SCIENCE

CLASS-10

REFLECTION AND REFRECTION

e Shiksha Pie
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ASPIRING YOUNG MINDS

E SHIKSHA PIE PROGRAMS

CLASSES VI, VII, VIII, IX & X

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THE NATURE OF LIGHT

Light is a form of energy (optical energy) which helps us in seeing objects by its presence.

THEORIES ABOUT NATURE OF LIGHT

(i) Particle nature of light (Newton's corpuscular theory) :

According to Newton light travels in space with a great speed as a stream of very small particles called corpuscles.

This theory was failed to explain interference of light and diffraction of light. So wave theory of light was discovered.

(ii) Wave nature of light :

Light waves are electromagnetic waves so there is no need of medium for the propagation of these waves. They can travel in vacuum also. The speed of these waves in air or in vacuum is maximum i.e., 3×10^8 m/s.

Photoelectric effect was not explained with the help of wave theory, so Plank gave a new theory which was known as quantum theory of light.

(iii)Quantum theory of light :

When light falls on the surface of metals like caesium, potassium etc., electrons are given out. These electrons are called 'photo-electrons' and phenomenon is called 'photo-electric effect'.

This was explained by Einstein. According to plank light consisted of packets or quanta's of energy called photons. The rest mass of photon is zero. Each quanta carries energy E = hn. h → Planck's constant = 6.6×10^{-34} J-s.

n → Frequency of light

Some phenomenons like interference of light, diffraction of light are explained with the help of wave theory but wave theory was failed to explain the photo electric effect of light. It was explained with the help of quantum theory. So, light has dual nature. (i) Wave nature (ii) Particle nature

SOURCES OF LIGHT

The objects which emit (give) light are called **luminous objects**. It may be natural or man-made. Sun is a natural source of light and electric lamp, and oil lamp, etc. are man-made source of light.

The **Non-luminous objects** do not emit light. However, such objects become visible due to the reflection of the light falling on them. Moon does not emit light. It becomes visible due to the reflection of the sunlight falling on it.

PROPAGATION OF LIGHT

Light travels along straight lines in a medium or in vacuum. The path of light changes only when there is an object in its path or where the medium changes. Apart from vacuum and gases, light can travel through some liquids and solids as well.

Transparent medium :

A medium in which light can travel freely over large distances is called a transparent medium.

Examples: Water, glycerin, glass and clear plastics are transparent.

Opaque :

A medium in which light cannot travel is called opaque.

Examples : Wood, metals, bricks, etc., are opaque.

Translucent :

A medium in which light can travel some distance, but its intensity reduces rapidly. Such materials are called **translucent**.

Examples : Oil

THE CHARACTERISTICS OF LIGHT

1. Light is an electromagnetic wave.
2. Light travels in a straight line.
3. Light is a transverse wave, and does not need any medium to travel. Light can travel through vaccum. Its speed through vaccum is 3×10^8 m/s.
4. The velocity of light changes when it travels from one medium to another.
5. The wavelength (l) of light changes when it goes from one medium to another.
6. The frequency (f) of the light wave remains the same in all media.
7. Light gets reflected back from polished surfaces, such as mirrors, polished metal surfaces, etc.
8. Light undergoes refraction (bending) when it travels from one transparent medium to another.
9. Light does not need a material medium to travel, that is, it can travel through a vacuum too. Scientists have assigned a value of 299, 792, 458 m/s to the speed of light in vacuum.
10. According to current scientific theories, no material particle can travel at a speed greater than that of light in vacuum.

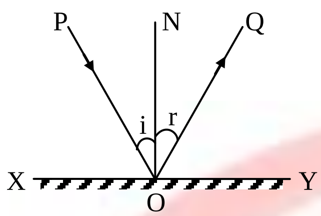
REFLECTION OF LIGHT

Definition.

When light rays are incident on an opaque polished surface (medium), these are returned back in the same medium.

This phenomenon of returning of ray of light in the same medium, is called reflection of light.

Definition of some associated terms :



1. **Reflecting surface :** The surface from which the light is reflected, is called the reflecting surface. In diagram, XY is the reflecting surface.
2. **Point of incidence :** The point on the reflecting surface at which a ray of light strikes, is called the point of incidence. In diagram, O is the point of incidence.
3. **Normal :** A perpendicular drawn on the reflecting surface at the point of incidence, is called the normal. In diagram, ON is the normal.
4. **Incident ray :** The ray of light which strikes the reflecting surface at the point of incidence is called the incident ray. In diagram, PO is the incident ray.
5. **Reflected ray :** The ray of light reflected from the reflecting surface from the point of incidence, is called the reflected ray. In diagram, OQ is the reflected ray.
6. **Angle of incidence :** The angle that the incident ray makes with the normal, is called the angle of incidence. It is represented by the symbol i. In diagram, angle PON is the angle of incidence.
7. **Angle of reflection :** The angle that the reflected ray makes with the normal, is called the angle of reflection. It is represented by the symbol r. In diagram, ∠QON is the angle of reflection.
8. **Plane of incidence :** The plane in which the normal and the incident ray lie, is called the plane of incidence. In diagram, the plane of the bookpage, is the plane of incidence.
9. **Plane of reflection :** The plane in which the normal and the reflected ray lie, is called the plane of reflection. In diagram, the plane of the book page, is the plane of reflection.

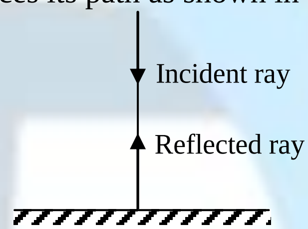
LAW OF REFLECTION OF LIGHT

1. **First law :** The incident ray, the reflected ray and the normal at the point of incidence, all lie in the same plane.
2. **Second law :** The angle of reflection ($\angle r$) is always equal to the angle of incidence ($\angle i$).
   i.e., $\angle r = \angle i$
   (For normal incidence, i = 0, r = 0. The ray is reflected back along normal).

(i)A ray of light striking the surface normally retraces its path.

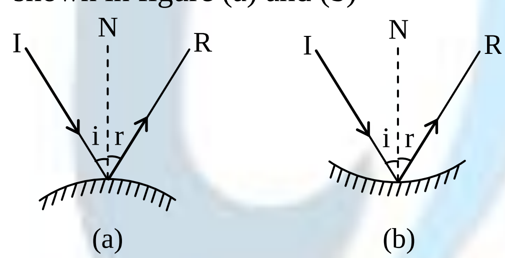
When a ray of light strikes a surface normally, then angle of incidence is zero i.e., $\angle i = 0$. According to the law of reflection,

$\angle r = \angle i$, $\angle r = 0$ i.e. the reflected ray is also perpendicular to the surface. Thus, an incident ray normal to the surface (i.e. perpendicular to the surface) retraces its path as shown in figure.



Normal Incidence

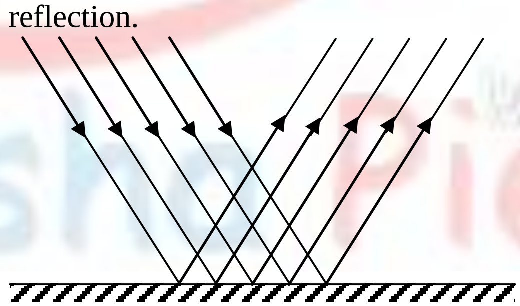
(ii) Laws of reflection are also obeyed when light is reflected from the spherical or curved surfaces as shown in figure (a) and (b)



Reflection from curved surface

(iii)Regular and Irregular Reflection :

1.**Regular Reflection** – The phenomenon due to which a parallel beam of light travelling through a certain medium, on striking some smooth polished surface, bounces off from it, as parallel beam, in some other fixed direction is called Regular reflection.

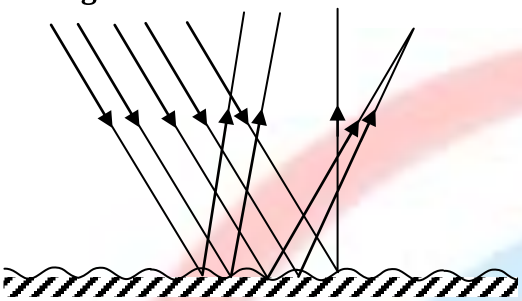


Regular reflection

Regular reflection takes place from the objects like looking glass, still water, oil, highly polished metals, etc.

Regular reflection is useful in the formation of images, e.g., we can see our face in a mirror only on account of regular reflection. However, it causes a very strong glare in our eyes.

2.**Irregular reflection or Diffused reflection :**



Irregular or diffused reflection

The phenomenon due to which a parallel beam of light, travelling through some medium, gets reflected in various possible directions, on striking some rough surface is called irregular reflection or diffused reflection.

The reflection which takes places from ground, walls, trees, suspended particles in air, and a variety of other objects, which are not very smooth, is irregular reflection.

Irregular reflection helps in spreading light energy over a vast region and also decreases its intensity. Thus, it helps in the general illumination of places and helps us to see things around us.

Note : Laws of reflection are always valid no matter whether reflection is regular or irregular.

NATURE OF IMAGE

Definition :

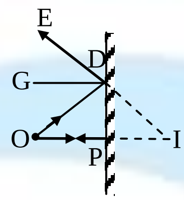
Incident rays starting from a point object, and reflected from a mirror, either actually meet at or appear to come from a point. The other point is called the **image** of the point object.

Real Image	Virtual Image
1. A real image is formed when two or more reflected rays meet at a point in front of the mirror.	1. A virtual image is formed when two or more rays appear to be coming from a point behind the mirror.
2. A real image can be obtained on a screen.	2. A virtual image cannot be obtained on a screen.
3. A real image is inverted with respect to the object.	3. A virtual image is erect with respect to the object.

REFLECTION FROM THE PLANE MIRROR

Relation between the distances of the object and the image from the plane mirror is that they are equal.

To verify this, consider the geometrical construction shown in figure. Rays OP and OD, starting from the object O, fall on the mirror. The ray OP is perpendicular to the mirror and hence, reflects back along PO. The incident ray OD and the reflected ray DE make equal angles with the normal DG. The two reflected rays when produced backwards meet at I, producing a virtual image there.



Now, $\angle EDG = \angle DIO$ (DG || IO),

$\angle EDG = \angle GDO$ (law of reflection), and

$\angle GDO = \angle DOI$ (DG || IO).

Hence, $\angle DIO = \angle DOI$ OR $OD = DI$

Now $OP^2 = OD^2 - DP^2$, and $PI^2 = DI^2 - DP^2$

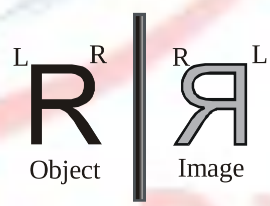
From (i), since $OD = DI$, $OP^2 = PI^2$ or $OP = PI$.

So, in the case of a plane mirror, the image is formed as far behind the mirror at the same distance as the object is in front of it.

SOME IMPORTANT RESULTS ABOUT REFLECTION FROM PLANE SURFACES

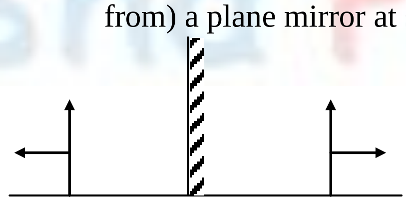
Lateral inversion :

When you see your image in a vertical plane mirror such as that fixed to an almirah, the head in the image is up and the feet are down, the same way as you actually stand on the floor. Such an image is called an erect image. However, if you move your right hand, it will appear as if the left hand of your image is moving. If you keep a printed page in front of a plane mirror, the image of the letters appear erect but inverted laterally, or sideways. Such an inversion is called lateral inversion.



Relative motion of object and image :

Case I : If an object moves towards (or away from) a plane mirror at speed v



The image will also approach (or recede) at speed v

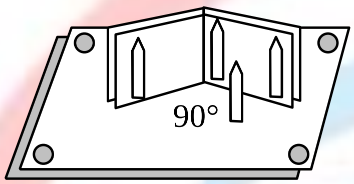
The speed of image relative to object will be
$v - (-v) = 2v$.

Case II : If the mirror is moved towards or (away from) the object with speed 'v'

The image will move towards (or away from) the object with a speed '2v'.

Multiple Reflection

Number of images formed by combination of plane mirrors depends upon angle between mirrors.

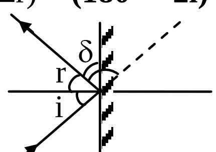


If there are two plane mirrors inclined to each other at an angle 90° , the number of images of a point object formed are 3.

Deviation :

d is defined as the angle between directions of incident ray and emergent ray. So if light is incident at an angle of incidence i,

$d = 180^o - (\angle i + \angle r) = \mathbf{(180^o - 2i)}$ [as $\angle i = \angle r$]



Plane mirror

So if light is incident at angle of 30º,

$d = (180^o - 2 \times 30^o) = 120^o$ and for normal incidence $\angle i = 0^o$, $d = 180^o$

Characteristics of the image formed by a plane mirror :

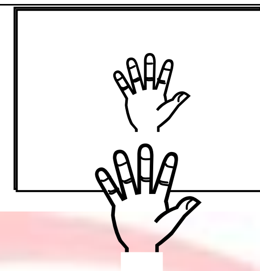
(i) The image formed by a plane mirror is virtual.

(ii) The image formed by a plane mirror is erect.

(iii) The size of the image formed by a plane mirror is same as that of the size of the object. If object is 10 cm high, then the image of this object will also be 10 cm high.

(iv) The image formed by a plane mirror is at the same distance behind the mirror as the object is in front of it. Suppose, an object is placed at 5 cm in front of a plane mirror then its image will be at 5 cm behind the plane mirror.

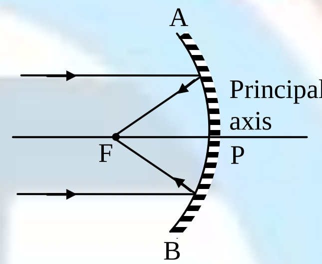
(v) The image formed by a plane mirror is laterally inverted, i.e., the right side of the object appears as the left side of its image and vice-versa.


Lateral Inversion

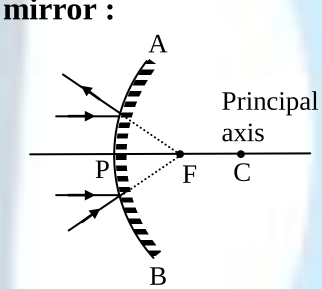
REFLECTION FROM SPHERICAL MIRROR

INTRODUCTION: There are two types of spherical mirrors:

(i) Concave mirror :



(ii) Convex mirror :



SOME TERMS ASSOCIATED WITH SPHERICAL MIRRORS.

1. **Aperture.** The diameter of the circular rim of the mirror. In diagram AB is the aperture of the mirror.
2. **Pole :** The centre of the spherical surface of the mirror is called the pole of the mirror. It lies on the surface. In diagram, P is the pole of the mirror.
3. **Centre of curvature :** The centre of the spherical shell, of which the mirror is a section, is called centre of curvature of the mirror. It lies outside the surface. Every point on mirror surface lies at same distance from it. In diagram, C is the centre of curvature of the mirror.
4. **Principal axis :** The straight line passing through the pole and the centre of curvature of the mirror, is called principal axis of the mirror.
5. **Principal focus :** It is a point on the principal axis of the mirror, such that the rays incident on the mirror parallel to the

principal axis after reflection, actually meet at this point (in case of a concave mirror) or appear to come from it (in case of a convex mirror). In diagram, F is the principal focus of the mirror.

6. **Radius of curvature :** The distance between the pole and the centre of curvature of the mirror, is called the radius of curvature of the mirror. It is equal to the radius of the spherical shell of which the mirror is a section. In diagram, PC is the radius of curvature of the mirror. It is represented by the symbol R.
7. **Focal length :** The distance between the pole and principal focus of the mirror, is called the focal length of the mirror. In diagram, PF is the focal length of the mirror. It is represented by the symbol f.

$$f = +\frac{R}{2} \text{ for convex}$$

$$f = -\frac{R}{2} \text{ for concave}$$

EXAMPLE – 1

A concave mirror is made by cutting of a hollow glass sphere of radius 30 cm. Find the focal length.

Solution:

Radius, R = 30 cm.

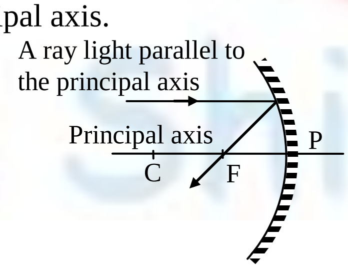
So, f = R/2 = 30/2 = 15 cm. Ans.

8. **Principal section :** A section of the spherical mirror cut by a plane passing through its centre of curvature and the pole of the mirror, is called a principal section of the mirror. It contains the principal axis. In diagram, APB is the principal section of the mirror cut by the plane of the book page.

RULES FOR IMAGE FORMATION BY RAY DIAGRAM METHOD

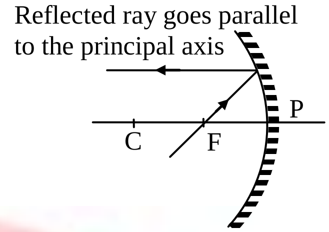
RULES FOR IMAGE FORMATION FROM CONCAVE MIRROR

(a) When the light ray incident parallel to the principal axis.

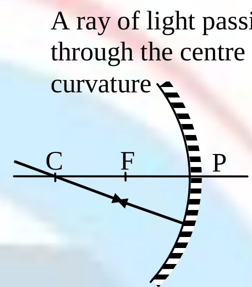


OR

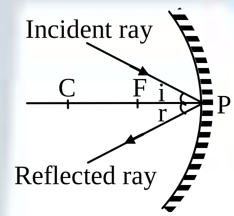
When the light ray incident towards focus.



(b) When the light ray incident towards centre of curvature.

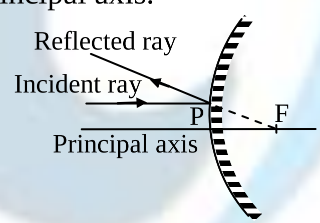


(c) When the light ray incident on the pole of the mirror.



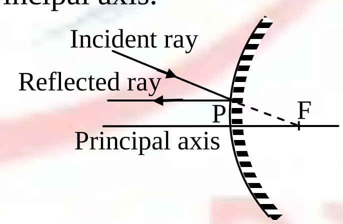
RULES FOR IMAGE FORMATION FROM CONVEX MIRROR

(a) When the light ray incident parallel to the principal axis.

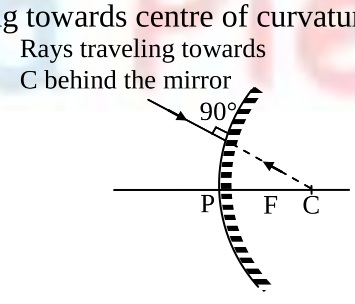


OR

When the light ray incident parallel to the principal axis.



(b) When the light ray incident on the mirror directing towards centre of curvature.



SIGN CONVENTION

(a) **Description :** It is a convention which fixes the signs of different distances measured. The sign c**onvention** to be followed is the **New Cartesian** sign convention. It gives the following rules :

1. All distances are measured from the **pole** of the mirror.
2. The distances measured in the **same** direction as the direction of incident light from pole are taken as **positive.**
3. The distances measured in the direction **opposite** to the direction on incident light from pole are taken as **negative.**
4. Distances measured **upward** and perpendicular to the principal axis, are taken as **positive.**
5. Distances measured **downward** and perpendicular to the principal axis, are taken as **negative.**

IMAGE FORMATION BY SPHERICAL MIRROR IN DIFFERENT CASES

Introduction : From mirror formula, we find that for a mirror of a fixed focal length f, as object distance u changes, image distance n also changes.

BY CONCAVE MIRROR

(1) Object at Infinity

A point object lying on the principal axis. Rays come parallel to the principal axis and after reflection from the mirror actually meet at the focus F.

The image is formed at F. It is real and point sized (fig.)

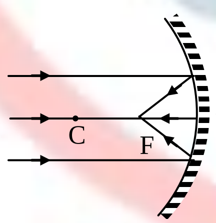
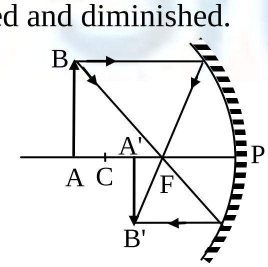


Fig. Concave mirror: point object at infinity, image at focus.

(2) Object Beyond Centre of Curvature

Real object AB has its image A\`B\` formed between focus and centre of curvature. The image is real-inverted and diminished.

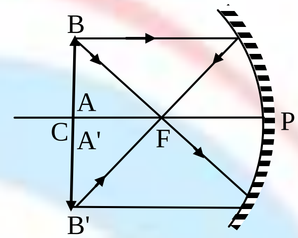


Concave mirror : object beyond centre of curvature, image between focus and centre of curvature.

(3) Object at Centre of Curvature

Real object AB, has its image A\`B\` formed at centre of curvature.

The image is real-inverted and has same size as the object. (fig.).

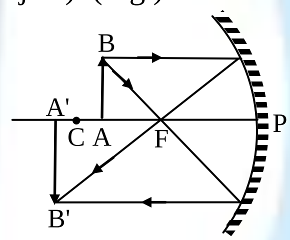


Concave mirror : object at centre of curvature, image at centre of curvature

(4) Object between Centre of Curvature and Focus

Real object AB has its image A\`B\` formed beyond centre of curvature.

The image is real-inverted and enlarged (bigger in size than the object). (Fig.)

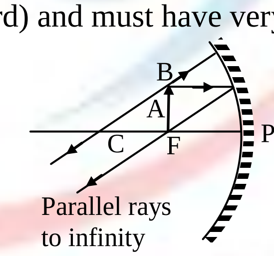


Concave mirror: object between centre of curvature and focus, image beyond centre of curvature.

(5) Object at Focus

Real object AB has its image formed at infinity.

The image is imaginary inverted (reflected rays go downward) and must have very large size.



Concave mirror : object at focus image at infinity.

(6) Object between Focus and Pole

Real object AB has its image A\`B\` formed behind the mirror. The image is virtual-erect and enlarged.

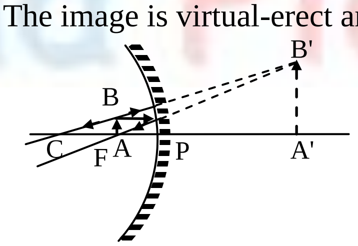


Fig. Concave mirror : Object between pole and focus, image behind the mirror.

BY CONVEX MIRROR

(1) Object at infinity

A point object lying on the principal axis.

Rays come parallel to the principal axis and after reflection from the mirror, appear to diverge from focus F behind the mirror.

The image is formed at F.

The image is virtual and point sized. [fig.]

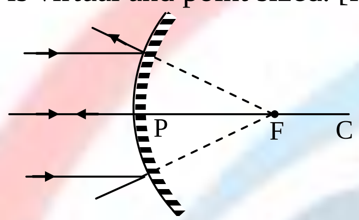


Fig. Convex mirror : point object at infinity, virtual image at focus.

(2) Object at anywhere on principle axis

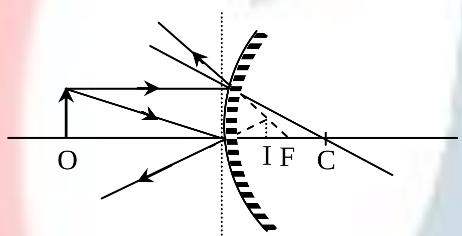


Image is virtual & point sized

NUMERICAL METHOD IN SPHERICAL MIRROR

(A) Mirror formula

1. **Definition :**

The equation relating the object distance (u) the image distance (v) and the mirror focal length (f) is called the mirror formula. $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

EXAMPLE – 2

An objective is placed at 30 cm away from a concave mirror of focal length 20 cm. Where will the image be formed?

Solution:

u = - 30 cm, f = - 20 cm.

Also, 1/v + 1/u = 1/f

So, 1/v = 1/f – 1/u = - 1/20 – 1/(- 30) = - 1/60

Hence, v = - 60 cm.

So, image will be 60 cm away from the mirror and left side of the mirror or front of the mirror.

2. **Assumptions made :**
   (i) The mirror has a small aperture.
   (ii) The object lies close to principal axis of the mirror.
   (iii)The incident rays make small angles with the mirror surface or the principal axis.

(B) linear magnification For spherical mirrors

Definition :

The ratio of the size of the image, as formed by reflection from the mirror to the size of the object, is called linear magnification produced by the mirror. It is represented by the symbol m.

$$m=-\frac{v}{u}=\frac{\text{height of image}}{\text{height of object}}$$

(C) Power of mirror

Power of a mirror [in Diopters] = $\frac{1}{\text{f (in metre)}}$

EXAMPLE – 3

The magnification produced by a plane mirror is + 1. What does it mean?

Solution:

m = + 1. We have m = h’/h

So, 1 = h’/h Or h’ = h. Hence the size of the image is equal to the height of object.

EXAMPLE – 4

If the radius of a mirror is 20 cm find the power of the mirror.

Solution:

R = 20 cm = 1/5 m. Or f = R/2 = 10 cm = 1/10 m.

So, power, p = 1/f

= 1/(1/10) = 10 D. Ans.

SUMMARY OF IMAGES BY SPHERICAL MIRROR

	Position of object	Position of Image	Size of Image	Nature of Image
Concave mirror	At infinity	At focus F	Highly diminished	Real and inverted
	Beyond C	Between F and C	Diminished	Real and inverted
	At C	At C	Same size	Real and inverted
	Between F and C	Beyond C	Enlarged	Real and inverted
	At F	At infinity	Highly enlarged	Real and inverted
	Between P and F	Behind the mirror	Enlarged	Virtual and erect

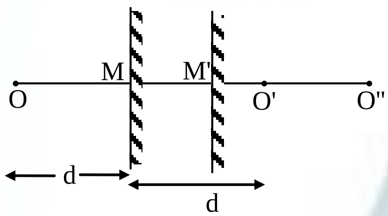
convex mirror	at infinite	at focus	highly diminished	virtual point size
	anywhere on principal axis	between pole & focus	diminished	virtual erect

EXAMPLE – 5

An object is placed in front of a plane mirror. If the mirror is moved away from the object through a distance x, by how much distance will the image move?

Solution

Suppose the object O was initially at a distance d from the plane mirror M as shown in fig. The image formed at O' is at a distance d behind the mirror. Now, the mirror is shifted by a distance x to M' such that the distance of the object from M' becomes d + x. The image now formed at O" which is also at a distance d + x from M'.



So, OM = MO' = d and OM' = M'O" = d + x

Thus, OO" = OM' + M'O" = 2(d + x) …...(1)

when OO' = OM + MO' = 2d ......(2)

Or O'O" = OO" – OO' = 2(d + x) – 2d = 2x

Thus, the image is shifted from O' to O" by a distance 2x.

EXAMPLE – 6

An insect is at a distance of 1.5m from a plane mirror. Calculate the following?

(i) Distance at which the image of the insect is formed.

(ii) distance between the insect and its image.

Solution

(i) The distance of insect from the mirror = 1.5 m

The distance of insect from the mirror is also equal to 1.5 m. The image is formed at 1.5 m behind the mirror.

(ii) The distance between the insect and image

= 1.5 + 1.5 = 3m

EXAMPLE – 7

A concave mirror is made up by cutting a portion of a hollow glass sphere of radius 30 cm. Calculate the focal length of the mirror.

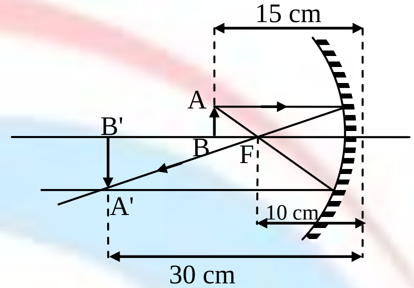
Solution

The radius of curvature of the mirror = 30 cm

Thus, the focal length of the mirror = $\frac{30\text{cm}}{2}$ = 15cm

EXAMPLE – 8

An object is placed at a distance of 15 cm from a concave mirror of focal length 10 cm. Find the position of the image.



Solution

We have u = –15 cm and f = –10 cm

Using the relation,, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ we get

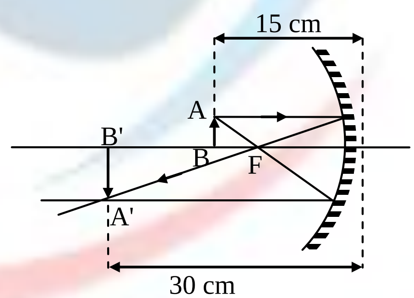
$\frac{1}{v} + \frac{1}{-15} = \frac{1}{-10}$ or $\frac{1}{v} = \frac{1}{15} - \frac{1}{10} = -\frac{1}{30}$

or v = –30 cm

So, the image will be formed 30 cm from the mirror. Since n has a negative sign, the image is formed to the left of the mirror, i.e. in front of the mirror as shown in fig.

EXAMPLE – 9

A 3 cm long object is placed perpendicular to the principal axis of a concave mirror. The distance of the object from the mirror is 15 cm, and its image is formed 30 cm from the mirror on the same side of the mirror as the object. Calculate the height of the image formed.



Solution

Here u = –15 cm and n = –30 cm

Size of the object, h = 2 cm

Magnification, m = m = $\frac{h'}{h} = -\frac{v}{u}$

Or $\frac{h'}{h} = -\frac{(-30)}{(-15)}$ = 2 or h' = – 2 ×h = – 2×3 = – 6 cm

So, the height of the image is 6 cm. The minus sign shows that it is on the lower side of the principal axis, i.e. the image is inverted.

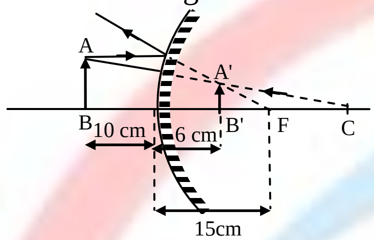
EXAMPLE – 10

A 1.4 cm long object is placed perpendicular to the principal axis of a convex mirror of focal length 15 cm at a distance of 10 cm from it. Calculate the following :

(i) location of the image

(ii) height of the image

(iii) nature of the image



Solution

(i) For a convex mirror, focal length is positive.
Therefore, f = +15 cm and u = –10 cm

Using the relation, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$, we get

$$\frac{1}{v}+\frac{1}{-10}=\frac{1}{15} \quad \text{or} \quad \frac{1}{v}=\frac{1}{15}+\frac{1}{10}=\frac{5}{30}=\frac{1}{6}$$

or v = 6 cm

Since n is positive, the image is formed to the right of the mirror at a distance 6 cm from it.

(ii) Magnification, $m=\frac{h'}{h}=--\frac{v}{u}$

$$\frac{h'}{h}=\frac{-6}{-10}=+0.6$$

or $h' = +0.6 \times h_0 = 0.6 \times 1.4 = 0.84$ cm.

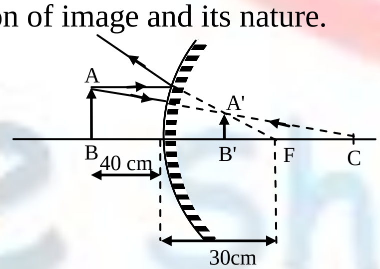
Thus, the height of the image is 0.84 cm.

(iii) Since h' is positive, the image will be on the same side of the principal axis as the object.

Hence, the image is virtual, erect and diminished.

EXAMPLE – 11

An object is placed at a distance of 40 cm from a convex mirror of focal length 30 cm. Find the position of image and its nature.



Solution

Here, object distance, u = –40 cm

Focal length of convex mirror, f = +30 cm

Now, using mirror formula, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ we get

$$\frac{1}{v}+\frac{1}{-40}=\frac{1}{30} \quad \text{or} \quad \frac{1}{v}=\frac{1}{40}+\frac{1}{30}=\frac{7}{120}$$

or $v=\frac{120}{7}$

The positive sign shows that the image is formed on the right, i.e. behind the mirror.

Now, magnification,

$$\Rightarrow m=-\frac{v}{u}=-\frac{120}{7\times(-40)}=+\frac{3}{7}$$

Since, the magnification is positive, the image is erect. Thus, the image is formed 17.1 cm behind the mirror. The image is virtual, erect and diminished.

EXAMPLE – 12

A 3 cm high object is placed at a distance of 30 cm from a concave mirror. A real image is formed 60 cm from the mirror. Calculate the focal length of the mirror and the size of the image.

Solution

Object distance, u = –30

Image distance, n = –60

(real image is formed on the same side)

Now, using the mirror formula, $\frac{1}{v}+\frac{1}{u}=$, we get:

$$\frac{1}{-60}+\frac{1}{-30}=\frac{1}{f} \quad \text{or} \quad \frac{1}{f}=-\frac{3}{60}=-\frac{1}{20}$$

or f = – 20 cm

Focal length of the mirror = 20 cm

Magnification $m=\frac{h'}{h}=-\frac{v}{u}$

or $\frac{h'}{3}=-\frac{(-60)}{(-30)}$ or $h' = 3 \times (-2) = -6$ cm

The height of the image is 6 cm. The negative sign shows that the image is inverted.

EXAMPLE – 13

A 1 cm high object is placed at 20 cm in front of a concave mirror of focal length 15 cm. Find the position and nature of the image.

Solution

u = –20 cm, f = –15 cm, h_0 = 1 cm

Using mirror formula, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ we get

$$\frac{1}{v}+\frac{1}{-20}=\frac{1}{-15} \quad \text{or} \quad \frac{1}{v}=-\frac{1}{15}+\frac{1}{20}=-\frac{1}{60}$$

So, v = – 60 cm

The image is formed 60 cm from the mirror. Since, the signs of u and n are the same, the object and image are formed on the same side of the mirror. Therefore, the image is real.

Now magnification, $m = \frac{h'}{h} = \frac{v}{u} = \frac{-60\,cm}{-20\,cm} = -3$

$h' = -3h = -3 \times 1$ cm $= -3$cm

The negative sign shows that the image is inverted. Thus, the image is real, inverted and of size 3 cm and formed 60 cm in front of the mirror.

EXAMPLE – 14

An object 4 cm high is placed 25 cm in front of a concave mirror of focal length 15 cm. At what distance from the mirror should a screen be placed in order to obtain a sharp image? Find the nature and size of image.

Solution

Here, u = –25 cm, f = –15 cm, h = + 4 cm

Using the mirror formula, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$, we get

or $\frac{1}{v} + \frac{1}{-25} = \frac{1}{-15}$

or $\frac{1}{v} = \frac{1}{-15} - \frac{1}{-25} = -\frac{1}{15} + \frac{1}{25} = -\frac{2}{75}$

or $v = \frac{-75}{2} = -37.5$ cm

Thus, the screen must be placed 37.5 cm from the mirror on the same side as the object.

Now, magnification, $m = \frac{h'}{h} = -\frac{v}{u}$

$\frac{h'}{4.0\,cm} = -\frac{(-37.5)}{(-25)} = -1.5$ or $h' = -1.5 \times 4 = -6$ cm

Negative sign shows that the image is inverted. Hence, the image is real, inverted and of size 6 cm.

EXAMPLE – 15

An object 5 cm high is placed at a distance of 20 cm from a convex mirror of radius of curvature 30 cm. Find the position, nature and size of image.

Solution

Here, u = –20 cm, h = 5 cm

Radius of curvature, r = +30 cm

Focal length, $f = \frac{r}{2} = +\frac{30}{2} = +15$ cm

Using the mirror formula, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$, we get

$\frac{1}{v} + \frac{1}{-20} = \frac{1}{+15}$ or $\frac{1}{v} = \frac{1}{15} + \frac{1}{20} = \frac{7}{60}$

Or $v = \frac{60}{7}$ cm

The image is formed 8.5 cm from the mirror. The positive sign shows that the image is formed on the other side or behind the mirror. So the image is virtual.

Magnification, $m = \frac{h'}{h} = -\frac{v}{u}$

or $\frac{h'}{5} = -\frac{60/7}{(-20)} = +\frac{60}{7 \times 20} = \frac{3}{7}$

or $h' = 5 \times \frac{3}{7} = \frac{15}{7}$ cm

The height of the image is 2.1 cm. Positive sign shows that the image is erect.

EXAMPLE – 16

A convex mirror used on an automobile has 3 m radius of curvature. If a bus is located 5 m from this mirror, find the position, nature and size of image.

Solution

Here, u = –5 m, r = +3m

$f = \frac{r}{2} = +3/2$m = 1.5 m.

Using the relation, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$, we get

Or $\frac{1}{v} + \frac{1}{-5} = \frac{1}{1.5}$ or $\frac{1}{v} = \frac{1}{1.5} + \frac{1}{5}$

Or v = + 1.15 m

The image is 1.15 m behind the mirror.

Magnification, $m = \frac{h'}{h} = -\frac{v}{u} = -\frac{1.15}{(-5)} = +0.23$

Thus, the image is virtual, erect and smaller in size than the object.

IMPORTANT POINTS TO BE REMEMBER

1. **Laws of reflection :**
   (a) Angle of incidence is equal to the angle of reflection .
   (b) The incident ray, the reflected ray and the normal all lie in the same plane.
2. **Mirror :** A smooth, highly polished reflecting surface is called a mirror. There are two types of mirrors :
   (a) plane mirror (b) curved mirrors
   Curved mirrors are classified as spherical mirrors or parabolic mirrors depending upon the curvature of the mirror.
3. **Concave mirror :** A spherical mirror whose inner hollow surface is the reflecting surface is called concave mirror. A concave mirror forms a real, inverted image of an object if the object is placed at any place outside F. However, when the object lies between F and P, the image formed is erect and virtual.
4. **Convex mirror :** A spherical mirror whose outer bulging at surface is the reflecting surface is called convex mirror. The image

formed by a convex mirror is always erect, virtual and smaller than the object whatever may be the position of the object. A convex mirror is used as a side-mirror (driver's mirror) on automobiles.

5. **Aperture of a mirror :** The effective width of a spherical mirror from which reflection can take place is called its aperture.
6. **Pole :** The centre of a curved mirror is called its pole.
7. **Centre of curvature :** The centre of the hollow sphere of which the spherical mirror is a part is called its centre of curvature. The centre of curvature of a concave mirror is in front of it, while that of a convex mirror is behind it.
8. **Radius of curvature :** Radius of the hollow sphere of which the mirror is a part is called its radius of curvature.
9. **Principal axis :** A straight line passing through the centre of curvature and pole of a spherical mirror is called its principal axis.
10. **Focus :** A point on the principal axis of a mirror at which the rays coming from infinity meet or appear to meet is called its focus. Focus is denoted by F.
11. **Focal length :** The distance between the pole of a spherical mirror and the focus is called the focal of a spherical mirror.
12. **Real image :** The image which can be obtained on a screen is called a real image. A real image is formed only when the reflected or refracted rays actually meet at a point.
13. **Virtual image :** The image which can be seen into a mirror but cannot be obtained on a screen is called a virtual image. A virtual image is formed only when the reflected or the refracted rays appear to come from a point.
14. **Sign convention for spherical mirrors :** According to the sign convention for mirror, the focal length of a concave mirror is negative and that of a convex mirror is positive.
15. **Mirrors formula :** The relationship, $\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$ is called the mirror formula.
16. **Magnification :** The ratio of the size of the image to that of the object is called magnification. For a mirror, magnification (M) is given by,

$$M = -\frac{v}{u} = \frac{h_i}{h_o}$$

$$\text{power (in diopters)} = \frac{1}{f\,(\text{metre})}$$

CONCLUSIONS FROM THE SIGN CONVENTION

For spherical mirror :

Distance of the object,	u is negative
Distance of the real image,	v is negative
Distance of the virtual image	v is positive
Focal length,	f is negative for concave & f is + ve for convex
Radius of curvature,	R is negative for concave & R is + ve for convex
Height of the object,	O is positive
Height of the inverted (real) image,	I is negative
Height of the erect (virtual) image,	I is positive

LEVEL – 1

1 A ray of light is incident on a plane mirror, i being the angle of incidence. What is the deviation suffered by the ray of light?

2 A plane mirror reflects a pencil of light to form a real image. What is the nature of the pencil of light incident on the mirror?

3 Define principal axis of a spherical mirror.

4 What is the focal length of a plane mirror?

5 Two perpendicular plane mirror forms .... number of images of a point source of light.

6 What is the magnification produced by a plane mirror?

7 Which mirror would you use for shaving?

8 Suppose x and y are distances of object and image respectively from a mirror. What shall be the shape of the graph between $\frac{1}{x}$ and $\frac{1}{y}$ for a concave mirror ?

9 An object is placed between two plane parallel mirrors. Why do the distant images get fainter and fainter?

10 Why mirrors used in search light are parabolic and not concave spherical?

11 You read a newspaper because of the light that it reflects. Then why do you not see even a faint image of yourself in the newspaper?

12 If you were driving a car, what type of mirror would you prefer to use for observing traffic at your back and why?

13 We known that plane and convex mirrors produce virtual images of objects. Can they produce real images under some circumstances ? Explain.

14 The wall of a room is covered with perfect plane mirror. Two movie films are made, one recording the movement of a man and the other of his mirror image. From viewing the films later, can an outsider tell which is which?

15 A concave mirror is held in water. What would be the change in the focal length of the mirror?

16 What is the difference between the virtual images produced by (i) plane mirror, (ii) concave mirror, (iii) convex mirror?

17 Show that if a ray of light is reflected successively from two mirrors inclined at an angle q, the deviation of the ray does not depend upon the angle of incidence.

18 Use the mirror equation to deduce that an object placed between f and 2f of a concave mirror produces a real image beyond 2f.

19 Show that a convex mirror always produces a virtual image independent of the location of the object.

20 Prove that the virtual image produced by a convex mirror is always diminished in size and is located between the focus and the pole.

21 Show analytically that an object placed between the pole and focus of a concave mirror produces a virtual and enlarged image.

22 We know that a virtual image cannot be obtained on a screen. But when we see a virtual image, we are obviously bringing it on the retina (may be regarded as a screen) of the eye. Point out the contradiction, if any.

23 Why a concave mirror of small aperture forms a sharper image?

24 What do you understand by the term ‘parallax’?

25 How can you distinguish between three different mirrors just by looking at them?

26 What is the effect of size of mirror on the nature of image ?

27 Is irregular reflection follows the laws of reflections or not ?

28 Prove that the radius of curvature of a spherical mirror is equal to twice the focal length of the mirror.

29 Derive mirror formula for a concave mirror when image formed is (i) real (ii) virtual Also give the sign convention used.

30 Find formulae for magnification produced in the following cases : (i) concave mirror, when image formed is real (ii) concave mirror, when image formed is virtual (ii) convex mirror.

31 Draw a ray diagram to show the formation of image of an object placed between the pole and centre of curvature of a concave mirror. Derive the formula connecting object distance (u), image distance (u) and focal length (f) for this particular case for the given concave mirror. State clearly the assumptions and sign conventions used.

32 Express magnification produced by a spherical mirror in terms of
(i) u and f (ii) u and f.

ANSWERS:

1. p – 2i **2.** virtual **5.** 3 **6.** 1

7. plane mirror **8.** $\frac{1}{v}+\frac{1}{u}=\frac{1}{f} \Rightarrow$ linear

9. as $I \propto \frac{1}{r^2}$ **10.** They reflect light parallel

15. No change

26. Image becomes brighter **27.** Yes

OBJECTIVE PROBLEMS

LEVEL – 2

1 A child walks towards a fixed plane mirror at a speed of 5 km h^{-1}. The velocity of the image with respect to mirror is -
(A) 5 km h^{-1} (B) –5 km h^{-1}
(C) 10 km h^{-1} (D) –10 km h^{-1}

2 The letter that does not show lateral inversion-
(A) Z (B) M (C) O (D) W

3 In a plane mirror, an object is 0.5 m in front of the mirror. The distance between object and image is -
(A) 0.5 m (B) 1 m
(C) 0.25 m (D) 0.75 m

4 An object 0.5 m tall is in front of a plane mirror at a distance of 0.2 m. The size of

the image formed is-
(A) 0.2 m (B) 0.5 m
(C) 0.1 m (D) 1 m

5 A plane mirror is approaching you at 10 cm s^{-1}. Your image shall approach you with a speed of-
(A) + 10 cm s^{-1} (B) – 10 cm s^{-1}
(C) + 20 cm s^{-1} (D) – 20 cm s^{-1}

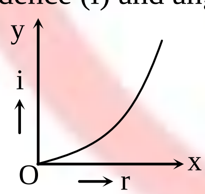
6 The path along which light travels in a homogeneous medium is called a-
(A) beam of light (B) ray of light
(C) pencil of light (D) none of these

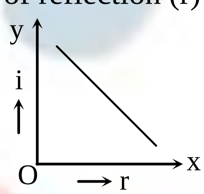
7 A thin layer of water is transparent but a very thick layer of water is-
(A) translucent (B) opaque
(C) most transparent (D) none of these

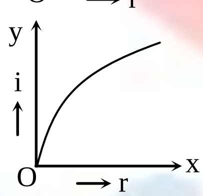
8 Air is not visible because it-
(A) is nearly a perfectly transparent
(B) neither absorbs nor reflects light
(C) transmits whole of light
(D) all of the above are correct

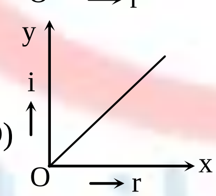
9 According to laws of reflection of light -
(A) Angle of incidence is equal to the angle of reflection
(B) Angle of incidence is less than the angle of reflection
(C) Angle of incidence is greater than the angle of reflection
(D) None of these

10 Which of the following correctly represents graphical relation between angle of incidence (i) and angle of reflection (r) ?

(A) 

(B) 

(C) 

(D) 

11 A light ray falls on a mirror and deviates by 60° then the angle of reflection will be
(A) 30° (B) 90°
(C) 60° (D) 180°

12 A ray of light is incident on a plane mirror at an angle If the angle between the incident and reflected rays is 80°, what is the value of
(A) 40° (B) 50° (C) 45° (D) 55°

13 Light shows -
(A) Random propagation
(B) Curvilinear propagation
(C) Rectilinear propagation
(D) None of these

14 The image of the moon is formed by a concave mirror whose radius of curvature is 4.8 m at a time when distance from the moon is 2.4×10^8 m . if the diameter is of the image is 2.2 cm, the diameter of the moon is-
(A) 1.1×10^6 m (B) 2.2×10^6 m
(C) 2.2×10^8 m (D) 2.2×10^{10} m

15 The focal length of a concave mirror is f and the distance of the object from the principal focus is a. The magnitude of magnification obtained will be-
(A) (f + a)/f (B) f /a
(C) $\sqrt{f}/\sqrt{a}$ (D) f^2/a^2

16 The magnification of an object placed 10 cm from a convex mirror of radius of curvature 20 cm will be-
(A) 0.2 (B) 0.5
(C) 1 (D) infinity

17 The image formed by a concave mirror is observed to be virtual, erect and larger than the object. then the position of the object should be-
(A) between the focus and the centre of curvature
(B) at the centre of curvature
(C) beyond the centre of curvature
(D) between the pole of the mirror and the focus

18 The magnification produced by a concave mirror -
(A) is always more than one
(B) is always less than one
(C) is always equal to one
(D) may be less than or greater than one

19 Choose the correct relation between u, v and R-
(A) $R = \frac{2uv}{u + v}$ (B) $R = \frac{2}{u + v}$
(C) $R = \frac{2(u + v)}{(uv)}$ (D) none of these

20 The image formed by a concave mirror is real, inverted and of the same size as that of the object. The position of the object should be-
(A) Beyond C (B) Between C and F
(C) At C (D) At F

21 A boy is standing in front of a plane mirror at a distance of 3m form it. What is the distance between the boy and his image ?

(A) 3 m (B) 4.5 m
(C) 6 m (D) none of these

ANSWERS:

1. B 2. A 3. B 4. B 5. C 6. B
7. A 8. D 9. A 10. D 11. C 12. B
13. C 14. B 15. B 16. B 17. D
18. D 19. A 20. C 21. C

REFRACTION OF LIGHT

DEFINITION : When light rays travelling in a medium are incident on a transparent surface of another medium they are bent as they travel in second medium.

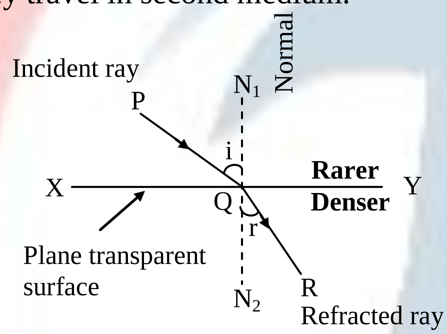


Fig. Refraction of light from a plane transparent denser surface.

SOME ASSOCIATED TERMS

1. **Transparent surface :** The plane surface which refracts light, is called transparent surface. In diagram, XY is the section of a plane transparent surface.
2. **Point of incidence :** The point on transparent surface, where the ray of light meets it, is called point of incidence. In diagram, Q is the point of incidence.
3. **Normal :** Perpendicular drawn on the transparent surface at the point of incidence, is called normal. In diagram, N_1QN_2 is the normal on surface XY.
4. **Incident ray :** The ray of light which strikes the transparent surface at the point of incidence, is called incident ray in diagram PQ is the incident ray.
5. **Refracted ray :** The ray of light which travels from the point of incidence into the other medium, is called refracted ray. In diagram, QR is the refracted ray.
6. **Angle of incidence :** The angle between the incident ray and the normal on the transparent surface at the point of incidence, is called the angle of incidence. It is represented by the symbol i. In diagram, angle PQN_1 is the angle of incidence.
7. **Angle of refraction :** The angle between the refracted ray and the normal on the transparent surface at the point of incidence, is called angle of refraction. It is represented by symbol r. In diagram angle RQN_2 is the angle of refraction.
8. **Plane of incidence :** The plane containing the normal and the incident ray, is called plane of incidence. For the diagram, plane of book page is the plane of incidence.
9. **Plane of refraction :** The plane containing the normal and the refracted ray, is called plane of refraction. For the diagram, plane of book page is the plane of refraction.

LAW OF REFRACTION OF LIGHT

1. **First Law :** The incident ray, the normal to the transparent surface at the point of incidence and the refracted ray, all lie in one and the same plane.
2. **Second Law :** The ratio of sine of angle of incidence to the sine of the angle of refraction is constant and is called refractive index of the second medium with respect to the first medium. $\frac{\sin i}{\sin r} = \mu$

REFRECTIVE INDEX

(a) Refractive Index in terms of Speed of Light:

The refractive index of a medium may be defined in terms of the speed of light as follows :

$$\text{Refractive index} = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}$$

or $\mu = \frac{c}{v}$

(b) Refractive Index in terms of Wavelength:

Since the frequency (ν) remains unchanged when light passes from one medium to another, therefore,

$$\mu = \frac{c}{v} = \frac{\lambda_{vac} \times \nu}{\lambda_{med} \times \nu} = \frac{\lambda_{vac}}{\lambda_{med}}$$

(c) Relative Refractive Index :

The relative refractive index of medium 2 with respect to medium 1 is defined as the ratio of speed of light (v_1) in the medium 1 to the speed of light (v_2) in medium 2 and is denoted by ${}_1\mu_2$.

Thus, ${}_1\mu_2 = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{\mu_2}{\mu_1}$

As refractive index is the ratio of two similar physical quantities, so it has no **unit and dimension**.

EXAMPLE – 1

The speed of light in water is 2.25×10^8 m/s and that of glass is 2×10^8 m/s. Calculate the reflective index of glass with respect to water.

Solution:

We have $^{water}n_{glass} = \frac{speed\ of\ light\ in\ water}{speed\ of\ light\ in\ glass}$

$= \frac{2.25\times10^8}{2\times10^8} = 1.125$

EXAMPLE – 2

If the reflective index for light going from air to water is 1.33, what will be the reflective index for light going from water to air?

Solution:

We have: $^{air}n_{water} = 1.33$

Or $^{water}n_{air} = 1/^{air}n_{water} = 1/1.33 = 0.75$. Ans.

FACTORS ON WHICH THE REFRACTIVE INDEX OF A MEDIUM DEPENDS ARE

(i) Nature of the medium.
(ii) Wavelength of the light used.
(iii) Temperature
(iv) Nature of the surrounding medium.

It may be noted that refractive index is a characteristic of the pair of the media and also depends on the wavelength of light, but is independent of the angle of incidence.

REFRACTION THROUGH GLASS SLAB

(a) Refraction through a rectangular glass slab and principle of reversibility of light :

Consider a rectangular glass slab, as shown in figure. A ray AE is incident on the face PQ at an angle of incidence i. On entering the glass slab, it bends towards normal and travels along EF at an angle of refraction r. The refracted ray EF is incident on face SR at an angle of incidence r'. The emerged ray FD bends away from the normal at an angle of refraction **e**.

Thus the emergent ray FD is parallel to the incident rays AE, but it has been laterally displaced with respect to the incident ray. There is shift in the path of light on emerging from a refracting medium with parallel faces.

Lateral shift :

Lateral shift is the perpendicular distance between the incident and emergent rays when light is incident obliquely on a refracting slab with parallel faces.

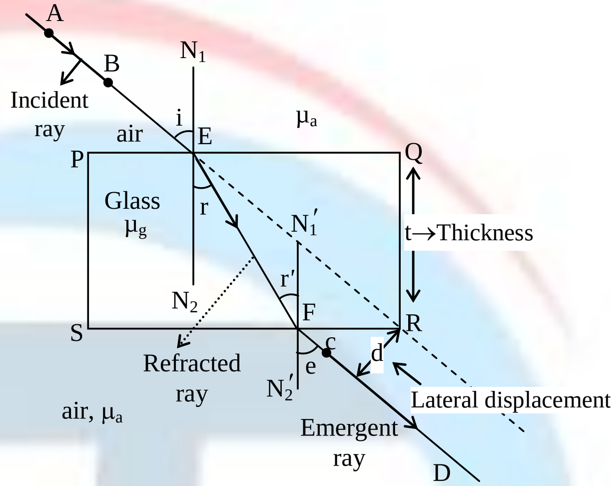
Factors on which lateral shift depends are :

(i) Lateral shift is directly proportional to the thickness of glass slab.

(ii) Lateral shift is directly proportional to the incident angle.

(iii) Lateral shift is directly proportional to the refractive index of glass slab.

(iv) Lateral shift is inversely proportional to the wavelength of incident light.



Proof for i = e

Case-I: For light going from air to glass at point E.

$\mu_a \sin i = \mu_g \sin r$ ..... (1)

Case-II: For light going from glass to air at point F.

$\mu_g \sin r = \mu_a \sin e$ .....(2)

From (1) & (2) we can say that i = e

incident & emergent rays are parallel to each other.

SPHERICAL LENS

Definition :

A piece of a transparent medium bounded by at least one spherical surface, is called a spherical lens.

Types : There are two types of spherical lenses:

(i) **Convex or Converging Lenses :** These are thick in the middle and thin at the edges.

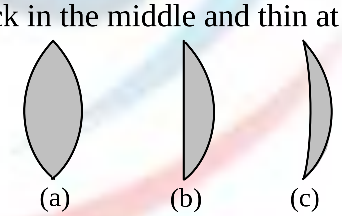


Fig. Three types of convex lenses

(a) **Double Convex Lens :** It has both the surfaces convex.

(b) **Plano–Convex Lens :** It has one surface plane and the other surface convex.

(c) **Concavo–Convex Lens :** It has one surface concave and the other surface convex.

(ii) **Concave or Diverging Lenses :** These are thin in the middle and thick at the edges.

There are three types of concave lenses :

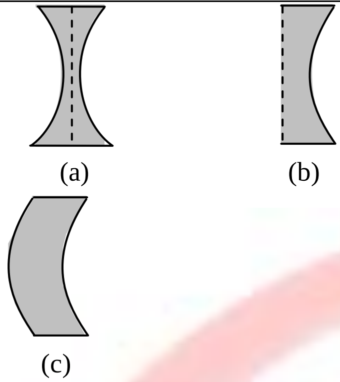


Fig. Three types of concave lenses

(a) **Double Concave Lens:** It has both the surfaces concave. (fig. a)

(b) **Plano–Concave Lens:** It has one surface plane and the other surface concave. (fig. (b).

(c) **Convexo–Concave Lens:** It has one surface convex and the other surface concave. (fig. c)

SOME ASSOCIATED TERMS

(i) Centre of curvature (C) :

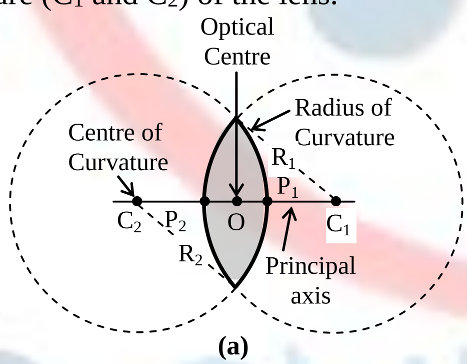
The centre of curvature of the surface of a lens is the centre of the sphere of which it forms a part, because a lens has two surfaces, so it has two centres of curvature. In figure (a) and (b) points, C_1 and C_2 are the centres of curvature.

(ii) Radius of curvature (R) :

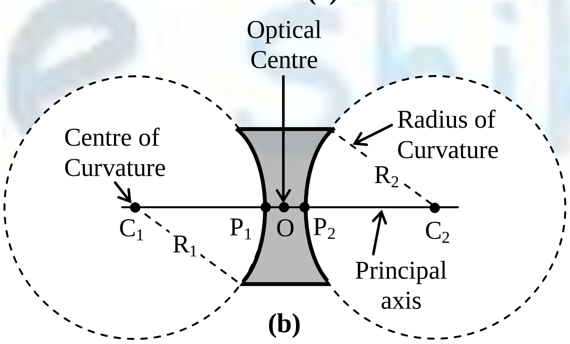
The radius of curvature of the surface of a lens is the radius of the sphere of which the surface forms a part. R_1 and R_2 in the figure (a) and (b) represents radius of curvature.

(iii)Principal axis (C_1C_2) :

It is the line passing through the two centres of curvature (C_1 and C_2) of the lens.



(a)



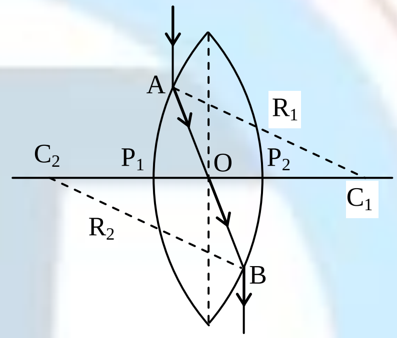
(b)

Figure : Characteristics of convex and concave lenses

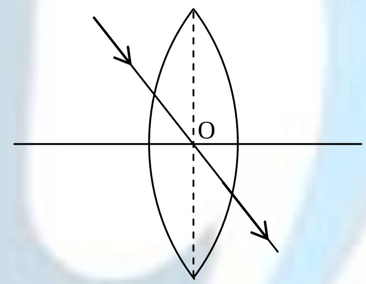
(iv)Optical centre : If a ray of light is incident on a lens such that after refraction through the lens the emergent ray is parallel to the incident ray, then the point at which the refracted ray intersects, the principal axis is called the optical centre of the lens.

$$\frac{OP_1}{OP_2} = \frac{P_1C_1}{P_2C_2} = \frac{R_1}{R_2}$$

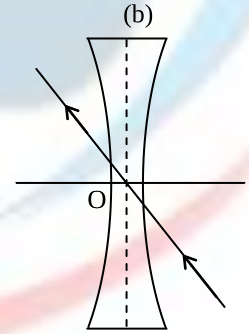
If the radii of curvature of the two surfaces are equal, then the optical centre coincides with the geometric centre of the lens.



(a)



(b)

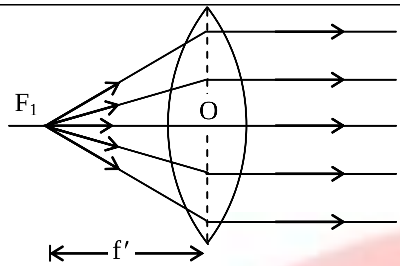


(c)

(v) Principal foci and focal length :

(A) First principal focus and first focal length :

It is a fixed point on the principal axis such that rays starting from this point (in convex lens) or appearing to go towards this point (concave lens), after refraction through the lens, become parallel to the principal axis. It is represented by F_1.



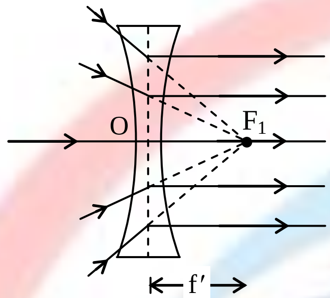
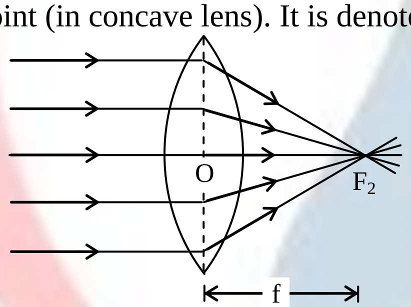


Figure : Ray diagram showing first principal focus

(B) Second principal focus and second focal length :

It is a fixed point on the principal axis such that the light rays incident parallel to the principal axis, after refraction through the lens, either converge to this point (in convex lens) or appear to diverge from this point (in concave lens). It is denoted by F_2.



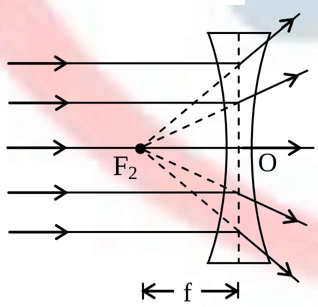


Figure : Ray diagram showing second principal focus

If the medium on both sides of a lens is same, then the numerical values of the first and second focal lengths are equal. Thus

$$f = f`$$

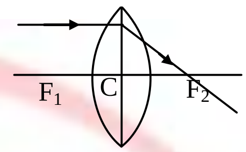
(vi) Aperture :

It is the diameter of the circular boundary of the lens.

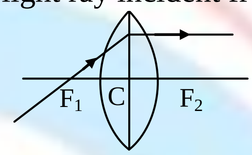
RULE FOR IMAGE FORMATION BY RAY DIAGRAM METHOD

THREE SPECIAL RAYS FOR CONVEX LENS

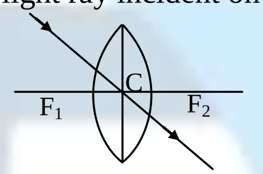
1. When light ray incident parallel to principal axis.



2. When light ray incident from focus.

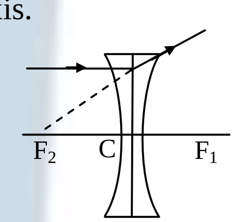


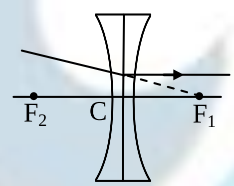
3. When light ray incident on the pole.



THREE SPECIAL RAYS FOR CONCAVE LENS

1. When light ray incident parallel to principal axis.





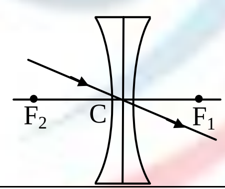


IMAGE FORMATION BY LENS

Introduction :

From lens formula, we find that for a lens of a fixed focal length as object distance u changes, image distance v also changes. Moreover, as u decreases or increases, this changes the position, the nature and the size of the image.

Different cases, are as given below with their ray diagrams.

CONVEX LENS IN DIFFERENT CASES

Case 1 : Object at Infinity

1. **A point object lying on the principal axis**

Rays come parallel to the principal axis and after refraction from the lens, actually meet at the second principal focus F_2.

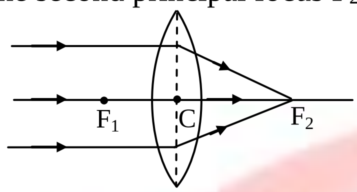


Fig. Convex lens point object at infinity, image at focus.

The image is formed at focus F_2. It is real and point sized.

2. **A big size object with its foot on the principal axis**

   Parallel rays come inclined to the principal axis. Image of foot is formed at the focus.

   Image is formed at the second principal focus F_2. It is real inverted and diminished (smaller in size than the object). (Fig.)

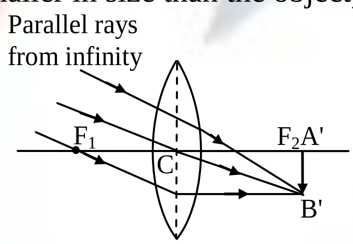


Fig. Convex lens : big size object at infinity, image at focus

Case 2 : Object at distance more than twice the Focal Length

Real object AB has its image A\`B\` formed between distance f and 2f.

The image is real inverted and diminished (smaller in size than the object)

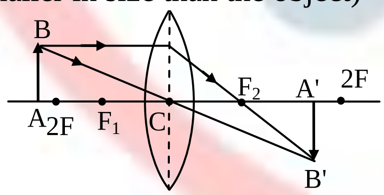


Fig. Convex lens : object beyond 2f, image between f and 2f.

Case 3. Object at distance twice the Focal Lengths

Real object AB has its image A\`B\` formed at distance 2f.

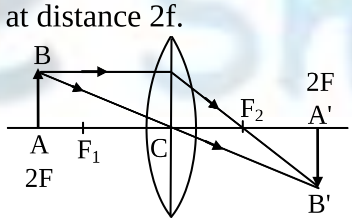


Fig. Convex lens : object at distance 2f, image at distance 2f.

The image is real, inverted and has same size as the object.

Case 4 : Object at distance more than Focal Length and less than twice is Focal Length

Real object AB has its image A\`B\` formed beyond distance 2f.

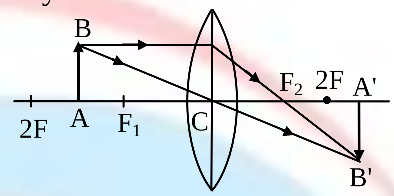


Fig. Convex lens : object at distance between f and 2f, image beyond 2f.

The image is real inverted and enlarged (bigger in size than the object).

Case 5 : Object at Focus

Real object AB has its image formed at infinity.

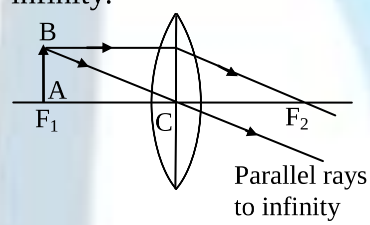
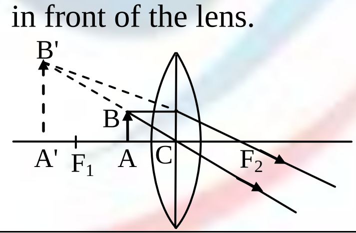


Fig. Convex lens : object at focus, image at infinity.

The image is imaginary inverted (refracted rays to downward) and must have very large size.

Case 6 : Object between Focus and Optical Centre

Real object AB has its image A\`B\` formed in front of the lens.



CONCAVE LENS IN DIFFERENT CASES

Case 1 : Object at infinity

1. A point object lying on the principal axis.

   Rays come parallel to the principal axis and after refraction from the lens, appears to come from the second principal focus F_2.

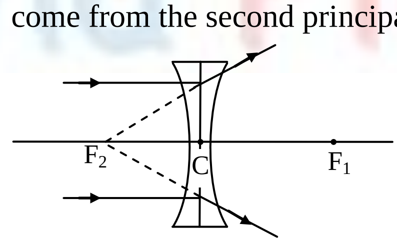


Fig. Concave lens point object at infinity, image at focus.

The image is formed at focus F_2. It is virtual and point sized (fig.)

2. A big size object with its foot on the principal axis.

Parallel rays come inclined to the principal axis. Image of foot is formed at focus.

The image is formed at the second principal focus F_2.

It is virtual–erect and diminished (fig.)

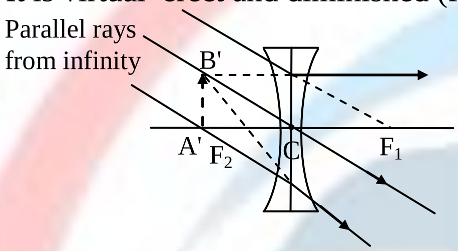


Fig. Concave lens : big size object at infinity image at focus.

Case 2 : Object at a Finite Distance

Real object AB has its image A\`B\` formed between second principal focus F_2 optical centre C. The image is virtual–erect and diminished.

NUMERICAL METHOD IN LENS

(A) LENS FORMULA

Definition : The equation relating the object distance (u), the image distance (v) and the focal length (f) of the lens is called the lens formula.

Assumptions made:

1. The lens is **thin.**
2. The lens has a **small aperture.**
3. The object lies **close** to principal axis.
4. The incident rays make **small angles** with the lens surface or the principal axis.

Lens Formula: $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

LINEAR MAGNIFICATION FOR LENS

LINEAR MAGNIFICATION

Definition :

The ratio of the size of the image formed by refraction from the lens to the size of the object, is called linear magnification produced by the lens. It is represented by the symbol m.

If I be the size of the image and O be the size of the object, then $m = \frac{I}{O} = \frac{v}{u}$

POWER OF LENS

Definition : It is the capacity or the ability of a lens to deviate (converge or diverge) the path of rays passing through it. A lens producing more converging or more diverging, is said to have more power

Power of lens (in diopter) $= \frac{1}{f\,(\text{in metre})}$

Power of a convex lens is +ve (As it has a real focus and its focal length measured is + ve.)Power of a concave lens is -ve (As it has a virtual focus and its focal length measured is - ve.)

NOTE :

(a) If two lenses are placed in contact, the combination has a power equal to the algebraic sum of the powers of two lenses,

$$P = P_1 + P_2 \Rightarrow \frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}.$$

(b) If two thin lenses are placed at d distance, then the combination has a power equal to-

$$P = P_1 + P_2 - dP_1P_2 \Rightarrow \frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}.$$

Here, f_1 and f_2 are the focal length of lenses and f is focal length of f combination of lenses.

EXAMPLE – 3

Find the power of a concave lens of focal length 2 m.

Solution:

We have: f = - 2 m (For concave)

Now, Power, P = 1/f = - ½ = - 0. 5 D. Ans.

EXAMPLE – 4

If the power of a lens is – 10 D, find the focal length and also find the nature of the lens.

Solution:

We have, f = 1/P = 1/(- 10) = - 10 cm.

And the lens is concave lens.

EXAMPLE – 5

If two lenses of power + 5D and – 12 D are placed in the combination, find the power of combination.

Solution:

P_1 = + 5 D and P_2 = - 12 D.

Now, $P = P_1 + P_2$ = + 5 – 12 = - 7 D. And.

EXAMPLE – 6

A convex lens of focal length 40 cm and a concave lens of focal length 25 cm are placed in contact in such a way that they have the common principal axis. Find the power of the combination.

Solution

Focal length of the convex lens,

f_1 = 40 cm = +0.4 m

Power of the convex lens, $P_1 = \frac{1}{+0.40}$ = +2.5D

Focal length of the concave lens,
$f_2 = -25 \text{ cm} = -0.25 \text{ m}$

Power of the concave lens, $P_2 = \frac{1}{-0.25} = -4D$

Power of the combination,
$P = P_1 + P_2 = 2.5 - 4D = -1.5D$

TOTAL INTERNAL REFLECTION

Definition :
When light travels from a denser medium to a rarer medium and is incident at an angle more than the critical angle for that medium, it is completely returned inwardly in the denser medium. This complete inward return of light is called **total** (complete) **internal** (inward) **reflection** (return).

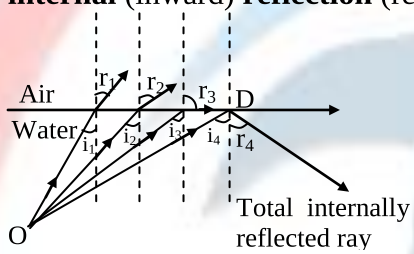


Fig. Total internal reflection.

CRITICAL ANGLE

The angle of incidence in denser medium for which angle of refraction is 90º, is called the critical angle. It is represented by the symbol C.

So, $\mu_w \sin i_3 = \mu_a \sin 90°$ Or $\sin i_3 = \frac{1}{\mu_w}$

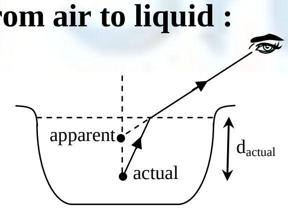
[Note. More is the value of μ, lesser will be angle C].

Condition (i) Light must travel from denser to rarer medium.
(ii) Light must be incident at an angle more than the critical angle for the denser medium.

Merit :
In total internal reflection 100% light is reflected, hence images formed are more bright.
In ordinary reflection from mirrors, only 85% light is reflected, rest 15% is either absorbed by mirror glass or transmitted due to poor polish. Images formed by ordinary reflection are less bright.

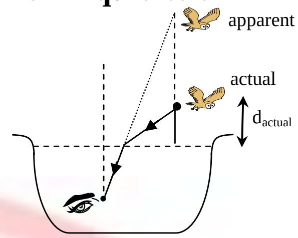
REAL AND APPARENT DEPTH AND HEIGHT

(A) Seeing from air to liquid :



apparent depth from surface = $\frac{d_{actual}}{\mu}$

(B) Seeing from liquid to air



apparent height from surface = $H_{actual} \times \mu$

EXAMPLE – 7

Speed of light in water is 2.25×10^8 m/s. Calculate the refractive index of water.

Solution

Refractive index is given by

$$n = \frac{\text{speed of light in vaccum(c)}}{\text{speed of light in water}(v)} = \frac{3\times10^8 \text{ m/s}}{2.25\times10^8 \text{ m/s}} = 1.33$$

EXAMPLE – 8

Refractive index of diamond is 2.42. Calculate the speed of light in diamond.

Solution

We know that refractive index,

$$n = \frac{c}{v} = \frac{\text{speed of light in vaccum}}{\text{speed of light in diamond}}$$

or $2.42 = \frac{3\times10^8}{v}$ or $v = \frac{3\times10^8}{2.42} = 1.24 \times 10^8$ m/s.

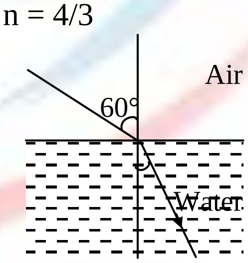
EXAMPLE – 9

A ray of light travelling in air falls on the surface of water. The angle of incidence is 60° with the normal to the surface. The refractive index of water = 4/3. Calculate the angle of refraction.

Solution

We know that $\frac{\sin i}{\sin r} = n$

Here, i = 60°, n = 4/3



So, $\frac{\sin 60°}{\sin r} = \frac{4}{3}$ or $\frac{\sqrt{3}/2}{\sin r} = \frac{4}{3}$

or $\sin r = \frac{3\sqrt{3}}{8} = 0.65$ Or $r = \sin^{-1} 0.65$

EXAMPLE – 10

If the refractive index of water is 4/3 and that of glass is 3/2. Calculate the refractive index of glass with respect to water.

Solution

We known that $\ ^{w}\mu_g = \frac{\mu_g}{\mu_w}$

where $\ ^{w}\mu_g$ = refractive index of glass with respect to water

μ_g = refractive index of glass = 3/2

μ_w = refractive index of water = 4/3

Or $\ ^{w}\mu_g = \frac{3/2}{4/3} = \frac{9}{8} = 1.1$

EXAMPLE – 11

A ray of light is incident on the plane surface of a transparent medium at an angle 60° with the normal. The angle of refraction is 30°. Calculate the refractive index of the transparent material.

Solution

Here, Angle of incidence, i = 60°

Angle of refraction, r = 30°

Refractive index,

$n = \frac{\sin i}{\sin r} = \frac{\sin 60°}{\sin 30°} = \frac{\sqrt{3}/2}{1/2} = \sqrt{3}$

EXAMPLE – 12

A ray of light travelling in air falls on the surface of a glass slab at an angle 45° with the normal. The refractive index of glass is 1.5. Calculate the angle of refraction.

Solution

Angle of incidence = 45°

Refractive index of glass, n = 1.5

Since, $n = \frac{\sin i}{\sin r}$ or $1.5 = \frac{\sin 45°}{\sin r}$

or $\sin r = \frac{\sin 45°}{1.5} = \frac{1/\sqrt{2}}{1.5} = \frac{1}{\sqrt{2}\times 1.5}$

$= \frac{1}{1.41\times 1.5} = \frac{1}{2.115} = 0.47$

Or $r = \sin^{-1} 0.47$

EXAMPLE – 13

The refractive index of diamond is 2.42 and that of carbon disulphide is 1.63. Calculate the refractive index of diamond with respect to carbon disulphide.

Solution

Refractive index of carbon disulphide, n_1= 1.63

Refractive index of diamond, n_2 = 2.42

Or Refractive index of diamond with respect for carbon disulphide, $\ ^{1}n_2 = \frac{n_2}{n_1} = \frac{2.42}{1.63} = 1.48$

EXAMPLE – 14

A coin is placed in a tumbler, water is then filled in the tumbler to a height of 20 cm. If the refractive index of water is 4/3, calculate the apparent depth of the coin.

Solution

Here, Real depth, h = 20 cm

Refractive index, n = 4/3

Now, $n = \frac{\text{real depth}}{\text{apparent depth}}$ or $\frac{4}{3} = \frac{20}{\text{apparent depth}}$

or Apparent depth $= \frac{20\times 3}{4}$ = 15 cm

EXAMPLE – 15

There is a black spot on a table. A glass slab of thickness 6 cm is placed on the table over the spot. Refractive index of glass is 3/2. At what depth from the upper surface will the spot appear when viewed from above?

Solution

Real depth of the spot = 6 cm

Refractive index of glass, $n = \frac{3}{2}$

Now, $n = \frac{\text{real depth}}{\text{apparent depth}}$ or $\frac{3}{2} = \frac{6}{\text{apparent depth}}$

Or Apparent depth $= \frac{6\times 2}{3}$ = 4 cm

EXAMPLE – 16

Refractive index of diamond is 2.42 and that of glass is 1.5. Calculate the critical angle for diamond-glass surface.

Solution

Refractive index of diamond, n_1 = 2.42

Refractive index of glass, n_2 = 1.5

Now, $\sin i_C = \frac{n_2}{n_1} = \frac{1.5}{2.42} = 0.6198$

Or $i_C = \sin^{-1} 0.62$

EXAMPLE – 17

Refractive index of glass is 3/2. A ray of light travelling in glass is incident on glass-water surface at an angle 30° with normal. Will it be able to come out into the water Refractive index of water = 4/3.

Solution

Refractive index of glass, n_1 = 3/2

Refractive index of water, n_2 = 4/3

Now, $\sin i_C = \frac{n_2}{n_1} = \frac{4/3}{3/2} = \frac{8}{9} = 0.88$ Or $i_C = 62°$

Since, the angle of incidence (30°) is less than the critical angle, the ray will be refracted into the water.

EXAMPLE – 18

The refractive index of dense flint glass is 1.65 and that of alcohol is 1.36, both with respect to air. What is the refractive index of flint glass with respect to alcohol ?

Solution

Refractive index of flint glass, $n_2 = 1.65$

Refractive index of alcohol, $n_1 = 1.36$

Or Refractive index of flint glass with respect to alcohol is given by $^1n_2 = \frac{n_2}{n_1} = \frac{1.65}{1.36} = 1.21$

EXAMPLE – 19

An object is placed 36 cm from a convex lens. A real image is formed 24 cm from the lens. Calculate the focal length of the lens.

Solution

According to the sign convention the object is placed on the left-hand side of the lens. So object distance (u) is negative. Real image is formed on the other side of the lens. So the image distance (v) is positive. Thus,

u = –36 cm, v = +24 cm, f = ?

Using lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, we get

$\frac{1}{+24} - \frac{1}{-36} = \frac{1}{f}$ or $\frac{1}{f} = \frac{1}{24} + \frac{1}{36} = \frac{5}{72}$

Or $f = \frac{72}{5} = 14.4$ cm

EXAMPLE – 20

A 2 cm long pin is placed perpendicular to the principal axis of a lens of focal length 15 cm at distance of 25 cm from the lens. Find the position of image and its size.

Solution

Here, u = –25 cm, f = +15

Using the lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ we get

or $\frac{1}{v} - \frac{1}{-25} = \frac{1}{+15}$ or $\frac{1}{v} = \frac{1}{15} - \frac{1}{25} = \frac{2}{75}$

or $v = \frac{75}{2} = 37.5$ cm

The positive sign shows that the image is formed on the right-hand side of the lens.

Magnification is given by

$m = \frac{h'}{h} = \frac{v}{u}$ or $\frac{h'}{h} = \frac{37.5}{-25} = -1.5$

Or h = – 1.5 × h = –1.5 × 2 cm = –3 cm

The image of the pin is 3 cm long.

The negative sign shows that it is formed below the principal axis, i.e. the image is inverted.

EXAMPLE – 21

A point object is placed at a distance of 18 cm from a convex lens on its principal axis. Its image is formed on the other side of the lens at 27 cm. Calculate the focal length of the lens.

Solution

According to the sign convention, the object is placed on the left-hand side of the lens, therefore object-distance is negative,

i.e. u = –18 cm. Since the image is formed on the other side, the image-distance is positive, i.e., v = +27 cm. Using lens formula,

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, we have $\frac{1}{+27} - \frac{1}{-18} = \frac{1}{f}$

or $\frac{1}{27} + \frac{1}{18} = \frac{5}{54} = \frac{1}{f}$ or $f = \frac{54}{5} = 10.8$ cm

EXAMPLE – 22

A convex lens forms an image of the same size as the object at a distance of 30 cm from the lens. Find the focal length of the lens. Also find power of the lens. What is the distance of the object from the lens ?

Solution

A convex lens forms the image of the same size as the object only when the object is placed at a distance 2f from the lens. In this case the image is also equal to 2f from the lens.

Hence, 2f = 30 cm or f = 15 cm = 0.15 m

Power of the lens, $P = \frac{1}{f} = \frac{1}{0.15}$ D = 6.6D

The distance of the object from the lens is also 2f = 30 cm.

EXAMPLE – 23

A 3 cm high object is placed at a distance of 80 cm from a concave lens of focal length 20 cm. Find the position and size of the image.

Solution

Here, u = –80 cm, f = – 20 cm

Using the lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, we get

Or $\frac{1}{v} - \frac{1}{-80} = \frac{1}{-20}$ or $\frac{1}{v} = -\frac{1}{20} - \frac{1}{80} = \frac{-5}{80} = -\frac{1}{16}$

or $v = -16$ cm

Magnification, $m = \frac{h'}{h} = \frac{v}{u} = \frac{-16}{-80} = \frac{1}{5}$

or $h' = \frac{h}{5} = \frac{3.0}{5} = 0.6$ cm

Length of image is 0.6 cm. Positive sign shows that the image is erect.

EXAMPLE – 24

An object is placed on the principal axis of a concave lens at a distance of 40 cm from it. If the focal length of the lens is also 40 cm, find the location of the image and the magnification.

Solution

For a concave lens focal length f is negative, i.e. f = –40 cm. Since by convention, object is placed on the left of the lens, so u = – 40 cm.

Using the lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, we get

or $\frac{1}{v} - \frac{1}{-40} = \frac{1}{-40}$ or $\frac{1}{v} = -\frac{1}{40} - \frac{1}{40} = -\frac{1}{20}$

or v = – 20 cm

The image is formed 20 cm from the lens. Minus sign shows that the image is formed on the same side of the lens as the object.

Now, magnification, $m = \frac{h'}{h} = \frac{v}{u} = \frac{-20}{-40} = \frac{1}{2}$

Positive sign shows that the image is erect.

EXAMPLE – 25

A beam of light travelling parallel to the principal axis of a concave lens appears to diverge from a point 25 cm behind the lens after refraction. Calculate the power of the lens.

Solution

When a parallel beam after refraction through the lens is incident on a concave lens, it appears to diverge from the focus of the lens. Hence, the focal length of the lens is 25 cm. According to sign convention, focal length of a concave lens is negative. f = –25 cm = –0.25 m

Power, $P = \frac{1}{f} = \frac{1}{-0.25} = -4D$

EXAMPLE – 26

A convex lens of power 5D is placed at a distance of 30 cm from a screen. At what distance from the lens should the screen be placed so that its image is formed on the screen?

Solution

Power of the lens, P = +5D

Focal length, $f = \frac{1}{5D} = \frac{1}{5} = 0.20$ m = 20 cm

Here, the screen is placed 30 cm from the lens.

Or v = +30 cm, f = +20 cm, u = ?

Using the lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, we get

Or $\frac{1}{30} - \frac{1}{u} = \frac{1}{20}$ or $\frac{1}{u} = \frac{1}{30} - \frac{1}{20} = -\frac{1}{60}$

or u = – 60 cm

Therefore, the screen should be placed at 60 cm from the lens.

EXAMPLE – 27

A pin 3 cm long is placed at a distance of 24 cm from a convex lens of focal length 18 cm. The pin is placed perpendicular to the principal axis. Find the position, size and nature of the image.

Solution

Here, u = –24 cm, f = +18 cm, v = ?

Using the lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, we get

$\frac{1}{v} - \frac{1}{-24} = \frac{1}{+18}$ or $\frac{1}{v} = \frac{1}{18} - \frac{1}{24} = \frac{1}{72}$

or v = 72 cm

The image is formed 72 cm from the lens on the other side. So the image is real.

Magnification, $m = \frac{h'}{h} = \frac{v}{u} = \frac{72}{-24} = -3$

or h' = –3 × h = –3 × 3.0 = – 9 cm

The image is 9 cm in size. Negative sign shows that the image is inverted.

EXAMPLE – 28

A concave lens has a focal length of 15 cm. At what distance should the object be from the lens placed so that it forms an image 10 cm from the lens ? Also find the magnification.

Solution

A concave lens always forms a virtual, erect image on the same side as the object.

Image distance, v = –10 cm
Focal length f = –15 cm
Object distance, u = ?

Using, the lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, we get

or $\frac{1}{-10} - \frac{1}{u} = \frac{1}{-15}$ or $-\frac{1}{10} = \frac{2-3}{30} = -\frac{1}{30}$

or u = –30 cm

Thus, the object should be placed 30 cm on the lens. Magnification, $m = \frac{v}{u} = \frac{-10}{-30} = \frac{1}{3} = 0.33$

The positive sign shows that the image is erect and virtual. The size of the image is one-third of that of the object.

EXAMPLE – 29

A 2 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 10 cm. The distance of object from the lens is 15 cm. Find the position, nature and size of the image. Calculate the magnification of the lens.

Solution

Object distance, $u = -15$ cm
Focal length, $f = +10$ cm
Object height, $h = +2$ cm
Image distance, $v = ?$
Image height, $h' = ?$

Using the lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$,

we get $\frac{1}{v} = \frac{1}{-15} = \frac{1}{+10}$ Or $\frac{1}{v} = \frac{1}{10} - \frac{1}{15} = \frac{+1}{30}$

or $v = +30$ cm

Positive sign of v shows that the image is formed at a distance of 30 cm on the right side of the lens. Therefore, the image is real and inverted

Magnification, $m = \frac{h'}{h} = \frac{v}{u}$

$\frac{h'}{2.0} = \frac{+30}{-15} = -2$ Or $h' = -2 \times 2 = -4$ cm

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

Negative sign with the magnification and height of the image shows that the image is inverted and real. Thus, a real image of height 4 cm is formed at a distance of 30 cm on the right side of the lens. Image is inverted and twice the size of the object.

IMPORTANT POINTS TO BE REMEMBER

1. **Refraction :** The bending of a ray of light as it passes from one medium to another is called refraction.
(a) A ray of light travelling from a rarer medium to denser medium (say, water or glass) bends towards the normal.
(b) A ray of light travelling from a denser to a rarer medium bends (or refractive) away from the normal.
2. **Laws of refraction :**
(a) The ratio of sine of the angle of incidence to the sine of the angle of refraction for a particular pair of media is constant, i.e. sin i / sin r = constant is equal to the refractive index of the medium into which the light is entering.
(b) The incident ray, the refracted ray and the normal all lie in the same plane.
3. **Lateral displacement :** The perpendicular distance of separation between the emergent ray and the original path of the incident ray is called lateral displacement.
4. **Lens :** A piece of any transparent material bound by two curved surfaces is called a lens. A lens which is thicker in the middle and thinner at the edges is called a convex lens. A convex lens is also called converging lens.
A lens which is thicker at the edges and thinner at the centre is called a concave lens.
A concave lens is also called a diverging lens.
5. **Optical centre of a lens :** The centre point of a lens is called its optical centre. A ray of light passing through the optical centre does not suffer any deviation.
6. **Image formed by the lenses :** A convex lens forms real and inverted images for all the positions of an object at and outside the focus (F). However, when the object is placed between F and O, the image formed by a convex lens is virtual and erect.
A concave lens always forms a virtual, erect and a diminished image whatever may be the distance of the object from the lens.
7. **Lens formula:**The lens formula is $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$.
8. **Power of a lens :** Reciprocal of the focal length of a lens measured in metres is called its power. Power of a lens is described in dioptre (D) unit.
9. **Refractive indices of various substances relative to vacuum with light of wavelength 589 mm.**
10. **Solids (at 20°C)**

Substance	Refractive index
Diamond	2.42
Ruby	1.71
Sapphire	1.77
Quartz (fused)	1.46
Canada Balsam	1.53
Rock salt	1.54
Glass (crown)	1.52
Glass (flint)	1.66
Ice	1.31

11. **Liquids (at 20°C)**

Substance	Refractive index
Water	1.33
Ethyl alcohol	1.36
Kerosene	1.44
Turpentine oil	1.47
Glycerine	1.47
Benzene	1.5
Carbon disulphide	1.63

12. Gases (at 0ºC, 1 atm)

Substance	Refractive index
Air	1.00029
Carbon dioxide	1.00045

PROBLEMS
LEVEL – 1

1. The angle of reflection is equal to the angle of incidence :
(a) always (b) sometimes
(c) under special conditions (d) never
2. The angle between an incident ray and the plane mirror is 30°. The total angle between the incident ray and reflected ray will be :
(a) 30° (b) 60° (c) 90° (d) 120°
3. A ray of light is incident on a plane mirror making an angle of 90° with the mirror surface. The angle of reflection for this ray of light will be :
(a) 45° (b) 90° (c) 0° (d) 60°
4. The image of an object formed by a plane mirror is :
(a) virtual (b) real
.(c) diminished (d) upside-down
5. The image formed by a plane mirror is :
(a) virtual, behind the mirror and enlarged.
(b) virtual, behind the mirror and of the same size as the object.
(c) real, at the surface of the mirror and enlarged. .
(d) real, behind the mirror and of the same size as the object.
6. In a convex spherical mirror, reflection of light takes place at :
(a) a flat surface
(b) a bent-in surface
(c) a bulging-out surface
(d) an uneven surface
7. A diverging mirror is :
(a) a plane mirror (b) a convex mirror
(c) a concave mirror (d) a shaving mirror
8. If R is the radius of curvature of a spherical mirror and f is its focal length, then :
(a) R = f (b) R = 2f
(c) R = 2f (d) R = 3f
9. The focal length of a spherical mirror of radius of curvature 30 cm is :
(a) 10 cm (b) 15 cm
(c) 20 cm (d) 30 cm
10. If the focal length of a spherical mirror is 12.5 less cm, its radius of curvature will be
(a) 25 cm (b) 15 cm
11. (c) 20 cm (d) 35 cm
12. The real image formed by a concave mirror is larger than the object when the object is :
(a) at a distance equal to radius of curvature
(b) at a distance less than the focal length
(c) between focus and centre of curvature
(d) at a distance greater than radius of curvature
13. The real image formed by a concave mirror is smaller than the object if the object is :
(a) between centre of curvature and focus
(b) at a distance greater than radius of curvature
(c) at a distance equal to radius of curvature
(d) at a distance equal to focal length
14. The image formed by a concave mirror is virtual, erect and magnified. The position of object is :
(a) at focus
(b) between focus and centre of curvature
(c) at pole
(d) between pole and focus
15. The image formed by a concave mirror is real, inverted and of the same size as the object. The position of the object must then be :
(a) at the focus
(b) between the centre of curvature and focus
(c) at the centre of curvature
(d) beyond the centre of curvature
16. The image formed by a concave mirror is real, inverted and highly diminished(much smaller than the object). The object must be:
(a) between pole and focus
(b) at focus
(c) at the centre of curvature
(d) at infinity
17. The angle of incidence for a ray of light passing through the centre of curvature of a concave mirror is :
(a) 45° (b) 90° (c) 0° (d) 180°
18. In the concave reflector of a torch, the bulb is placed :
(a) between the pole and focus of reflector
(b) at the focus of reflector
(c) between focus and centre of curvature of reflector

(d) at the centre of curvature of reflector

19. The focal length of a small concave mirror is 2.5 cm. In order to use this concave mirror as a dentist's mirror, the distance of tooth from the mirror should be :
(a) 2.5 cm (b) 1.5 cm
(c) 4.5 cm (d) 3.5 cm

20. According to New Cartesian Sign Convention :
(a) focal length of concave mirror is positive and that of convex mirror is negative
(b) focal length of both concave and convex mirrors is positive
(c) focal length of both concave and convex mirrors is negative
(d) focal length of concave mirror is negative and that of convex mirror is positive

21. One of the following does not apply to a concave mirror. This is :
(a) focal length is negative
(b) image distance can be positive or negative
(c) image distance is always positive
(d) height of image can be positive or negative

ANSWERS:

1. (a) 2. (d) 3. (c) 4. (a) 5. (b) 6. (c)
7. (b) 8. (b) 9. (b) 10. (a) 11. (c) 12. (b)
13. (d) 14. (c) 15. (d) 16. (c) 17. (b) 18. (b)
19. (d) 20. (c) 21. (c).

PROBLEMS FOR PRACTICE
LEVEL – 2

1. According to the "New Cartesian Sign Convention" for mirrors, what sign has been given to the focal length of :
(i) a concave mirror ?
(ii) a convex mirror ?
2. Which type of mirror has :
(a) positive focal length ?
(b) negative focal length ?
3. What is the nature of a mirror having a focal length of, +10 cm ?
4. What kind of mirror can have a focal length of, – 20 cm ?
5. Fill in the following blanks with suitable words :
(a) Parallel rays of light are reflected by a concave mirror to a point called the ....
(b) The focal length of a concave mirror is the distance from the ....to the mirror.
(c) A concave mirror.............rays of light whereas a convex mirror..........rays of light.
(d) For a convex mirror, parallel rays of light appear to diverge from a point called the.......... .

ANSWERS:

(a) principal focus (b) principal focus
(c) converges ; diverges (d) principal focus

PROBLEM FOR PRACTICE
LEVEL – 3

1. A ray of light is incident normally on a plane mirror. What will be the :
(a) angle of incidence ?
(b) angle of reflection ?
2. What type of image is formed :
(a) in a plane mirror ?
(b) on a cinema screen ?
3. Name the phenomenon responsible for the following effect : When we sit in front of a plane mirror and write with our right hand, it appears in the mirror that we are writing with the left hand.
4. If an object is placed at a distance of 10 cm in from of a plane mirror, how far would it be from its image ?
5. Which property of light makes a pencil cast a shadow when it is held in front of a light source ?
6. The image seen in a plane mirror cannot be formed on a screen. What name is given to this type of image ?
7. Fill in the following blank with a suitable word : When light is reflected, the angles of incidence and reflection are..........
8. State whether the following statement is true or false :
A student says that we can see an object because light from our eyes is reflected back by the object.
9. Where is the image when you look at something in a mirror
10. The letter F is placed in front of a plane mirror :
(a) How would its image look like when seen in a plane mirror ?
(b) What is the name of the phenomenon involved?

11. What is lateral inversion? Explain by giving a suitable example.
12. What is meant by 'reflection of light'? Define the following terms used in the study of reflection of light by drawing a labelled ray-diagram :
    (a) Incident ray (b) Point of incidence
    (c) Normal (d) Reflected ray
    (e) Angle of incidence
    (f) Angle of reflection

ANSWER THE FOLLOWING
LEVEL – 4

1 What is the maximum angle of refraction when a ray of light is refracted from glass into air ?

2 What should be the position of an object relative to biconvex lens so that this lens behaves like a magnifying glass?

3 Can the absolute refractive index of a medium be less than unity?

4 To a fish under water viewing obliquely a fisherman standing on the bank of a lake, does the man look taller or shorter than what actually he is?

5 Does the apparent depth of a tank of water change if viewed obliquely? If so, does the apparent depth increase or decrease?

6 A substance has critical angle of 45° for yellow light. What is its refractive index?

7 What is critical angle for a material of refractive index $\sqrt{2}$?

8 A ray of light is incident normally on a glass slab. What is the angle of refraction?

9 What is the power of the combination of a convex lens and a concave lens of the same focal length?

10 How is power of a lens related to its focal length?

11 Define critical angle for total internal reflection.

12 Explain the shining of an air bubble in water.

13 For the same angle of incidence, the angles of refraction in media P, Q and R are 35°, 25°,15° respectively, In which medium will the velocity of light be minimum ?

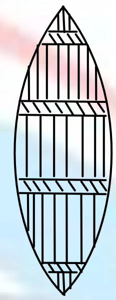
14 Define focus and principal focus of a lens.

15 A virtual image, we always say, cannot be caught on a screen. Yet when we 'see' a virtual image, we are obviously bringing it on to the 'screen' i.e., retina of our eye. Is there a contradiction?

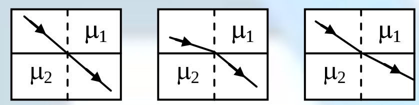
16 A convex lens is held in water. What would be the change in the focal length ?

17 Why goggles (Sun glasses) have zero power even though their surfaces are curved?

18 The lens shown in fig. is made of two different materials. A point objects is placed on the principal axis of this lens. How many images will be obtained?



19 Refer to fig. (a), (b) and (c). Give relationship between μ_1 and μ_2 in each case.



(a) (b) (c)

20 Images formed by totally reflected light are brighter than the images formed by ordinary reflected light. why ?

21 Can light travelling from air to glass suffer total internal reflection? Justify your answer.

22 What are the five general features of the image formed by a plane mirror ?

23 (a) What is total internal reflection? How is critical angle related to refractive index?

(b) A ray of light while travelling from a denser to a rarer medium undergoes total internal reflection. Derive the expression for the critical angle in terms of the speed of light in the respective media.

24 Discuss in detail refraction at
(i) convex surface (ii) concave surface.

25 Derive lens formula for a thin lens.

26 What is critical angle? Give one application of total internal reflection.

27 State Snell's law of refraction.

28 What is meant by power of a lens? What is one dioptre ?

NUMERICAL PROBLEMS

29 The speed of light in air is 3×10^8 m/s. Calculate the speed of light in glass given that the refractive index of glass is 1.5.

30 The refractive index of water with respect to air is 4/3. Calculate the refractive index of air with respect to water.

31 The refractive index of glass is 3/2. What is the critical angle for the glass-water surface?

32 A ray of light travelling in air falls on the surface of a glass slab at an angle of incidence 45°. Find the angle made by the refracted ray with the normal within the slab where refractive index for glass is 3/2.

33 A ray of light travelling in air is incident on the surface of a transparent material of refractive index $\sqrt{3}$. If the angle of refraction is 30°, calculate the angle of incidence.

34 Focal length of a convex lens is 50 cm. Calculate its power.

35 A point object is placed at a distance of 12 cm from a convex lens on its principal axis. Its image is formed 18 cm from the lens on the other side. Calculate the focal length of the lens.

36 An object is placed at a distance of 20 cm from a concave lens on its principal axis. If the focal length of the lens is 20 cm, find the position of the image.

37 A beam of light incident parallel to the principal axis of a concave lens appears to diverge from a point 20 cm behind the lens after refraction through the lens. Calculate the power of the lens.

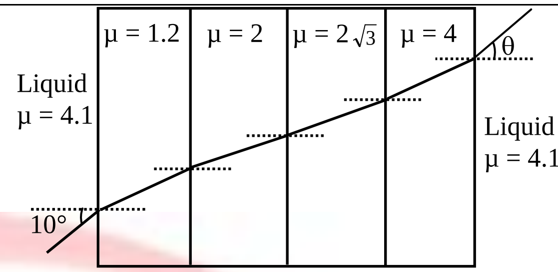
38 A pin 2 cm long is placed at a distance of 16 cm from a convex lens of focal length 12 cm perpendicular to the principal axis. Find the position, nature and size of the image.

39 A convex lens of focal length 20 cm and a concave lens of focal length 12.5 cm are placed in contact having the same principal axis. Calculate the power of the combined lens.

40 Two thin lenses of power +3.5D and –2.5D are placed in contact. Find the power and focal length of the lens combination.

41 An illuminated slit is kept at a distance of 40 cm in front of a convex lens of focal length 15 cm. Find the position of the screen to obtain the image.

42 A ray incident at a slab at angle 10° as shown in figure. Find angle of emergent



ANSWERS:

29. 2×10^8 m/s **30.** 3/4
31. 42º **32.** 28º **33.** 60º **34.** + 2D
35. 7.2 cm **36.** 10 cm on the same side of lens
37. –5D
38. At 48 cm from the lens on the other side. Image is real, inverted and of size 6 cm.
39. –8D **40.** + 1D, 100 cm
41. 24 cm **42.** q = 10°.

OBJECTIVE PROBLEMS
LEVEL – 5

1. Linear magnification produced by a concave mirror may be :
(a) less than 1 or equal to 1
(b) more than 1 or equal to 1
(c) less than 1, more than 1 or equal to 1
(d) less than 1 or more than 1
2. Magnification produced by a convex mirror is always :
(a) more than 1 (b) less than 1
(c) equal to 1 (d) more or less than 1
3. Magnification produced by a plane mirror is :
(a) less than one (b) greater than one
(c) zero (d) equal to one
4. In order to obtain a magnification of, –2 (minus 2) with a concave mirror, the object should be placed :
(a) between pole and focus
(b) between focus and centre of curvature
(c) at the centre of curvature
(d) beyond the centre of curvature
5. A concave mirror produces a magnification of + 4. The object is placed :
(a) at the focus
(b) between focus and centre of curvature
(c) between focus and pole
(d) beyond the centre of curvature
6. If a magnification of, –1 (minus one) is to be obtained by using a converging mirror, then the object has to be placed :
(a) between pole and focus
(b) at the centre of curvature

(c) beyond the centre of curvature
(d) at infinity

7. In order to obtain a magnification of, – 0.6 (minus 0.6) with a concave mirror, the object must be placed :
(a) at the focus
(b) between pole and focus
(c) between focus and centre of curvature
(d) beyond the centre of curvature

8. An object is placed at a large distance in front of a concave mirror of radius of curvature 40 cm. The image will be formed in front of the mirror at a distance of :
(a) 20 cm (b) 30 cm
(c) 40 cm (d) 50 cm

9. 40. In order to obtain a magnification of, –1.5 with a concave mirror of focal length 16 cm, the object will have to be placed at a distance :
(a) between 6 cm and 16 cm
(b) between 32 cm and 16 cm
(c) between 48 cm and 32 cm
(d) beyond 64 cm

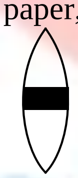
10. Linear magnification (m) produced by a rear view mirror fitted in vehicles :
(a) is equal to one
(b) is less than one
(c) is more than one
(d) can be more or less than one depending on the position of object

ANSWERS:

1. (c) 2. (b) 3. (d) 4. (b) 5. (c) 6. (b)
7. (d) 8. (a) 9. (b) 10. (b)

OBJECTIVE PROBLEMS
LEVEL – 6

1 How will the image formed by a convex lens be affected, if the central portion of the lens is wrapped in black paper, as shown in the fig.



(A) No image will be formed
(B) Full image will be formed but it is less bright
(C) Full image will be formed but without the central portion
(D) Two images will be formed, one due to each exposed half.

2 The critical angle for light going from medium X into medium Y is q. The speed of light in medium X is u. The speed of light in medium Y is
(A) u (1 – cos q) (B) u/cos q
(C) u cos q (D) u/sin q

3 One surface of a lens is convex and the other is concave. If the radii of curvature are r_1 and r_2 respectively, the lens will be convex, if
(A) $r_1 > r_2$ (B) $r_1 = r$
(C) $r_1 < r_2$ (D) $r_1 = 1/r_2$

4 An object is immersed in a fluid. In order that the object becomes invisible, it should
(A) behave as a perfect reflector
(B) absorb all light falling on it
(C) have refractive index one
(D) have refractive index exactly matching with that of the surrounding fluid.

5 R.I. of glass w.r.t. air is $\frac{3}{2}$, then the R.I. of air w.r.t. glass is:
(A) $\frac{3}{4}$ (B) $\frac{2}{3}$ (C) $\frac{1}{3}$ (D) 3

6 Refractive index of glass with respect to air is 1.5 and refractive index of water with respect to air is $\frac{4}{3}$. What will be the refractive index of glass with respect to water?
(A) 1 (B) 1.5 (C) 1.125 (D) –10

7 The refractive index of a medium depends upon
(A) Nature of material of the medium
(B) Optical density of the medium
(C) Wavelength of light
(D) All of these

8 If refractive index of water w.r.t. air is $\frac{4}{3}$, then refractive index of air w.r.t. water will be-
(A) 4 × 3 (B) $\frac{3}{4}$ (C) $\sqrt{\frac{4}{3}}$ (D) $\sqrt{\frac{3}{4}}$

9 A ray of light is incident normally on a rectangular piece of glass. The value of angle of refraction will be
(A) 180° (B) 90° (C) 45° (D) 0°

10 What is the angle of deviation?
(A) Angle between the reflected ray and incident ray
(B) Angle between the reflected ray and refracted ray
(C) Angle between the incident ray and refracted ray

(D) angle between the incident ray and emergent ray

11 The speed of light in vacuum is 3.0×10^8 m/s. If the refractive index of a transparent liquid is 4/3, then the speed of light in the liquid is
(A) 2.25×10^8 m/s (B) 3×10^8 m/s
(C) 4×10^8 m/s (D) 4.33×10^8 m/s

12 A swimming pool appears to be 2m deep. Its actual depth is (m for water = 1.33)
(A) 2.66 m (B) 2 m
(C) 2.34 (D) 2.54 m

13 To get a real and inverted image of the same size as that of the object the object should be placed in front of the convex lens at
(A) F (B) 2F
(C) between F and 2F
(D) away from 2F, where F is focus

14 A spherical mirror and a spherical lens each have focal length of –10 cm. The mirror and lens are
(A) both convex (B) both concave
(C) mirror is convex and lens is concave
(D) mirror is concave and lens is convex

15 The power of a lens having focal length 50 cm is
(A) $\frac{1}{2}$D (B) 2D (C) 3D (D) 0.2 D

16 The focal length of a lens of power –2.0 D is
(A) –2.0 m (B) 0.2 m
(C) –0.5 m (D) 0.5 m

17 Two lenses of power + 5D and –5D are placed in close contact. The focal length of the combination is
(A) Zero (B) 0
(C) Zero or 0 (D) None of these

18 A student needs a lens of power –2.0 diopter to correct his distant vision. The focal length of the given lens is
(A) +50 cm (B) –50 cm
(C) 100 cm (D) –100 cm

19 Focal length of coloured goggles (Without number) is-
(A) zero (B) infinity
(C) between zero and infinity
(D) None of these

20 Where should an object be placed so that a real and inverted image of very large size is obtained, using a convex lens ?
(A) At the focus (B) At 2F
(C) Between F and 2F (D) Beyond 2F

21 A convex lens is
(A) Thicker at the middle, thinner at the edges
(B) Diverging
(C) Thicker at the edges thinner in the middle
(D) Of uniform thickness everywhere

22 A glass rod of refractive index 1.42 is immersed in kerosene. The refractive index of kerosene is 1.42. Then the rod will
(A) appear bent
(B) appear raised above the liquid
(C) become invisible (D) none of the above

23 The power of a lens whose focal length is 25 cm is
(A) 4 Diopter (B) 25 Diopter
(C) 0.04 Diopter (D) 2.5 Diopter

24 A thin lens is made with a material having refractive index m = 1.5. Both the sides are convex. It is dipped in water (m = 1.33). It will behave like
(A) convergent lens (B) a divergent lens
(C) a rectangular slab (D) a prism

25 Choose the correct option
(A) If the final rays are converging, we have a real image
(B) If the incident rays are converging, we have a real image
(C) If the image is virtual, the corresponding object is called a virtual object
(D) The image of a virtual object is called a virtual image

26 A convex lens forms a real image of a point object placed on its principal axis. If the upper half of the lens is painted black.
(A) the image will be shifted backward
(B) the image will not be shifted
(C) the intensity of the image will decrease
(D) both (B) and (C)

27 The minimum distance between an object and its real image formed by a convex lens of focal length f is
(A) f (B) 2f (C) 3f (D) 4f

ANSWERS:

1. B 2. D 3. C 4. D 5. B 6. C 7. D
8. B 9. D 10. D 11. A 12. A 13. B 14. B
15. B 16. C 17. B 18. B 19. B 20. A 21. A
22. C 23. A 24. A 25. A 26. D 27. D

OBJECTIVE PROBLEMS
LEVEL – 7

1. The image formed by a spherical mirror is virtual. The mirror will be :
(a) concave (b) convex
(c) either concave or convex (d) metallic

2. hatever be the position of the object, the image formed by a mirror is virtual, erect and smaller than the object. The mirror then must be :
(a) plane (b) concave
(c) convex (d) either concave or convex
3. The mirror used by a dentist to examine the teeth of a person is :
(a) convex (b) concave
(c) plane (d) any one of the above
4. If the image formed is always virtual, the mirror can be :
(a) concave or convex (b) concave or plane
(c) convex or plane (d) only convex
5. A concave mirror cannot be used as :
(a) a magnifying mirror (b) a torch reflector
(c) a dentist's mirror (d) a rear view mirror
6. A boy is standing in front of and close to a special mirror. He finds the image of his head bigger than normal, the middle part of his body of the same size, and his legs smaller than normal. The special mirror is made up of three types of mirrors in the following order from top downwards :
(a) Convex, Plane, Concave
(b) Plane, Convex, Concave
(c) Concave, Plane, Convex
(d) Convex, Concave, Plane
7. The mirror which can form a magnified image of an object is :
(a) convex mirror (b) plane mirror
(c) concave mirror
(d) both convex and concave mirrors
8. A real image of an object is to be obtained. The mirror required for this purpose is :
(a) convex (b) concave
(c) plane (d) either convex or concave
9. Consider two statements A and B given below : A : real image is always inverted B : virtual image is always erect Out of these two statements :
(a) only A is true (b) only B is true
(c) both A and B are true (d) none is true
10. Light travelling from a denser medium to a rarer medium along a normal to the boundary :
(a) is refracted towards the normal
(b) is refracted away from the normal
(c) goes along the boundary
(d) is not refracted
11. A ray of light passes from glass into air. The angle of refraction will be :
(a) equal to the angle of incidence
(b) greater than the angle of incidence
(c) smaller than the angle of incidence
(d) 45°
12. A ray of light travelling in air goes into water. The angle of refraction will be :
(a) 90°
(b) smaller than the angle of incidence
(c) equal to the angle of incidence
(d) greater than the angle of incidence
13. When a ray of light travelling in glass enters into water obliquely :
(a) it is refracted towards the normal
(b) it is not refracted at all
(c) it goes along the normal
(d) it is refracted away from the normal
14. A ray of light travelling in water falls at right angles to the boundary of a parallel-sided glass block. The ray of light :
(a) is refracted towards the normal
(b) is refracted away from the normal
(c) does not get refracted
(d) is reflected along the same path.
15. A ray of light passes from a medium X to another medium Y. No refraction of light occurs if the ray of light hits the boundary of medium Y at an angle of :
(a) 0° (b) 45° (c) 90° (d) 120°
16. The refractive indices of four substances P, Q, R and S are 1.50, 1.36, 1.77 and 1.31 respectively. The speed of light is the maximum in the substance :
(a) P (b) Q (c) R (d) S
17. The refractive indices of four materials A, B, C and D are 1.33, 1.43, 1.71 and 1.52 respectively. When the light rays pass from air into these materials, they refract the maximum in :
(a) material A (b) material B
(c) material C (d) material D
18. The refractive index of glass for light going from air to glass is 3/2 . The refractive index for light going from glass to air will be :
(a) 1/ 3 (b) 4/5 (c) 4/6 (d) 5/2
19. The refractive indices of four media A, B, C and D are 1.44, 1.52, 1.65 and 1.36 respectively. When light travelling in air is incident in these media at equal angles, the angle of refraction will be the minimum :
(a) in medium A (b) in medium B
(c) in medium C (d) in medium D
20. The refractive indexes of four substances P, Q, R and S are 1.77, 1.50, 2.42 and 1.31 respectively. When light travelling in air is

incident on these substances at equal angles, the angle of refraction will be the maximum in:
(a) substance P (b) substance Q
(c) substance R (d) substance S

21. The refractive index of water is :
(a) 1.33 (b) 1.50 (c) 2.42 (d) 1.36

22. The refractive index of water with respect to air is 4/3 . The refractive index of air with respect to water will be :
(a) 1.75 (b) 0.50 (c) 0.75 (d) 0.25

23. Refractive indices of water, sulphuric acid, glass and carbon disulphide are 1.33, 1.43, 1.53 and 1.63 respectively. The light travels slowest in :
(a) sulphuric acid (b) glass
(c) water (d) carbon disulphide

24. The refractive index of glass with respect to air is 3/2 and the refractive index of water with respect to air is 4/3 . The refractive index of glass with respect to water will be :
(a) 1.525 (b) 1.225 (c) 1.425 (d) 1.125

ANSWES:

1. (c) 2. (c) 3. (b) 4. (c) 5. (d) 6. (c)
7. (c) 8. (b) 9. (c) 10. (d) 11. (b) 12. (b)
13. (d) 14. (c) 15. (c) 16. (d) 17. (c) 18. (c)
19. (c) 20. (d) 21. (a) 22. (c) 23. (d) 24. (d)

OBJECTIVE PROBLEMS

LEVEL – 8

1. A convex lens has a focal length of 10 cm. At which of the following position should an object be placed so that this convex lens may act as a magnifying glass ?
(a) 15 cm (b) 7 cm (c) 20 cm (d) 25 cm

2. Which one of the following materials cannot be used to make a lens ?
(a) Water (b) Glass
(c) Plastic (d) Clay

3. A small bulb is placed at the focal point of a converging lens. When the bulb is switched on, the lens produces :
(a) a convergent beam of light
(b) a divergent beam of light
(c) a parallel beam of light
(d) a patch of coloured light

4. An illuminated object is placed at a distance of 20 cm from a converging lens of focal length 15 cm. The image obtained on the screen is :
(a) upright and magnified
(b) inverted and magnified
(c) inverted and diminished
(d) upright and diminished

5. An object is placed between f and 2f of a convex lens. Which of the following statements correctly describes its image ?
(a) real, larger than the object
(b) erect, smaller than the object
(c) inverted, same size as object
(d) virtual, larger than the object

6. Which of the following can make a parallel beam of light when light from a bulb falls on it?
(a) concave mirror as well as concave lens
(b) convex mirror as well as convex lens
(c) concave mirror as well as convex lens
(d) convex mirror as well as concave lens

7. In order to obtain a real image twice the size of the object with a convex lens of focal length 15 cm, the object distance should be :
(a) more than 5 cm but less than 10 cm
(b) more than 10 cm but less than 15 cm
(c) more than 15 cm but less than 30 cm
(d) more than 30 cm but less than 60 cm

8. A spherical mirror and a spherical lens each have a focal length of, –15 cm. The mirror and the lens are likely to be :
(a) both concave. (b) both convex.
(c) the mirror is concave but the lens is convex.
(d) the mirror is convex but the lens is concave.

9. Linear magnification produced by a convex lens can be :
(a) less than 1 or more than 1
(b) less than 1 or equal to 1
(c) more than 1 or equal to 1
(d) less than 1, equal to 1 or more than 1

10. Magnification produced by a concave lens is always :
(a) more than 1 (b) equal to 1
(c) less than 1
(d) more than 1 or less than 1

11. In order to obtain a magnification of, – 3 (minus 3) with a convex lens, the object should be placed :

(a) between optical centre and F
(b) between F and 2F
(c) at 2F (d) beyond 2F

12. A convex lens produces a magnification of +5. The object is placed :
(a) at focus (b) between f and 2f
(c) at less than f (d) beyond 2f

13. If a magnification of, –1 (minus 1) is obtained by using a converging lens, then the object has to be placed :
(a) within f (b) at 2f
(c) beyond 2f (d) at infinity

14. To obtain a magnification of, – 0.5 with a convex lens, the object should be placed :
(a) at F (b) between optical centre and F
(c) between F and 2F
(d) beyond 2F

15. An object is 0.09 m from a magnifying lens and the image is formed 36 cm from the lens. The magnification produced is :
(a) 0.4 (b) 1.4 (c) 4.0 (d) 4.5

16. To obtain a magnification of, –2 with a convex lens of focal length 10 cm, the object should be placed :
(a) between 5 cm and 10 cm
(b) between 10 cm and 20 cm
(c) at 20 cm (d) beyond 20 cm

17. A convex lens of focal length 15 cm produces a magnification of + 4. The object is placed :
(a) at a distance of 15 cm
(b) between 15 cm and 30 cm
(c) at less than 15 cm
(d) beyond 30 cm

18. If a magnification of, –1 is to be obtained by using a converging lens of focal length 12 cm, then the object must be placed :
(a) within 12 cm (b) at 24 cm
(c) at 6 cm (d) beyond 24 cm

19. In order to obtain a magnification of, – 0.75 with a convex lens of focal length 8 cm, the object should be placed :
(a) at less than 8 cm
(b) between 8 cm and 16 cm
(c) beyond 16 cm (d) at 16 cm

20. A diverging lens is used in :
(a) a magnifying glass
(b) a car to see objects on rear side
(c) spectacles for the correction of short sight
(d) a simple camera

21. When an object is kept at any distance in front of a concave lens, the image formed is always :
(a) virtual, erect and magnified
(b) virtual, inverted and diminished.
(c) virtual, erect and diminished
(d) virtual, erect and same size as object

22. A concave lens produces an image 20 cm from the lens of an object placed 30 cm from the lens. The focal length of the lens is :
(a) 50 cm (b) 40 cm
(c) 60 cm (d) 30 cm

23. Only one of the following applies to a concave lens. This is :
(a) focal length is positive
(b) image distance can be positive or negative
(c) height of image can be positive or negative
(d) image distance is always negative

24. The magnification produced by a spherical mirror and a spherical lens is + 0.8.
(a) The mirror and lens are both convex
(b) The mirror and lens are both concave
(c) The mirror is concave but the lens is convex
(d) The mirror is convex but the lens is concave

25. The magnification produced by a spherical lens and a spherical mirror is + 2.0.
(a) The lens and mirror are both concave
(b) The lens and mirror are both convex
(c) The lens is convex but the mirror is concave
(d) The lens is concave but the mirror is convex

26. The focal lengths of four convex lenses P, Q, R and S are 20 cm, 15 cm, 5 cm and 10 cm, respectively. The lens having greatest power is:
(a) P (b) Q (c) R (d) S

27. A converging lens has a focal length of 50 cm. The power of this lens is :
(a) + 0.2 D (b) – 2.0 D
(c) + 2.0 D (d) – 0.2 D

28. A diverging lens has a focal length of 0.10 m. The power of this lens will be :

(a) + 10.0 D (b) + 1.0 D
(c) – 1.0 D (d) – 10.0 D

29. The power of a lens is + 2.0 D. Its focal length should be :
(a) 100 cm (b) 50 cm
(c) 25 cm (d) 40 cm

30. If a spherical lens has a power of, – 0.25 D, the focal length of this lens will be :
(a) – 4 cm (b) – 400 mm
(c) – 4 m (d) – 40 m

31. The power of a concave lens is 10 D and that of a convex lens is 6 D. When these two lenses are placed in contact with each other, the power of their combination will be :
(a) + 16 D (b) + 4 D
(c) –16 D (d) – 4 D

32. The power of a converging lens is 4.5 D and that of a diverging lens is 3 D. The power of this combination of lenses placed close together is :
(a) + 1.5 D (b) + 7.5 D
(c) – 7.5 D (d) – 1.5 D

33. A convex lens of focal length 10 cm is placed in contact with a concave lens of focal length 20 cm. The focal length of this combination of lenses will be :
(a) + 10 cm (b) + 20 cm
(c) – 10 cm (d) – 20 cm

ANSWERS:

1. (b) 2. (d) 3. (c) 4. (b) 5. (a) 6. (c)

7. (c) 8. (a) 9. (d) 10. (c) 11. (b)

12. (c) 13. (b) 14. (d) 15. (c) 16. (b)

17. (c) 18. (b) 19. (c) 20. (c) 21. (c)

22. (c) 23. (d) 24. (d) 25. (c) 26. (c)

27. (c) 28. (d) 29. (b) 30. (c) 31. (d)

32.. (a) 33. (b)

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