Chapter 1

Geometrical Optics (Reflection)

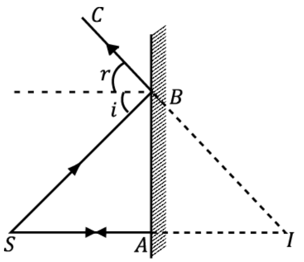
Day – 1

Plane Surfaces

Reflection at Smooth Surfaces

(i) The angle of incidence is equal to the angle of reflection.

(ii) The incident ray, the reflected ray and the normal to the reflecting surface are coplanar.



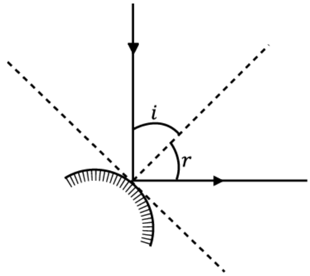
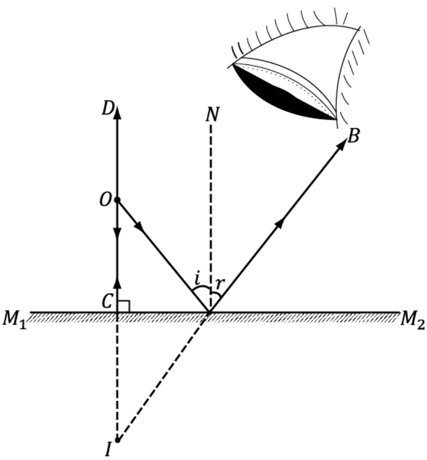


Image formed by a Plane Mirror

Let M_1M_2 be a plane mirror and O a point – object infront of the mirror. To find the position of the image of O formed by the mirror, we consider two incident rays OA and OC. The ray OA falls on the mirror at an angle of incidence I and is reflected along AB at an angle of reflection r, where $r = i$. the ray OC falling normally on the mirror is reflected back along its initial path $(i = r = 0)$. The two reflected rays AB and CD, which form a divergent beam, appear to come from a point I. hence the point I is the virtual image of O.



Now from the geometry of the figure, we have $\angle COA = \angle OAN$ (alternate angles) and $\angle CIA = \angle NAB$ (corresponding angles). But $\angle OAN = \angle NAB$ $(i = r)$.

Therefore

$$\angle COA = \angle CIA$$

Also,

$$\angle OCA = \angle ICA\ (= 90^0)$$

It means

$$\Delta OCA \equiv \Delta ICA$$
$$\therefore OC = IC$$

That is, **the image formed by a plane mirror lies behind the mirror at the same perpendicular distance as the object is in front the mirror.** Besides this, the image of a finite – size object formed by a plane mirror has the following characteristics

(i) ***The image is virtual.*** *It cannot be taken on a screen*

(ii) ***It is of the same size as the object.***

(iii) The image is erect with respect to the object.

(iv) it is laterally inverted, *that is, the right – side of the object appears as the left – side of the image and vice – versa*.

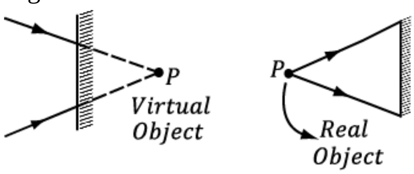
Some Important Points:- In Case of Plane Mirror

(i) For real object, image is virtual.

(ii) For virtual object, image is real.

(iii) Image size =Object, image size.

(iv) If reflected beam or refracted beam from an optical instrument is converging in nature, Image is real.



(v) If reflected beam or refracted beam from an optical instrument is diverging in nature, image is virtual.

(vi) If the plane mirror is rotated through an angle θ, the reflected ray and image is rotated through an angle 2θ in the same sense.

(vii) If the plane mirror is cut into a number of pieces, then the focal length does not change.

(viii) The minimum height of mirror required to see the full image of a man of height h is *h/2*.

Number of Images formed by Combination of two Plane Mirror

$Let\ \theta =$ angle between mirrors, then

$(i)\ If\ \frac{360^0}{\theta}$ is even number, the number of images is $n - 1$.

$(ii)\ If\ \frac{360^0}{\theta}$ is odd number and object is placed on bisector of angle between mirrors then number of image is $n - 1$.

$(iii)\ If\ \frac{360^0}{\theta}$ is odd and object is not situated on bisector of angle between mirrors, then the number of images is equal to n.

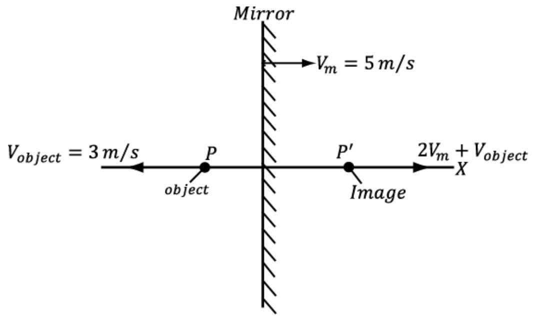
Illustration

A plane mirror is placed along the *y- axis* as such *x- axis* is normal to the plane of the mirror. The reflecting surface of the mirror is towards negative *x- axis*. The mirror moves in positive x-direction with uniform speed of *5 m/s* and a point object *P* is moving with constant speed *3 m/s* in negative x- direction. The speed of image with respect to mirror is

$(a)\ 8\,m/s$ $(b)\ 16\,m/s$

$(c)\ 5\,m/s$ $(d)\ 10\,m/s$

Solution



From figure

$$v_{image} = 2v_m + v_{object}$$
$$= 2 \times 5 + 3 = 13\,m/s$$

Speed of image with respect to mirror

$$v = v_{image} - v_{mirror}$$
$$= 13 - 5 = 8\,m/s$$

Illustration

A plane mirror which rotates *10^4* times per minute reflects light on to a stationary mirror *50m* away. This mirror reflects the light normally so that it strikes the rotating mirror again. The image observed in the rotating mirror is shifted through *2.4* minutes from the position it occupies. When the rotating mirror is stationary, what is the speed of light ?

$(a)\ 3 \times 10^8\,m/s$ $(b)\ 4 \times 10^8\,m/s$

$(c)\ 5 \times 10^8 m/s$ $(d)\ 6 \times 10^8\,m/s$

Solution

When the plane mirror is rotated through θ, the image formed by the mirror is rotated through 2θ. Here

$$2\theta = \left(\frac{2.4}{60}\right)^0$$
$$\therefore\ \theta = \left(\frac{1.2}{60}\right)^0 = \left(\frac{1.2}{60}\right)\left(\frac{\pi}{180}\right) rad$$

Here,

$$\omega = 2\pi n = \frac{2\pi \times 10^4}{60}$$

$$= \frac{\pi}{30} \times 10^4 rad/s$$

$$\therefore\ \theta = \omega t\ \cdots\cdots (i)$$

But t = time taken by light to go from M_1 to M_2 and returned back

$$\therefore t = \frac{2l}{c} = \frac{2 \times 50}{c}\ \cdots\cdots (ii)$$

From Eqs. (i) and (ii)

$$c = 3 \times 10^8\, m/s$$

Illustration

A source of light lies on the angle bisector of two plane mirrors inclined at an angle θ, so that the light reflected from one mirror does not each the other mirror will be

$(a)\ \theta \geq 120^0$ $(b)\ \theta \geq 90^0$

$(c)\ \theta \leq 120^0$ (d) none of these

Solution

$$\therefore \quad \frac{360}{\theta} = n$$

For the given condition, no successive reflection takes place. So, the number of images will be $N \leq 2$.

$$\therefore n - 1 \leq 2$$

Or

$$n \leq 3$$

Or

$$\frac{360}{\theta} \leq 3$$

Or

$$120 \leq \theta$$

$$\therefore\ \theta \geq 120^0$$

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