

# REFLECTION

When a narrow beam of light wave strikes a flat surface, the wave is in general partly reflected and partly refracted into the medium that received the incident light. The angle of incidence ( $\theta_i$ ) is defined as the angle it makes with the normal (perpendicular) to the surface and the angle of reflection, ( $\theta_r$ ), is the angle the reflected ray also makes with the normal. We can also define the glancing angle ( $\theta_g$ ) as the angle between the reflected ray and the reflecting surface.

When a ray of light is incident on a plane surface, the light is either absorbed, transmitted (refracted) or it is reflected.

## LAWS OF REFLECTION

- i. The incident and reflected rays lie on the same plane with the normal to the surface
- ii. The angle of incidence is equal to the angle of reflection, for all wavelengths and for any pair of materials. That is

## TYPES OF REFLECTION ON PLANE

### SURFACES

1. **Regular Reflection:** This is the reflection that occurs on a smooth surface such as a (plane) mirror. It is also called specular reflection.
2. **Irregular Reflection:** This is the reflection that happens on a rough surface such as paper or cloth. It is also called scattered or diffused reflection.

## TYPES OF IMAGES

1. **Real Images:** These are the ones in which the rays of light can be obtained on a screen. A real image is that image which is formed when the light rays coming from an object actually meet each other after reflection or refraction. A real image is most times inverted. Typical examples of real images are the ones formed in pin hole cameras and the one in cinemas. It can also be defined as a collection of focus points actually made by converging rays.
2. **Virtual Images:** This is the one in which the rays of light do not reach yet visible to the eye. It can be said that this is an image formed if the

rays of light do not actually pass through the image point. The ray of light touches the object, and then reflected into the mirror where the image is formed. A virtual image cannot be viewed on a screen (or a sheet of paper) and is usually erect. A virtual image is the collection of focus points made by extensions of diverging rays. In other words, it is an image which is located in the plane of convergence of the light rays that originate from a given object (divergent rays).

The image formed on a plane mirror is an example of a virtual image.

## **PLANE MIRRORS**

### **CHARACTERISTICS OF THE IMAGE**

#### **FORMED ON A PLANE MIRROR**

1. The image is virtual
2. The image is upright
3. The magnification is equal to one
4. The distance of the image from the mirror is the distance of the object from the mirror
5. The image is laterally inverted (i.e. the left of the object is the right of the image and vice versa)

### **INCLINATION OF A (PLANE) MIRROR**

When two plane mirrors are inclined at an angle( $\theta$ ), a number of images will be formed. The number of images formed depends on the angle. The formula for calculating the number of images is given by

$$n = \frac{360}{\theta} - 1$$

### **ROTATION OF A MIRROR**

This slightly defies the laws of reflection of light on a plane surface

When a plane mirror is rotated through an angle( $\theta$ ), the incident ray and the normal remain unchanged (i.e. they stay at the same point). However, the

reflected ray will move through an angle that is twice the angle of rotation ( $2\theta$ ) in the direction of the rotation of the mirror.

That means if a mirror is rotated through an angle  $30^\circ$ , the new reflected ray will be  $60$  (i.e.  $(2 \times 30)$ )

## USES OF PLANE MIRRORS

1. They are used as common looking glasses.
2. They are used to construct sextants (devices used to measure the angle of elevation of the sun)
3. They are used to create periscopes (A device used to view objects above you without being seen. They are used a lot in submarines)
4. They can be used to construct kaleidoscopes (A toy which produces beautiful patterns. This is done by inclining two mirrors at  $60$  degrees)
5. They are used to make solar cookers
6. They are also used in various scientific instruments

## DEVIATION OF LIGHT

When a ray of light is incident on a plane mirror, the angle between the incident ray and the normal is called the angle of incidence ( $i$ ) while the angle between the reflected ray and the normal is the angle of reflection ( $r$ ).

The angle the incident ray makes with the surface of the reflecting material (not the angle with the normal) is called the **glancing angle** ( $g$ ). This is also equal to the angle the reflected ray makes with the glass (since the incident angle and the reflected angle are the same) and it is also called the glancing angle.

The divergence ( $d$ ) of that setup is twice the glancing angle

$$d = 2g$$

Since the incident ray, reflected ray and the glancing angles are all on a straight line,

$$g + i + r + g = 180 \quad \left( \sum \text{of angles on a straight line} \right)$$

$$i + r + 2g = 180$$

But

$$d = 2g$$

$$i+r+d=180$$

Also,

$$i=r$$

We can say

$$i+i+d=180$$

$$2i+d=180$$

$$d=180-2i$$

Similarly,

$$d=180-2r$$

# **REFLECTION OF LIGHT ON CURVED SURFACES (MIRRORS)**

Rays of light can also be reflected from curved mirrors. There are two types of curved mirrors:

1. Concave mirrors
2. Convex mirrors

## **TERMS USED IN CURVED MIRRORS**

1. Pole (p): The pole of a mirror is the (approximate) center of the mirror
2. Center of curvature (c): This can be defined as the point at which the mirror forms a path
3. Radius of curvature (r): This can be defined as the distance between the pole and the center of curvature
4. Principal axis (x): This can be defined as an imaginary line that joins the pole to the center of curvature. The length of the principal axis is the radius of curvature.
5. Principal focus (f): This can be defined as the point at which rays of light that are parallel and close to the principal axis converge (for a concave mirror) or diverge from (for a convex mirror) after the rays have been reflected

## **Concave Mirrors**

In this type of mirror, rays of light converge at the center. They are also known as converging mirrors.

## **FORMATION OF IMAGES BY A CONCAVE MIRROR**

A ray diagram is used to show (or determine) the nature and type of image formed by a concave mirror. The nature of the image formed depends on the distance and position of the object in relation to the mirror.

The following rules should be taken when drawing a ray diagram

### **RULES FOR DRAWING RAY DIAGRAMS**

1. A ray of light (or ray of an object) parallel to the principal axis is first reflected.
2. The reflected ray then converges at the principal focus ( $f$ ) [and passes through it]
3. Then a line is drawn from the (top of the) object and passes through the center of curvature ( $c$ ).
4. The lines that pass through the center of curvature and the principal focus then meet at a point.

### **RAY DIAGRAMS OF CONCAVE MIRRORS**

1. For an object placed behind the center of curvature, the image is:
  - Diminished (of smaller size)
  - Inverted
  - Real
2. For an object placed exactly on the center of curvature, the image is:
  - Same size
  - Inverted
  - Real
3. For an object placed between the center of curvature ( $c$ ) and the principal focus ( $f$ ), the image is:
  - Magnified
  - Inverted
  - Real
4. For an object placed exactly on the principal focus, the image is:
  - At infinity (i.e. it will not be seen)

5. For an object placed between the principal focus and the pole, the image is:

- Magnified
- Upright (Erect)
- Virtual

NB: For a concave mirror to be used as a shaving mirror, the object has to be placed between the principal focus and the pole of the mirror

## **USES OF CONCAVE MIRRORS**

1. Concave mirrors are used as shaving mirrors
2. They can also be used as head mirrors
3. Ophthalmoscope
4. They are also used in astronomical telescopes
5. They are also used by dentists to magnify the image of a hole present in the teeth
6. They are used in headlights
7. They are also used to start fires and in solar furnaces.

## **Convex Mirrors**

In this type of mirror, rays of light diverge from the center. They are also known as diverging mirrors

### **CHARACTERISTICS OF IMAGES FORMED BY A CONVEX MIRROR**

They are always:

- i. Erect
- ii. Virtual
- iii. Diminished

### **USES OF A CONVEX MIRROR**

1. They are used to make sunglasses
2. They are also used for security purposes
3. They are used as street light reflectors
4. They are also used as driving mirrors because it usually forms an erect image and gives a wide field view.

In curved mirrors, a virtual image is usually formed behind the mirror while a real image is formed in front of the mirror

## MIRROR FORMULAE

These formulae are used in solving most questions pertaining to mirrors  
For the following

$$u = \text{object distance (mirror)}$$

$$v = \text{image distance}$$

$$f = \text{focal length (length of the principal focus | the pole)}$$

$$m = \text{magnification}$$

$$r = \text{radius of curvature}$$

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

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

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

$$f = \frac{r}{2}$$

$$r = 2f$$

$$u = f \left( 1 + \frac{1}{m} \right)$$

$$v = f(1+m)$$

## SIGN CONVENTION

For all mirrors, the object distance is always positive

For a concave mirror,

$$f = +ve$$

For a convex mirror,

$$f = -ve$$

$$v = -ve$$

For a real or inverted image,

$$m = +ve$$

$$v = +ve$$

For a virtual or upright image,

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

$$m = -ve$$

$$v = -ve$$

### DISTANCE BETWEEN THE OBJECT AND THE IMAGE IN MIRRORS

For a virtual image,

$$d = |v| + u$$

For a real image,

$$d = |v| - u$$

In the graph of  $\frac{1}{u}$  against  $\frac{1}{v}$ , the focal length can be found by

First adding the intercepts of the y axis and the x-axis then finding the reciprocal of the sum