Ray Optics and Optical Instruments

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Introduction

Light is the agency which helps us to see objects which are very far away e.g., the sun and the stars as well as nearby objects. The science of light is called *optics*.

A beam of light suggests that light travels in straight lines. This is referred to as the *rectilinear propagation* of light. The direction of propagation is shown in a diagram as a *ray*. It is represented by a line and an arrow. The ray is thus a geometrical line and it has no physical existence. In spite of this, the concept of light ray is useful. Geometrical optics, also called as ray optics, is one of the branches of optics which employs the ray concept throughout and is of much practical use. Ray optics does not deal with the physical nature of light and its propagation. The other branch, Physical optics, deals with the nature of light. Physical optics gives us a better understanding of light and furnishes us with more accurate laws than ray optics does. It is found that the laws of ray optics are only approximate.

Reflection of Light

Reflection at a plane surface

A great majority of bodies around us are visible to us due to light reflected by them. Reflection is regular or irregular depending on the nature of reflecting surface.

In the case of smooth surfaces like plane mirrors or a shiny metal surface, a parallel beam of light incident on the surface is reflected only in one particular direction as can be seen from Fig. 1. This is a *regular* reflection.

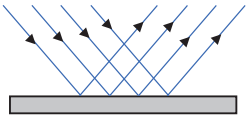


Fig. 1

In the case of a rough reflecting surface like paper, surfaces of wooden plank, or surface of a cloth, light incident in one direction on them will be reflected in various directions or scattered as shown in Fig. 2. This is called *diffused* or *irregular* reflection.

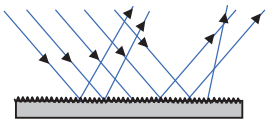


Fig. 2

Terminology

Some of the terms commonly used are described below – which are applicable for reflection from any reflecting surface either plane or curved.

Incident ray: Ray striking the mirror from an object or a source of light.

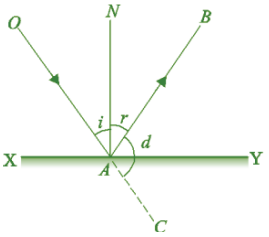
Reflected ray: Ray emerging from the mirror from the point of incidence.

Normal: A perpendicular to the surface of the mirror, usually drawn at the point of incidence.

Angle of incidence (i): Angle between the incident ray and the normal to the mirror at the point of incidence is called angle of incidence.

Angle of reflection (r): Angle between the reflected ray and the normal to the mirror at the point of incidence is called angle of reflection.

Angle of deviation (d): Angle between the direction of the incident ray in the absence of the mirror and the direction of reflected ray is called the angle of deviation.



Reflection from a plane mirror XY

OA – Incident ray

AB – Reflected ray

NA – normal to plane mirror. XY at point of incidence A.

$\angle OAN = i$ = angle of incidence.

$\angle BAN = r$ = angle of reflection.

$\angle BAC = d$ = angle of deviation.

Laws of Reflection

1. Angle of reflection is equal to angle of incidence (r = i).
2. The incident ray, the reflected ray and the normal at the point of incidence lie in the same plane.

These laws are valid at each point on any reflecting surface whether plane or curved.

Important points in the context of reflection from a plane mirror

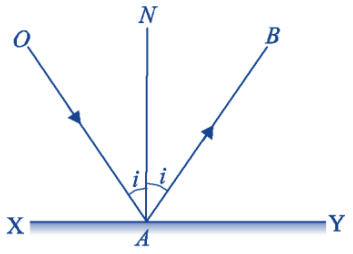
- When the object is real,

(i) the image is virtual , erect and laterally reversed

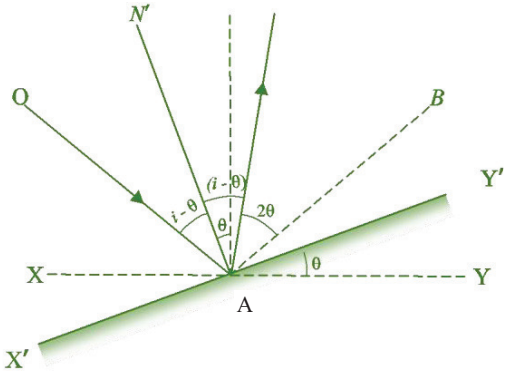
(ii) the image is of same size as the object

(iii) the image is as far behind the mirror as the object is in front of it.

- If the object is virtual then a real image is formed in front of the mirror which need not be of the same size as the object.
- The angle of deviation between incident and reflected rays is d = (180° – 2i) as r = i
- If a plane mirror is rotated by an angle θ keeping the incident ray direction fixed, then the reflected ray rotates by the angle 2θ along the same sense as that of the rotation of the mirror.



(a)

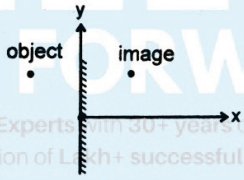


(b)

Relation between velocity of object and image

From mirror property: $x_{im} = -x_{om}$, $y_{im} = y_{om}$ and $z_{im} = z_{om}$

Here x_{im} means 'x' coordinates of image with respect to mirror. Similarity others have meaning



Differentiating w.r.t time, we get

$v_{(im)x} = -v_{(om)x}$; $v_{(om)y}$; $v_{(im)z} = v_{(om)z}$

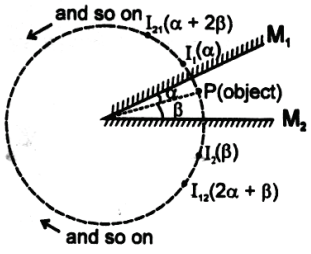
$\Rightarrow$ for x axis $v_{iG} - v_{mG} = -(v_{oG} - v_{mG})$

but for y axis and z axis $v_{iG} - v_{mG} = (v_{oG} - v_{mG})$ or $v_{iG} = v_{oG}$

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

Locating all the images formed by two plane mirrors

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



Point P is an object kept such that it makes angle that it makes angle α with mirror M_1 and angle β with mirror M_2. Image of object P formed by M_1, denoted by I_1, will be inclined by angle α

on the other side of mirror M_1. This angle is written in bracket in the figure besides I_1. Similarly image of object P formed by M_2, denoted by I_2, will be inclined by angle β on the other side of mirror M_2. This angle is written in bracket in the figure besides I_2.

Now I_2 will act as an object for M_1 which is at an angle $(\alpha + 2\beta)$ from M_1. Its image will formed at an angle $(\alpha + 2\beta)$ on the opposite side of M_1. This image will be denoted as I_{21}, and so on. Think when this process will stop. Hint. The virtual formed by a plane mirror not be in front of the mirror or its extension.

Number of imaged formed by two inclined mirrors

(i) If $\frac{360^\circ}{\theta} = \text{even number}$; number of image $= \frac{360^\circ}{\theta} - 1$

(ii) If $\frac{360^\circ}{\theta} = \text{odd number}$; number of image $= \frac{360^\circ}{\theta} - 1$ if the object is placed on the angle bisector.

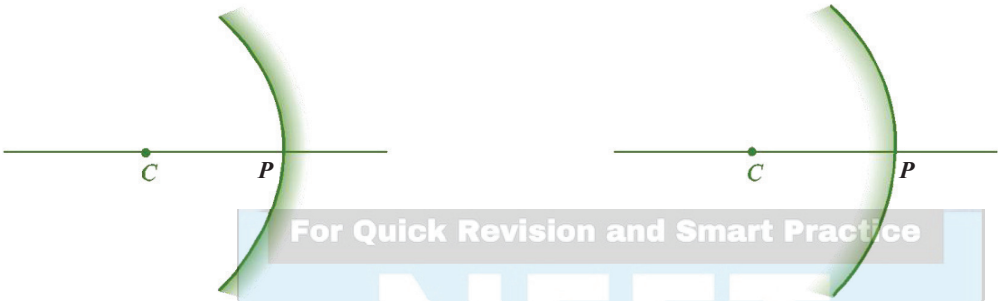
(iii) If $\frac{360^\circ}{\theta} = \text{odd number}$; number of image $= \frac{360^\circ}{\theta}$, if the object is not placed on the angle bisector

(iv) $\frac{360^\circ}{\theta} \neq \text{integer}$, then count the number of images as explained above.

Reflection at a spherical surface

Spherical mirror

A spherical mirror is a part of a hollow sphere whose one side is reflecting and the other side is silvered. There are two types of spherical mirrors – concave and convex.



(a) Concave mirror (b) Convex mirror

Concave mirror

It is a spherical mirror whose reflecting surface is concave and the silvered surface is convex.

Convex mirror

It is a spherical mirror whose reflecting surface is convex and the silvered surface is concave.

Terminology

1. **Aperture**: Area of the spherical surface available for reflection is called its aperture.
2. **Pole:** Mid-point of the aperture (or spherical surface) is called pole.
3. **Centre of curvature:** The centre of the sphere of which the given spherical surface forms a part is called centre of curvature.
4. **Radius of curvature:** The radius of the sphere of which the given spherical surface forms a small part of it is called radius of curvature.

   (OR) Distance between the pole and the centre of curvature of a spherical mirror is the radius of curvature.
5. **Principal axis:** A straight line passing through the pole and centre of curvature of a spherical mirror is called its principal axis.

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

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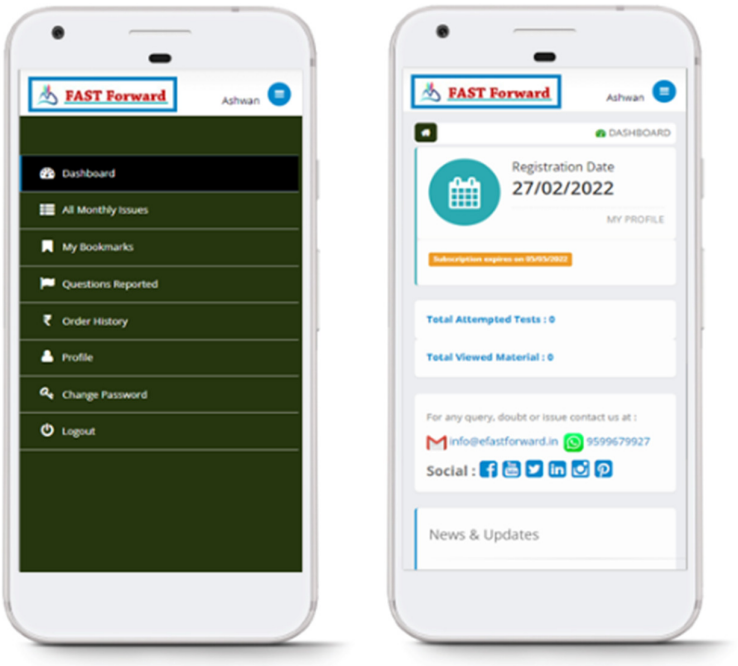

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