# 1 CHAPTER

# Light-Reflection and Refraction

## School Level

### Introduction

We see a variety of objects in the world around us. However, we are unable to see anything in the dark room. On lighting up the room, things become visible. It is light that makes things visible.

Light is a form of energy (optical energy) that helps us to see objects around us.

### Reflection of Light

- **Definition:** When rays of light are incident on an opaque smooth polished surface, they are bounced back in the same medium. This phenomenon of bouncing back of rays of light in the same medium, is called reflection of light.

**Some useful terms associated with the reflection of light:**

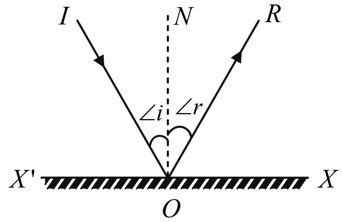



Fig. 1

- **Point of incidence:** The point on the reflecting surface at which a ray of light strikes at the time of reflection is known as the point of incidence. In the diagram shown, $O$ is the point of incidence.
- **Reflecting surface:** The reflecting surface is the surface from which the light is reflected after striking. In the diagram shown, $X'X$ is the reflecting surface.
- **Normal:** A perpendicular drawn on the reflecting surface at the point of incidence, is called the normal. In the diagram shown, $ON$ is the normal.
- **Incident ray:** The light ray which strikes the reflecting surface at the point of incidence is known as the incident ray. In the diagram shown, $IO$ is the incident ray.
- **Reflected ray:** The ray of light reflected from the reflecting surface at the point of incidence, is known as the reflected ray. In the diagram shown, $OR$ is the reflected ray.
- **Angle of incidence:** The angle that the incident ray makes with the normal at a point of incidence, is known as the angle of incidence. It is represented by the symbol '$i$'. In the diagram, shown, $\angle ION$ is the angle of incidence.
- **Angle of reflection:** The angle that the reflected ray makes with the normal at a point of incidence, is known as the angle of reflection. It is represented by the symbol '$r$'. In the diagram shown, $\angle RON$ is the angle of reflection.
- **Plane of incidence:** The plane in which the normal and the incident ray lie, is known as the plane of incidence. In the diagram shown, the plane of the book page, is the plane of incidence.
- **Plane of reflection:** The plane in which the normal and the reflected ray lie, is known as the plane of reflection. In the diagram shown, the plane of the book page, is the plane of reflection.

### Laws of Reflection of Light

- **First law of reflection:** The second law of reflection states that, the angle of incidence ($\angle i$) is equal to the angle of reflection ($\angle r$).

  i.e., $\angle i = \angle r$
- **Second law of reflection:** The incident ray, the reflected ray and the normal to the reflecting surface at a point of incidence all lie in the same plane.

## Some Special Cases in Reflection

- **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. According to the law of reflection, $\angle r = \angle i$, since $\angle i = 0$ therefore $\angle r = 0$ i.e., the reflected ray is also perpendicular to the surface. Thus, an incident ray normal to the surface retraces its path as shown in the figure.

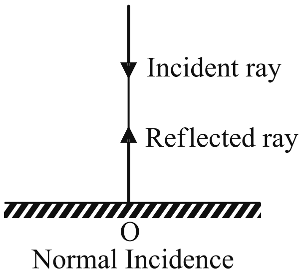


Fig. 2

- **Reflection through spherical or curved surface**

  Laws of reflection are also obeyed when light is reflected from the spherical or curved surfaces as shown in the figure below.

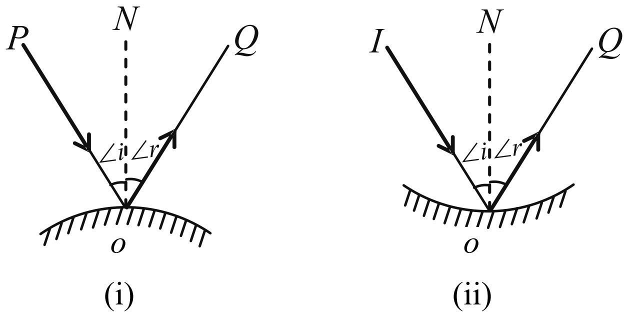


**Fig. 3:** Reflection from curved surface

## Plane Mirror

Consider the geometrical construction shown in the figure. Rays $OP$ and $OD$, starting from the object $O$, fall on the mirror. The another ray $OP$ is perpendicular to the mirror and reflects back along $PO$. The incident ray $OD$ and the respective reflected ray $DQ$ make equal angles with the normal $DG$. When the two reflected rays are produced backwards they meet at $I$, forming a virtual image there.

Here, $\angle QDG = \angle DIO$ ($DG \parallel IO$).

$\angle QDG = \angle GDO$ (From laws of reflection)

Also, $\angle GDO = \angle DOI$

$\therefore$ $\angle DIO = \angle DOI$

$OD = DI$

Now, $OD^2 - DP^2 = OP^2$

and $DI^2 - DP^2 = PI^2$

As, $OD = DI$,

$\therefore$ $OP^2 = PI^2$ or $OP = PI$.

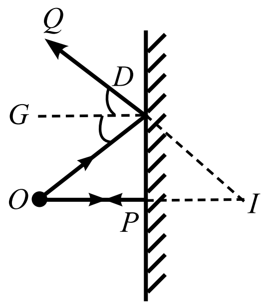


Fig. 4

So, in case of a plane mirror, the image distance from the mirror and the object distance from the mirror are equal

## Properties of Image formed by a Plane Mirror

- The size of the image is same as the size of the object.
- The distance between the image obtained from the mirror is same as the distance between the object from the mirror.
- Image obtained is virtual.
- The image is erect.
- The image is laterally inverted.

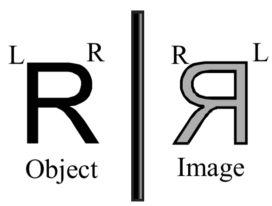


Fig. 5

- Lateral inversion: When you see your image in a vertical plane mirror then in the image the head is up and the feet are down, the same way as we actually stand on the floor. Such an image is known as an erect image. However, if you move your left hand, it will appear as your right hand is the image. Such an image in known as laterally inverted image and the phenomenon is known as lateral inversion.

## Spherical Mirror

A spherical mirror is a mirror that has the shape of a piece cut out of a spherical surface.

There are two types of spherical mirrors:

**(i) Concave mirror:** Spherical mirrors in which outward surfaces are painted and in ward surfaces polishe dare known as concave mirrors.

**(ii) Convex mirror:** Spherical mirrors in which inward surfaces are painted and out ward surfaces polished are known as convex mirrors.

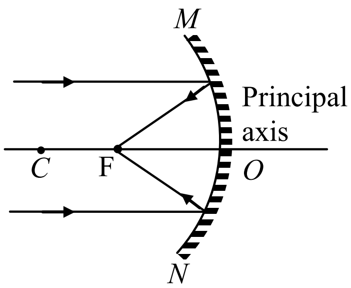


**Fig. 6:** Concave mirror

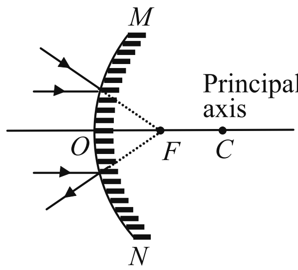


**Fig. 7:** Convex mirror

## Important Terms Related to Spherical Mirrors

- **Aperture:** An aperture of a spherical mirror gives the size of the mirror. In the above diagram, MN is the aperture of the mirror.
- **Pole:** The centre of the spherical surface of the mirror is know n as the pole of the mirror. It lies on the surface of the mirror. In the above diagram, O is the pole of the mirror.
- **Centre of curvature:** The centre of the spherical shell, of which the spherical mirror is a part, is known as centre of curvature of the mirror. It lies outside the surface of the mirror. Every point on mirror surface lies at the same distance from it. Here, C is the centre of curvature of the mirror as shown in above diagram.
- **Principal axis:** An imaginary straight line joining the pole of the mirror and the centre of curvature is known as the principal axis of the mirror.
- **Principal focus:** Principal focus 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 meet at this point (in case of a concave mirror) or appear to emerge from this point (in case of a convex mirror). In the above diagram, F is the principal focus of the mirror.
- **Radius of curvature:** The distance between the pole of the mirror and the centre of curvature, is known as the radius of curvature of the mirror. Radius of curvature is equal to the radius of the spherical shell of which the spherical mirror is a part. Here, OC is the radius of curvature of the mirror. It is represented by the symbol R.
- **Focal length:** Focal length is the distance between the pole and principal focus of the mirror. In the above diagram, OF is the focal length of the mirror. It is represented by the symbol f.

  For convex mirror $f = +\frac{R}{2}$

  For concave mirror $f = -\frac{R}{2}$

- **Principal section:** Principal section of a mirror is the part of the spherical mirror cut by a plane passing through its centre of curvature and the pole of the mirror. It contains the principal axis. In the diagram, *MPN* is the principal section of the mirror.

## Ray Diagram Method for Image Formation

### Rules for the Image Formation from Concave Mirror

(i) If the incident light ray is parallel to the principal axis, then the reflected ray passes through the focus.

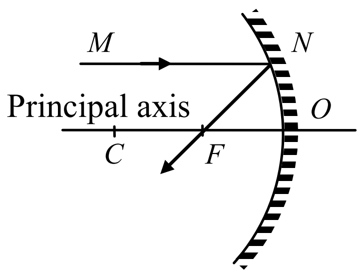



**Fig. 8**

(ii) If the incident light ray passes through the focus, the reflected ray becomes parallel to the principal axis.

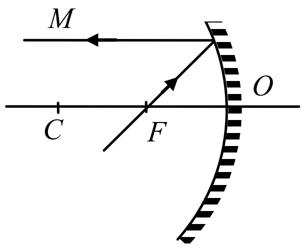



**Fig. 9**

(iii) If the light ray is incident on the pole of the mirror, it reflect back by following law of reflection

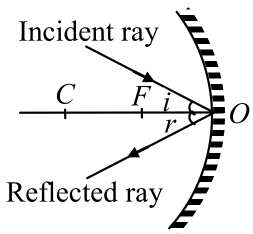



**Fig. 10**

(iv) If the incident light ray passes through the centre of curvature, it is reflected back and the reflected ray retraces its entire path.

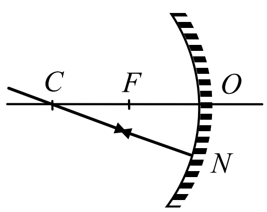



**Fig. 11**

## Rules for Image Formation from Convex Mirror

(i) If the incident light ray is parallel to the principal axis then after reflection it seems to be emerging from the focus.

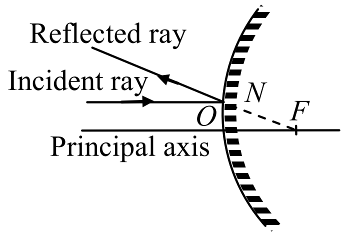



**Fig. 12**

(ii) If the incident light ray seems to pass through the focus, the reflected ray becomes parallel to the principal axis.

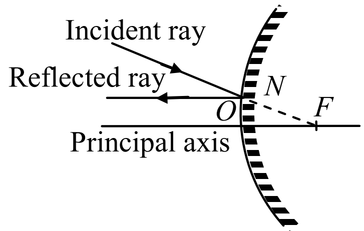



**Fig. 13**

(iii) If the light ray is incident on the mirror such that it is directed towards the centre of curvature, then after reflection the ray retraces its path.

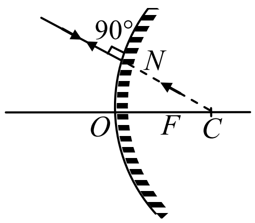



**Fig. 14**

# Image Formation by Spherical Mirror

## Concave Mirror

**When the Object is at Infinity**

If object is at infinity, rays come parallel to the principal axis and after reflection from the mirror meet at the principal focus $F$.

The image is formed at $F$. It is real inverted and point sized

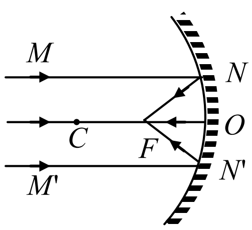



**Fig. 15:** Concave mirror : object placed at infinity, image at focus.

## When the Object is Beyond the Centre of Curvature

Object $PQ$ has its image $P'Q'$ formed between focus and centre of curvature of the mirror. The image is real, inverted and diminished.

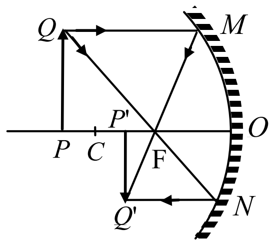



Fig. 16

## When the Object is at the Centre of Curvature

Object $PQ$ has its image $P'Q'$ formed at the centre of curvature of the mirror.

The image formed is real and inverted and has the same size as that of the object.

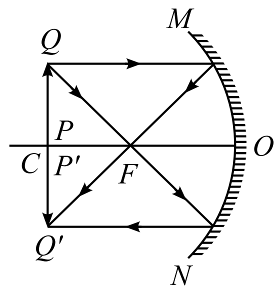



Fig. 17

## When the Object is between the Centre of Curvature and the Focus

Object $PQ$ has its image $P'Q'$ formed beyond centre of curvature The image is real, inverted and enlarged.

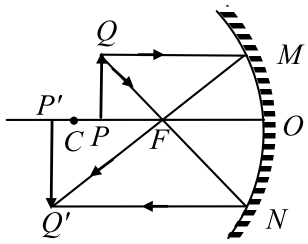



Fig. 18

## Object is placed at the Focus

Object $PQ$ has its image formed at infinity. The image is real, inverted and highly enlarged.

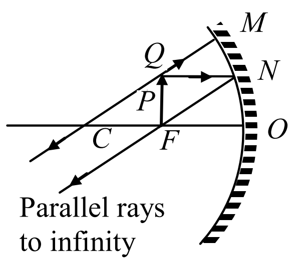



Fig. 19

**Object is placed between the Focus and the Pole**

Object $PQ$ has its image $P'Q'$ formed behind the mirror. The image is virtual, erect and enlarged.

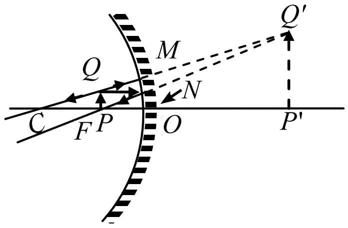



**Fig. 20:** Concave mirror : Object is between pole and focus, image is behind the mirror.

## Convex Mirror

**Object is at infinity**

Incident rays are parallel to the principal axis and after reflection from the mirror, the rays appear to diverge from focus $F$ behind the mirror. The image is formed at the focus, it is virtual erect and point sized.

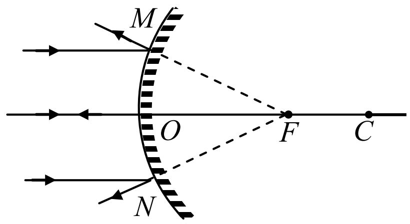



**Fig. 21:** Convex mirror : object at infinity, virtual image is at focus.

**Object is placed anywhere on the principal axis**

The image is formed between pole and focus and it is virtual, erect and diminished.

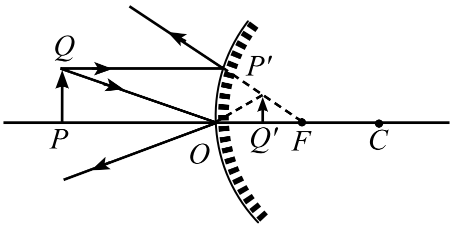



**Fig. 22**

## Images by Spherical Mirror

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

| | | | | |
|---|---|---|---|---|
| Convex mirror | At infinity | At $F$ | Virtual and erect | Highly diminished |
| | Between infinity and Pole | Between Pole & Focus | Virtual and erect | Diminished |

## Try it Yourself

Suppose that lower half of concave mirrors reflecting surface is covered with an opaque (non-reflecting) material. What effect will this have on the image of an object placed in front of the mirror?

## Sign Convention

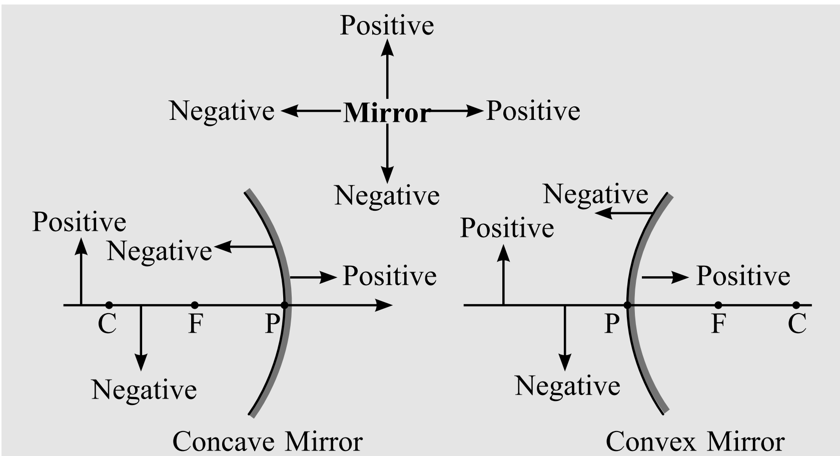
A sign convention is a used to provide the signs of distances measured from a pole.

The sign **convention** to be followed is the **New Cartesian** sign convention. It has the following rules:

(*a*) All distances are measured from the **pole** of the minor.

(*b*) The distances measured in the direction of the incident light are taken as **positive**. The distances measured in a direction **opposite** to the direction of the incident light are taken as **negative**.

(*c*) Distances measured **upward** and perpendicular to the principal axis are taken as **positive**, whereas the distances measured **downward** and perpendicular to the principal axis are taken as **negative**.




## Numerical Tools in Spherical Mirror

### Mirror Formula

- **Definition:** Mirror formula is the formula which gives the relationship between the object distance ($u$), the image distance ($v$) and the focal length ($f$) of the mirror It is applicable for both plane and spherical mirrors.

  **Mirror Formula:** $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

### Linear Magnification

- **Definition:** The ratio of the size of the image to the size of the object is known as linear magnification produced by the mirror. It is represented by the symbol m.

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

### Power of Mirror

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

## Refraction of Light

- **Definition:** Refraction is the phenomenon of bending of light as it travels from one medium to another medium.

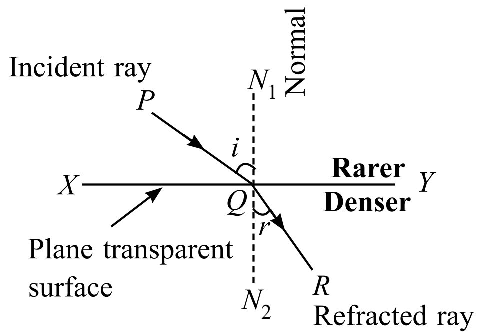



**Fig. 23:** Refraction of light from rarer to denser medium

### Important Terms Related to Refraction

- The plane surface that refracts light is known as the surface of refraction. In the above diagram, *XY* is the surface of refraction.
- **Point of incidence:** The point on the surface of refraction, where the ray of light is incident is known as the point of incidence. In the diagram, *Q* is the point of incidence.
- **Incident ray:** The ray of light which strikes the surface of refraction at the point of incidence, is known as the incident ray. In the diagram, *PQ* is the incident ray.
- **Refracted ray:** The ray which travels from the point of incidence to the other medium, is known as the refracted ray. In the diagram, *QR* is the refracted ray.
- **Normal:** Perpendicular drawn on the surface of refraction at the point of incidence, is called normal. In the diagram, $N_1N_2$ is the normal on the surface *XY*.
- **Angle of incidence:** The angle between, the incident ray and the normal at the point of incidence, is known as the angle of incidence. Angle of incidence is represented by the symbol '*i*'. In the diagram above, angle $PQN_1$ is the angle of incidence.
- **Angle of refraction:** The angle between, the refracted ray and the normal at the point of incidence, is known as the angle of refraction. It is represented by symbol '*r*'. In the diagram angle $RQN_2$ is the angle of refraction.
- **Plane of incidence and plane of refraction:** The plane containing the normal and the incident ray, is called plane of incidence. In the given diagram, plane of book page is the plane of incidence. The plane containing the normal and the refracted ray, is called plane of refraction. In the given diagram, plane of book page is the plane of refraction.

## Cause of Refraction

Every transparent medium has a property known as optical density. The optical density of a transparent medium is closely related to the speed of light in the medium. If the optical density of a transparent medium is low, then speed of light in that medium is high, such a medium in known, as optically rarer medium. So, the optically rarer medium is that medium through, which light travels faster.

Whereas, if optical density of a transparent medium is high, then the speed of light in that medium will be less. Such a medium is known as optically denser medium. So, a medium in which speed of light is slow is known as optically denser medium.

Speed of light in air is more than the speed of light in water, so air is optically rarer medium as compared to the water. Also, the speed of light in water is more than the speed of light in glass, so water is optically rarer medium as compared to the glass.

When light travels from air to glass then due to change in the speed of the light, its actual path get distorted and it bends from its original direction of propagation. Also, if light goes from glass to air, it bends from its original direction of propagation. This phenomena of bending of light from its path, is known as refraction. So, we can say that refraction of light takes place because the speed of light is different in different media. Thus, the cause of refraction of light is the change in the speed of light in different media.

### Knowledge Hub

- Refraction is the deviation of light from its path when it crosses the boundary between two different media (of different optical densities) and due to refraction, there is a change in both wavelength and speed of light, but the frequency of the refracted ray remains unchanged.
- The intensity of the incident ray is more than that of the refracted ray. This is because there is partial reflection and partial absorption of light at the interface.

## Laws of Refraction of Light

During refraction of light, the following two laws hold:

1. The incident ray, the refracted ray, and the normal at the point of incidence to the interface of two transparent media all lie in the same plane.
2. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant for the light of a given colour and a given pair of media. This law is also known as Snell's law.

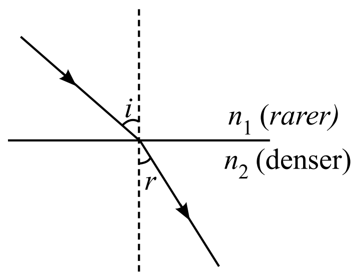


Fig. 24

If "$i$" is the angle of incidence and "$r$" is the angle of refraction, then,

$$\frac{\sin i}{\sin r} = \text{constant}$$

This constant value is the refractive index of the second medium with respect to the first medium $\left(n_{21} = \frac{n_2}{n_1}\right)$

## Refraction From a Glass Slab

### Refraction Through a Rectangular Glass Slab

Let us consider a rectangular glass slab *OPMN*, as shown in the figure. A ray *KL* is incident on the face *PM* at an angle of incidence '$i$'. On entering the glass slab, it bends towards the normal and travels along *LF* at an angle of refraction $r$. The refracted ray *LF* is incident on face ON at an angle of incidence $r'$. The emergent ray *FD* bends away from the normal at an angle of refraction '$e$', also called angle of emergence.

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

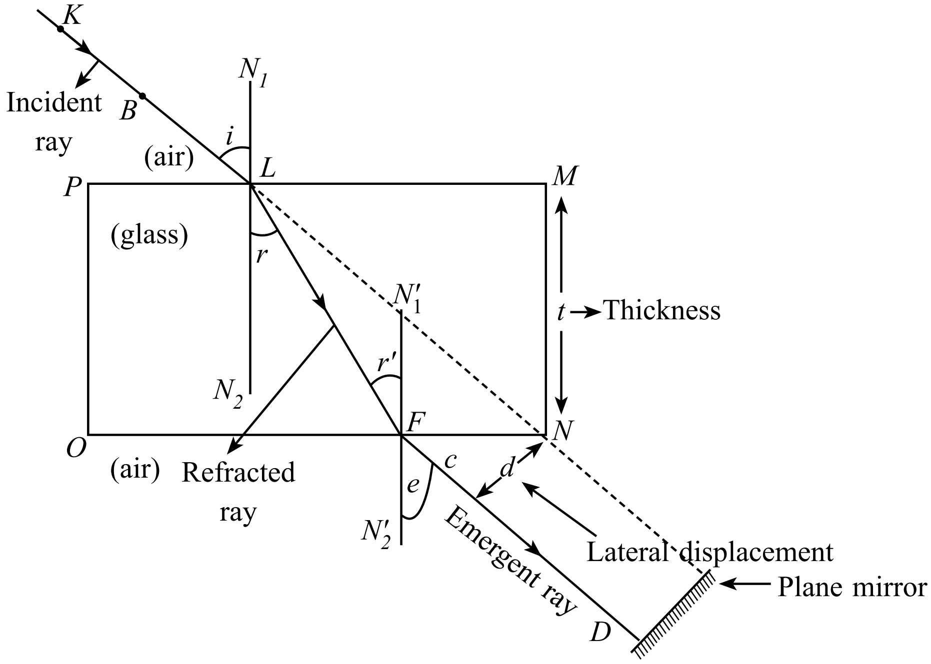



**Fig. 25:** Refraction of light through in glass slab

**Lateral shift:**

When light is incident obliquely on a refracting slab with parallel faces, then there is a shift in the path of light and the perpendicular distance between the incident and emergent ray is known as the lateral shift or lateral displacement.

**Factors affecting lateral shift are:**

(i) Thickness of the glass slab.

(ii) Refractive index of the glass slab.

(iii) Incident angle.

(iv) Wavelength of the incident light.

**Note:** Lateral shift is directly proportional to the thickness of the glass slab, the incident angle and the refractive index of the glass slab.

## Optically Rarer and Optically Denser Medium

- A transparent substance in which light travels is known as a medium.
- A medium in which the speed of light is more is known as an **optically rarer medium**. Air is an optically rarer medium than glass and water.

- A medium in which the speed of light is less is known as an **optically denser medium**. Glass is an optically denser medium than air and water.
- The term optical density is a relative factor; it means a substance can be **denser** if compared to one medium and **rarer** when compared to another.

We will now understand two rules that give the direction of bending a ray of light when it goes from one medium to another.

1. When the light ray enters from an optically rarer medium to the optically denser medium, it bends towards the normal. **(See figure 26 (*a*)).**
2. When the light ray enters from an optically denser medium to the optically rarer medium, it bends away from the normal. **(See figure 26 (*b*)).**

When a light ray is an incident normally on the surface, it refracts, but it does not bend or pass un-deviated. **(See figure 26 (c)).**

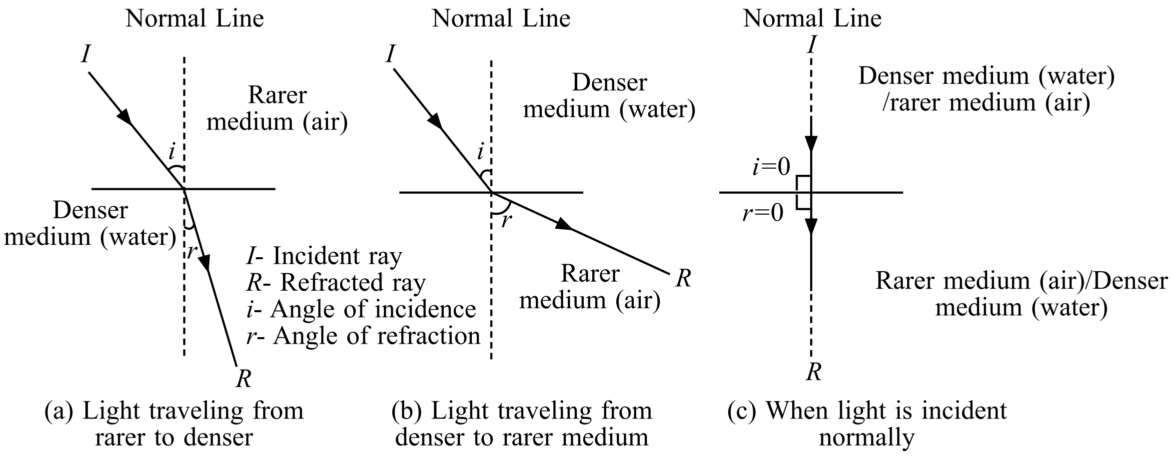



**Fig. 26:** Line Diagram to show Refraction of Light Through Different Media

## Refractive Index of a Medium

**(i) Refractive Index in terms of Speed of Light:**

The refractive index of a medium is defined as the ratio of speed of light in vacuum to the speed of light in that medium.

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

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

**(ii) Refractive Index in terms of Wavelength:**

Since the frequency ($f$) remains unchanged when light travels from one medium to another, therefore, refractive index ($\mu$) $= \dfrac{c}{v} = \dfrac{\lambda_{vac} \times f}{\lambda_{med} \times f} = \dfrac{\lambda_{vac}}{\lambda_{med}}$

**(iii) 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 it is denoted as ${}_1\mu_2$. Thus, relative refractive index of medium 2 with respect to medium 1.

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

Refractive index of a medium is unitless as it is the ratio of two similar physical quantities.

## Knowledge Hub

**The Refractive Index of a Medium Depends On the Following Factors:**

(i) Wavelength of the light used.

(ii) Nature of the medium.

Refractive index is the characteristic of the pair of the media and it also depends on the wavelength of light, but is independent of the angle of incidence.

## Absolute Refractive Index of Some Materials

**Table** 10.3 Absolute refractive index of some material media.

| Material medium | Refractive index | Material medium | Refractive index |
|---|---|---|---|
| Air | 1.0003 | Canada Balsam | 1.53 |
| Ice | 1.31 | | |
| Water | 1.33 | Rock salt | 1.54 |
| Alcohol | 1.36 | | |
| Kerosene | 1.44 | Carbon disulphide | 1.63 |
| Fused quartz | 1.46 | Dense flint glass | 1.65 |
| Turpentine oil | 1.47 | Ruby | 1.71 |
| Benzene | 1.50 | Sapphire | 1.77 |
| Crown glass | 1.52 | Diamond | 2.42 |

## Spherical Lens

- **Definition:** A Spherical lens is a piece of a transparent medium bounded by at least one spherical surface.
- **Types:** There are two types of spherical lenses:

  **(a) Convex or Converging Lenses:** These are thick in the middle and thin at the edges. These are the lenses that converge light rays that are travelling parallel to its principal axis.

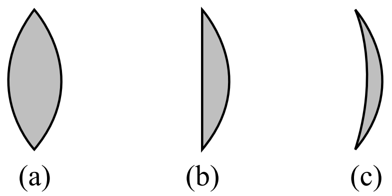



**Fig. 27:** Three types of convex lenses

**Convex lenses are mainly of three types:**

(i) **Double Convex Lens:** Lenses that has both the surfaces convex as shown in fig. (a).

(ii) **Plano-Convex Lens:** Lenses that has one surface plane and the other surface convex as shown in fig. (b).

(iii) **Concavo-Convex Lens:** Lenses that has one surface concave and the other surface convex as shown in fig. (c).

(b) **Concave or Diverging Lenses:** These are thin in the middle and thick at the edges. These lenses diverge a parallel beam of rays which are incident parallel to their principal axis.

**There are three types of concave lenses:**

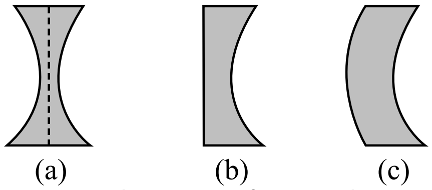



**Fig. 28:** Three types of concave lenses

(i) **Double Concave Lens:** It has both the surfaces concave as shown in Fig. (a).

(ii) **Plano-Concave Lens:** It has one surface plane and the other surface concave as shown in Fig. (b).

(iii) **Convexo-concave Lens:** It has one surface convex and the other surface concave as shown in Fig. (c).

## Some Important Terms Related to Spherical Lenses

(i) **Radius of curvature (*R*):**

The radius of curvature of the surface of a lens is defined as the radius of the sphere of which each surface of lens is a part. $R_1$ and $R_2$ in the diagrams (*a*) and (*b*) are the radii of curvature of the lenses

(ii) **Centre of curvature (*C*):**

The centre of curvature of the each surface of a lens is the centre of the spheres of which each surface of the lens is a part, because a lens has two surfaces, so it has two centres of curvature. In diagram (*a*) and (*b*) points, $C_1$ and $C_2$ are the centres of curvature.

(iii) **Principal axis ($C_1C_2$):**

It is the line joining the two centres of curvature ($C_1$ and $C_2$) of the lens.

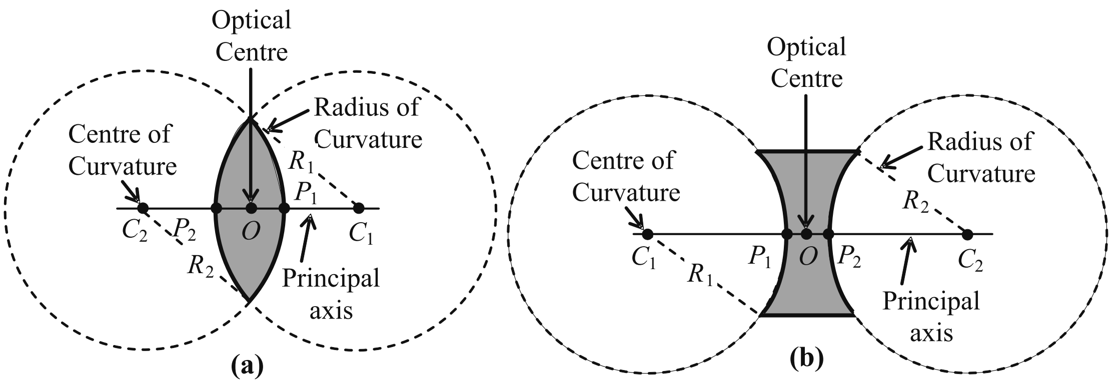



**Fig. 29:** Characteristics of convex and concave lenses

(iv) **Aperature:** Aperture of a lens is the actual diameter of the circular outline of the spherical lens.

(v) **Optical centre:** A point on the axis of a lens that is so located inside the lens that any ray of light passing through it suffers no net deviation.

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

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

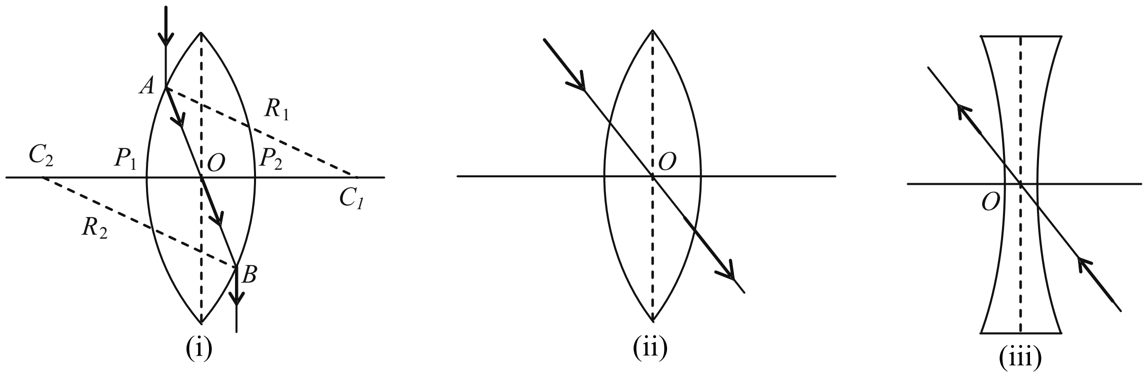



**Fig. 30**

**(vi) Principal foci and focal length:**

**(a) First principal focus and first focal length:**

It is a point on the principal axis of the lens such that the rays emerging from this point (in case of convex lens) or appearing to converge towards this point (in case of concave lens), after refraction from the lens, become parallel to the principal axis. It is represented by $F_1$.

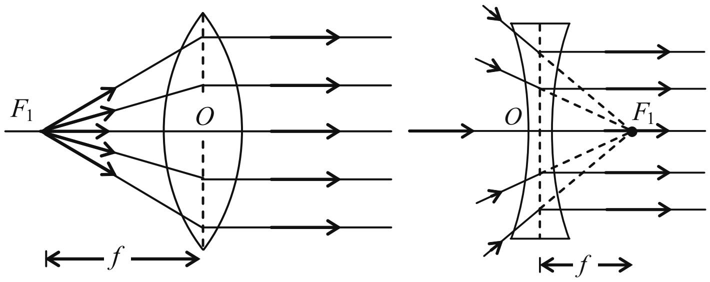



**Fig. 31:** First principal focus

**(b) Second principal focus and second focal length:**

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

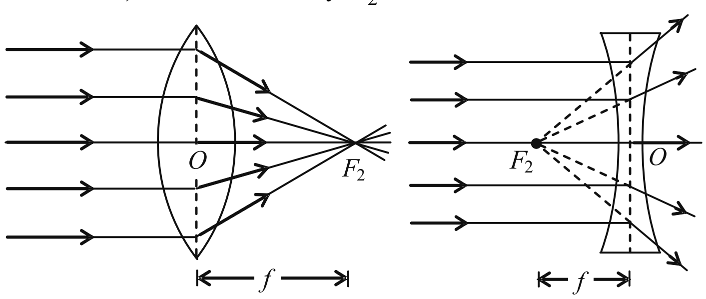



**Fig. 32:** Second principal focus

In case the medium on both sides of the lens is same, then the first and second focal lengths are equal in magnitude. Thus, $f_1 = f_2$

## Ray Diagram Method for the Image Formation

### Rules For Convex Lens

- Light ray incident parallel to the principal axis, meet at focus.

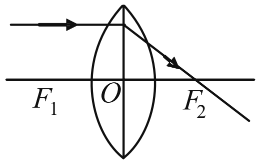



Fig. 33

- Light ray incident from focus, become parallel to the principal axis after refraction.

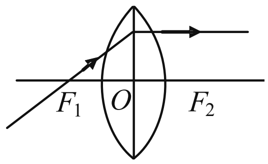



Fig. 34

- Light ray incident on the pole of the lens passes without any deviation.

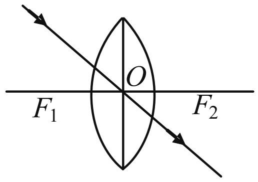



Fig. 35

### Rules For Concave Lens

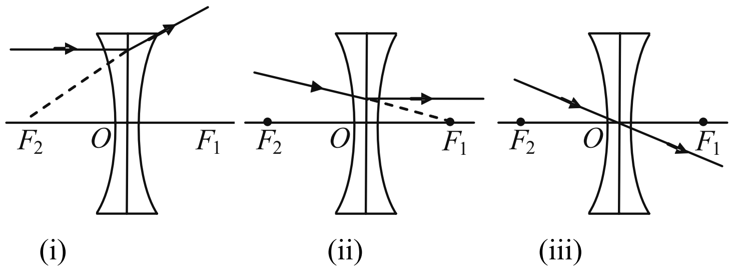



Fig. 36

## Image Formation by Lens

Different cases of image formation by a lens are as given below with their ray diagrams.

### Image Formation by a Convex Lens

**(i) Object placed at Infinity**

Rays coming from the object is parallel to the principal axis and after refraction from the lens they actually meet at the second principal Focus $F_2$. The image formed is real and point sized.

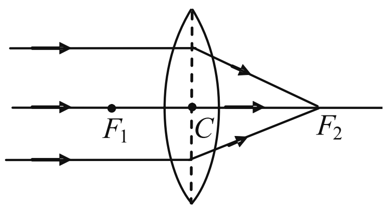



**Fig. 37:** Point object at infinity, image will be formed at the focus.

**(ii) Object placed at a distance more than twice the Focal Length**

Object $PQ$ has its image $P'Q'$ formed between distance $f_2$ and $2f_2$.

The image is real inverted and diminished.

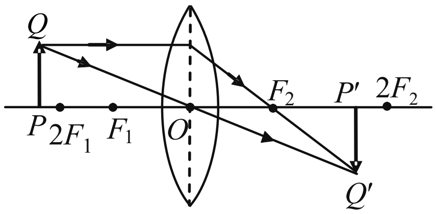



**Fig. 38:** Object beyond $2f_1$ image between $f_2$ and $2f_2$.

**(iii) Object placed at a distance twice the Focal Length**

Object $PQ$ has its image $P'Q'$ formed at distance $2f_1$.

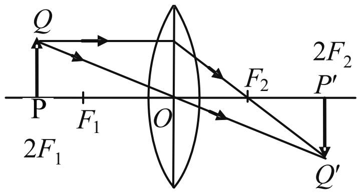



**Fig. 39:** Convex lens : object at distance $2f_1$, image at distance $2f_2$.

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

**(iv) Object at distance more than Focal Length and less than twice its Focal Length**

Object $PQ$ has its image $P'Q'$ formed beyond distance $2f_2$.

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

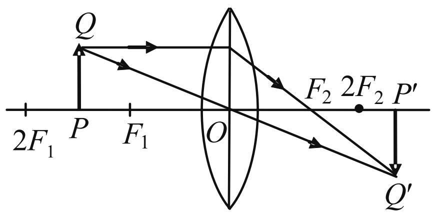



**Fig. 40:** Object at distance between $f_1$ and $2f_1$ image beyond $2f_2$.

**(v) Object at Focus**

If the object $PQ$ is placed at the focus its image is formed at infinity.

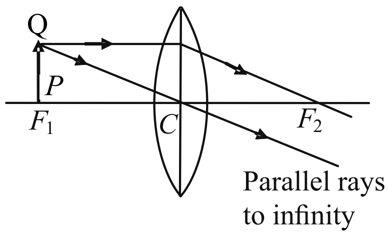



**Fig. 41:** Object at focus, image at infinity.

The image is real, inverted and highly enlarged.

**(vi) Object between Focus and Optical Centre**

Object $PQ$ has its image $P'Q'$ formed in front of the lens, i.e. on the same side as that of the object.

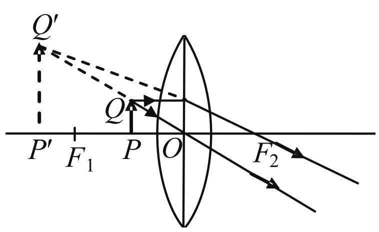



**Fig. 42:** Object between focus and optical centre, image formed in front of the lens

## Image Formation by a Concave Lens

**(i) Object at infinity**

Rays come parallel to the principal axis and after refraction from the lens, appears to come from the second principal focus $F_1$ The image formed is virtual and point sized.

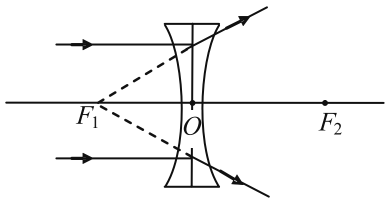



**Fig. 43:** Point object at infinity, image at focus.

**(ii) Object at a Finite Distance**

Object $PQ$ has its image $P'Q'$ formed between second principal focus $F_1$ and optical centre $O$.

The image is virtual-erect and diminished.

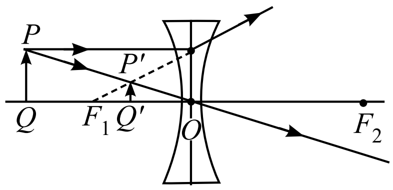



**Fig.44**

**Try it Yourself**

- An object is placed in front of a convex lens and an image is formed at some place due to refraction of light by the lens. What happens to the image if some portion of the lens is covered by an opaque paper?

| | Position of object | Position of Image | Relative size of the image | Nature of the image |
|---|---|---|---|---|
| Convex lens | At infinity | At focus $F_2$ | Highly diminished, point-sized | Real and inverted |
| | Beyond $2F_1$ | Between $F_2$ and $2F_2$ | Diminished | Real and inverted |
| | At $2F_1$ | At $2F_2$ | Same size | Real and inverted |
| | Between $F_1$ and $2F_1$ | Beyond $2F_2$ | Enlarged | Real and inverted |
| | At focus $F_1$ | At infinity | Infinitely large or highly enlarged | Real and inverted |
| | Between focus $F_1$ and optical centre $O$ | On the same side of the lens as the object | Enlarged | Virtual and erect |
| Concave lens | At infinity | At focus $F_1$ | Highly diminished, point-sized | Virtual and erect |
| | Between infinity and optical centre $O$ of the lens | Between focus $F_1$ and optical centre $O$ | Diminished | Virtual and erect |

## Sign Convention for Spherical Lenses

We use a new Cartesian sign convention for measuring various distances in ray diagrams of spherical lenses. These are:

1. Optical centre is treated as the origin, and all distances should be measured from the optical centre.
2. Distances measured in the direction of the incident ray should be taken as positive.
3. Distances measured against the direction of the incident ray 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.
6. Focal length of the convex lens is taken as positive.
7. Focal length of the concave lens is taken as negative.

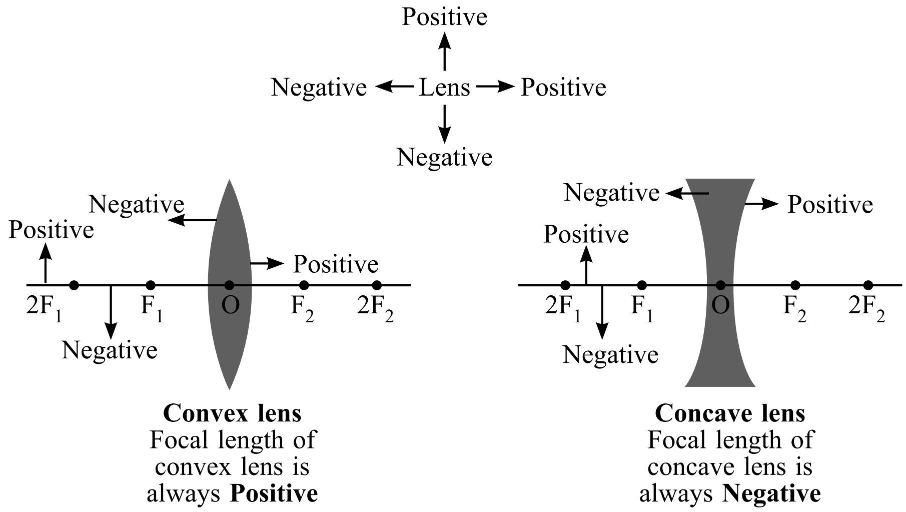



**Fig. 45:** Sign Convention in Lenses

### Lens Formula

Lens equation or lens formula is an equation that relates the object distance u, image distance v and the focal length f of a lens. It is given by: $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$.

### Linear Magnification

Linear magnification (m) is defined as the ratio of the size of the image to the size of the object.

$$m = \frac{h_i}{h_o} = \frac{\text{height of image}}{\text{height of object}},$$

also $m = \frac{v}{u}$

if m is +ve (image is virtual & erect)

if m is –ve (image is real & inverted)

## Power of the Lens

We know that a convex lens is converging in nature and a concave lens is diverging in nature.

This ability of convex and concave lenses to converge and diverge the light rays depend on the focal length of the lens.

Certainly, if the focal length of the lens is less, it will converge or diverge the light to a greater extent when compared to a lens of a large focal length, as shown in figure 46.

This degree of convergence and divergence is expressed in terms of power.

The power of the lens is reciprocal to its focal length. It is represented by the letter $P$.

If $f$ is the focal length of the lens, then its power is given by:

$$P = \frac{1}{\text{focal length}} \text{ or } P = \frac{1}{f\,(\text{in metres})}$$

If the focal length is in meters, then power is expressed in Dioptre ($D$). Thus, the SI unit of the power of the lens is Dioptre.

Thus, one Dioptre is the power of a lens whose focal length is 1 meter.

As the focal length of the convex lens is taken positive, the power of the convex lens is positive; similarly, the power of the concave lens is negative.

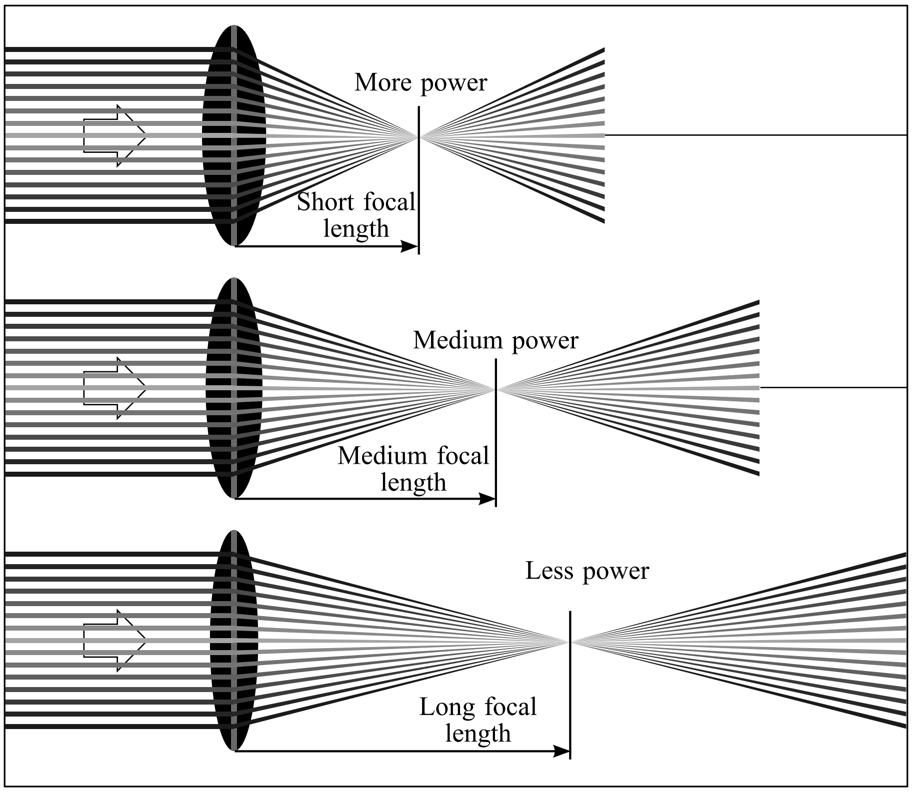



**Fig. 46:** Lenses of Different Focal Lengths have Different Power

## Summary

- Light seems to travel in straight lines.
- Mirrors and lenses form images of objects. Images can be either real or virtual, depending on the position of the object.
- The reflecting surfaces, of all types, obey the laws of reflection. The refracting surfaces obey the laws of refraction.
- New Cartesian Sign Conventions are followed for spherical mirrors and lenses. Mirror formula, gives the relationship between the object-distance(u), image-distance (v), and focal length (f) of a spherical mirror.
- The focal length of a spherical mirror is equal to half its radius of curvature.
- The magnification produced by a spherical mirror is the ratio of the height of the image to the height of the object.
- A light ray travelling obliquely from a denser medium to a rarer medium bends away from the normal. A light ray bends towards the normal when it travels obliquely from a rarer to a denser medium.
- Light travels in vacuum with an enormous speed of $3\times108$ m s-1. The speed of light is different in different media.
- The refractive index of a transparent medium is the ratio of the speed of light in vacuum to that in the medium.
- In case of a rectangular glass slab, the refraction takes place at both air-glass interface and glass-air interface. The emergent ray is parallel to the direction of incident ray.
- Lens formula, gives the relationship between the object-distance(u), image-distance (v), and the focal length (f) of a spherical lens.
- Refractive Index: It represents the amount or extent of bending of light when it passes from one medium to another.

  There are two types of refractive index
  - Relative refractive index
  - Absolute refractive index.
- Power of a lens is the reciprocal of its focal length. The SI unit of power of a lens is dioptre.

## NCERT Corner

**1.** A convex mirror used for rear-view on an automobile has a radius of curvature of 3.00 m. If a bus is located at 5.00m from this mirror, find the position, nature and size of the image?

**Ans.** Radius of curvature, $R$ = + 3.00 m;

Object-distance, $u$ = – 5.00 m;

Image-distance, $v$ = ?

Height of the image, $h'$ = ?

Focal length, $f = R/2 = +\frac{3.00\text{m}}{2} = +1.50\text{m}$

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

or, $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=+\frac{1}{1.50}-\frac{1}{(-5.00)}=\frac{1}{1.50}+\frac{1}{5.00}$

$=\frac{5.00+1.50}{7.50}$

$v=\frac{+7.50}{6.50}=+1.15\text{m}$

The image is 1.15 m at the back of the mirror.

Magnification, $m = \frac{h'}{h}=-\frac{v}{u}=-\frac{1.15\text{ m}}{-5.00\text{ m}}$

= +0.23

The image is virtual, erect and smaller in size by a factor of 0.23.

**2.** An object, 4.0cm in size, is placed at 25.0cm in front of a concave mirror of focal length 15.0 cm. At what distance from the mirror should a screen be placed in order to obtain a sharp image? Find the nature and the size of the image.

**Ans.** Object-size, $h$ = + 4.0cm;

Object-distance, $u$ = – 25.0cm;

Focal length, $f$ = –15.0cm;

Image-distance, $v$ = ?

Image-size, $h'$ = ?

By mirror formula,

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

or, $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{-15.0}-\frac{1}{-25.0}$

$=-\frac{1}{15.0}+\frac{1}{25.0}$

or, $\frac{1}{v}=\frac{-5.0+3.0}{75.0}=\frac{-2.0}{75.0}$ or, $v$ = –37.5cm

The screen should be placed at 37.5cm from the mirror. The image is real.

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

or, $h'=-\frac{vh}{u}=-\frac{(-37.5\text{cm})\times(+4.0\text{cm})}{(-25.0\text{cm})}$

Height of the image, $h'$ = – 6.0cm

The image is inverted and enlarged.

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

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

Image-distance $v$ = –10cm;

Focal length $f$ = –15cm;

Object-distance $u$ = ?

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

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

$\frac{1}{u}=\frac{1}{-10}-\frac{1}{(-15)}=-\frac{1}{10}+\frac{1}{15}$

$\frac{1}{u}=\frac{-3+2}{30}=\frac{1}{-30}$

or, $u$ = – 30cm

Thus, the object-distance is 30cm.

Magnification $m = \frac{v}{u}$

$m = \frac{-10\text{ cm}}{-30\text{ cm}}=\frac{1}{3}=+0.33$

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

**4.** A 2.0cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 10cm. The distance of the object from the lens is 15cm. Find the nature, position and size of the image. Also find its magnification.

**Ans.** Height of the object, $h_o$ = + 2.0cm;

Focal length $f$ = + 10cm;

object-distance $u$ = –15cm;

Image-distance $v$ = ?

Height of the image $h_i$ = ?

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

$$\frac{1}{v} = \frac{1}{(-15)} + \frac{1}{10} = -\frac{1}{15} + \frac{1}{10}$$

$$\frac{1}{v} = \frac{-2+3}{30} = \frac{1}{30}$$

or, $v$ = +30cm

The positive sign of $v$ shows that the image is formed at a distance of 30cm on the other side of the optical centre. The image is real and inverted.

Magnification $m = \frac{h_i}{h_o} = \frac{v}{u}$

or, $h_i = h_o = \frac{v}{u}$

Height of the image, $h_i = (2.0)\left(\frac{30}{-15}\right) = -4.0$cm

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

or, $m = \frac{+30\,\text{cm}}{-15\,\text{cm}} = -2$

The negative signs of $m$ and $h_i$ show that the image is inverted and real. It is formed below the principal axis. Thus, a real, inverted image, 4cm tall, is formed at a distance of 30cm on the other side of the lens. The image is two times enlarged

**5.** Define the principal focus of a concave mirror.

**Ans.** Light rays' incident parallel to the principal axis of a concave mirror after reflection from the mirror converges at a specific point on its principal axis. This point is known as the principal focus of a concave mirror.

**6.** The radius of curvature of a spherical mirror is 20cm. What is its focal length?

**Ans.** Radius of curvature ($R$) = 20cm

$R = 2f$ ($f$ = focal length)

$\therefore f = \frac{R}{2} = \frac{20}{2} = 10\text{ cm}$

Hence, the focal length of the spherical mirror is 10cm.

**7.** Name the mirror that can give an erect and enlarged image of an object.

**Ans.** Concave mirror is the mirror that can give an erect and enlarged image of an object.

**8.** Why do we prefer a convex mirror as a rear-view mirror in vehicles?

**Ans.** Convex mirror is preferred as a rear-view mirror in vehicles such as cars, as this mirror gives a wider field of view, which helps the driver to see most of the traffic behind him. It always forms an erect, virtual, and diminished image of the objects placed in front of it.

**9.** Find the focal length of a convex mirror whose radius of curvature is 32cm.

**Ans.** Given, Radius of curvature ($R$) = 32cm

$R = 2 \times f \Rightarrow f = \frac{R}{2} = \frac{32}{2} = 16\text{cm}$

Hence, the focal length of the given convex mirror is 16cm.

**10.** A concave mirror produces three times magnified (enlarged) real image of the object placed at 10cm in front of it. Where is the image located?

**Ans.** Magnification produced by the spherical mirror:

$$\text{m} = \frac{\text{Height of the image}}{\text{Height of the object}} = \frac{\text{–Image Distance}}{\text{Object Distance}}$$

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

According to the question,

Height of the image $h_i$ = –3h

(Image formed is real)

$\therefore -\frac{3h_0}{h_0} = -\frac{v}{u}$

$\because u$ = –10cm

$\Rightarrow v - 3 \times (-10) = -30$cm

Here, the negative sign indicates that an inverted image is formed in front of the concave mirror at a distance of 30cm

**11.** A ray of light travelling in air enters obliquely into water. Does the light ray bends towards the normal or away from the normal? Why?

**Ans.** As water is an optically denser medium than air so the light ray travelling from air to water bends towards the normal.

**12.** Light enters from air to glass having refractive index 1.50. What is the speed of light in the glass? The speed of light in vacuum is $3 \times 10^8 ms^{-1}$.

**Ans.** Speed of light in vacuum ($c$) = $3 \times 10^8$m/s

Refractive index of glass ($\mu_g$) = 1.50

Speed of light in the glass ($v$) = Speed of light in refractive index of glass vacuum.

$$= \frac{3 \times 10^8}{1.50} = 2 \times 10^8 ms^{-1}.$$

**13.** Find out, from Table, the medium having highest optical density. Also find the medium with lowest optical density.

| Material medium | Refractive Index | Material Medium | Refractive Index |
|---|---|---|---|
| Air | 1.0003 | Canada Balsam | 1.53 |
| Ice | 131 | – | – |
| Water | 1.33 | Rock salt | 1 54 |
| Alcohol | 136 | – | – |
| Kerosene | 1.44 | Cartion disulphide | 1.63 |
| Fused quartz | 1.46 | Dense flint glass | 1.65 |
| Turpentine oil | 1.47 | Ruby | 1.71 |
| Benzene | 1.50 | Sapphire | 1.77 |
| Crown glass | 1.52 | Diamond | 2.42 |

**Ans.** The optical density of a medium depends on its refractive index. A medium with the highest refractive index will have the highest optical density and vice-versa.

So, Lowest optical density = Air

Highest optical density = Diamond

**14.** You are given kerosene, turpentine ond water. In which of these does the light travel fastest? Use the information given in Table.

| Material Medium | Refractive Index | Material Medium | Refractive Index |
|---|---|---|---|
| Air | 1.0003 | Canada Balsam | 1.53 |
| Ice | 1.31 | – | – |
| Water | 1.33 | Rock salt | 1.54 |
| Alcohol | 1.36 | . | . |
| Kerosene | 1.44 | Carbon disulphide | 1.63 |
| Fused quartz | 1.46 | Dense flint glass | 1.65 |
| Turpentine oil | 1.47 | Ruby | 1.71 |
| Benzene | 1.50 | Sapphire | 1.77 |
| Crown glass | 1.52 | Diamond | 2.42 |

**Ans.** Speed of light is inversely proportional to the refractive index of the medium.

Therefore, light travels faster in water as compared to kerosene & turpentine as the refractive index of water is lower than that of kerosene and turpentine.

**15.** The refractive index of diamond is 2.42. What is the meaning of this statement?

**Ans.** Diamond has a refractive index of 2.42. It means that the speed of light in diamond will reduce by a factor of 2.42 as compared to its speed in the air. Or we can say that the speed of light in vacuum is 2.42 times the speed of light in diamond.

**16.** Define 1 dioptre power of a lens.

**Ans.** Power of a lens is said to be 1 dioptre if its focal length is 1 m.

**17.** A convex lens forms a real and inverted image of a needle at a distance of 50cm from it. Where is the needle placed in front of the convex lens if the image is equal to the size of the object? Also, find the power of the lens.

**Ans.** The position of image should be at, 2f as the image is real and has the same size as that of the object. It is given that the image of the needle must be formed at a distance of 50cm from the convex lens. Therefore, the needle is placed in front of the lens at a distance of 50cm.

Object distance, ($u$) = –50cm

Image distance, ($v$) = 50cm

Focal length, $f$ = ?

Using the lens formula,

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

$$\frac{1}{f}=\frac{1}{50}-\frac{1}{-50}$$

$$=\frac{1}{50}+\frac{1}{50}=\frac{1}{25}$$

Power of lens, $P = \dfrac{1}{f\text{(in metres)}}=\dfrac{1}{0.25}=+4D$

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

**Ans.** Focal length of the concave lens ( $f$ ) = –2m

Power of lens ($P$) = $\dfrac{1}{f}=\dfrac{1}{(-2)}=-0.5\text{D}$ .

## NCERT Exercise

**1.** Which one of the following materials cannot he used to make a lens?

($a$) Water ($b$) Glass

($c$) Plastic ($d$) Clay

**Ans.** ($d$) Clay is an opaque object so it cannot be used to make a lens because if the lens is made up of clay the light rays cannot pass through it

**2.** The image formed by a concave mirror is observed to be virtual, erect and larger than the object. Where should be the position of the object?

($a$) Between the principal 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 its principal focus.

**Ans.** ($d$) For the given nature of the image the position of the object should be between the pole of the mirror and its principal focus.

**3.** Where should an object be placed in front of a convex lens to get a real image same as the size of the object?

($a$) At the principal focus of the lens.

($b$) At twice the focal length.

($c$) At infinity.

($d$) Between the optical centre of the lens and its principal focus.

**Ans.** ($b$) The object should be placed at twice the focal length in front of a convex lens.

**4.** A spherical mirror and a thin spherical lens has a focal length of –15cm. The mirror and the lens are likely to be

($a$) both concave.

($b$) both convex.

($c$) the mirror is concave and the lens is convex.

($d$) the mirror is convex, but the lens is concave.

**Ans.** ($a$) Both the mirror as well as the lens are likely to be concave.

**5.** No matter how far you stand from a mirror, your image appears erect. The mirror is likely to be:

($a$) plane ($b$) concave

($c$) convex ($d$) either plane or convex

**Ans.** ($d$) The mirrors are likely to be either plane or convex.

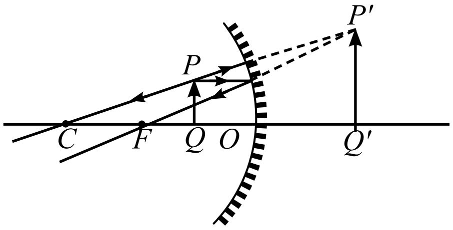
6. Which of the following lenses would you prefer to use while reading small letters found in a dictionary?
   (*a*) A convex lens of focal length 50cm.
   (*b*) A concave lens of focal length 50cm.
   (*c*) A convex lens of focal length 5cm.
   (*d*) A concave lens of focal length 5cm.

**Ans.** (*c*) A convex lens of focal length 5cm can be used while reading small letters found in a dictionary as a convex lens gives a magnified image of an object.

7. We wish to obtain an erect image of an object, using a concave mirror of focal length 15cm. What should be the range of distance of the object from the mirror? What is the nature of the image? Is the image larger or smaller than the object? Draw a ray diagram to show the image formation in this case.

**Ans.** Range of the distance of the object = 0 to 15cm from the pole of the minor.

So the nature of the image is virtual, erect, and larger than the object.




8. Name the type of mirror used in the following situations.
   (*a*) Headlights of a car.
   (*b*) Side/rear-view mirror of a vehicle.
   (*c*) Solar furnace.

   Support your answer with a reason.

**Ans.** (*a*) Concave mirrors are used in the headlights of a car because concave mirrors can produce a powerful parallel beam of light when the light source is placed at their principal focus.

(*b*) Convex Mirror: It is used as a rear-view mirror in motor vehicles because they form virtual, erect, and diminished images irrespective of the distance of the object.

(*c*) Concave Mirror: Because it converges the parallel rays of the sun at its principal focus.

9. One-half of a convex lens is covered with black paper. Will this lens produce a complete image of the object? Verify your answer experimentally. Explain your observations.

**Ans.** Yes, it will produce a complete image of the object. However, the intensity or brightness of the image will reduce.

10. An object 5cm in length is held 25cm away from a converging lens of focal length 10cm. Draw the ray diagram and find the position, size, and nature of the image formed.

**Ans.** Given,

Height of object, $h_o$ = 5cm

Object distance, $u$ = –25cm

Focal length of converging lens, $f$ = 10cm

Now from lens formula,

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

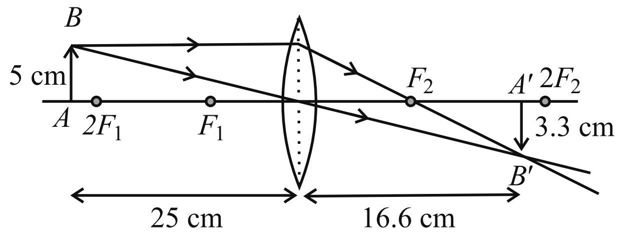
$$\frac{1}{v} = \frac{1}{10}-\frac{1}{25}=\frac{15}{250}$$

$$\Rightarrow v = 16.66\text{cm}$$

$$\text{Also, } \frac{h_i}{h_0}=\frac{v}{u}$$

$$\therefore\ h_i = \frac{v}{u}\times h_0 = \frac{50\times 5}{3\times(-25)}=\frac{10}{-3}=-3.3\text{cm}$$

Therefore, the image is inverted and formed at a distance of 16.7cm on other side of the lens and measures 3.3cm. The ray diagram is shown below.




11. A concave lens of focal length 15cm forms an image, 10cm from the lens. How far is the object placed from the lens? Draw the ray diagram.

**Ans.** Given,

focal length of the concave lens, ($f$) = –15 cm

Image distance, ($v$) = –10cm

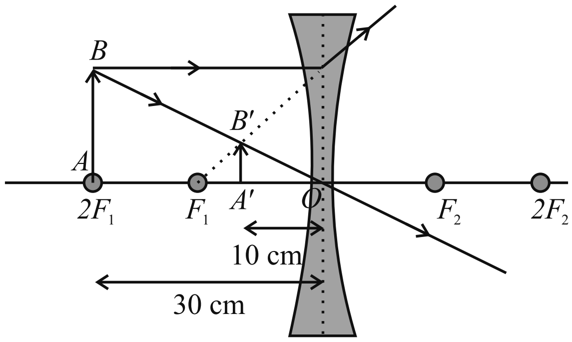
Using the lens formula.

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

$$\Rightarrow \frac{1}{u} = \frac{1}{v}-\frac{1}{f}=-\frac{1}{10}-\frac{1}{-15}$$

$$\Rightarrow \frac{1}{u} = \frac{-1}{30} \Rightarrow u = -30\,\text{cm}$$

The ray diagram for this can be shown as.




**12.** An object is placed at a distance of 10cm from a convex mirror of focal length 15cm. Find the position and nature of the image.

**Ans.** Given, focal length of mirror ($f$) = +15cm

Object distance ($u$) = –10cm

Using the mirror formula,

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

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

$$v = \frac{30}{5} = 6\text{cm}$$

$$\text{Magnification} = \frac{-v}{u} = \frac{-6}{-10} = 0.6$$

Therefore, the position of the image is located at a distance of 6cm from the mirror on the same side of the mirror.

Magnification (m) is positive and its value is less than 1 that indicates that the image formed is virtual, erect and diminished.

**13.** The magnification produced by a plane mirror is +1. What does this mean?

**Ans.** The positive sign indicates that the image formed by the plane mirror is virtual and erect. The magnification is 1 means that the size of the image formed is equal to the size of the object placed.

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

**Ans.** Object distance ($u$) = –20cm

Height of the object ($h$) = 5cm

Radius of curvature ($R$) = 30cm

Radius of curvature = 2 × Focal length

$$\text{Focal length } (f) = \frac{\text{Radius of the curvature}}{2}$$

$\Rightarrow f$ = 15cm

From the mirror formula,

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

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{15} + \frac{1}{20} = \frac{4+3}{60} = \frac{7}{60}$$

$v$ = 8.57cm

Therefore, the image is formed at 8.57cm on the same side of the mirror

$$\text{Magnification } (m) = \frac{\text{Image Distance}}{\text{Object Distance}} = \frac{-v}{u}$$

$$= \frac{-8.57}{-20} = 0.428$$

The magnification is positive so the image formed is virtual.

$$\text{Magnification, } m = \frac{\text{Height of the image}}{\text{Height of the object}} = \frac{h_i}{h_o}$$

$h_i = m \times h_o$ = 0.428 × 5 = 2.14cm

Therefore, the image formed is virtual, erect and smaller in size.

**15.** An object of size 7.0cm is placed at 27cm in front of a concave mirror of focal length 18cm. At what distance from the mirror should a screen be placed, so that a sharp focused image can be obtained? Find the size and the nature of the image.

**Ans.** Given,

Object distance ($u$) = –27cm

Height of Object ($h$) = 7cm

Focal length ($f$) = –18cm

Using the mirror formula,

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

$$\frac{1}{v} - \frac{1}{27} = \frac{-1}{18}$$

$$\Rightarrow v = -54\text{ cm}$$

The screen should be placed at a distance of 54cm in front of the given mirror.

Magnification,

$$m = \frac{\text{Image Distance}}{\text{Object Distance}} = \frac{-54}{27} = -2$$

The magnification is negative, so the image formed is real.

$$m = \frac{\text{height of the image}}{\text{height of the object}} = \frac{h_i}{h_o}$$

$$h_1 = m \times h_o = -2 \times 7 = -14\text{cm}$$

Negative sign indicates that the image formed is inverted.

**16.** Find the focal length of a lens of power –2.0D. What type of lens is this?

**Ans.** Power of lens ($P$) = $\frac{1}{f}$ (where f is in metre)

$P = -2D$

$$f = \frac{1}{P} = -0.5\text{m} \qquad [\because P = -2D]$$

As the given lens has a negative focal length. Therefore, it is a concave lens.

**17.** A doctor has prescribed a corrective lens of power +1.5 D. Find the focal length of the lens. Is the prescribed lens diverging or converging?

**Ans.** Given, $P = 1.5D$

$$f = \frac{1}{1.5} = \frac{10}{15} = 0.66\text{m}$$

A convex lens has a positive focal length. Therefore, the given lens is a convex lens or a converging lens.

# Quick Recall

## Fill in the Blanks

1. Image formed by a plane mirror is always ______ and ________.
2. A spherical mirror, whose reflecting surface is curved inwards, that is,faces towards the centre of the sphere, is called a ______.
3. The focal length of a spherical mirror is equal to _________ its radius of curvature.
4. Speed of light is _______.
5. Light rays always travels in _________.
6. A ray travelling towards the mirror is the __________.
7. Angle between reflected ray and normal is the _________.
8. The angle between the reflecting surface and the reflected ray is called________.
9. When light travels from a rarer to a denser medium, its speed ________.
10. The refractive index of glass with respect to air is 3/2. The refractive index of air with respect to glass will be ________.

## True and False Statements

1. A person standing in front of a mirror finds his image larger than himself. This nature of the image shows that mirror is convex in nature.
2. Image formed by any mirror gives an idea about the nature of the mirror.
3. A convex mirror and a concave lens diverge the rays falling parallel to the principal axis.
4. Lateral displacement increases with the thickness of the given slab.
5. When incident angle i satisfies $\mu = \frac{1}{\sin i}$, where $\mu$ is the refractive index. The refracted light will pass along the surface.
6. A convex lens of refractive index = $\frac{3}{2}$ is placed in water of refractive index $\frac{4}{3}$, the focal length of the lens will increase inside water.
7. Angle of refraction from any medium cannot exceed 90°.
8. The power of a concave lens must be positive.
9. Aperture is the diameter of the lens.
10. Convex lens always has a positive focal length.

## Match the Following

**In this section, each question has two matching lists. Choices for the correct combination from Column-I and Column-II are g(iv)en as options (*a*), (*b*), (*c*) and (*d*) out of which one is correct.**

**1.** Match the following with correct response.

| | Column-I | | Column-II |
|---|---|---|---|
| P. | Convex lens | (i) | Diverging |
| Q. | Concave lens | (ii) | Virtual image smaller than the object |
| R. | Concave mirror | (iii) | Virtual image larger than the object |
| S. | Convex mirror | (iv) | Converging |

(*a*) P-(iv), Q-(iii), R-(i), S-(ii)
(*b*) P-(i), Q-(ii), R-(iii), S-(iv)
(*c*) P-(iv), Q-(i), R-(iii), S-(ii)
(*d*) P-(i), Q-(iii), R-(ii), S-(iv)

**2.** Match the following with correct response.

| | Column-I | | Column-II |
|---|---|---|---|
| P. | Mirror formula | (i) | $\frac{R}{2}$ |
| Q. | Lens formula | (ii) | $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$ |
| R. | Magnification of mirror | (iii) | $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ |
| S. | Focal length | (iv) | $-\frac{v}{u}$ |

(*a*) P-(i), Q-(iii), R-(iv), S-(ii)
(*b*) P-(iii), Q-(iv), R-(ii), S-(i)
(*c*) P-(i), Q-(ii), R-(iii), S-(iv)
(*d*) P-(iii), Q-(ii), R-(iv), S-(i)

**3.** Match the following with correct response.

| | Column-I | | Column-II |
|---|---|---|---|
| P. | Highest refractive index | (i) | Convex mirror |
| Q. | Lowest refractive index | (ii) | Vacuum |
| R. | Head lights of a car | (iii) | Diamond |
| S. | Side rear view of a mirror | (iv) | Concave mirror |

(*a*) P-(i), Q-(iii), R-(ii), S-(iv)
(*b*) P-(iii), Q-(ii), R-(iv), S-(i)
(*c*) P-(iv), Q-(i), R-(iii), S-(ii)
(*d*) P-(i), Q-(ii), R-(iii), S-(iv)

**4.** Match the following with correct response for a concave mirror of focal length 20 cm.

| | Column-I | | Column-II |
|---|---|---|---|
| P. | When the object is at 20cm | (i) | Image formed is magnified and erect |
| Q. | When the object is at 5cm | (ii) | Image formed is at infinity |
| R. | When the object is at 30cm | (iii) | Image formed is real and inverted |
| S. | When the object is at 40cm | (iv) | Image formed is of same size as that of the object |

(*a*) P-(iv), Q-(iii), R-(ii), S-(i)
(*b*) P-(ii), Q-(iii), R-(i), S-(iv)
(*c*) P-(iv), Q-(i), R-(iii), S-(ii)
(*d*) P-(ii), Q-(i), R-(iii), S-(iv)

**5.** Match the following with correct response.

| | Column-I | | Column-II |
|---|---|---|---|
| P. | Concave mirror | (i) | The distance between the Pole (P) and focal point |
| Q. | Focal length | (ii) | Objects originally on the left appear to be on the right in the image |
| R. | Convex mirror | (iii) | A spherical mirror having their reflecting surface curved outwards |
| S. | Lateral inversion | (iv) | A spherical mirror having its reflecting surface curved inwards |

(*a*) P-(iv), Q-(iii), R-(i), S-(ii)
(*b*) P-(i), Q-(ii), R-(iii), S-(iv)
(*c*) P-(iv), Q-(i), R-(iii), S-(ii)
(*d*) P-(i), Q-(iii), R-(ii), S-(iv)

## Assertion & Reason Type Questions

**Direction (Qs. 1 to 7): The following questions consist of two statements–Assertion (A) and Reason (R). Answer these questions by selecting the appropriate option given below:**

**(*a*) Both (A) and (R) are true, and (R) is the correct explanation of A.**

**(*b*) Both (A) and (R) are true, but (R) is not the correct explanation of (A).**

**(*c*) (A) is true, but (R) is false**

**(*d*) (A) is false, but (R) is true.**

1. **Assertion (A):** Magnification of the plane mirror is always +1.

   **Reason (R):** A plane mirror forms a virtual image and size is same as that of an object.

2. **Assertion (A):** The plane mirror always forms a virtual image.

   **Reason (R):** Convex mirror always forms a real image.

3. **Assertion (A):** A light ray incident from the center of curvature follows the same path after reflection.

   **Reason (R):** Normal lies on the path of incident ray when it comes from the center of curvature.

4. **Assertion (A):** Refraction is the bending of light.

   **Reason (R):** Refraction occurs due to a change in the speed of light.

5. **Assertion (A):** The power of the lens is inversely proportional to its focal length.

   **Reason (R):** Power is measured in dioptres.

6. **Assertion (A):** Concave lens has a negative focal length.

   **Reason (R):** In a concave lens, the focal length is measured to the left of the pole.

7. **Assertion (A):** The magnification of the real image is negative.

   **Reason (R):** Real image is inverted in nature.

## Statement Type Questions

**These questions consist of two statements each, printed as Statement-I and Statement-II. While answering these questions, you are required to choose any one of the following four responses.**

(***a***) Statement-I and Statement-II both are correct

(***b***) Statement-I and Statement-II both are incorrect

(***c***) Statement-I is correct and Statement-II is incorrect

(***d***) Statement-I is incorrect but Statement-II is correct

1. **Statement-I:** Size of image is same as the object in a plane mirror.

   **Statement-II:** Magnification of a plane mirror is infinity.

2. **Statement-I:** Image formed by a plane mirror is laterally inversed

   **Statement-II:** Image formed by a plane mirror is diminished.

3. **Statement-I:** The speed of light doesn't change while refraction.

   **Statement-II:** The speed of light changes while reflection.

4. **Statement-I:** The direction of incident light remains unchanged while refraction through a rectangular glass slab.

   **Statement-II:** The perpendicular distance between the direction of the incident ray and the emergent ray is called lateral displacement.

5. **Statement-I:** The power of a lens depends on the focal length of the lens.

   **Statement-II:** Focal length of a convex lens is always positive.

6. **Statement-I:** Convex lens and concave mirror can form both the types of images, real as well as virtual.

   **Statement-II:** The virtual image formed by the concave mirror is always diminished.

7. **Statement-I:** Convex mirror is used as the side mirror as well as in headlights of vehicles.

   **Statement-II:** Convex mirrors form images of a wider area in a shorter area behind the mirror between the pole and the focus.

# Multiple Choice Questions

1. Ravi placed an object at a distance of 0.25m in front of a plane mirror. The distance between the object and image will be:
   (*a*) 1.5 m (*b*) 0.5 m
   (*c*) 1 m (*d*) 0.20 m

2. The angle of incidence for a ray of light having zero reflection angle is
   (*a*) 30° (*b*) 0
   (*c*) 45° (*d*) 60°

3. Which of the following optical devices can produce a real image for a real object?
   (*a*) Concave lens (*b*) Concave mirror
   (*c*) Plane mirror (*d*) Convex mirror

4. Mirror that is used by a dentist to examine a dental cavity is:
   (*a*) Plane mirror
   (*b*) Convex mirror
   (*c*) Combination of concave mirror and convex
   (*d*) Concave mirror

5. An object that is placed at a distance of 30cm from a concave mirror gets its image at the same point. The focal length of the mirror is
   (*a*) –45 cm (*b*) 45 cm
   (*c*) –15 cm (*d*) +15 cm

6. For an object that is at a distance of +15cm and is moved slowly towards the pole of a convex mirror. The image will get
   (*a*) enlarged and real (*b*) shortened and real
   (*c*) enlarge and virtual (*d*) diminished and virtual

7. For a concave mirror of radius 30cm which is placed in water the focal length in air and water differ by
   (*a*) 25 cm (*b*) 20 cm
   (*c*) 0 cm (*d*) 30 cm

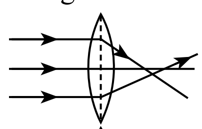
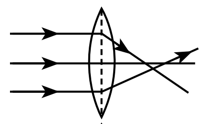
8. A concave mirror of focal length 20cm forms an image twice the size of object. What will be the position of the object for the virtual image?
   (*a*) 20 cm (*b*) 30 cm
   (*c*) 10 cm (*d*) At infinity

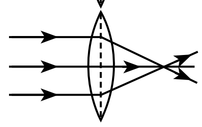
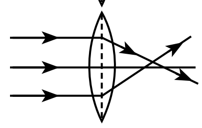
9. The refractive index of water is 1.33. The speed of light in water will be:
   (*a*) $1.33 \times 10^8$ m/s (*b*) $1.5 \times 10^8$ m/s
   (*c*) $2.26 \times 10^8$ m/s (*d*) $2.66 \times 10^8$ m/s

10. Anil is given three media A, B and C of refractive index 1.33, 1.65 and 1.46. The medium in which the light will travel fastest is
    (*a*) B
    (*b*) A
    (*c*) C
    (*d*) equal in all the three media

11. Light coming from the Sun falling on a convex lens will converge at a point called:
    (*a*) radius of curvature (*b*) optical centre
    (*c*) centre of curvature (*d*) focus

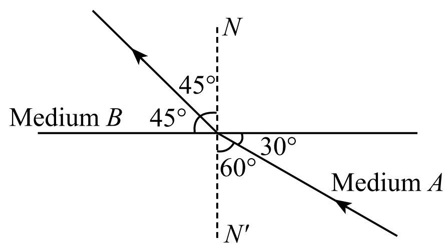
12. The distance between the optical centre and point of convergence is called focal length in which of the following cases?

    (*a*)  (*b*) 

    (*c*)  (*d*) 

13. A 10mm long pin is placed vertically in front of a concave mirror. A 5mm long image of the pin is formed at 30cm in front of the mirror. The focal length of this mirror is
    (*a*) –30 cm (*b*) –20 cm
    (*c*) –40 cm (*d*) –60 cm

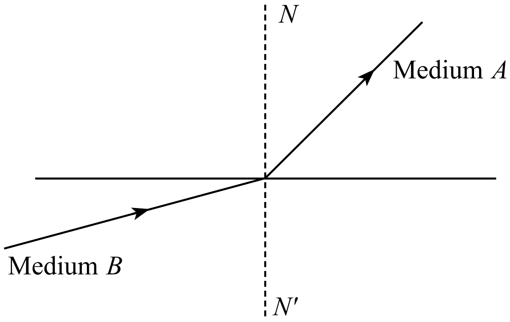
14. A ray of light travels from medium A to medium B as shown in the figure below. Refractive index of the medium B relative to medium A is




    (*a*) $\frac{\sqrt{3}}{\sqrt{2}}$ (*b*) $\frac{\sqrt{2}}{\sqrt{3}}$

    (*c*) $\frac{1}{\sqrt{2}}$ (*d*) $\sqrt{3}$

**15.** A light ray enters from medium B to medium A as shown in the figure. The refractive index of medium A relative to B will be




($a$) $n_B > n_A$ ($b$) $n_B < n_A$

($c$) $n_B = n_A$ ($d$) None of these

**16.** A student obtains a blurred image of a distant object on a screen using a convex lens. To obtain a distinct image on the screen he should move the lens

**(CBSE 2017)**

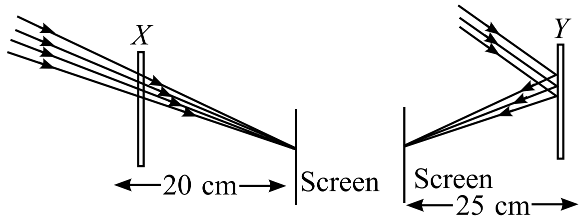
($a$) away from the screen.

($b$) towards the screen.

($c$) to a position very far away from the screen.

($d$) either towards or away from the screen depending upon the position of the object.

**17.** Study the given ray diagrams and select the correct statement from the following: **(CBSE 2017)**




($a$) Device $X$ is a concave mirror and device $Y$ is a convex lens, whose focal lengths are 20cm and 25cm respectively.

($b$) Device $X$ is a convex lens and device $Y$ is a concave mirror, whose focal lengths are 10cm and 25cm respectively.

($c$) Device $X$ is a concave lens and device $Y$ is a convex mirror, whose focal lengths are 20cm and 25cm respectively.

($d$) Device $X$ is a convex lens and device $Y$ is a concave mirror, whose focal lengths are 20cm and 25cm respectively.

**18.** A student very cautiously traces the path of a ray through a glass slab for different values of the angle of incidence ($\angle i$). He then measures the corresponding values of the angle of refraction ($\angle r$) and the angle of emergence ($\angle e$) for every value of the angle of incidence. On analysing these measurements of angles, his conclusion would be:

**(CBSE 2017)**

($a$) $\angle i > \angle r > \angle e$ ($b$) $\angle i = \angle e > \angle r$

($c$) $\angle i < \angle r < \angle e$ ($d$) $\angle i = \angle e < \angle r$

# Subjective Questions

## Very Short Answer Type Questions

**1.** Define light?

**2.** What is a beam of light?

**3.** Define a ray of light?

**4.** Write an observation which shows that light travels in a straight line.

**5.** Is light a ray or a wave?

**6.** Can any spherical surface act as a reflector?

**7.** For what position of an object, a real image equal to the size of the object is formed in front of the concave mirror.

**8.** What should be the position of the object for which a concave mirror forms a real image that is highly enlarged?

**9.** What should be the position of the object placed on the side of the reflecting surface of a concave mirror of focal length 15cm if the image is formed at a distance of 30cm from the mirror?

**10.** Specify the size of the image formed by a concave mirror when $m > 1$.

11. Why does a ray of light bend when it travels from one medium into another?

12. The power of a lens is measured in?

13. The image formed by which lens is always diminished?

14. The image formed by which lens can be real as well as virtual?

15. Where should an object be placed to get a virtual and magnified image formed by a convex lens?

16. When do light rays bend towards the normal during refraction?

17. Define the aperture of a lens.

18. Define the second principal focus.

## Short Answer Type Questions

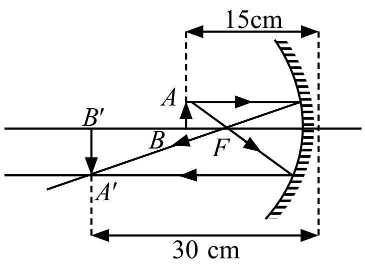
1. An object is kept in front of a plane mirror. If the mirror is moved away from the object through a distance $x$, by what distance will the image move?

2. An insect is at a distance of 1.5m from a plane mirror. Calculate the distance: (i) At which the image of the insect is formed. (ii) Between the insect and its image.

3. An object 4.0cm in size, is placed 25.0cm in front of a concave mirror of focal length 15.0cm.
   (*a*) At what distance from the mirror should a screen be placed in order to obtain a sharp image?
   (*b*) Find the size of the image.
   (*c*) Draw a ray diagram to show the formation of the image in this case. **(CBSE-2020)**

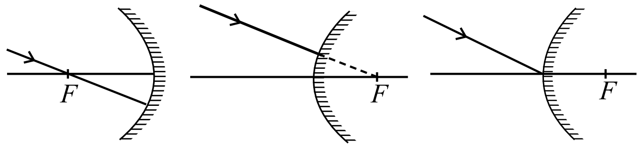
4. A concave mirror is cut out of a hollow glass sphere of radius 30cm. Calculate the focal length of the mirror.

5. An object of height 3cm is placed on the principal axis of a concave mirror. The distance of the object from the mirror is 15cm, and the image formed is 30cm away from the mirror on the same side of the mirror as the object. Calculate the height of the image formed.




6. State two positions in which a concave mirror produces a magnified image of a given object. List the differences between the two images. **(CBSE-2016)**

7. Draw the following diagram, in which a ray of light is incident on a concave/convex mirror, on your answer sheet. Show the path of this ray, after reflection, in each case. **(CBSE-2016)**




8. An object is placed at a distance of 30cm from a concave lens of focal length 15cm. List four characteristics (nature, position, etc.) of the image formed by the lens. **(CBSE-2017)**

9. If the image formed by a spherical mirror for all positions of the object placed in front of it is always erect and diminished, what type of mirror is it? Draw a labelled ray diagram to support your answer. **(CBSE-2018)**

10. A 1.2cm long pin is placed perpendicular to the principal axis of a convex mirror of focal length 12cm, at a distance of 8cm from the mirror.
    (*a*) Find the location of the image.
    (*b*) Find the height of the image.
    (*c*) Is the image erect or inverted?

11. What happens after refraction, when: (i) a ray of light parallel to the principal axis passes through a concave lens? (ii) a ray of light falls on a convex lens while passing through its principal focus. (iii) a ray of light passes through the optical center of a convex lens? **(CBSE-2020)**

12. A student focuses the image of a well illuminated distant object on a screen using a convex lens. After that he gradually moves the object towards the lens and each time focuses its image on the screen by adjusting the lens.
    (i) In which direction towards the screen or away from the screen, does he move the lens?
    (ii) What happens to the size of the image does it decrease or increase?
    (iii) What happens to the image on the screen when he moves the object very close to the lens? **(CBSE-2016)**

13. An object is placed at a distance of 60cm from a concave lens of focal length 30cm.
    (i) Use lens formula to find the distance of the image from the lens.

(ii) List four characteristics of the image (nature, position, size, erect/inverted) formed by the lens in this case.

(iii) Draw ray diagram to justify your answer of part (ii). **(CBSE-2019 /set 3)**

**14.** If the image formed by a lens for all positions of an object placed in front of it is always erect and diminished, what is the nature of this lens? Draw a ray diagram to justify your answer. If the numerical value of the power of this lens is 10D, what is its focal length in the Cartesian system? **(CBSE-2017)**

**15.** A student focuses the image of a candle flame, placed at about 2m from a convex lens of focal length 10 cm, on a screen. After that he moves gradually the flame towards the lens and each time focuses its image on the screen.

(*a*) In which direction does he move the lens to focus the flame on the screen?

(*b*) What happens to the size of the image of the flame formed on the screen?

(*c*) What difference is seen in the intensity (brightness) of the image of the flame on the screen?

(*d*) What is seen on the screen when the flame is very close (at about 5 cm) to the lens? **(CBSE-2017)**

**16.** A teacher gives a convex lens and a concave mirror of a focal length of 20cm each to his student and asks him to find their focal lengths by obtaining the image of a distant object. The student uses a distant tree as the object and obtains its sharp image, one by one, on a screen. The distances $d_1$ and $d_2$ between the lens/mirror and the screen in the two cases and the nature of their respective sharp images are likely to be

(*a*) (20 cm, 40 cm) and (erect and erect)

(*b*) (20 cm, 40 cm) and (inverted and inverted)

(*c*) (20 cm, 20 cm) and (inverted and inverted)

(*d*) (20 cm, 40 cm) and (erect and inverted)

Give a reason for your answer. **(CBSE-2019)**

**17.** State the laws of refraction of light. Explain the term 'absolute refractive index' of a medium and write an expression to relate it with the speed of light in a vacuum. **(CBSE-2018)**

**18.** What is meant by power of a lens? Write its SI unit. A student uses a lens of focal length 40cm and another of –20cm. Write the nature and power of each lens. **(CBSE-2018)**

**19.** An object of height 4.0cm is placed at a distance of 30cm from the optical centre '*O*' of a convex lens of focal length 20cm. Draw a ray diagram to find the position and size of the image formed. Mark optical centre '*O*' and principal focus 'F' on the diagram. Also find the approximate ratio of size of the image to the size of the object. **(CBSE-2018)**

## Long Answer Type Questions

**1.** (*a*) A concave mirror of focal length 10cm can produce a magnified real as well as virtual image of an object placed in front of it. Draw ray diagrams to justify this statement.

(*b*) An object is placed perpendicular to the principal axis of a convex mirror of focal length 10cm. The distance of the object from the pole of the mirror is 10cm. Find the position of the image formed. **(CBSE-2020)**

**2.** (*a*) Define the following terms in the context of spherical mirrors:

(i) Pole (ii) Centre of curvature

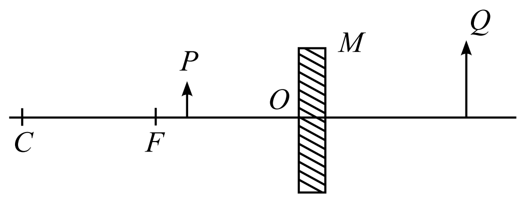
(iii) Principal axis (iv) Principal focus

(*b*) Draw ray diagrams to show the principal focus of *a*:

(i) Concave mirror

(ii) Convex mirror

(*c*) Consider the following diagram in which *M* is a mirror and *P* is an object and *Q* is its magnified image formed by the mirror.




State the type of the mirror *M* and one characteristic property of the image *Q*. **(CBSE-2016)**

**3.** (*a*) If the image formed by a mirror for all positions of the object placed in front of it is always diminished, erect and virtual, state the type of the mirror and also draw a ray diagram to justify your answer. Write one use such mirrors are put to and why.

(*b*) Define the radius of curvature of spherical mirrors. Find the nature and focal length of a spherical mirror whose radius of curvature is + 24cm. **(CBSE-2017)**

**4.** Draw ray diagrams showing the image formation by a concave mirror when an object is placed

**(NCERT Exemplar)**

(*a*) between the pole and focus of the mirror.
(*b*) between focus and center of curvature of the mirror.
(*c*) at the center of curvature of the mirror.
(*d*) a little beyond the center of curvature of the mirror.
(*e*) at infinity.

**5.** Draw a ray diagram in each of the following cases to show the formation of image, when the object is placed:
(i) between the optical centre and principal focus of a convex lens.
(ii) State the signs and values of magnifications in the above-mentioned cases (i) and (ii). **(CBSE-2020)**

**6.** (*a*) Define the following terms: (i) Power of a lens (ii) Principal focus of a concave mirror.
(*b*) Write the relationship among the object distance ($u$), image distance ($v$) and the focal length ($f$) of *a* (i) Spherical lens (ii) Spherical mirror
(*c*) An object is placed at a distance of 10cm from optical centre of a convex lens of focal length 15 cm. Draw a labelled ray diagram to show the formation of image in this case. **(CBSE-2020)**

**7.** Analyse the following observation table showing variation of image-distance ($v$) with object-distance ($u$) in case of a convex lens and answer the questions that follow without doing any calculations:

**(CBSE-2017)**

| S. No. | Object-Distance $u$ (cm) | Image-Distance $v$ (cm) |
|---|---|---|
| 1 | – 100 | +25 |
| 2 | – 60 | +30 |
| 3 | – 40 | + 40 |
| 4 | – 30 | + 60 |
| 5 | – 25 | + 100 |
| 6 | – 15 | + 120 |

(*a*) What is the focal length of the convex lens? Give reason to justify your answer.
(*b*) Write the serial number of the observation which is not correct. On what basis have you arrived at this conclusion?
(*c*) Select an appropriate scale and draw a ray diagram for the observation at S.No.2. Also find the approximate value of magnification.

**8.** A student focused the image of a candle flame on a white screen using a convex lens. He noted down the position of the candle screen and the lens as under

Position of candle = 12.0 cm

Position of convex lens = 50.0 cm

Position of the screen = 88.0 cm

**(NCERT Exemplar)**

(*a*) What is the focal length of the convex lens?
(*b*) Where will the image be formed if he shifts the candle towards the lens at a position of 31.0 cm?
(*c*) What will be the nature of the image formed if he further shifts the candle towards the lens?
(*d*) Draw a ray diagram to show the formation of the image in the case as said above.

## Case-Based Type Questions

### Case Study-I

**The radius of curvature of a convex mirror of a moving automobile is 2.0m. A truck is coming behind and is at a distance of 3.5m.**

**1.** What is the image distance behind the mirror?
(*a*) 0.48m (*b*) 0.24m
(*c*) 0.78m (*d*) 0.84m

**2.** The nature of the image is
(*a*) Diminished and inverted
(*b*) Virtual and erect
(*c*) Virtual and inverted
(*d*) Real and erect

**3.** The size of the image relative to the size of the truck is
(*a*) 22% (*b*) 24%
(*c*) 26% (*d*) 28%

### Case Study-II

**A converging mirror forms a real image of height 4 cm, of an object of height 1cm placed 20cm away from the mirror.**

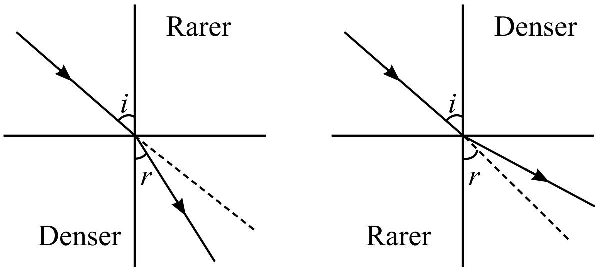
**1.** The image distance is
(*a*) –80cm (*b*) –90cm
(*c*) –100cm (*d*) –110cm

**2.** Magnitude of the focal length of the mirror is:
(*a*) 15cm (*b*) 16cm
(*c*) 17cm (*d*) 18cm

**3.** The mirror used here is a mirror.
(*a*) concave (*b*) convex
(*c*) plano convex (*d*) plano concave

## Case Study-III

**When the rays of light travel from one transparent medium to another, the path of light are deviated. This phenomenon is called the refraction of light. The bending of light depends on the optical density of the medium through which the light pass.**




The speed of light varies from medium to medium. A medium in which the speed of light is more is an optically rarer medium whereas in which the speed of light is less is an optically denser medium. Whenever light goes from one medium to another, the frequency of light does not change however, speed and wavelength change. It concluded that change in the speed of light is the basic cause of refraction.

1. When light travels from air to glass, the ray of light bends:
   (*a*) towards the normal (*b*) away from normal
   (*c*) anywhere (*d*) none of these
2. A ray of light passes from medium *A* to another medium *B*. No bending of light occurs if the ray of light hits the boundary of medium *B* at an angle of:
   (*a*) 0° (*b*) 45°
   (*c*) 90° (*d*) 120°
3. When light passes from one medium to another, the frequency of light:
   (*a*) increases (*b*) decreases
   (*c*) remains same (*d*) none of these
4. When light passes from glass to water, the speed of light:
   (*a*) increases
   (*b*) decreases
   (*c*) remains same
   (*d*) first increases then decrease
5. The bottom of a pool filled with water appears to be ______ due to the refraction of light.
   (*a*) shallower (*b*) deeper
   (*c*) at same depth (*d*) empty

## Competitive Level

### Different Theories: Defining Nature of Light

**(i) Newton's corpuscular theory (Particle nature of light):** According to Newton's corpuscular theory light travels in space with a great speed as a stream of very small particles called corpuscles.

However, this theory failed to explain diffraction of light and interference of light. That is why wave theory of light was proposed.

**(ii) Wave nature of light:** According to wave nature of light, light is a wave and it is electromagnetic in nature. It can travel through vacuum also. The speed of light waves in vacuum is maximum and is equal to $3 \times 10^8$ m/s.

**(iii) Quantum theory of light:** Photoelectric effect could not be explained with the help of wave theory of light. Therefore, quantum theory of light was proposed. Photoelectric effect was successfully explained with the help of quantum theory of light.

**Photoelectric effect:** When light of definite frequency falls on the surface of metals like Caesium, electrons come out of it. These electrons are called 'photo-electrons' and this phenomenon is known as 'photo-electric effect'.

According to Max Planck, light consists of packets or quantas of energy called photons. Each photon carries energy given by $E = h\nu$.

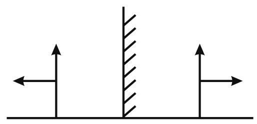
Where, $h \rightarrow$ Planck's constant = $6.6 \times 10^{-34}$ Js. and $\nu \rightarrow$ Frequency of light

❖ **Relative motion of object and image:**

**Case I:**

If an object moves towards (or moves away) from a plane mirror with speed v, its image will also approach (or moves away) with speed $v$.

So, the speed of the image relative to the object will be $v - (-v) = 2v$. Therefore, it appears that the object and the image are moving away or approaching each other with a relative speed of 2v.

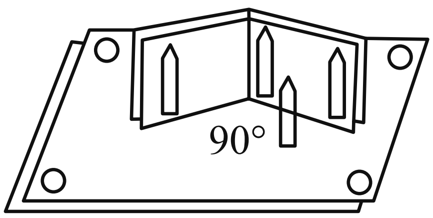


**Case II:**

If the mirror is moved towards (or away from) the object with speed '$v$'. Then. the image will move towards (or away from) the object with a speed '$2v$'

❖ **Multiple Reflection**

- Number of images formed by combination of two plane mirrors depends on the angle between the mirrors.
- If θ (in degrees) is the angle between the plane mirrors then number of images formed are given as, $n = \dfrac{360}{\theta} - 1$
- If there are two plane mirrors inclined to each other at an angle 90° the number of images of a point object is equal to 3.




❖ **Deviation (δ) :** Deviation (δ) is defined as the angle between directions of incident ray and the emergent ray. So if light is incident at an angle of incidence i,

$\delta = 180° - (\angle i + \angle r) = (180° - 2i)$ [$\because i = \angle r$]

So, if light is incident at angle of 45°

Deviation (δ) = $(180° - 2 \times 45°) = 90°$

and for normal incidence angle $\angle i = 0°$, $\delta = 180°$

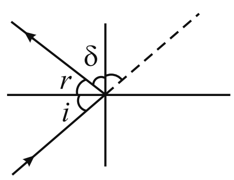



**Fig.** Plane mirror

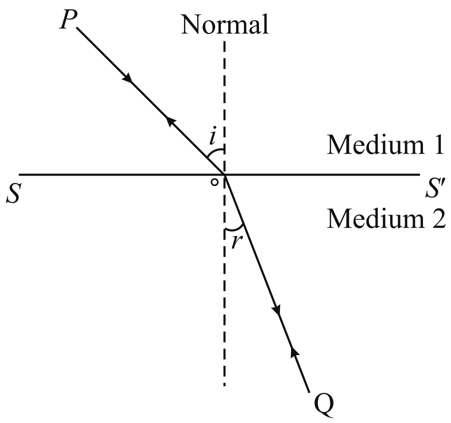
## Principle of Reversibility of the Path of Light

### The Path of the Light Ray is Reversible

A ray of light *PO* is incident at an angle i on a plane surface *SS'* separating the two media 1 and 2.

It is refracted along *OQ* at an angle of refraction r. The refractive index of medium 2 with respect to medium 1 is

$$^1n_2 = \frac{\sin r}{\sin i} \quad ...(i)$$




Now, if refraction takes place from medium 2 to 1, the principle of reversibility recommends that the ray of the light incident along *QO* at *O* at an angle of incident r in medium 2 will get refracted only along with *OP* at an angle of refraction i in medium 1, and in no other direction than *OP*.

The refractive index of medium 1 with respect to medium 2 is then

$$^2n_1 = \frac{\sin i}{\sin r} = \frac{\sin i}{\sin r} \quad ...(ii)$$

From equations (*i*) and (*ii*)

$$^1n_2 \times {}^2n_1 = \frac{\sin i}{\sin r} \times \frac{\sin r}{\sin i}$$

$$^1n_2 \times {}^2n_1 = 1$$

$$^2n_1 = \frac{1}{^1n_2} \text{ or } {}^1n_2 = \frac{1}{^2n_1}$$

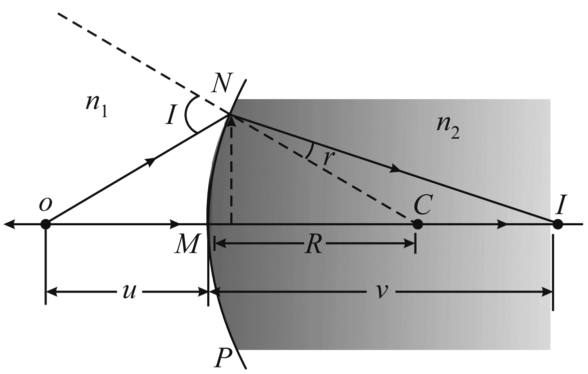
Thus, if the refractive index of glass with respect to air is $^an_g = \frac{3}{2}$ the refractive index of air with respect to glass will be $^gn_a = \frac{1}{3/2} = \frac{2}{3}$

### Refraction at a Spherical Surface

Let *MNP* be a spherical surface. The rays are incident from a medium of refractive index $n_1$ and refracted to another medium of refractive index $n_2$.

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

The above equation gives us a relation between object and image distance in terms of the refractive index of the medium and the radius of curvature of the curved spherical surface. It holds for any curved spherical surface.




## Lens Maker's Formula

The lens maker's formula is a formula that relates focal length, radii of curvature, and refractive index of the lens. It is used by the lens manufacturers to make lenses of particular power from the glass of a given refractive index.It is given as: $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

## Power of Combination of Lenses

Sometimes many optical instruments consist of several lenses, and then the net power of all the lenses kept together is the algebraic sum of individual powers of lenses.

If $P_1$, $P_2$, $P_3$… $P_n$ are individual powers of lenses kept in close contact, then the total power $P_t$ is given by $P_1 + P_2 + P_3 + \ldots + P_n$

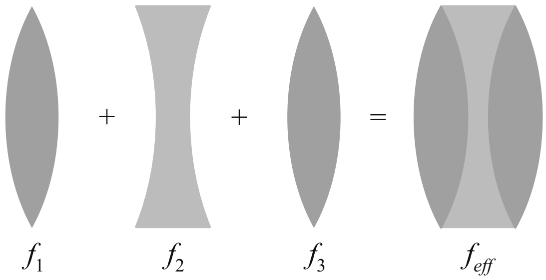



**Fig.** Combination of Lenses

In the given figure, three lenses whose focal lengths are $f_1$, $f_2$, and $f_3$ are combined together, and the focal length of the combination is written as $f_{\text{eff}}$ (effective focal length).

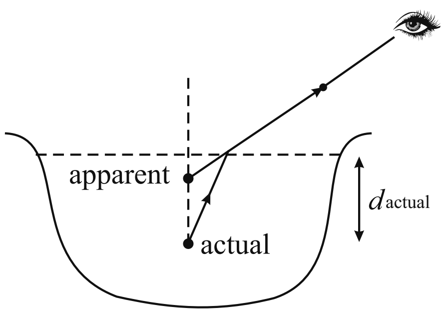
Also, total magnification is given by the product of individual magnifications. If $m_1$, $m_2$, and $m$ ... are the magnification of lenses, then total magnification $m_t$ is given by $m_1 \times m_2 \times m_3 \times \ldots$

## Try it Yourself

1. The power of a combination of two lenses *A* and *B* is 5D. The focal length of *A* is 15cm. What is the focal length of *B*?
2. A convex lens of focal length 25cm and a concave lens of focal length 10cm are placed in close contact with one another.
   (*a*) What is the power of the combination?
   (*b*) What is the focal length of the combination?
   (*c*) Is this combination converging or diverging?

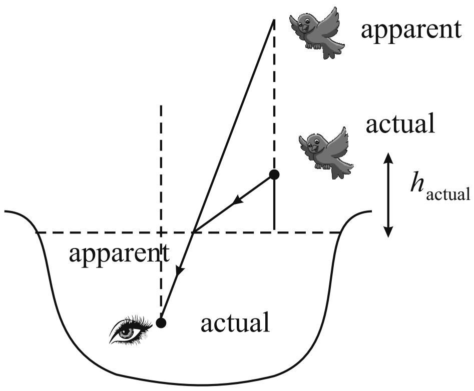
## Real & Apparent Depth & Height

**(*a*) Seeing from air to liquid:**




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

**(b) Seeing from liquid to air**




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

## Multiple Choice Questions

1. A 10mm long awl pin is placed vertically in front of a concave mirror. A 5mm long image of the awl pin is formed at 30cm in front of the mirror. The focal length of this mirror is: **(NCERT Exemplar)**
   (a) –30cm (b) –20 cm
   (c) –40cm (d) –60 cm
2. According to the laws of reflection:
   (a) sin $i$/sin $r$ = constant (b) tan $i$ = tan $r$
   (c) angle $i$ = angle $r$ (d) All of these
3. Which of the following does a Dentist use to view the teeth for treatment?
   (a) Concave Mirror (b) Convex lens
   (c) Concave lens (d) Convex Mirror
4. A real and enlarged image can be formed by using:
   (a) concave mirror.
   (b) plane mirror.
   (c) convex mirror.
   (d) Both concave and a plane mirror.
5. For an incident ray directed towards centre of curvature of a spherical mirror the reflected ray
   (a) retraces its path
   (b) passes through focus
   (c) passes through the pole
   (d) becomes parallel to the principal axis
6. When a plane mirror is rotated through a certain angle, the reflected ray turns through twice as much and the size of the image:
   (a) is doubled (b) is halved
   (c) becomes infinite (d) remains same
7. If an object is placed symmetrically between two plane mirrors, inclined at angle of 72 degree, then total no. of images formed:
   (a) 5 (b) 4
   (c) 2 (d) infinite
8. Focal length of a plane mirror is:
   (a) 0 (b) infinite
   (c) 25 cm (d) –25
9. Which statement is true for the reflection of light?
   (a) The angle of incidence and reflection are equal.
   (b) The reflected light is less bright than the incident light.
   (c) The sum of angle of incidence and reflection is always greater than 90°.
   (d) The beams of incident light after reflection diverge at unequal angles.
10. Rahul conducts an experiment using an object of height 10cm and a concave lens with focal length 20 cm. The object is placed at a distance of 25cm from the lens. Can the image be formed on a screen?

(*a*) Yes, as the image formed will be real
(*b*) Yes, as the image formed will be erect
(*c*) No, as the image formed will be virtual
(*d*) No, as the image formed will be inverted

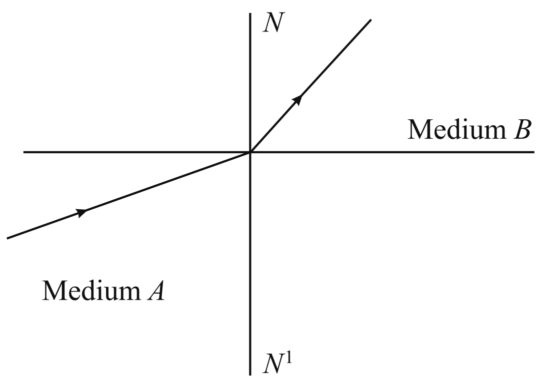
**11.** The distance between a spherical lens and the image is –15 cm. The lens is:
(*a*) Concave lens
(*b*) either concave lens or convex lens with the object between *O* and *F*.
(*c*) either of the two irrespective of the object distance
(*d*) Convex lens

**12.** A ray of light propagates from an optically denser medium to an optically rarer medium.
(*a*) It will bend towards the normal after refraction.
(*b*) It will refract in a way such that the angle of refraction = angle of incidence.
(*c*) It will continue to go on the same path after refraction.
(*d*) It will bend away from the normal after refraction.

**13.** Light of velocity $3 \times 10^8$ m/s, falls on a glass prism. The frequency of light is $2 \times 10^3$ Hz. What will be its frequency after passing through the glass prism:
(*a*) $\frac{2}{3} \times 10^{-5}$ Hz (*b*) $\frac{3}{2} \times 10^{-5}$ Hz
(*c*) $2 \times 10^3$ Hz (*d*) None of these

**14.** A light ray enters from medium *A* to medium *B*, as shown in the figure. The refractive index of medium *B* relative to *A* will be

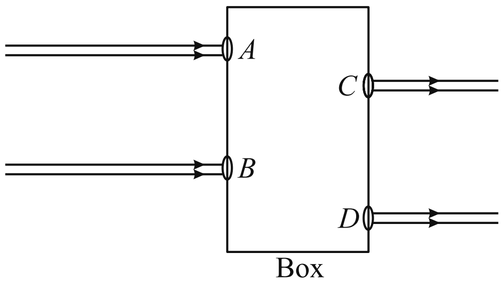
**(NCERT Exemplar)**




(*a*) greater than unity (*b*) less than unity
(*c*) equal to unity (*d*) zero

**15.** Beams of light are incident through the holes *A* and *B* and emerge out of box through the holes *C* and *D* respectively as shown in the Figure. Which of the following could be inside the box?

**(NCERT Exemplar)**




(*a*) A rectangular glass slab
(*b*) A convex lens
(*c*) A concave lens
(*d*) A prism

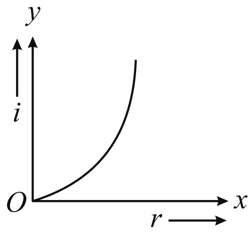
**16.** Absolute refractive index of any medium is:
(*a*) $\dfrac{\text{speed of light in vacuum}}{\text{speed of light in the medium}}$
(*b*) $\dfrac{\text{speed of light in water}}{\text{speed of light in the medium}}$
(*c*) $\dfrac{\text{speed of light in the medium}}{\text{speed of light in air}}$
(*d*) All of the above

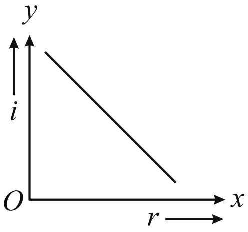
**17.** If an object is placed between 2*F* and *F* in front of the convex lens, then the image will form at
(*a*) At the focus
(*b*) At 2*F*
(*c*) Between *F* and 2*F*
(*d*) Beyond 2*F*

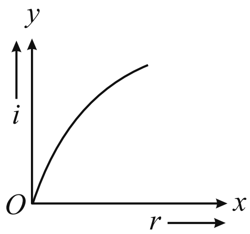
**18.** If an object is placed at *F* in front of the convex lens, then the image forms at
(*a*) At the focus (*b*) At infinity
(*c*) Between *F* and 2*F* (*d*) Beyond 2*F*

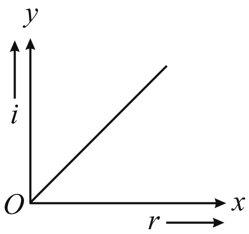
**19.** $m = +2$ : image is virtual and enlarged : : $m = -2$ : ………..
(*a*) The image is real and enlarged.
(*b*) Image is virtual and enlarged.
(*c*) Image is real and diminished.
(*d*) Image is virtual and diminished

**20.** Which of the following correctly represents graphical relation between angle of incidence (i) and angle of reflection($r$)?

(*a*) 


(*b*) 


(*c*) 


(*d*) 


**21.** Which of the following can make a parallel beam of light from a point source incident on it?

(*a*) concave mirror as well as convex lens

(*b*) convex mirror as well as concave lens

(*c*) two plane mirrors placed at 90° to each other

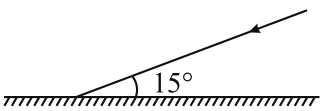
(*d*) concave mirror as well as concave lens

**22.** Question: An observer runs towards a plane mirror with a velocity $x$ m/s. What is the velocity of his image which will appear to move towards him?

(*a*) $2x$ m/s (*b*) $\frac{x}{2}$ m/s

(*c*) $x$ m/s (*d*) $\frac{x}{4}$ m/s

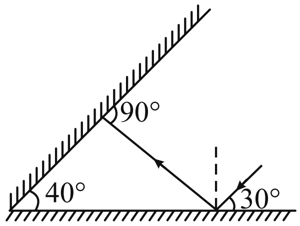
**23.** When a ray of light strikes a plane mirror at an angle of 15° with the mirror, what will be the angle through which the ray get deviated?

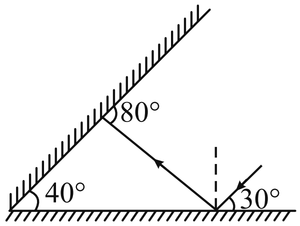


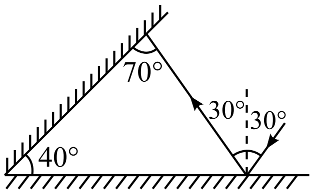

(*a*) 150° (*b*) 30°

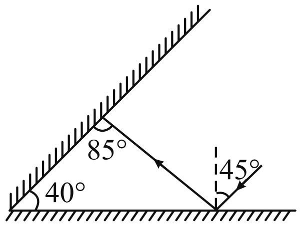
(*c*) 75° (*d*) None of these

**24.** Which of the following correctly depicts reflections in case of plane mirrors inclined at 40°?

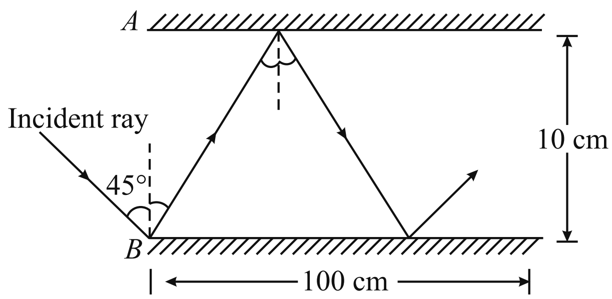
(*a*) 


(*b*) 


(*c*) 


(*d*) 


**25.** Two parallel plane mirrors $A$ and $B$ are placed at a separation 10cm as shown is figure. A ray incident on the corner of mirror $B$ at an angle of incidence 45%. Find the number of times rays is reflected from mirror:




(*a*) 4 (*b*) 5

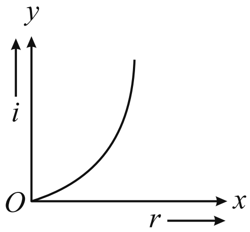
(*c*) 6 (*d*) 7

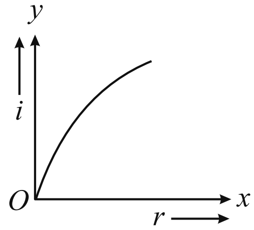
**26.** The linear magnification for a mirror is the ratio of the size of the image to the size of the object, and is denoted by m. Then m is equal to (symbols have their usual meanings):

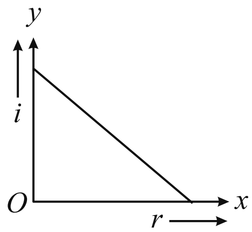
(*a*) $\frac{uf}{u-f}$  (*b*) $\frac{uf}{u-f}$

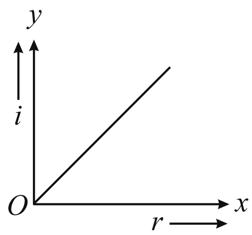
(*c*) $\frac{f}{u-f}$  (*d*) None of these

**27.** Which of the following correctly depicts the graphical variation in case of spherical mirror?

(*a*) 


(*b*) 


(*c*) 


(*d*) 


**28.** A student studies that the speed of light in air is 300000km/sec where that of speed in a glass slab is about 197000km/sec. What causes the difference in speed of light in these two media?

(*a*) difference in density

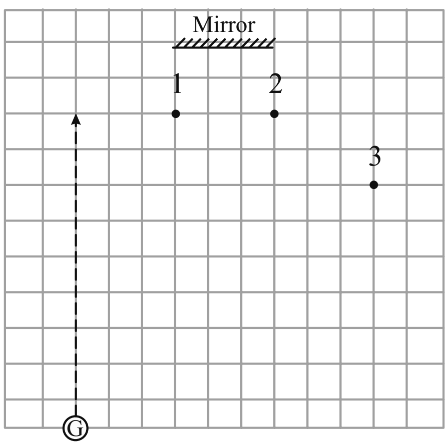
(*b*) difference in temperature

(*c*) difference in amount of light

(*d*) difference in direction of wind flow

## Competitive Corner

**1.** A girl (*G*) walks into a room along the path shown by the dashed line (see figure). She tries to observe images of small toys numbered 1, 2, and 3 in the plane mirror on the wall. **(IOQJS 2021)**




The order in which she will see images of the toys is:

(*a*) 3, 2, 1.  (*b*) 3, 2.

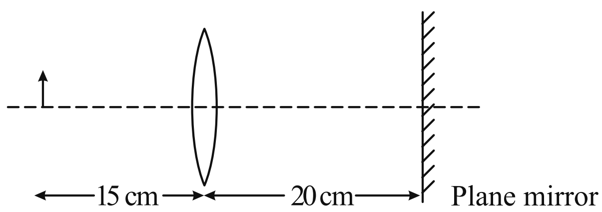
(*b*) 1, 2, 3  (*d*) 2, 3.

**2.** Two illuminated point objects $O_1$ and $O_2$ are placed at a distance 24cm from each other along the principal axis of a thin convex lens of focal length 9cm such that images of both the objects are formed at the same positions. Then the respective distances of the lens from $O_1$ and $O_2$ (in cm) are **(IOQJS 2021)**

(*a*) 12 and 12  (*b*) 18 and 6

(*c*) 14 and 10  (*d*) 16 and 8

**3.** Focal length of a thin convex lens is 10cm. An object is placed at a distance 15cm in front of the lens and a plane mirror is kept at 20cm on the other side as shown in figure. **(NSEJS 2022-23)**



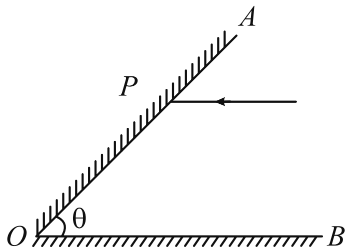

(*a*) The final image is formed at distance 10cm from lens towards the mirror

(*b*) The final image is formed at a distance 30cm from lens means 10cm behind the mirror

(*c*) The final image has magnification $m = -2$

(*d*) The final image has magnification $m = +2$

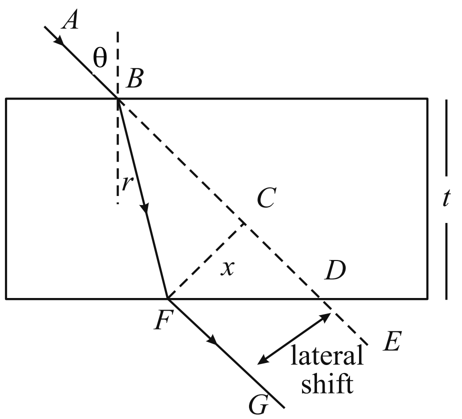
**4.** Two plane mirrors $OA$ and $OB$ are inclined at an angle $\theta$ as shown in figure. A ray of light incident parallel to $BO$ strikes the mirror $OA$ at point $P$. It gets reflected from mirror $OA$ and then reflected from the mirror $OB$, the ray finally emerges parallel to $OA$. The value of angle $\theta$ is **(NSEJS 2022-23)**




($a$) 90° ($b$) 60°

($c$) 45° ($d$) 30°

**5.** A glass plate of uniform thickness t and refractive index $\mu$ is as shown in the diagram. $AB$ is the incident ray and $FG$ is the emergent ray. The angles of incidence and refraction are $i$ and $r$ respectively. The perpendicular distance $FC = x$ between the incident and the emergent rays is called the lateral shift. Then **(IOQJS 2021-22)**



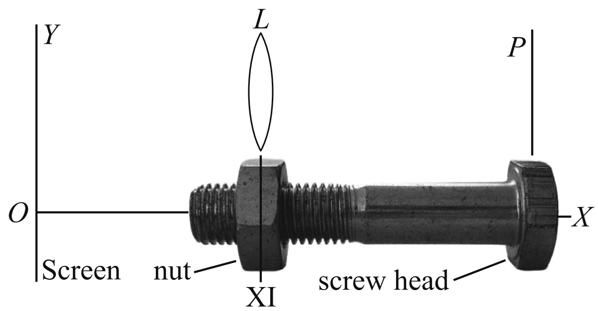

($a$) $x = t\left(\sin i - \frac{\cos i \sin r}{\cos r}\right)$

($b$) $x$ depends on refractive index $\mu$

($c$) $x$ is independent of the wavelength $\lambda$ of light

($d$) Maximum value of $x = t$ when i is close to 90°

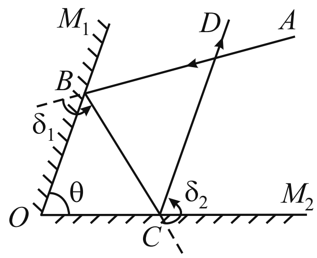
**6.** In a screw-nut assembly (shown below) the nut is held fixed in its position and the screw is allowed to rotate inside it. A convex lens ($L$) of focal length 6.0cm is fixed on the nut. An object pin ($P$) is attached to the screw head. The image of the object is observed on a screen $Y$. When the screw head to rotated through one rotation, the linear distance moved by the screw tip is 1.0mm. The observation are made only when the image is obtained in the same orientation on the screen. At a certain position of $P$, the image formed is three times magnified as that of the pin height. Through how many turns should the screw head be rotated so that the image is two times magnified? **(NSEJS 2019)**




($a$) 8 ($b$) 10

($c$) 12 ($d$) 14

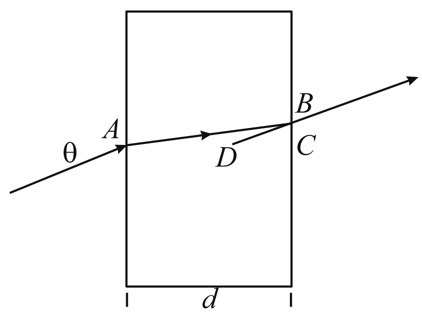
**7.** Two plane mirrors $M_1$ and $M_2$ have their reflecting faces inclined at $\theta$. Mirror $M_1$ receives a ray $AB$, reflects it at $B$ and sends it as $BC$. It is now reflected by mirror $M_2$ along $CD$, as shown in the figure. Total angular deviation suffered by the incident ray $AB$ is: **(NSEJS 2018)**




($a$) $\delta = 90° + 2\theta$ ($b$) $\delta = 180° + 2\theta$

($c$) $\delta = 270° - 2\theta$ ($d$) $\delta = 360° - 2\theta$

**8.** A ray of light passes through a thick glass sheet with some angle of incidence as shown. The refractive index of glass is: **(INJSO 2018)**



(*a*) Exactly *d/DC*
(*b*) Approximately *d/DC*
(*c*) Approximately *d/AD*
(*d*) Approximately *AD/AC*

**9.** The focal length of a convex lens is 20cm. The image formed is double the length of the object. The distance of the object from the lens is: **(NTSE- 2021/Bihar)**

(*a*) –30cm (*b*) –20cm
(*c*) –60cm (*d*) 30cm

**10.** The refractive indices of four substances, *A*, *B*, *C* and *D* are respectively 1.50, 1.36, 1.70 and 1.31. Out of these substances which substance will have a maximum speed of light: **(NTSE-2021/Chhattisgarh)**

(*a*) *A* (*b*) *B*
(*c*) *C* (*d*) *D*

**11.** A convex lens of focal length 8cm forms a real image of the same size as the object. Then the distance between the object and the image will be: **(NTSE-2021/Chhattisgarh)**

(*a*) 8cm (*b*) 16cm
(*c*) 32cm (*d*) 24cm

**12.** Light travels through a glass slab of thickness t and having refractive index n. If c is the velocity of light in a vacuum, then the time taken by light to travel this thickness of glass is **(NTSE-2021/Delhi)**

(*a*) $\frac{t}{nc}$ (*b*) $\frac{nt}{c}$
(*c*) $\frac{n^2t}{c}$ (*d*) $\frac{t}{n^2c}$

**13.** An object of height 2.0cm is placed on the principal axis of a concave mirror at a distance of 12cm from the pole. If the image is inverted, real and 5cm in height then location of the image and focal length of the mirror respectively are **(NTSE-2021/Delhi)**

(*a*) (–30cm, +8.6cm) (*b*) (–30cm, –8.6cm)
(*c*) (+30cm, +8.6cm) (*d*) (+30cm, –8.6cm)

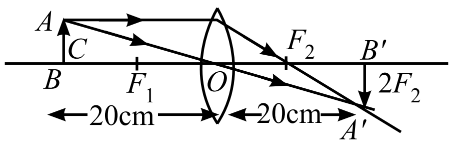
**14.** The object distance *u*, image distance *v* and focal length *f* for a spherical mirror are related as **(NTSE-2021/Jharkhand)**

(*a*) $av - au = \frac{1}{f}$ (*b*) $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$
(*c*) $v - u = \mathrm{f}$ (*d*) $v + u = \mathrm{f}$

**15.** The image formed by a concave mirror is observed to be virtual, erect, and larger than the object. Where should be the position of the object? **(NTSE-2021/Jharkhand)**

(*a*) Between the principal focus and the center of curvature
(*b*) At the center of curvature
(*c*) Beyond the center of curvature
(*d*) Between the pole of the mirror and its principal focus

**16.** The image formation in a convex lens is shown in the following figure, *AB* is the object and *A'B'* is the image. The focal length of the lens is **(NTSE-2021/Karnataka)**




(*a*) 40cm (*b*) 10cm
(*c*) 20cm (*d*) 05cm

**17.** The lenses of power +3.5D, +2.5D, and +1D are placed in contact with each other in an optical device. The effective power of the combination of these lenses is **(NTSE-2021/Karnataka)**

(*a*) 5D (*b*) 6D
(*c*) 7D (*d*) 8D

**18.** An object approaches a plane mirror with a speed of 5 m/s. The speed with which the image moves with respect to the object will be: **(NTSE-2021/Kerala)**

(*a*) 5m/s (*b*) 2.5m/s
(*c*) 10m/s (*d*) 20m/s

**19.** When light enters from one medium to another medium of different optical densities which of the following remains unchanged? **(NTSE-2021/Kerala)**

(*a*) Speed (*b*) Wavelength
(*c*) Frequency (*d*) None of these

**20.** The incident light is light from a point source. Which of the following can produce a parallel beam of light? **(NTSE-2021/Odisha)**

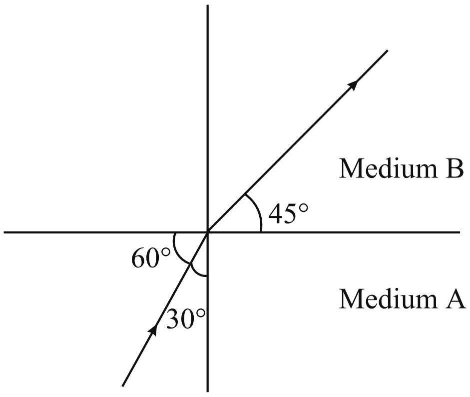
(*a*) concave mirror only
(*b*) Two plane mirrors placed at 90° to each other
(*c*) convex lens only
(*d*) Both concave mirror and convex lens

**21.** A 2cm long alpin is fixed vertically in front of a vertically placed concave mirror. A 1cm long image of the alpin is formed at a distance of 30cm in front of the mirror. The focal length of the concave mirror is **(NTSE-2021/Odisha)**

(*a*) – 60cm (*b*) –45cm

(*c*) –30cm (*d*) –20cm

**22.** The refractive index of medium *B* with respect to medium *A* in the given figure is given by **(NTSE-2021/Punjab)**




(*a*) $\frac{\sqrt{3}}{\sqrt{2}}$ (*b*) $\frac{1}{2}$

(*c*) $\frac{\sqrt{3}}{2}$ (*d*) $\frac{1}{\sqrt{2}}$

**23.** Focal length of a lens is 50cm. In dioptre, the power of the lens will be: **(NTSE-2021/Rajasthan)**

(*a*) 0.02 (*b*) 2

(*c*) 0.2 (*d*) 50

**24.** Correct relation between the radius of curvature ($R$) and the Focal length ($F$) of a spherical mirror is **(NTSE-2021/Rajasthan)**

(*a*) $R = \frac{F}{2}$ (*b*) $R = F$

(*c*) $R = 2F$ (*d*) $R = (F)^2$

**25.** Refraction from denser to rarer medium for a light ray, the value of angle of refraction at the condition of critical angle is: **(NTSE-2021/Rajasthan)**

(*a*) 0° (*b*) 180°

(*c*) 45° (*d*) 90°

**26.** A man used a convex lens of a focal length of 20cm in his spects, the power of the lens is: **(NTSE-2021/Uttar Pradesh)**

(*a*) +2D (*b*) –2D

(*c*) +5D (*d*) –5D

**27.** For a concave mirror of focal length 10cm. to form twice magnified image, distance of object from its pole is/are **(NTSE-2021/Uttar Pradesh)**

(*a*) –5cm (*b*) –15cm

(*c*) –10cm (*d*) Both (*a*) and (*b*)

**28.** In the case of refraction of light from a medium to air, the critical angle is found to be 45°. What is the refractive index of the medium with respect to air? **(NTSE-2021/West Bengal)**

(*a*) $\sqrt{2}$ (*b*) $\sqrt{3}$

(*c*) 2 (*d*) 3

**29.** In case of a convex lens, what is the minimum distance between an object and its real image? **(NTSE-2021/West Bengal)**

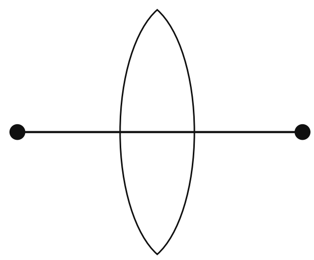
(*a*) 2.5 times of focal length

(*b*) 2 times of focal length

(*c*) 4 times of focal length

(*d*) equal to focal length

**30.** A convex lens of focal length 20cm is cut into two halves horizontally. Each of which is placed 0.5mm and a point object placed at a distance of 30cm from the lens as shown. Then the image is at: **(NTSE-2019/Andhra Pradesh)**



(*a*) 70cm (*b*) 30cm

(*c*) 50cm (*d*) 60cm

**31.** A point object is placed at a distance of 10cm and its real image is formed at a distance of 20cm from a concave mirror. When the object is moved by 0.1cm toward the mirror, then the image will be moved by about **(NTSE-2019/Andhra Pradesh)**

(*a*) 0.8cm away from the mirror

(*b*) 0.4cm away from the mirror

(*c*) 0.8cm toward the mirror

(*d*) 0.4 cm toward the mirror

**32.** The radius of curvature of concave mirror is 10cm If the object is placed at 20cm in front of it, then what will be the position of image and magnification: **(NTSE 2020/Chhattisgarh)**

(*a*) $\frac{20}{3}\text{cm}, 3$ (*b*) $-\frac{20}{3}\text{cm}, -\frac{1}{3}$

(*c*) – 20 cm, 3 (*d*) $-\frac{20}{3}\text{cm}, 6$

**33.** A concave mirror of a focal length of 15cm forms an image. The position of the object when the image is virtual and linear magnification is 2 is.

**(NTSE 2020/Delhi)**

(*a*) 22.5cm (*b*) 7.5cm

(*c*) 30cm (*d*) 45cm

**34.** A spherical mirror and a thin spherical lens each of focal lengths –10cm are given. The mirror and lens are likely to be: **(NTSE 2020/Karnataka)**

(*a*) The mirror is concave mirror and the lens is concave lens

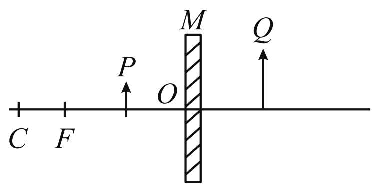
(*b*) The mirror is convex mirror and the lens is convex lens

(*c*) The mirror is convex mirror and the lens is concave lens

(*d*) The mirror is concave mirror and the lens is convex lens

**35.** In the following diagram '*M*' is an mirror and '*P*' is an object and '*Q*' is its magnified image of '*P*' formed by the mirror. The mirror '*M*' is:

**(NTSE 2020/Karnataka)**




(*a*) Concave mirror (*b*) Convex mirror

(*c*) Plane mirror (*d*) Plano convex mirror

**36.** Which of the following are true?

(A) A convex lens always form a real image for a real object.

(B) An air bubble inside water acts like a convex lens.

(C) The real image formed by a lens is always inverted.

(D) Focal length of a plane mirror is infinite.

**(NTSE 2020/Odisha)**

(*a*) (A), (C) (*b*) (C), (D)

(*c*) (B), (C) (*d*) (A), (D)

**37.** In which of the following cases, the position and properties of the image formed remain almost the same, independent of the position of the object?

**(NTSE 2020/Kerala)**

(*a*) Convex mirror, Convex lens

(*b*) Convex mirror, Concave lens

(*c*) Convex lens, Concave mirror

(*d*) Convex lens, Concave lens

**38.** By keeping the incident ray fixed, a plane mirror is rotated so as to vary the angle of incidence. When the mirror is turned by 10°, the reflected ray is turned by: **(NTSE 2020/Kerala)**

(*a*) 10° (*b*) 5°

(*c*) 20° (*d*) 40°

**39.** ______ is located behind a convex mirror:

**(NTSE 2020/Madhya Pradesh)**

(*a*) the focal point (*b*) a ray

(*c*) a real image (*d*) the object

**40.** A ray of light is incident on the surface of transparent medium at an angle of 45° and is refracted in the medium at an angle of 30°. What will be the velocity of light in the transparent medium?

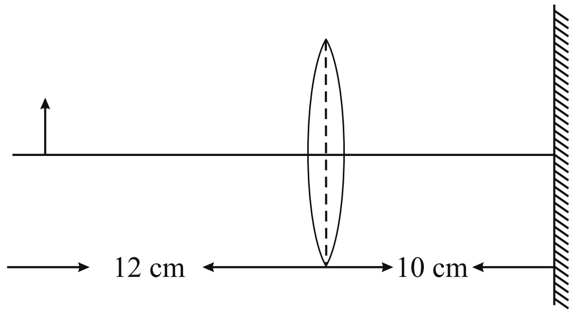
**(NTSE 2020/Maharashtra)**

(*a*) $1.96 \times 10^3$ m/s (*b*) $2.12 \times 10^8$ m/s

(*c*) $2.65 \times 10^8$ m/s (*d*) $1.25 \times 10^3$ m/s

**41.** An object, a convex lens of focal length 20cm and a plane mirror are arranged as shown in figure. How far behind the mirror is the position of the final image of the object?

**(NTSE 2020/Maharashtra)**




(*a*) 40cm (*b*) 30cm

(*c*) 20cm (*d*) 10cm

**42.** Three lenses have a combined power of 2.7D. If the powers of two lenses are 2.5D and 1.7D respectively, find the focal length of the third lens.

**(NTSE 2020/Maharashtra)**

(*a*) –66.66cm (*b*) –6.666 cm
(*c*) –66.66m (*d*) –6.666m

**43.** A small source of light casts a sharp shadow on an opaque object shows **(NTSE 2020/Punjab)**

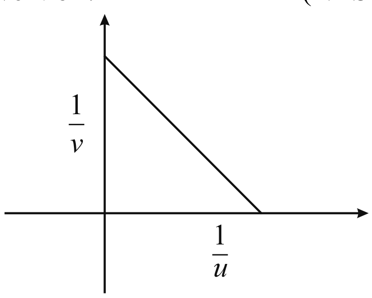
(*a*) Ray Nature of Light
(*b*) Wave Nature of Light
(*c*) Particle Nature of Light
(*d*) Dual Nature of Light

**44.** An object is placed at point *A* in front of a convex lens of focal length *f*. Its real inverted and magnified image is formed behind the lens. When the object is brought closer to the lens and placed at point *B* a virtual and erect image but with exactly the same magnification (in magnitude) as before is formed in front of the convex lens. Let *F* be the focus of the lens in front of it. Which of the following relations is correct? **(NTSE Stage II-2020)**

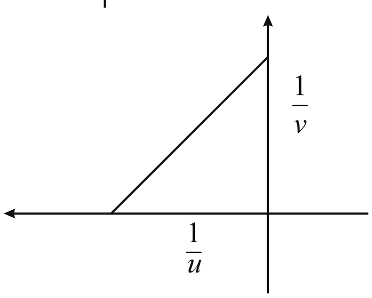
(*a*) $AF = FB$ (*b*) $AB = f$
(*c*) $AF - BF = f$ (*d*) $AB = 2F$

**45.** Four graphs between $\frac{1}{u}$ and $\frac{1}{v}$ given for spherical mirrors. Which one of them suitable represents a convex mirror, as per the new Cartesian sign convention? **(NTSE Stage II-2020)**

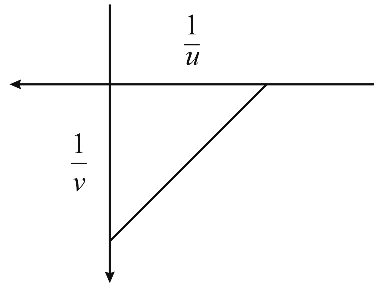
(*a*)



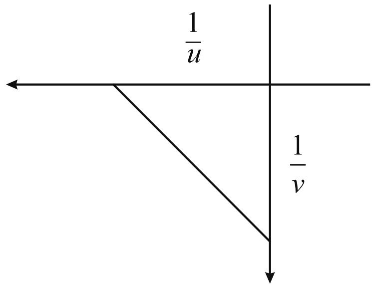

(*b*)




(*c*)




(*d*)

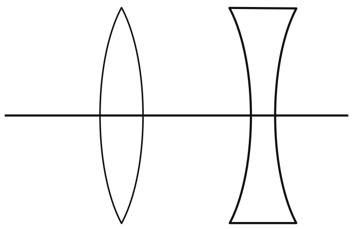



**46.** A small pencil of length 10cm is kept along the axis of a concave mirror of radius of curvature 40cm with its tip touching the mirror. The size of pencil's image would appears to be: **(NTSE Stage II-2021)**

(*a*) 5cm (*b*) 10cm
(*c*) 20cm (*d*) infinite

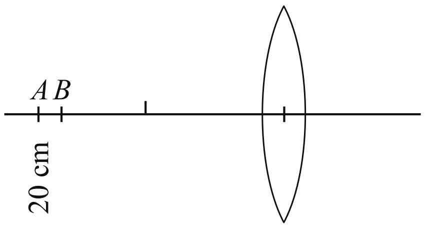
**47.** A convex lens and a con)cave lens, each of focal length 10cm, are kept separated by a distance of 2cm as shown in the figure. If the light is incident from left, the combinations of lenses will be:

**(NTSE Stage II-2019)**



(*a*) converging
(*b*) diverging
(*c*) behaving like a glass slab
(*d*) converging or diverging depending on whether the lenses are arranged as shown in the figure or in the reverse order.

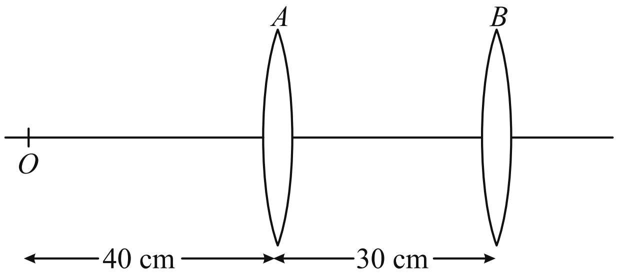
**48.** A pin *AB* of length 2cm is kept on the axis of a convex lens between 18cm and 20cm as shown in figure. Focal length of convex lens is 10cm. Find magnification produced for the image of the *p* in. **(NTSE Stage II-2019)**




($a$) 0.83 ($b$) 1.00

($c$) 1.25 ($d$) 6.78

**49.** Two convex lens $A$ and $B$ each of focal length 30cm are separated by 30cm as shown in the figure. An object $O$ is placed at a distance of 40cm to the left of lens $A$.




What is the distance of the final image formed by this lens system? **(NTSE Stage II-2018)**

($a$) 120cm to right of lens $A$

($b$) 90cm to right of lens $A$

($c$) 22.5cm to right of lens $B$

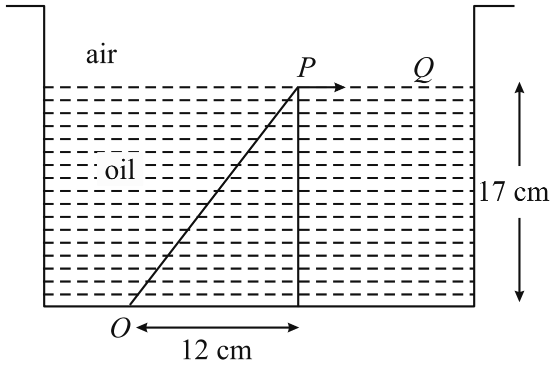
($d$) 45cm to right of lens $B$

**50.** A ray of light of pure single colour is incident on the face of a prism having angle of the prism 30° at an angle of incidence 45°. The refracted ray does not change its direction as it crosses the other face and emerges out of the prism. The refractive index of the material of the prism is: **(NTSE Stage II-2018)**

($a$) $\frac{2}{\sqrt{3}}$ ($b$) 2

($c$) $\sqrt{2}$ ($d$) $\sqrt{3}$

**51.** A vessels is filled with oil as shown in the diagram. $A$ ray of light from point $O$ at the bottom of vessels is incident on the oil - air interface at point $P$ and grazes the surface along $PQ$. The refractive index of the oil is closed to - **(NTSE Stage II-2017)**




($a$) 1.41 ($b$) 1.50

($c$) 1.63 ($d$) 1.73

**52.** A ray of light in air is incident on an equilateral glass prism at an angle θ° to the normal. After refraction, the light travelled parallel to the base of prism and emerged in air at an angle θ to the normal. If the angle between the incident and the emergent rays is 60°, then the refractive index of glass with repect ot air is: **(NTSE Stage II-2016)**

($a$) 1.33 ($b$) 1.5

($c$) 1.73 ($d$) 1.66

**53.** A ray of light is incident in medium 1 on a surface that separates medium 1 from medium 2. Let $v_1$ and $v_2$ represent the velocity of light in medium 1 and medium 2 respectively. Also let $n_{12}$ and $n_{21}$ represent the refractive index of medium 1 with respect to medium 2 and refractive index of medium 2 with respect to medium 1, respectively. If $i$ and $r$ denote the angle of incidence and angle of refraction, then **(NTSE Stage II-2016)**

($a$) $\frac{\sin i}{\sin r} = n_{21} = \frac{v_1}{v_2}$ ($b$) $\frac{\sin i}{\sin r} = n_{21} = \frac{v_2}{v_1}$

($c$) $\frac{\sin i}{\sin r} = n_{12} = \frac{v_1}{v_2}$ ($d$) $\frac{\sin i}{\sin r} = n_{12} = \frac{v_2}{v_1}$

**54.** A convex lens has a focal length of 0.5m. It has to be combined with a second lens, so that the combination has a power of 1.5 dioptre. Which of the following could be the second lens? **(NTSE Stage II-2014)**

($a$) A concave lens of focal length 2m

($b$) Another convex lens of focal length 0.5m.

($c$) A concave lens of focal length 0.5m.

($d$) A convex lens of focal length 2m.

# Explanations

## School Level

### Quick Recall

#### Fill in the Blanks

1. Erect and Virtual
2. Concave miror
3. Half
4. $3 \times 10^8$ m/s
5. Straight line
6. incident ray
7. angle of reflection
8. glancing angle of reflection
9. decreases
10. $\frac{2}{3}$

#### True and False Statements

1. False 2. True 3. True 4. True
5. True 6. True 7. True 8. False
9. True 10. True

#### Match the Following

1. (*c*) 2. (*d*) 3. (*b*) 4. (*d*) 5. (*c*)

#### Assertion & Reason Type Questions

1. (*a*) 2. (*c*) 3. (*b*) 4. (*a*)
5. (*a*) 6. (*a*) 7. (*a*)

#### Statement Type Questions

1. (*c*) 2. (*c*) 3. (*b*) 4. (*a*) 5. (*a*)
6. (*c*) 7. (*d*)

### Multiple Choice Questions

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

### Subjective Questions

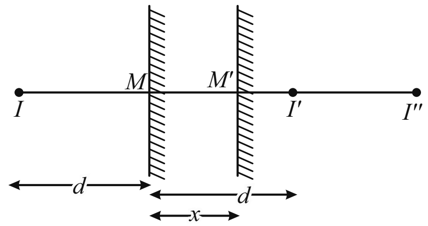
#### Very Short Answer Type Questions

1. Light is a form of energy that brings the sensation of sight. It is a part of electromagnetic radiation.
2. A bundle of rays originating from a single source of light in a particular direction is called a beam of light.
3. The light traveling in any one direction in a straight line is called a ray of light.
4. A small source of light casts a sharp shadow of an opaque object tells us that light travels in a straight line.
5. Light can be is considered in both the forms. i.e., ray or wave.
6. Yes, a polished surface can act as reflectors.
7. When object is placed at the centre of curvature (C), a real image of size equal to that of the object is formed by a concave mirror.
8. When the object is placed at the focus, the image formed by the concave mirror is highly enlarged.
9. Image is formed at the radius of curvature so the object distance must be equal to the image distance.
   $\therefore$ Object distance ($u$) = 30 cm.
10. The image is enlarged.
11. Light has different speeds in different media which causes refraction.
12. The power of a lens is measured in Dioptre.
13. Concave lens forms a virtual and diminished image always.
14. The image formed by the convex lens can be real as well as virtual.
15. The object should be placed between the focus and the optical center of the lens.
16. When light rays go from a rarer medium to a denser medium.
17. The diameter of the lens is called the aperture of the lens.

**10.** It is a point on the principal axis of the lens such that the light rays incident parallel to the principal axis, after refraction from the lens Converge or appear to diverge from it.

## Short Answer Type Questions

**1.** **Let** the object $I$ was placed initially at a distance d from the plane mirror $M$. The image formed at $I'$ is at a distance $d$ behind the mirror. If the mirror is shifted by a distance $x$ to $M'$ such that the distance of the object from $M'$ becomes $d + x$. The image is now formed at $I''$ which is also at a distance $d + x$ from $M'$.




So, $IM = MI'$ Object distance = $d$

$IM' = M'I' = d + x$

Thus, $II'' = IM' + M'I' = 2(d + x)$ ...(1)

where $II' = IM + MI' = 2d$ ...(2)

$\therefore\ I'I'' = II'' - II'$

$= 2(d + x) - 2d$

$= 2x$

Hence, the image is shifted from $I'$ to $I''$ by a distance $2x$.

**2.** **(i)** It is given that the distance of insect from the plane mirror = 1.5m

Therefore the image must be formed 1.5m behind the mirror, since for a plane mirror image distance and the object distance are equal.

(ii) The distance between the insect and its image = 1.5 + 1.5 = 3 m

**3.** **Given:**

The size of object = 4.0cm

Distance of the object = 25cm (–ve as it is in front of mirror)

focal length of concave mirror = 15cm (–ve) Distance of the image is given by-

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

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

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

$$\frac{1}{v}=\frac{-10+6}{150}$$

$$\frac{1}{v}=\frac{-4}{150}\Rightarrow v=-37.5\text{ cm}$$

The screen should be at 37.5cm in front of the mirror.

(i) The size of the image is given by–

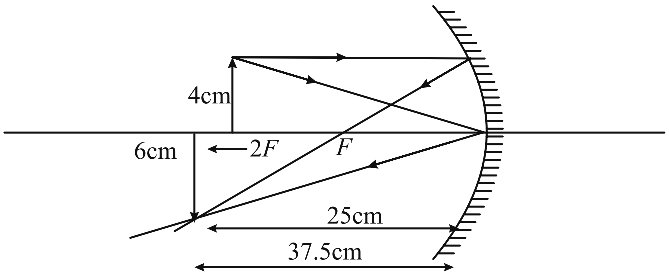
$$\frac{h_i}{h_o}=\frac{-v}{u}$$

$$\Rightarrow h_i=\frac{-v\times h_o}{u}=\frac{-(-37.5)\times 4}{-25}$$

$$h_i=-\frac{150}{25}=-6\text{ cm}$$

The image will be 6cm high and it will be inverted.

(ii) The image will be formed at a distance of 37.5cm from the mirror. It will be an inverted image.




**4.** The radius of sphere = 30cm

$\therefore$ Radius of Curvature = 30cm

Thus, the focal length of the mirror

$= \dfrac{30\text{ cm}}{2} = 15\text{cm}$

**5.** Given $u$ = – 15cm and $v$ = –30cm

By using,

$$\frac{h_i}{h_o}=\frac{-v}{u}=\frac{h_i}{-3}=\frac{-(-30)}{-15}$$

$= h_i$ = 6cm

**6.** When the object is placed in front of the mirror–

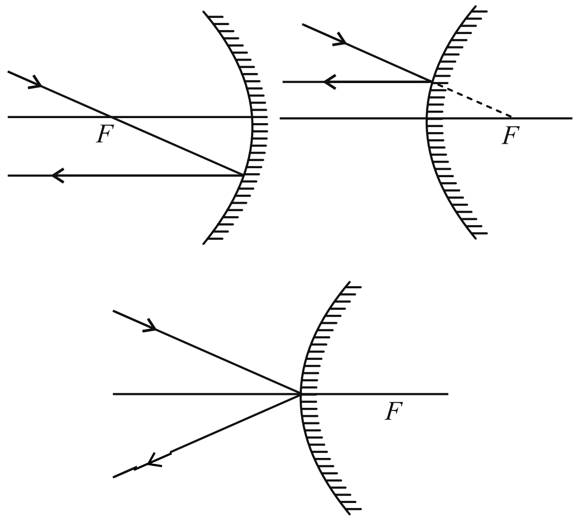
(i) between its pole and focus

(ii) between the focus and centre of curvature

In case (i) the image is virtual and erect

In case (ii) the image is real and inverted

**7.**




**8.** Virtual

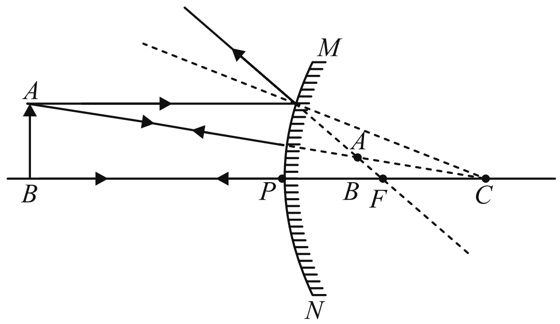
Erect

Diminished

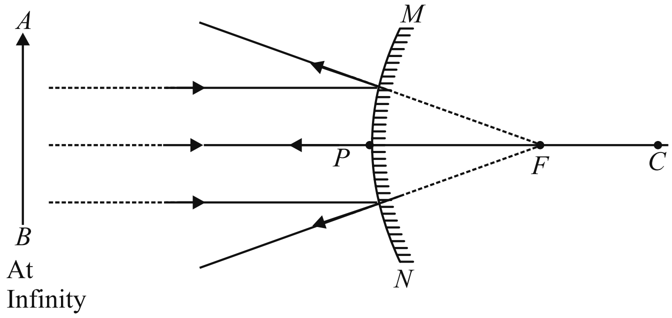
On the same side as the object / or any other characteristic

**9.** Convex Mirror

Labelled Ray diagram for any position of object




**OR**




**10.** **(*a*)** Given $f = 12$cm

so $u = -8$cm

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

$$\Rightarrow \frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{12}+\frac{1}{8}=\frac{5}{24}$$

$\therefore\ v = 4.8$ cm

(*b*) Given, $h = 1.2$ cm

We have $\frac{h_i}{h_o}=-\frac{v}{u} \Rightarrow h_i=\frac{v}{u}\times h_o = 0.72$cm

(*c*) Therefore, the Image formed is erect.

**11.** (i) A ray of light parallel to the principal axis of the concave lens appears to be coming from focus after refraction through the lens.

(ii) A ray of light crossing through a principal focus, after refraction from a convex lens, will appear parallel to the principal axis.

(iii) A ray of light passing through the optical centre suffers no refraction, that is, it passes undeviated.

**12.** (i) Lens towards the screen/ screen away from the lens

(ii) Increase

(iii) No image on the screen

**13.** We have, (i) Object distance, $u = -60$cm

Focal length of the concave lens, $f = -30$cm

Using lens formula,

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

$$\frac{1}{v}-\frac{1}{(-60)}=\frac{1}{(-30)}$$

$$\frac{1}{v}=\frac{-1}{30}-\frac{1}{60}$$

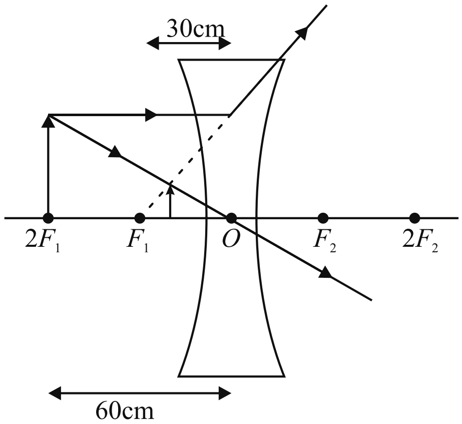
$$\frac{1}{v}=\frac{-3}{60}$$

$v = -20$cm

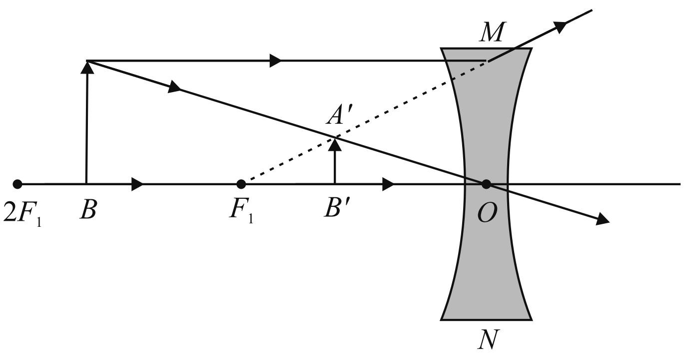
The image will be formed at a distance of 20cm in front of the lens.

(ii) Nature of the image is virtual. The position of the image is between $F_1$ and optical center 0. Size of the image is diminished. The image is Erect.

(iii)




**14.** Concave / diverging lens.




Direction of rays

$f = \frac{1}{P}$,

$P = -10\text{D}$,

$f = \frac{1}{-10\text{D}}$, $= -\ 0.1$ m/–10 cm

**15.** (*a*) As the candle is moved towards the lens, the image distance increases. Thus, the student moves the lens away from the screen to focus the image.

(*b*) The size of the image increases when the object is moved towards the lens.

(*c*) Intensity decreases.

(*d*) When the candle is moved very close to the lens, no image is formed on the screen. A virtual image is formed behind the candle on the same side of the lens.

**16.** A convex lens and a concave mirror both converge the rays coming from a distant object to their focal point to form an inverted image. If images formed by them are obtained on a screen, then the distance of the screen from the lens or the mirror would be the focal length of the lens or the mirror respectively. Similarly, in the given case, the distances $d_1$ and $d_2$ are the focal lengths of the given convex lens and concave mirror respectively and the nature of the image would be inverted for both lens and the mirror.

Hence, the correct answer is an option (*c*).

**17.** **1st law:** The incident ray, the refracted ray and normal to the interface at the point of incidence lie in the same plane.

**2nd law:** The sine of angle of incidence bears a constant ratio with sine of angle of refraction for a given pair of media.

Or $\frac{\sin i}{\sin r}$ = constant

Absolute Refractive Index of a medium

$$= \frac{\text{Speed of light in air or vacuum}}{\text{Speed of light in the medium}}$$

**18.** Power of lens = Ability to converge/ diverge light rays passing through it. It is the reciprocal of the focal length in metres

$P = \frac{1}{f}$ (in meters)

SI unit of power is Dioptre.

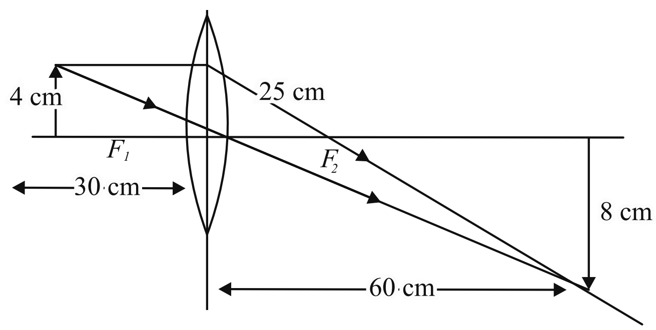
Power of 1st lens $P_1 = \frac{100}{f_1} = \frac{100}{40\text{ cm}} = +2.5$ D

Nature: Converging lens / Convex lens

Power of 2nd lens $P_2 = \frac{100}{f_2} = \frac{100}{-20\text{ cm}} = -\ 5$D

Nature: Diverging lens / Concave lens

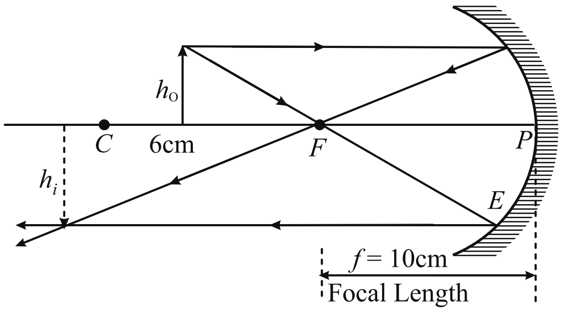
**19.**




Ratio $= \frac{h_i}{h_o}$ = 2:1 (approx.)

## Long Answer Type Questions

**1.** (*a*) A concave mirror of focal length 10cm can produce a magnified real image when the object is placed between the centre of curvature $C$ and principal focus $F$.

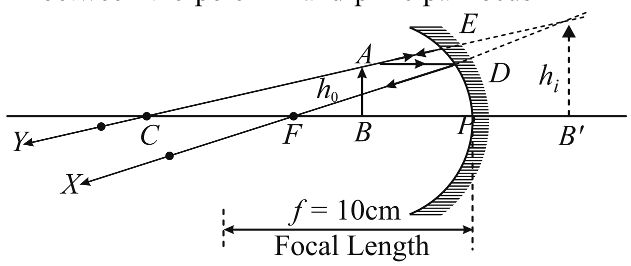



Position of object = between $C$ and $F$

Position of Image = Beyond $C$.

properties of the image = enlarged, real and inverted.

A concave mirror of focal length 10cm can produce a magnified virtual image when the object is placed between the pole $PP$ and principal focus $F$




(*b*) Focal length, $f = 10$ cm

Object distance, $u = -10$cm (object distance is always taken negative as it is on the left side)

**To find:** Position of the image or image distance, $v$.

**Solution:**

From the mirror formula, we know that-

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

Substituting the given values in the formula, we get-

$$\frac{1}{v}+\frac{1}{(-10)}=+\frac{1}{10}$$

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

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

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

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

$$\frac{1}{v}=\frac{1}{5}$$

$v = +\ 5$cm

Thus, the position of the image is 5cm from the mirror.

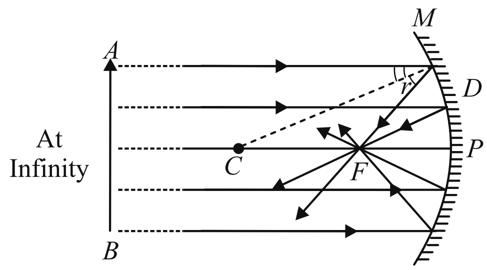
**2.** (*a*) (i) Pole – Centre of the reflecting surface of the mirror.

(ii) Centre of curvature – The centre of the hollow sphere of which the reflecting surface of mirror forms a part.

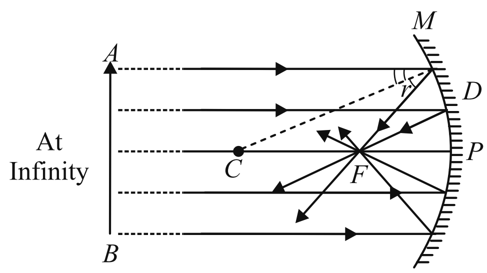
(iii) Principal axis – Straight-line passing through the pole and the centre of curvature of a spherical mirror.

(iv) Principal focus Incident rays parallel to principal axis, after reflection, either converge to or appear to diverge from a fixed point on the principal axis called principal focus of the spherical mirror.

(*b*) (i)



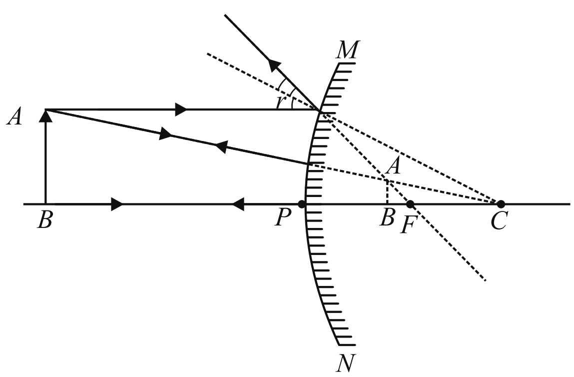

(ii)




(*c*) Concave mirror

Image formed is virtual and erect.

**3.** (*a*) Convex/diverging mirror



**Use:-** As a rear view mirror/any other use

**Reason:-** Always give erect and diminished image/ Large field of view

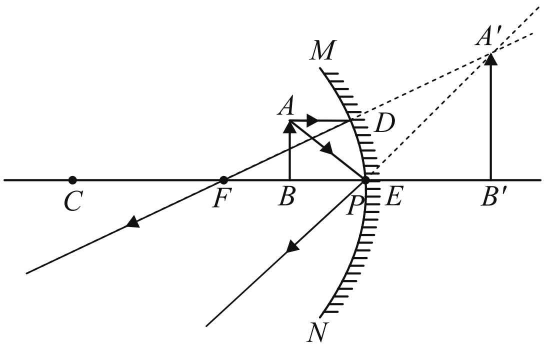
(*b*) The radius of the sphere of which the mirror forms a part/The distance between pole and center of curvature of a mirror.

Nature of the mirror-convex/diverging mirror

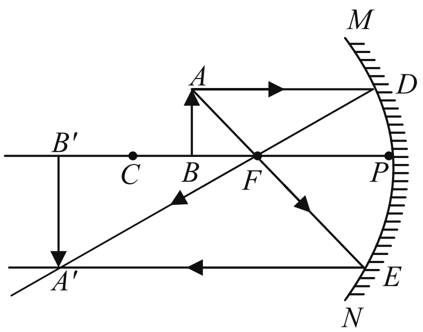
$R = 2f = 24\text{cm}$

$\therefore f = +12\text{cm}$

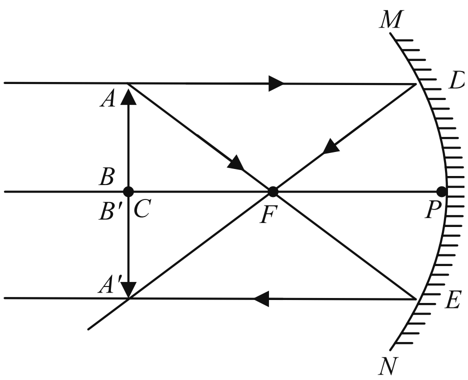
**4.** (*a*)



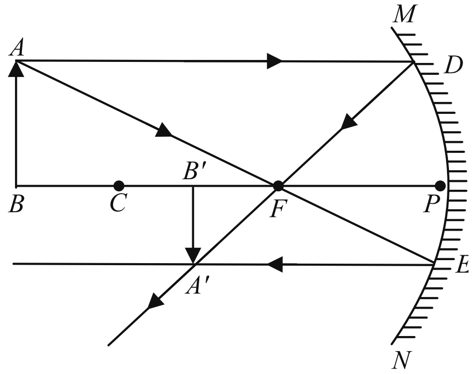

**(b)**



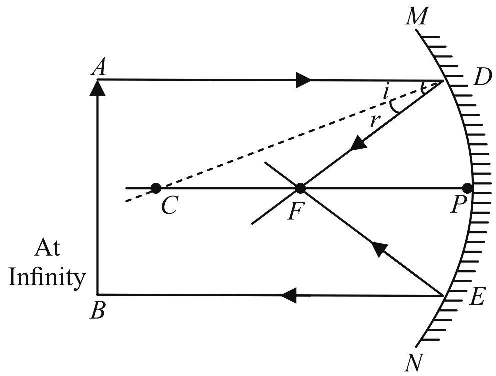

**(c)**




**(d)**

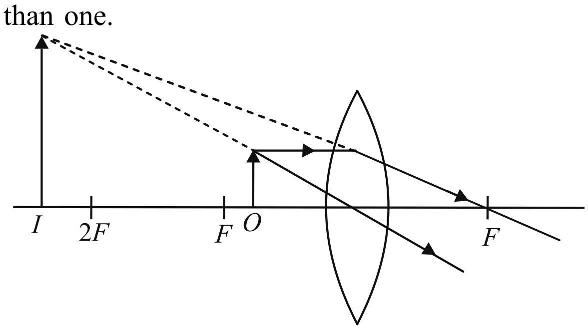



**(e)**




**5.** **(i)** Let us suppose $O$ be the object and I be the image then the image can be formed as:

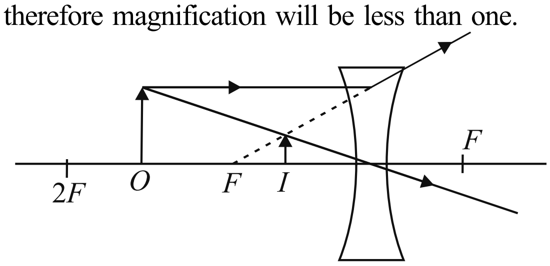
The image formed is enlarged and erect. Therefore its magnification will be positive and since it is enlarged therefore magnification will be greater than one.




(ii) anywhere in front of a concave lens.

Ans: Let us suppose $O$ be the object and I be the image then the image can be formed as:

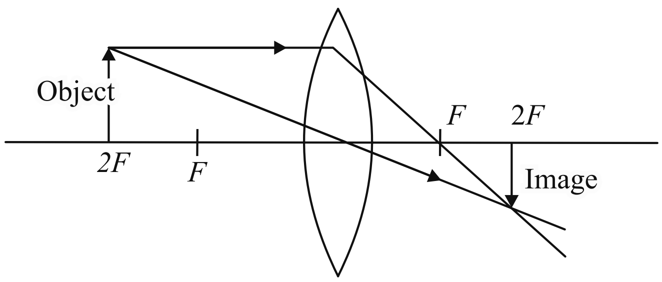
The image formed is diminished and erect. Therefore its magnification will be positive and since it is diminished therefore magnification will be less than one.



(iii) at $2F$ of a convex lens.

Ans: Let us suppose $O$ be the object and $I$ be the image then the image can be formed as:

The image will be formed at $2F$ on the other side of the lens and its magnification will be the same as that of the object.




**6.** (*a*) (i) Power of lens is the reciprocal of the focal length of the lens.

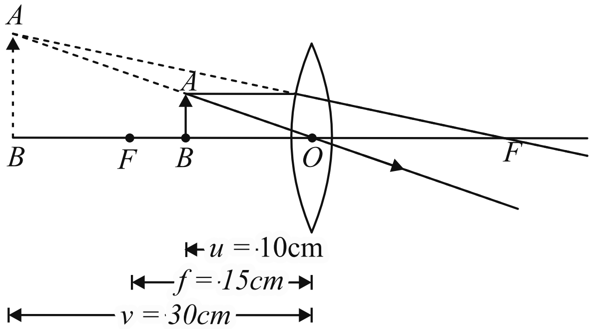
i.e., $P = \dfrac{1}{f\,(\text{in metre})}$

(ii) The point on which parallel beam of light converges is known as principal focus.

(*b*) (i) $\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f}$

(ii) $\dfrac{1}{v} + \dfrac{1}{u} = \dfrac{1}{f}$

(*c*)



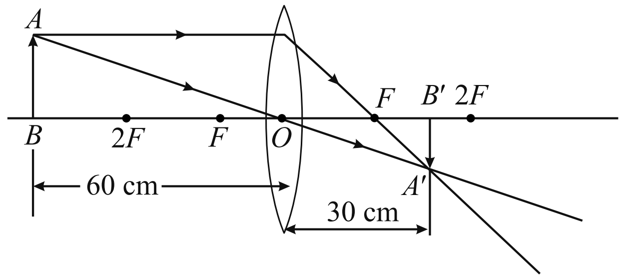

**7.** (*a*) $f$ = 20 cm

Sl. No. 3, Since $u$ = –40cm and $v$ = +40 cm, it may be concluded that object is at 2F

(*b*) Sl. No. 6

When $u$ = –15 cm, the object is between optical centre and principal focus. So image is virtual and it forms on the same side as the object. Hence, $v$ should be -ve, but here it is +ve (+120 cm)

(*c*)




Direction of rays

Magnification,m = $\dfrac{v}{u} = \dfrac{30\,cm}{-60\,cm} = -0.5 / -\dfrac{1}{2}$ .

**8.** (*a*) $u$ = Distance of candle from the lens

$u$ = 50 – 12

$u$ = 38cm

As per the sign conversion, $u$ = –38 cm

Image distance $v$ = Distance of screen from the lens

$v$ = 88 – 50

$v$ = + 38cm

Using the formula,

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

$\dfrac{1}{38} - \left(-\dfrac{1}{38}\right) = \dfrac{1}{f}$

$\dfrac{2}{38} = \dfrac{1}{f}$

$f$ = 19 cm

The focal length of the convex lens is 19cm

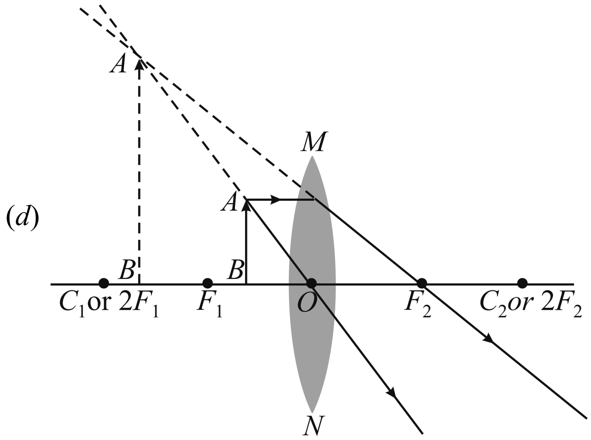
(*b*) Object distance $u$ = 50 – 31= 19 cm

Here, Object distance = focal length

Hence the image is formed at infinity. If the student moves the candle to a distance of 31.0cm from the lens, the object distance is $u$ = (50 -31) =19cm. As a result, the candle lies at the focus. Hence an infinite image will be formed.

(*c*) If he further shifts the candle towards the lens. The object comes between $F$ and 0. In this case. The image is virtual, enlarged, and erect and is formed on the same side of the lens.

(d)




## Case-Based Type Questions

### Case Study-I

1. (c) Given Radius of curvature, $R$ = 2m

From mirror formula We have

$$\frac{2}{R}=\frac{1}{v}+\frac{1}{u} \; i.e., \frac{2}{2\text{m}}=\frac{1}{v}+\frac{1}{-3.5\text{ m}}$$

$$\Rightarrow \frac{1}{v}=\frac{2}{2\text{m}}+\frac{1}{3.5\text{m}} \Rightarrow v=0.78\, m$$

2. (b)

3. (a) Magnification = $\frac{-v}{u}=\frac{0.78\text{ m}}{(-3.5\text{ m})}=0.22$

i.e., 22% of the size of the object.

### Case Study-II

1. (a) Here $h_o$ = 1 cm,

$h_i$ = – 4 cm,

$u$ = – 20 cm

We have, $m = \frac{h_i}{h_o}=-\frac{v}{u} \; i.e., \frac{-4}{1}=\frac{-v}{-20}$

or $v$ = – 80cm

2. (b) Here, we have $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$

i.e., $\frac{1}{f}=\frac{1}{-20}+\frac{1}{-80}=\frac{-4-1}{80}=\frac{-5}{80}$

$f=\frac{-80}{5}$ = – 16cm

3. (a) Negative sign of $f$ indicates that mirror is concave.

### Case Study-III

1. (a) When, a ray of light travels from air to glass, it bends towards the normal.
2. (c) No bending of light occurs when light is incident normally or perpendicularly on a boundary of two media since angle of incidence and angle of refraction both are zero.
3. (c) When light goes from one medium to other medium, its frequency does not change.
4. (a) The speed to light increases when light passes from glass to water as water is optically rarer medium.
5. (a) The bottom of a pool of water appears to be less deep than it actually is due to refraction.

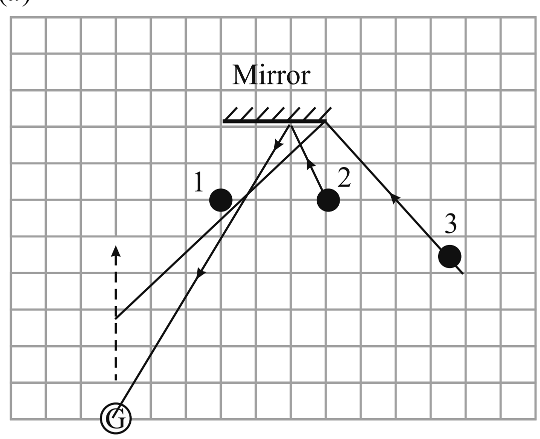
## Competitive Level

## Multiple Choice Questions

| | | | | |
|---|---|---|---|---|
| 1. (b) | 2. (c) | 3. (a) | 4. (a) | 5. (a) |
| 6. (d) | 7. (b) | 8. (b) | 9. (a) | 10. (c) |
| 11. (c) | 12. (d) | 13. (c) | 14. (a) | 15. (a) |
| 16. (a) | 17. (d) | 18. (b) | 19. (a) | 20. (d) |
| 21. (a) | 22. (a) | 23. (b) | 24. (a) | 25. (b) |
| 26. (d) | 27. (c) | 28. (a) | | |

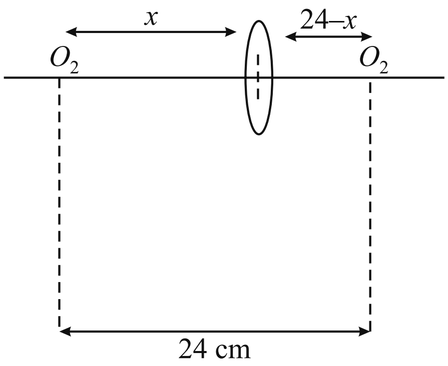
## Competitive Corner

1. (d)




$G$ will be able to see image of 2 then image of 3.

**2.** (*b*)




Given that focal length of convex lens = 9 cm

Let first object is at a distance $x$ from the convex lens.

By using lens formula i.e. $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$

We get, $\frac{1}{f}-\frac{1}{-x}=\frac{1}{9} \quad \Rightarrow \frac{1}{v}=\frac{1}{9}-\frac{1}{x}$ ...(1)

Now for second object

$\frac{1}{-v}-\frac{1}{-(24-x)}=\frac{1}{9} \quad \Rightarrow \frac{1}{v}-\frac{1}{24-x}=\frac{-1}{x}$

$\Rightarrow \frac{1}{v}=\frac{1}{24-x}-\frac{1}{9}$ ...(2)

$\therefore$ Image formed at the same distance from the lens for both the objects

$\therefore$ From equation (1) and (2)

$\frac{1}{9}-\frac{1}{x}=\frac{1}{24-x}-\frac{1}{9}$

$\frac{2}{9}=\frac{1}{x}+\frac{1}{24-x}$

$\frac{2}{9}=\frac{24-x+x}{x(24-x)}$

$x(24-x) = \frac{24\times 9}{2} = 108$

$x^2 - 24x + 108 = 0$

From Sridharacharya rule

$x = \frac{-b\pm\sqrt{b^2-4ac}}{2a}$

$x = \frac{24\pm\sqrt{576-4\times 1\times 108}}{2}$

$x = \frac{24\pm\sqrt{144}}{2}$

$x$ =18, 6

$\therefore$ The correct option is (*b*).

**3.** (*a*), (*c*)

For lens, using

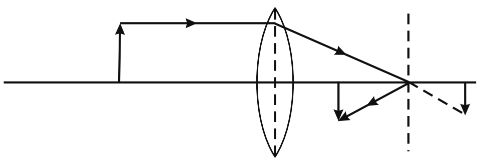
$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$

$u = -15$cm

$f = 10$ cm, we get $v = 30$cm

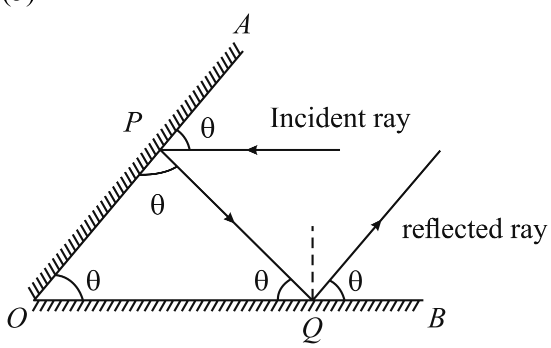
$m = \frac{v}{u}=\frac{30}{-15} = -2$

For plane mirror, $u$ = 10cm and $v$ = 10cm Hence, final image is formed at 10cm between plane mirror and lens



Option (*a*) and (*c*)

**4.** (*b*)




From $\Delta POQ$, $3\theta = 180°$

$\Rightarrow \theta = 60°$

**5.** (*a, b, d*)

1. lateral shift = $\frac{t(\sin(i-r))}{\cos r}$

$\because \sin(B - B) = \sin B \cos B - \cos B \sin B$

$x = \frac{t(\sin i\cos r-\cos i\sin r)}{\cos r}$

$x = t\left(\sin i-\frac{\cos i\sin r}{\cos r}\right)$

2. For maximum value of $x$, $i$ = 90°

$x = \frac{t(\sin(90-r))}{\cos r}$

$x = t\frac{\cos r}{\cos r}$

$x = t$

3. The angle of refraction and angle of incidence are related with refractive index in accordance with Snell's law, Hence lateral shift also depends on the refractive index
4. Refractive index increases with decrease in wavelength, so lateral displacement also depends on the wavelength.

**6.** (*b*) $m = \frac{f}{f+u}$

Given: f = 6 cm

**Case-I.** say u = – x

$\therefore -3 = \frac{6}{6+x} \quad \Rightarrow x = 8$

**Case-II.** Now u = – [x + n(0.1)]

Here, n is number of rotations and 0.1cm is linear distance travelled in each rotation.

$\therefore -2 = \frac{6}{6-[x+n(0.1)]}$

$\Rightarrow n = 10$

**7.** (*d*) The net deviation is given as 360° – 2θ.

**8.** (*b*) Approxmately d/DC

**9.** (*a*) –30cm

**10.** (*d*) D

**11.** (*c*) 32cm

**12.** (*b*) nt/c

**13.** (*b*) –30cm, –8.6cm

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

**15.** (*d*) Between the pole of the mirror and its principal focus.

**16.** (*b*) 10cm

**17.** (*c*) 7D

**18.** (*c*) 10m/s

**19.** (*c*) Frequency

**20.** (*d*) Both concave mirror and convex lens

**21.** (*d*) –20cm

**22.** (*d*) $\frac{1}{\sqrt{2}}$

**23.** (*b*) 2

**24.** (*c*) R = 2F

**25.** (*d*) 90°

**26.** (*c*) +5D

**27.** (*d*) Both (*a*) and (*b*)

**28.** (*a*) $\sqrt{2}$

**29.** (*c*) 4 times of focal length

**30.** (*b*) 30cm

**31.** (*b*) 0.4cm away from the mirror

**32.** (*b*) $-\frac{20}{3}\text{cm}, -\frac{1}{3}$

**33.** (*b*) 7.5cm

**34.** (*a*) The mirror is concave mirror and the lens is concave lens.

**35.** (*a*) Concave mirror

**36.** (*b*) (C), (D)

**37.** (*b*) Convex mirror, Concave lens

**38.** (*c*) 20°

**39.** (*a*) the focal point

**40.** (*b*) $2.12\times10^8$m/s

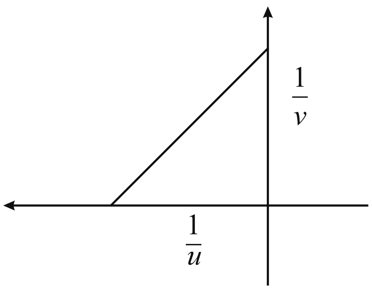
**41.** (*a*) 40cm

**42.** (*a*) –66.66cm

**43.** (*a*) Ray nature of light

**44.** (*a*) AF = FB

**45.** (*b*)




**46.** (*c*) 20cm

**47.** (*a*) converging

**48.** (*c*) 1.25

**49.** (*c*) 22.5cm to right of lens B

**50.** (*c*) $\sqrt{2}$

**51.** (*d*) 1.73

**52.** (*c*) 1.73

**53.** (*a*) $\frac{\sin i}{\sin r} = n_{21} = \frac{v_1}{v_2}$

**54.** (*a*) A concave lens of focal length 2m.