suffers minimum deviation. It is found that the angle of incidence is double the angle of refraction within the prism. Then, the angle of prism is ________ (in degrees)

[C. 13.08%, I.C. 8.93%, U.A. 77.99%] (JEE Main 2021)

27. The same size images are formed by a convex lens when the object is placed at 20 cm or at 10 cm from the lens. The focal length of convex lens is ______ cm.

[C. 11.28%, I.C. 60.06%, U.A. 28.66%] (JEE Main 2021)

28. A ray of light is incident from air on a glass plate having thickness $\sqrt{3}$ cm and refractive index $\sqrt{2}$. The angle of incidence of a ray is equal to the critical angle for glass-air interface. The lateral displacement of the ray when it passes through the plate is ____________ $\times 10^{-2}$ cm. (given $\sin 15^\circ = 0.26$)

[C. 11.21%, I.C. 28.51%, U.A. 60.28%] (JEE Main 2023)

29. A light wave travelling linearly in a medium of dielectric constant 4, incident on the horizontal interface separating medium with air. The angle of incidence for which the total intensity of incident wave will be reflected back into the same medium will be :

(Given : relative permeability of medium $\mu_r = 1$)

(A) 10° **(B)** 20°

(C) 30° **(D)** 60°

[C. 10.78%, I.C. 49.10%, U.A. 40.12%] (JEE Main 2022)

30. A convex lens of refractive index 1.5 and focal length 18 cm in air is immersed in water. The change in focal length of the lens will be ___________cm.

$\left(\text{Given refractive index of water} = \frac{4}{3}\right)$

[C. 9.62%, I.C. 28.72%, U.A. 61.66%] (JEE Main 2023)

31. Unpolarised light is incident on the boundary between two dielectric media, whose dielectric constants are 2.8 (medium -1) and 6.8 (medium-2), respectively. To satisfy the condition, so that the reflected and refracted rays are perpendicular to each other, the angle of incidence should be $\tan^{-1}\left(1+\frac{10}{\theta}\right)^{1/2}$ the value of θ is

(Given for dielectric media, $\mu_r = 1$)

[C. 9.29%, I.C. 52.42%, U.A. 38.29%] (JEE Main 2023)

32. The refractive index of a converging lens is 1.4. What will be the focal length of this lens if it is placed in a medium of same refractive index? Assume the radii of curvature of the faces of lens are R_1 and R_2 respectively.

(A) Zero

(B) $\frac{R_1R_2}{R_1-R_2}$

(C) Infinite

(D) 1

[C. 8.16%, I.C. 71.43%, U.A. 20.41%] (JEE Main 2021)

33. Two identical thin biconvex lenses of focal length 15 cm and refractive index 1.5 are in contact with each other. The space between the lenses is filled with a liquid of refractive index 1.25. The focal length of the combination is ______ cm.

[C. 6.21%, I.C. 36.52%, U.A. 57.27%] (JEE Main 2022)

34. A microscope is focused on an object at the bottom of a bucket. If liquid with refractive index $\frac{5}{3}$ is poured inside the bucket, then microscope have to be raised by 30 cm to focus the object again. The height of the liquid in the bucket is :

(A) 12 cm

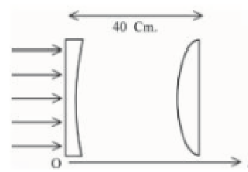
(B) 50 cm

(C) 18 cm

(D) 75 cm

[C. 5.91%, I.C. 57.08%, U.A. 37.01%] (JEE Main 2023)

35. As shown in the figure, a combination of a thin plano concave lens and a thin plano convex lens is used to image an object placed at infinity. The radius of curvature of both the lenses is 30 cm and refraction index of the material for both the lenses is 1.75. Both the lenses are placed at distance of 40 cm from each other. Due to the combination , the image of the object is formed at distance x = _______ cm, from concave lens.



[C. 4.08%, I.C. 29.25%, U.A. 66.67%] (JEE Main 2023)

36. A deviation of 2° is produced in the yellow ray when prism of crown and flint glass are achromatically combined. Taking dispersive powers of crown and flint glass as 0.02 and 0.03 respectively and refractive index for yellow light for these glasses are 1.5 and 1.6 respectively. The refracting angles for crown glass prism will be _______ $^\circ$ (in degree). (Round off to the Nearest Integer)

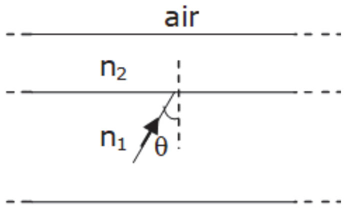
[C. 4.06%, I.C. 30.00%, U.A. 65.94%] (JEE Main 2021)

37. In an experiment for estimating the value of focal length of converging mirror, image of an object placed at 40 cm from the pole of the mirror is formed at distance 120 cm from the pole of the mirror. These distances are measured with a modified scale in which there are 20 small divisions in 1 cm. The value of error in measurement of focal length of the mirror is $\frac{1}{K}$ cm. The value of K is ___________

[C. 0.64%, I.C. 22.65%, U.A. 76.71%] (JEE Main 2023)

Exercise 4 (Level-B) JEE Advanced (Previous Year Questions)

1. A wide slab consisting of two media of refractive indices n_1 and n_2 is placed in air as shown in the figure. A ray of light is incident from medium n_1 to n_2 at an angle θ, where $\sin\theta$ is slightly larger than $1/n_1$. Take refractive index of air as 1. Which of the following statement(s) is(are) correct?



(A) The light ray enters air if $n_2 = n_1$

(B) The light ray is finally reflected back into the medium of refractive index n_1 if $n_2 < n_1$

(C) The light ray is finally reflected back into the medium of refractive index n_1 if $n_2 > n_1$

(D) The light ray is reflected back into the medium of refractive index n_1 if $n_2 = 1$

[C. 58.84%, I.C. 26.42%, U.A. 14.74%] (JEE Adv. 2021)

2. For an isosceles prism of angle A and refractive index μ, it is found that the angle of minimum deviation $\delta_m = A$. Which of the following options is/are correct?

(A) At minimum deviation, the incident angle i_1 and the refracting angle r_1 at the first refracting surface are related by $r_1 = (i_1/2)$

(B) For this prism, the refractive index μ and the angle of prism A are related as $A = \frac{1}{2}\cos^{-1}\left(\frac{\mu}{2}\right)$

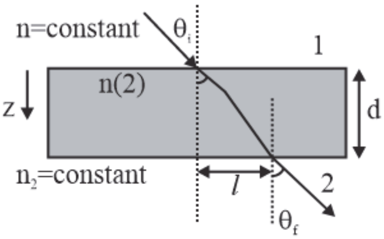
(C) For the angle of incidence $i_1 = A$, the ray inside the prism is parallel to the base of the prism

(D) For this prism, the emergent ray at the second surface will be tangential to the surface when the angle of incidence at the first surface is

$$i_1 = \sin^{-1}\left[\sin A\sqrt{4\cos^2\frac{A}{2} - 1} - \cos A\right]$$

[C. 57.00%, I.C. 23.00%, U.A. 20.00%] (JEE Adv. 2017)

3. A transparent slab of thickness d has a refractive index n(z) that increases with z. Here z is the vertical distance inside the slab, measured from the top. The slab is placed between two media with uniform refractive indices n_1 and n_2 ($>n_1$), as shown in the figure. ray of light is incident with angle θ_i from medium 1 and emerges in medium 2 with refraction angle θ_f with a lateral displacement l.



Which of the following statement(s) is(are) true?

(A) ℓ is independent of n_2

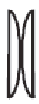
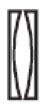
(B) ℓ is dependent on n(z)

(C) $n_1 \sin\theta_2 = n_2 \sin\theta_f$

(D) $n_1 \sin\theta_1 = (n_2 - n_1)\sin\theta_f$

[C. 53.60%, I.C. 20.80%, U.A. 25.60%] (JEE Adv. 2016)

4. Four combinations of two thin lenses are given in List I. The radius of curvature of all curved surface is r and the refractive index of all the lenses is 1.5. Match lens combinations in List I with their focal length in List II and select the correct answer using the code given below the lists.

List I	List II
P. 	1. 2r
Q. 	2. r/2
R. 	3. -r
S. 	4. r

(A) P-1, Q-2, R-3, S-4

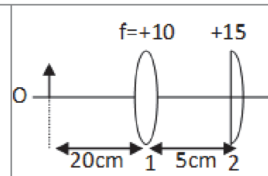
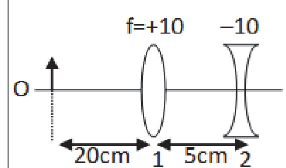
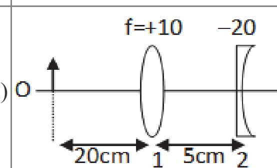
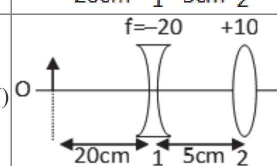
(B) P-2, Q-4, R-3, S-1

(C) P-4, Q-1, R-2, S-3

(D) P-2, Q-1, R-3, S-4

[C. 47.37%, I.C. 33.08%, U.A. 19.55%] (JEE Adv. 2014)

5. List I contains four combinations of two lenses (1 and 2) whose focal lengths (in cm) are indicated in the figures. In all cases, the object is placed 20 cm from the first lens on the left, and the distance between the two lenses is 5 cm. List II contains the positions of the final images.

List-I		List-II	
(I)		P	Final image is formed at 7.5 cm on the right side of lens 2.
(II)		Q	Final image is formed at 60.0 cm on the right side of lens 2.
(III)		R	Final image is formed at 30.0 cm on the left side of lens 2.
(IV)		S	Final image is formed at 6.0 cm on the right side of lens 2.
		T	Final image is formed at 30.0 cm on the right side of lens 2.

Which one of the following opotions is correct ?

(A) I→P, II→R, III→Q, IV→T

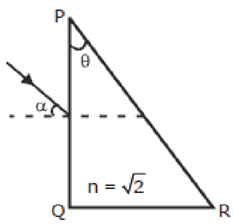
(B) I→Q, II→P, III→T, IV→S

(C) I→P, II→T, III→R, IV→Q

(D) I→T, II→S, III→Q, IV→R

[C. 45.17%, I.C. 35.48%, U.A. 19.35%] (JEE Adv. 2022)

6. A parallel beam of light is incident from air at angle α on the side PQ of a right angled triangular prism of refractive index $n = \sqrt{2}$. Light undergoes total internal reflection in the prism at the face PR when α has a minimum value of 45°. The angle θ of the prism is



(A) 15° **(B)** 22.5°
(C) 30° **(D)** 45°

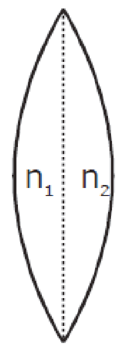
[C. 43.57%, I.C. 33.57%, U.A. 22.86%] (JEE Adv. 2016)

7. A plano-convex lens is made of a material of refractive index n. When a small object is placed 30 cm away in front of the curved surface of the lens, an image of double the size of the object is produced. Due to reflection from the convex surface of the lens, another faint image observed at a distance of 10 cm away from the lens. Which of the following statement(s) is(are) true?

(A) The refractive index of the lens is 2.5
(B) The radius of curvature of the convex surface is 45 cm
(C) The faint image is erect and real
(D) The focal length of the lens is 20 cm

[C. 41.51%, I.C. 33.02%, U.A. 25.47%] (JEE Adv. 2016)

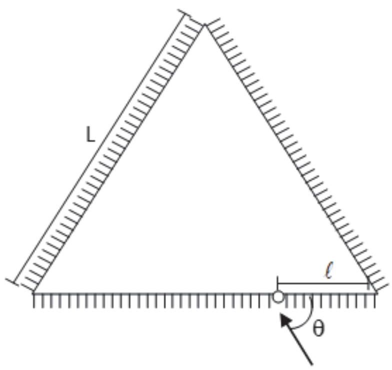
8. A thin convex lens is made of two materials with refractive indices n_1 and n_2, as shown in figure. The radius of curvature of the left and right spherical surfaces are equal. f is the focal length of the lens when $n_1 = n_2 = n$. The focal length is $f + \Delta f$ when $n_1 = n$ and $n_2 = n + \Delta n$. Assuming $\Delta n << (n - 1)$ and $1 < n < 2$, the correct statement(s) is/are.



(A) If $\frac{\Delta n}{n} < 0$ then $\frac{\Delta f}{f} > 0$
(B) $\left|\frac{\Delta f}{f}\right| < \left|\frac{\Delta n}{n}\right|$
(C) The relation between $\frac{\Delta f}{f}$ and $\left|\frac{\Delta n}{n}\right|$ remains unchanged if both the convex surfaces are replaced by concave surfaces of the same radius of curvature.
(D) For $n = 1.5$, $\Delta n = 10^{-3}$ and $f = 20$ cm, the value of $|\Delta f|$ will be 0.02 cm (round off to 2^{nd} decimal place).

[C. 40.20%, I.C. 23.53%, U.A. 36.27%] (JEE Adv. 2019)

9. Three plane mirrors form an equilateral triangle with each side of length L. There is a small hole at a distance $l > 0$ from one of the corners as shown in the figure. A ray of light is passed through the hole at an angle θ and can only come out through the same hole. The cross section of the mirror configuration and the ray of light lie on the same plane.

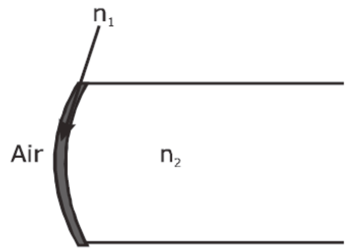


Which of the following statement(s) is(are) correct?

(A) The ray of light will come out for $\theta = 30^\circ$, for $0 < l < L$.
(B) There is an angle for $l = \frac{L}{2}$ at which the ray of light will come out after two reflections.
(C) The ray of light will **NEVER** come out for $\theta = 60^\circ$, and $l = \frac{L}{3}$
(D) The ray of light will come out for $\theta = 60^\circ$ and $0 < l < \frac{L}{2}$ after six reflections.

[C. 39.43%, I.C. 30.99%, U.A. 29.58%] (JEE Adv. 2022)

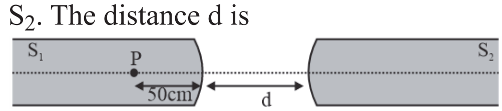
10. A transparent thin film of uniform thickness and refractive index n_1=1.4 is coated on the convex spherical surface of radius R at one end of a long solid glass cylinder of refractive index n_2 = 1.5, as shown in the figure. Rays of light parallel to the axis of the cylinder traversing through the film from air to glass get focused at distance f_1 from the film, while rays of light traversing from glass to air get focused at distance f_2 from the film. Then



(A) $|f_1| = 3R$ **(B)** $|f_1| = 2.8R$
(C) $|f_2| = 2R$ **(D)** $|f_1| = 1.4R$

[C. 38.10%, I.C. 32.14%, U.A. 29.76%] (JEE Adv. 2014)

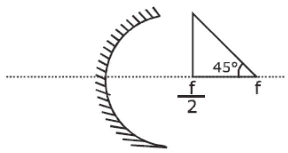
11. Two identical glass rods S_1 and S_2 (refractive index =1.5) have one convex end of radius of curvature 10 cm. They are placed with the curved surfaces at a distance d as shown in the figure, with their axes (shown by the dashed line) aligned. When a point source of light P is placed inside rod S_1 on its axis at a distance of 50 cm from the curved face, the light rays emanating from it are found to be parallel to the axis inside S_2. The distance d is

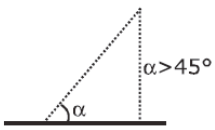


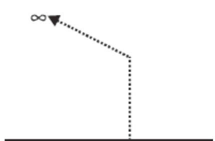
(A) 60 cm **(B)** 70 cm
(C) 80 cm **(D)** 90 cm

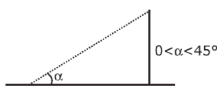
[C. 35.46%, I.C. 29.09%, U.A. 35.45%] (JEE Adv. 2015)

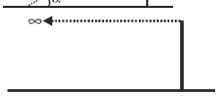
12. A wire is bent in the shape of a right angled triangle and is placed in front of a concave mirror of focal length f, as shown in the figure. Which of the figures shown in the four options qualitatively represent(s) the shape of the image of the bent wire ? (These figures are not to scale.) ?



(A) 

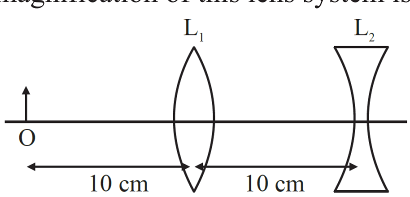
(B) 

(C) 

(D) 

[C. 35.16%, I.C. 50.00%, U.A. 14.84%] (JEE Adv. 2018)

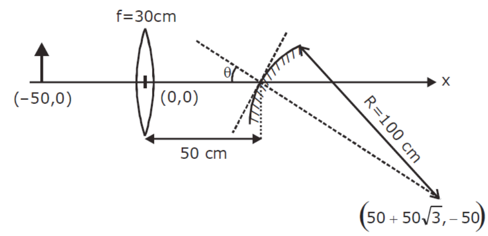
13. An extended object is placed at point O, 10 cm in front of a convex lens L_1 and a concave lens L_2 is placed 10 cm behind it, as shown in the figure. The radii of curvature of all the curved surfaces in both the lenses are 20 cm. The refractive index of both the lenses is 1.5. The total magnification of this lens system is



(A) 0.4 **(B)** 0.8 **(C)** 1.3 **(D)** 1.6

[C. 32.68%, I.C. 38.05%, U.A. 29.27%] (JEE Adv. 2021)

14. A small object is placed 50 cm to the left of a thin convex lens of focal length 30 cm. A convex spherical mirror of radius of curvature 100 cm is placed to the right of the lens at a distance of 40 cm. The mirror is tilted such that the axis of the mirror is at an angle θ = 30º to the axis of the lens, as shown in the figure.



If the origin of the coordinate system is taken to be at the centre of the lens, the coordinates (in cm) of the point (x, y) at which the image is formed are

(A) (0, 0)

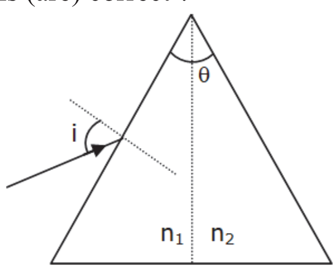
(B) $(50-25\sqrt{3},25)$

(C) $(25,25\sqrt{3})$

(D) $(125/3,25\sqrt{3})$

[C. 28.83%, I.C. 42.34%, U.A. 28.83%] (JEE Adv. 2016)

15. For a prism of prism angle $\theta = 60°$, the refractive indices of the left half and the right half are, respectively, n_1 and n_2 ($n_2 \geq n_1$) as shown in the figure. The angle of incidence i is chosen such that the incident light rays will have minimum deviation if $n_1 = n_2 = n = 1.5$. For the case of unequal refractive indices, $n_1 = n$ and $n_2 = n + \Delta n$ (where $\Delta n << n$), the angle of emergence $e = i + \Delta e$. Which of the following statement(s) is (are) correct ?



(A) The value of Δe (in radians) is greater than that of Δn

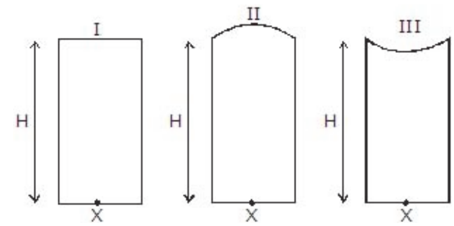
(B) Δe is proportional to Δn

(C) Δe lies between 2.0 and 3.0 milliradians, if $\Delta n = 2.8 \times 10^{-3}$

(D) Δe lies between 1.0 and 1.6 milliradians, if $\Delta n = 2.8 \times 10^{-3}$

[C. 28.23%, I.C. 13.88%, U.A. 57.89%] (JEE Adv. 2021)

16. Three glass cylinders of equal height H = 30 cm and same refractive index n = 1.5 are placed on a horizontal surface as shown in figure. Cylinder I has a flat top, cylinder II has a convex top and cylinder III has a concave top. The radii of curvature of the two curved tops are same (R = 3m). If H_1, H_2 and H_3 are the apparent depths of a point X on the bottom of the three cylinder, respectively, the correct statement(s) is/are :



(A) $H_3 > H_1$

(B) $0.8 \text{ cm} < (H_2 - H_1) < 0.9 \text{ cm}$

(C) $H_2 > H_1$

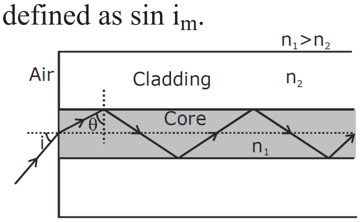
(D) $H_2 > H_3$

[C. 25.22%, I.C. 19.20%, U.A. 55.58%] (JEE Adv. 2019)

Paragraph:

Que. No. 17 - 18

Light guidance in an optical fiber can be understood by considering a structure comprising of thin solid glass cylider of refractive index n_1 surrounded by a medium of lower refractive index n_2. The light guidance in the structure takes place due to successive total internal reflections at the interface of the media n_1 and n_2 as shown in the figure. All rays with the angle of incidence i less than a particular value i_m are confined in the medium of refractive index n_1. The numerical aperture (NA) of the structure is defined as sin i_m.



17. For two structures namely S_1 with $n_1 = \sqrt{45}/4$ and $n_2 = 3/2$, and S_2 with $n_1 = 8/5$ and $n_2 = 7/5$ and taking the refractive index of water to be 4/3 and that of air to be 1, the correct option (s) is (are)

(A) NA of S_1 immersed in water is the same as that of S_2 immersed in a liquid of refractive index $\frac{16}{3\sqrt{15}}$

(B) NA of S_1 immersed in liquid of refractive index $\frac{16}{\sqrt{15}}$ is the same as that of S_2 immersed in water

(C) NA of S_1 placed in air is the same as that of S_2 immersed in liquid of refractive index $\frac{4}{\sqrt{15}}$

(D) NA of S_1 placed in air is the same as that of S_2 placed in water

[C. 23.53%, I.C. 27.73%, U.A. 48.74%] (JEE Adv. 2015)

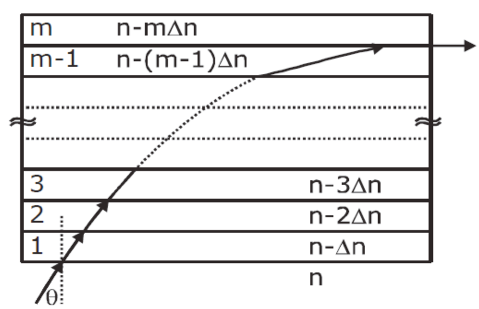
18. If two structures of same cross-sectional area, but different numerical apertures NA_1 and NA_2 ($NA_2 < NA_1$) are joined longitudinally, the numerical aperture of the combined structure is

(A) $\frac{NA_1 NA_2}{NA_1+NA_2}$ **(B)** $NA_1 + NA_2$

(C) NA_1 **(D)** NA_2

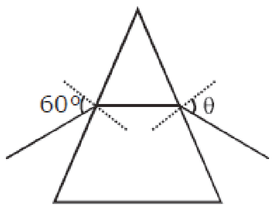
[C. 20.00%, I.C. 60.00%, U.A. 20.00%] (JEE Adv. 2015)

19. A monochromatic light is travelling in a medium of refractive index n = 1.6. It enters a stack of glass layers from the bottom side at an angle θ = 30°. The interfaces of the glass layers are parallel to each other. The refractive indices of different glass layers are monotonically decreasing as $n_m = n - m\Delta n$, where n_m is the refractive index of the m^{th} slab and $\Delta n = 0.1$ (see the figure). The ray is refracted out parallel to the interface between the $(m-1)^{th}$ and m^{th} slabs from the right side of the stack. What is the value of m?



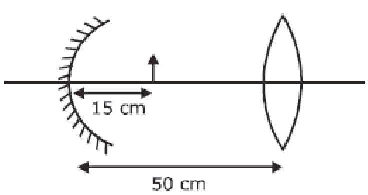
[C. 18.56%, I.C. 51.54%, U.A. 29.90%] (JEE Adv. 2017)

20. A monochromatic beam of light is incident at 60° on one face of an equilateral prism of refractive index and emerges from the opposite face making an angle θ (n) with the normal (see the figure). For $n = \sqrt{3}$ the value of θ is 60° and $\frac{d\theta}{dn} = m$. The value of m is-



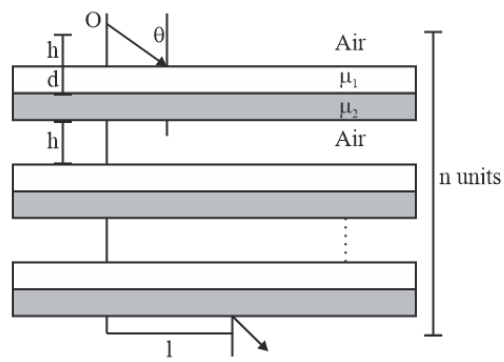
[C. 14.61%, I.C. 68.54%, U.A. 16.85%] (JEE Adv. 2015)

21. Consider a concave mirror and a convex lens (refractive index = 1.5) of focal length 10 cm each,separated by a distacne of 50 cm in air (refractive index = 1) as shown in the figure. An object is placed at a distacne of 15 cm from the mirror. Its erect image formed by this combination has magnification M_1. When the set-up is kept in a medium of refractive index 7/6, the magnification becomes M_2. The magnitude $\left|\frac{M_2}{M_1}\right|$ is



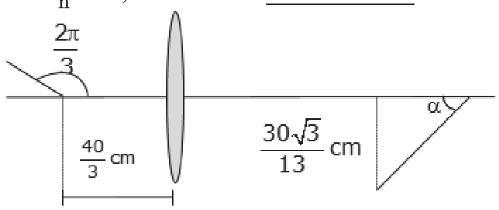
[C. 12.12%, I.C. 54.55%, U.A. 33.33%] (JEE Adv. 2015)

22. Consider a configuration of n identical units, each consisting of three layers. The first layer is a column of air of height $h = \frac{1}{3}$cm, and the second and third layers are of equal thickness $d = \frac{(\sqrt{3}-1)}{2}$ cm, and refractive indices $\mu_1 = \sqrt{\frac{3}{2}}$ and $\mu_2 = \sqrt{3}$ respectively. A light source O is placed on the top of the first unit, as shown in the figure. A ray of light from O is incident on the second layer of the first unit at an angle of $\theta = 60^\circ$ to the normal. For a specific value of n, the ray of light emerges from the bottom of the configuration at a distance $l = \frac{8}{\sqrt{3}}$cm, as shown in the figure. The value of n is ____.



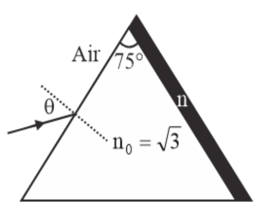
[C. 12.05%, I.C. 45.78%, U.A. 42.17%] (JEE Adv. 2022)

23. A rod of length 2 cm makes an angle $\frac{2\pi}{3}$ rad with the principal axis of a thin convex lens. The lens has a focal length of 10 cm and is placed at a distance of $\frac{40}{3}$ cm from the object as shown in the figure. The height of the image is $\frac{30\sqrt{3}}{13}$ cm and the angle made by it with respect to the principal axis is α rad. The value of α is $\frac{\pi}{n}$ rad, where n is __________.



[C. 11.49%, I.C. 22.98%, U.A. 65.53%] (JEE Adv. 2022)

24. A monochromatic light is incident from air on a refracting surface of a prism of angle 75° and refractive index $n_0 = \sqrt{3}$. The other refracting surface of the prism is coated by a thin film of material of refractive index n as shown in figure. The light suffers total internal reflection at the coated prism surface for an incidence angle of $\theta \le 60^\circ$. The value of n^2 is ___________.



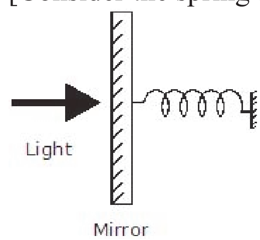
[C. 7.32%, I.C. 58.53%, U.A. 34.15%] (JEE Adv. 2019)

25. Sunlight of intensity 1.3kW m^{-2} is incident normally on a thin convex lens of focal length 20 cm. Ignore the energy loss of light due to the lens and assume that the lens aperture size is much smaller than its focal length. The average intensity of light, in kW m^{-2}, at a distance 22 cm from the lens on the other side is __________.

[C. 5.41%, I.C. 60.36%, U.A. 34.23%] (JEE Adv. 2018)

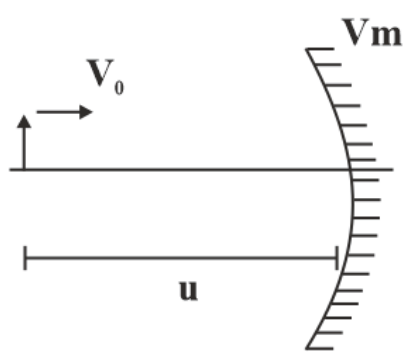
26. A perfectly reflecting mirror of mass M mounted on a spring constitutes a spring-mass system of angular frequency Ω such that $\frac{4\pi M\Omega}{h} = 10^{24} m^{-2}$ with h as Planck's constant. N photons of wavelength $\lambda = 8\pi \times 10^{-6}$ m strike the mirror simultaneously at normal incidence such that the mirror gets displaced by 1 μm. If the value of N is x x 10^{12}, then the value of x is ___

[Consider the spring as massless]



[C. 4.92%, I.C. 52.46%, U.A. 42.62%] (JEE Adv. 2019)

27. An object and a concave mirror of focal length f = 10 cm both move along the principal axis of the mirror with constant speeds. The object moves with speed $V_0 = 15$ cm s^{-1} towards the mirror with respect to a laboratory frame. The distance between the object and the mirror at a given moment is denoted by u. When u = 30 cm, the speed of the mirror V_m is such that the image is instantaneously at rest with respect to the laboratory frame, and the object forms a real image. The magnitude of V_m is___ cm s^{-1}.



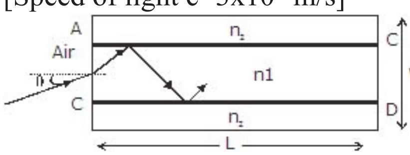
[C. 3.87%, I.C. 10.88%, U.A. 85.25%] (JEE Adv. 2022)

28. An optical bench has 1.5 m long scale having four equal divisions in each cm. While measuring the focal length of a convex lens, the lens is kept at 75 cm mark of the scale and the object pin is kept at 45 cm mark. The image of the object pin on the other side of the lens overlaps with image pin that is kept at 135 cm mark. In this experiment, the percentage error in the measurement of the focal length of the lens is——

[C. 3.45%, I.C. 51.72%, U.A. 44.83%] (JEE Adv. 2019)

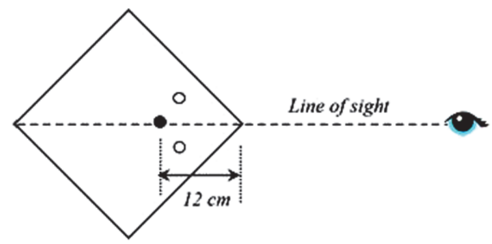
29. A planar structure of length L and width W is made of two different optical media of refractive indices n_1=1.5 and n_2=1.44 as shown in figure. If L>>W. a ray entering from end AB will emerge from end CD only if the total internal reflection condition is met inside the structure. For L=9.6m, if the incident angle is varried, the maximum time taken by ray to exit the plane CD is t x 10^{-9} S, where t is ——

[Speed of light c=3x10^8 m/s]



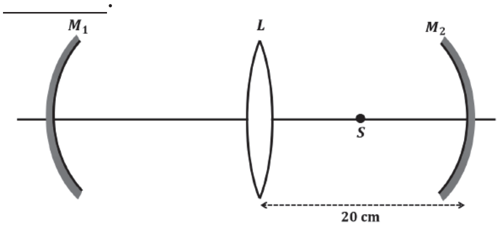
[C. 2.46%, I.C. 44.26%, U.A. 53.28%] (JEE Adv. 2019)

30. A large square container with thin transparent vertical walls and filled with water $\left(\text{refractive index} = \frac{4}{3}\right)$ is kept on a horizontal table. A student holds a thin straight wire vertically inside the water 12 cm from one of its corners, as shown schematically in the figure. Looking at the wire from this corner, another student sees two images of the wire, located symmetrically on each side of the line of sight as shown. The separation (in cm) between these images is ____________.



[C. 1.15%, I.C. 45.59%, U.A. 53.26%] (JEE Adv. 2020)

31. An optical arrangement consists of two concave mirrors M_1 and M_2, and a convex lens L with a common principal axis, as shown in the figure. The focal length of L is 10 cm. The radii of curvature of M_1 and M_2 are 20 cm and 24 cm, respectively. The distance between L and M_2 is 20 cm. A point object S is placed at the mid-point between L and M_2 on the axis. When the distance between L and M_1 is n/7 cm, one of the images coincides with S. The value of n is ________.



[C. 1.10%, I.C. 31.86%, U.A. 67.04%] (JEE Adv. 2023)

Answer Key

Exercise 1 (Level-A) — JEE Main Level

1. B	**2.** B	**3.** B	**4.** A	**5.** A	**6.** B	**7.** D	**8.** A
9. A	**10.** B	**11.** A	**12.** B	**13.** B	**14.** D	**15.** B	**16.** A
17. D	**18.** D	**19.** C	**20.** A	**21.** A	**22.** B	**23.** A	**24.** A
25. A	**26.** D	**27.** C	**28.** A	**29.** C	**30.** A	**31.** B	**32.** A
33. C	**34.** A	**35.** D	**36.** D	**37.** C	**38.** C	**39.** B	**40.** C
41. C	**42.** C	**43.** B	**44.** B	**45.** D	**46.** B	**47.** D	**48.** A
49. B	**50.** A	**51.** C	**52.** A	**53.** C	**54.** C	**55.** D	**56.** B
57. B	**58.** A	**59.** B	**60.** C	**61.** B	**62.** A	**63.** B	**64.** A
65. B	**66.** C	**67.** B	**68.** C	**69.** C	**70.** C	**71.** A	**72.** D
73. C	**74.** B	**75.** B	**76.** B	**77.** A	**78.** A	**79.** B	**80.** B
81. C							

Exercise 1 (Level-B) — Basic Learning

1. First mirror

2. 3d

3. $\theta = 30^\circ$

4. 240° clockwise, 120° anticlockwise

5. 30° clockwise

6. 20

7. **Real, inverted, height = 4 cm**

8. $\frac{1}{15}\,\mathrm{ms}^{-1}$

9. $\frac{4}{9}\,\mathrm{ms}^{-1}$

10. 0

11. $\frac{r}{d+\sqrt{d^2+r^2}}$

12. towards right

13. D

14. 32

15. 12

16. 30

17. $\frac{2}{3} \times 10^8$ sec

18. 6m

19. $\theta = \sin^{-1}\left(\frac{\sqrt{3}-1}{\sqrt{2}}\right)$

20. $\theta = \sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$

21. $\mu = 1.17$

22. 90

23. 30

24. -0.5 D

25. $P = +2D$

26. 6

27. $\tan\theta > \frac{2}{\sqrt{17}}$

28. Dispersive power=0.2
Angular dispersion is 7.2

29. 7.2°

30. Red

31. $x = 240$cm

32. -4.93 cm

33. $+50$ cm from 2^{nd} surface

34. (a) $v = \frac{\mu_3 \times R}{2\mu_2 - \mu_3 - \mu_1}$
(b) $v = \frac{\mu_1 R}{2\mu_2 - \mu_3 - \mu_1}$

35. Converging lens, Real image

36. Case(1)=(24 cm)– double convex
Case 2 =(–24 cm)– double concave
Case 3 = (–120 cm)– concavo concave
Case 4 = (+120 cm)– concavo convex

37. 1.67

38. 30.3

39. 4

40. 5D

41. $\frac{\pi}{4}$cm^2

42. 0.2 m

43. 1.5

44. $f_0 = 200$ cm

45. $P = -2.5$ D

46. 151.5 cm

47. 270

Exercise 2 — JEE Advanced Level

1. B	**2.** D	**3.** C	**4.** A	**5.** B,C	**6.** B,D	**7.** D	**8.** C
9. B	**10.** D	**11.** B	**12.** B	**13.** A,B	**14.** C	**15.** B,C	**16.** B
17. C	**18.** A,D	**19.** A,B,C	**20.** A	**21.** C	**22.** D	**23.** D	**24.** B,C,D
25. B,C,D	**26.** B	**27.** C	**28.** C	**29.** B,C,D	**30.** A,C	**31.** A,C	**32.** A
33. A	**34.** D	**35.** A,B,C	**36.** A	**37.** D	**38.** C	**39.** D	**40.** A,B
41. A,C	**42.** B	**43.** C	**44.** C	**45.** B,C,D	**46.** A,C	**47.** A,C	**48.** B
49. C	**50.** A	**51.** A,B,C,D	**52.** A,B	**53.** A,C,D	**54.** A,C	**55.** B,C	**56.** B
57. A	**58.** B	**59.** D	**60.** A,B,C,D	**61.** A,B,C,D	**62.** C	**63.** B	**64.** B
65. B	**66.** A	**67.** C	**68.** A	**69.** D			

Exercise 3 — Numerical Type

1. -18	**2.** 12	**3.** 1.5	**4.** 7	**5.** 10	**6.** 1.5	**7.** 1.6	**8.** 8
9. 90	**10.** 835.24	**11.** -1	**12.** 16	**13.** 3	**14.** 1.13	**15.** 2	**16.** 1.625
17. 3.1	**18.** 2.1						

Exercise 4 (Level-A) — JEE Main (Previous Year Questions)

1. C	**2.** D	**3.** A	**4.** A	**5.** B	**6.** C	**7.** A	**8.** B
9. B	**10.** 30	**11.** 12	**12.** C	**13.** 60	**14.** A	**15.** 5	**16.** 1
17. 90	**18.** A	**19.** 9	**20.** 6.25	**21.** C	**22.** A	**23.** C	**24.** 5
25. B	**26.** 60	**27.** 15	**28.** 52	**29.** D	**30.** 54	**31.** 7	**32.** C
33. 10	**34.** D	**35.** 120	**36.** 12	**37.** 32			

Exercise 4 (Level-B) — JEE Advanced (Previous Year Questions)

1. B,C,D	**2.** A,C,D	**3.** A,B,C	**4.** B	**5.** A	**6.** A	**7.** A,D	**8.** A,C,D
9. A,B	**10.** A,C	**11.** B	**12.** D	**13.** B	**14.** C	**15.** B,C	**16.** C,D
17. A,C	**18.** D	**19.** 8	**20.** 2	**21.** 7	**22.** 4	**23.** 6	**24.** 1.5
25. 130	**26.** 1	**27.** 3	**28.** 1.38	**29.** 50	**30.** 1.73	**31.** 150	