Welcome to

BYJU'S Classes

GEOMETRICAL OPTICS

S12: Laws of Refraction

What you already know

- Mirror formula
- Newton's formula
- Image formation by concave and convex mirror
- Combination of Mirrors

What you will learn

- Cutting of Mirror
- Laws of Refraction

EXAMPLE

Find the number of images formed by combination of mirror as shown in the figure.

a) 1 b) 2 c) 3 d) ∞

Solution

MAIN

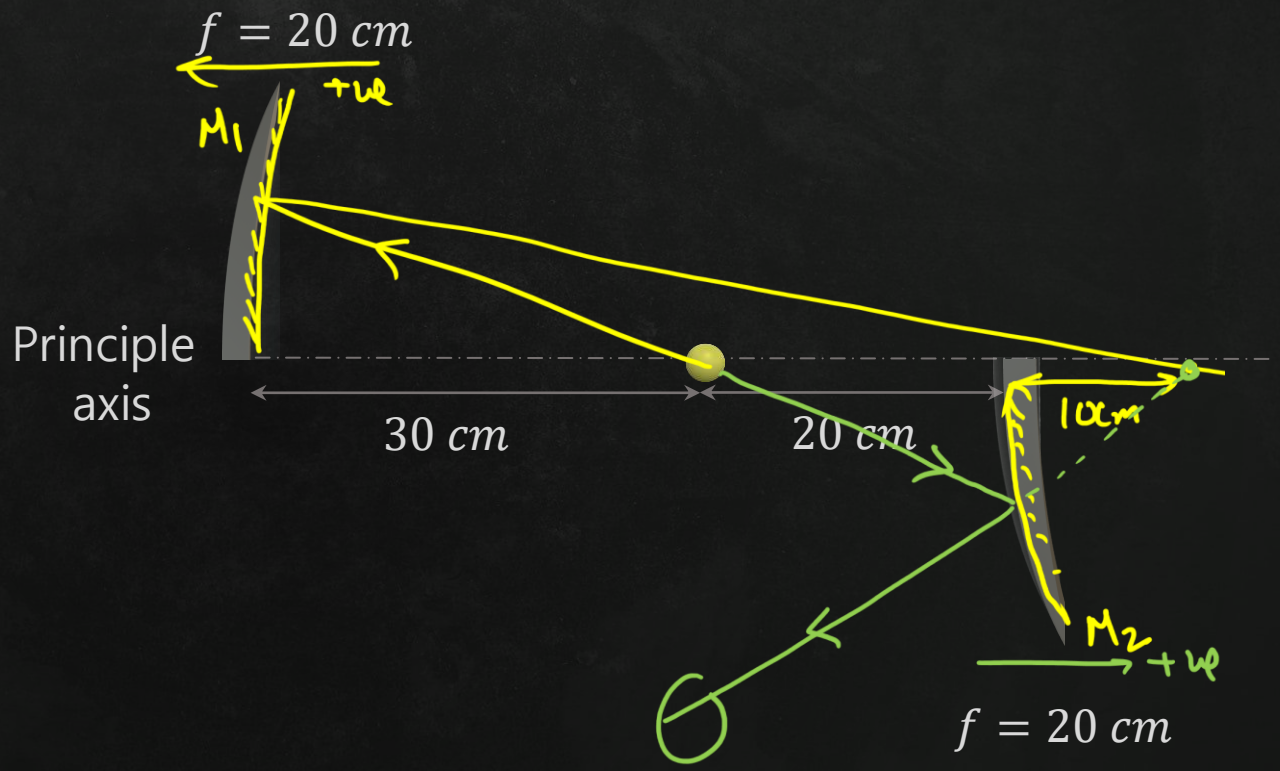


Image by mirror M_1

Given,

$u = -30\ cm$

$f = -20\ cm$

Distance of image,

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

$$= \frac{(-30)\times(-20)}{(-30)-(-20)} = -60\ cm$$

Thus, the image forms $60\ cm$ right of mirror M_1 and $10\ cm$ to the right of M_2. As this doesn't fall on M_2, it wont form a secondary image i.e., there will not be any further image due to this image of M_1.

B

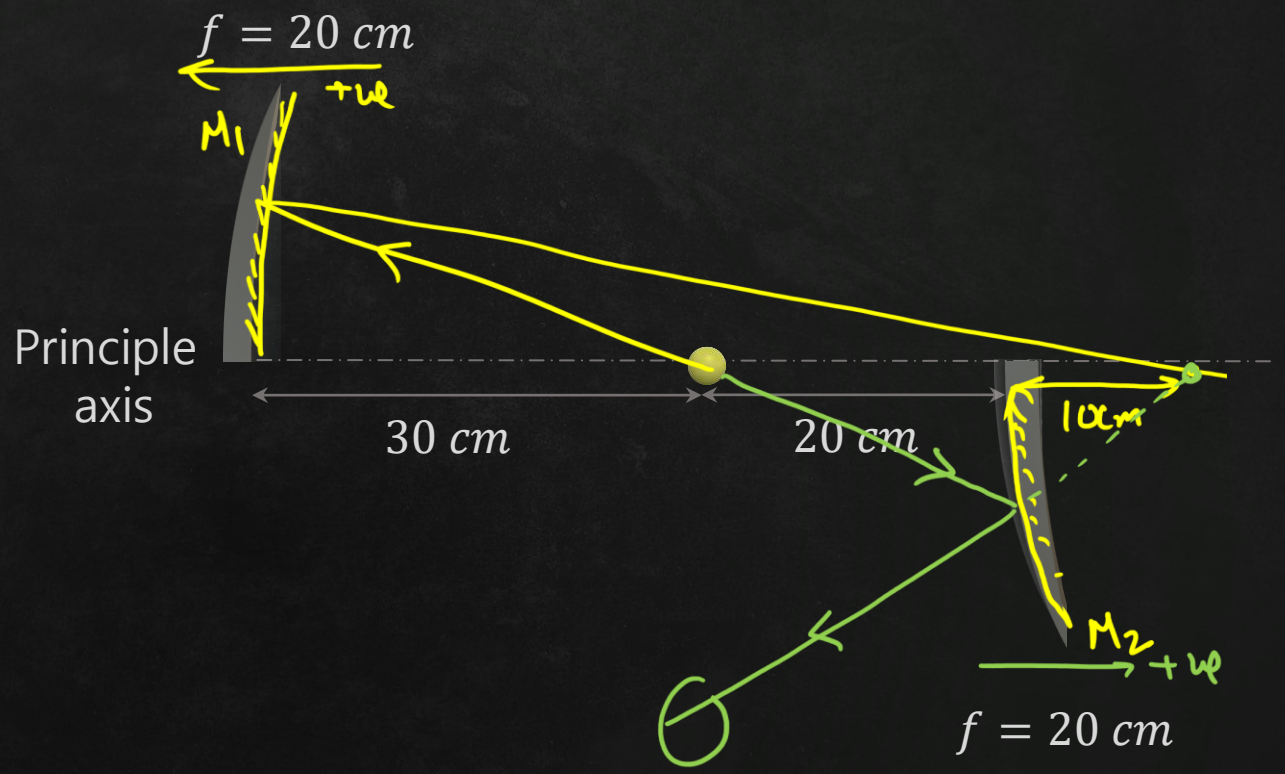
Image by mirror M_2

Given,
$u = -20\ cm$
$f = 20\ cm$

Distance of image,

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

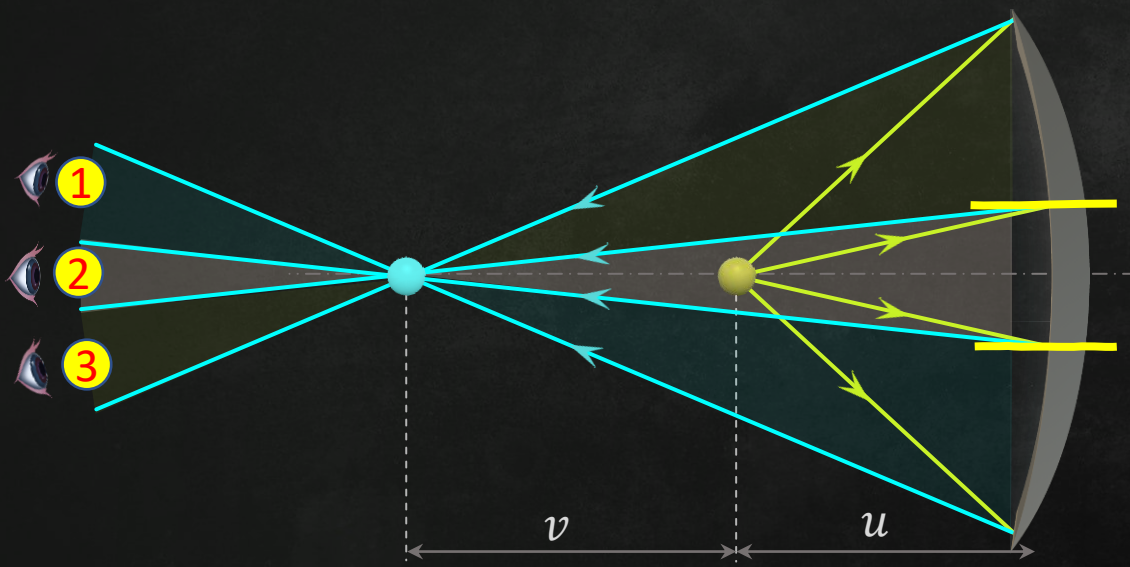
$$= \frac{(-20)\times(20)}{(-20)-(20)} = 10\ cm$$

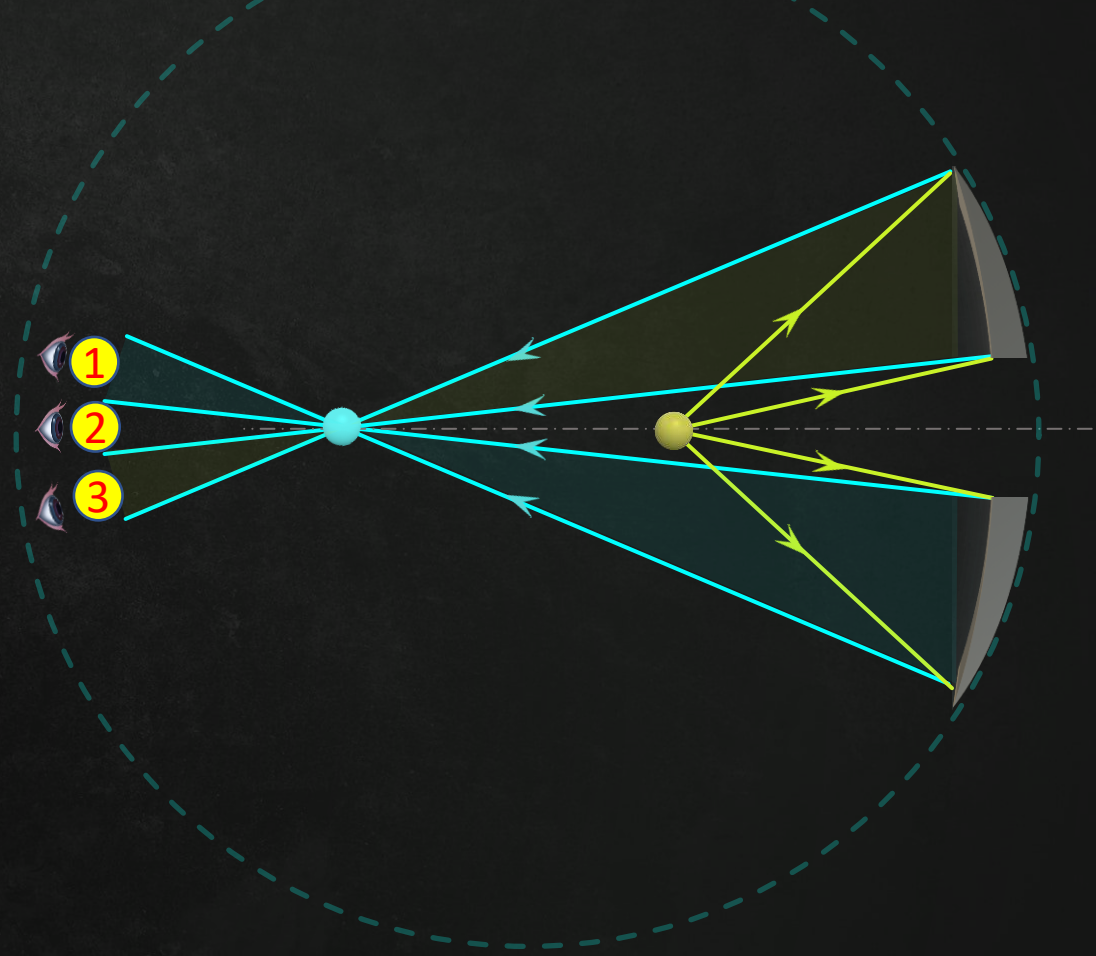


Thus, the image forms $10\ cm$ right of mirror M_2. As both the images of the object by M_1 and M_2 coincide and there is no chance of forming secondary image, only one image forms in this case. Thus, option (a) is the correct answer.

1

Cutting of Mirror





- अगर mirror को काटने पर अलग-अलग हिस्से **एक ही गोले** का हिस्सा है, तो image **एक ही बनेगा**।
- Mirror को काटने पर number of rays forming the image decreases.
- Intensity of the image depends on the position of the observer.

Agar hum dhyan de to Payenge ki observer 1 & 3 ke liye Intensity Pere Kor Jorak Nahi Padega Pere observer - 2 ke liye to Intensity Zero ki Ho jayegi.

EXAMPLE

A concave mirror of focal length $20\ cm$ is cut into two parts from the middle and the two parts are moved perpendicularly by a distance $1\ mm$ from the previous principal axis AB. For an object at a distance $30\ cm$, find distance between the images formed by the two parts?

Solution

BOARDS MAIN

Image by mirror M_1

Given,

$u = -30\ cm$

$f = -20\ cm$

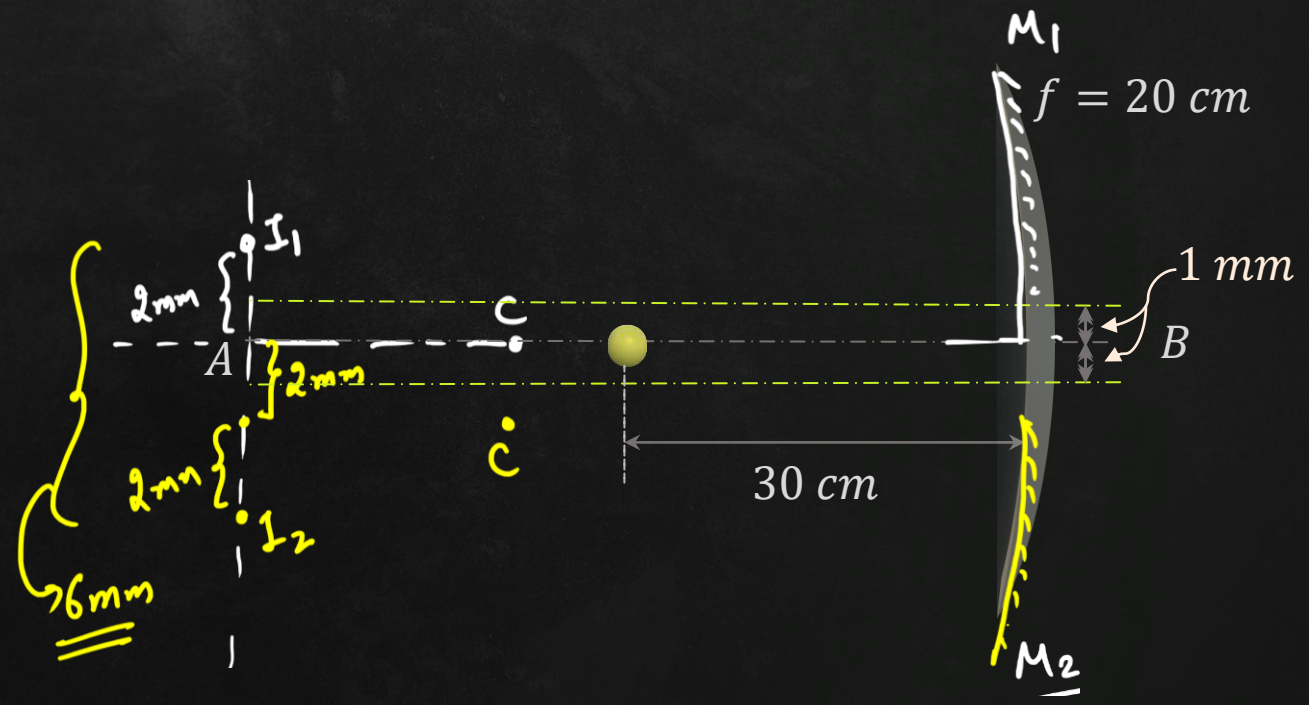
Distance of image,

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

$$= \frac{(-30)\times(-20)}{(-30)-(-20)} = -60\ cm$$

As the parts of mirror are moved by $1\ mm$, its principal axes also gets moved.

Thus, for M_1, $h_o = -1\ mm$



Height of the image due to M_1 :

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

$$h_i = -(-1) \times \frac{-60}{-20} = 2\ mm$$

B

Image by mirror M_2

Given,

$u = -30\ cm$

$f = -20\ cm$

Distance of image,

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

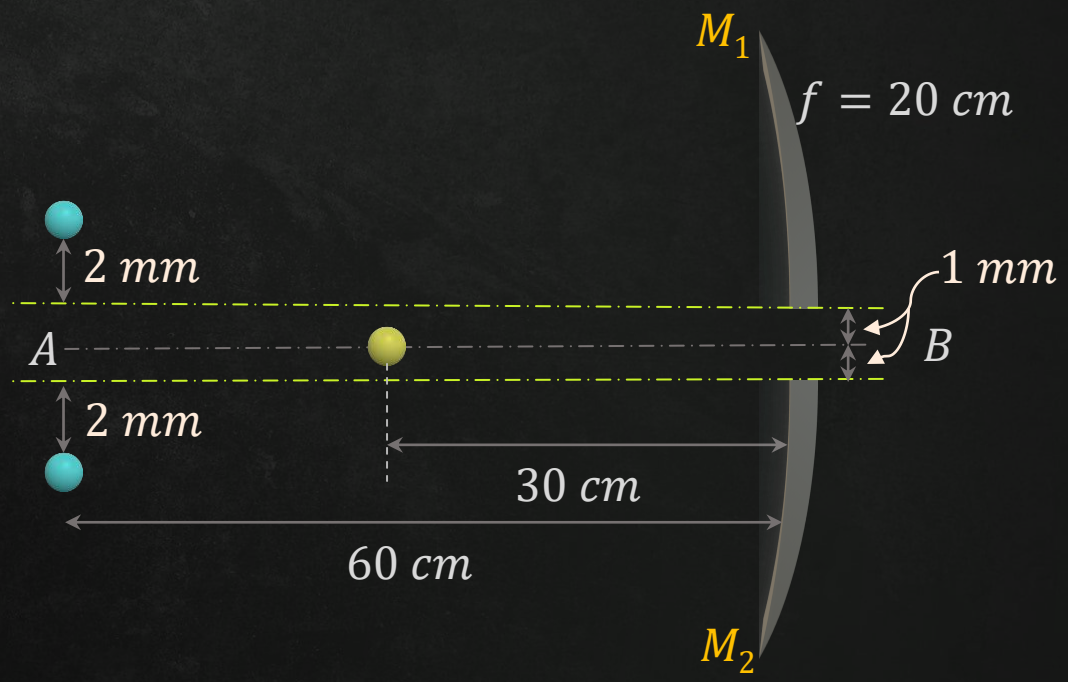
$$= \frac{(-30)\times(-20)}{(-30)-(-20)} = -60\ cm$$

For M_2, $h_o = 1\ mm$

Height of the image due to M_2:

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

$$h_i = -(1) \times \frac{-60}{-20} = -2\ mm$$



As the distance between principal axes of mirrors is $2\ mm$, the total distance between the two images is $6\ mm$.

$6\ mm$

EXAMPLE

A $2\ mm$ piece is cut from concave mirror of focal length $20\ cm$ from the middle and the two parts are moved perpendicularly toward the previous principal axis. For an object at a distance $30\ cm$, find distance between the images formed by the two parts?

a) $2\ mm$ b) $4\ mm$ c) $6\ mm$ d) $8\ mm$

Solution

MAIN

Image by mirror M_1

Given,

$u = -30\ cm$

$f = -20\ cm$

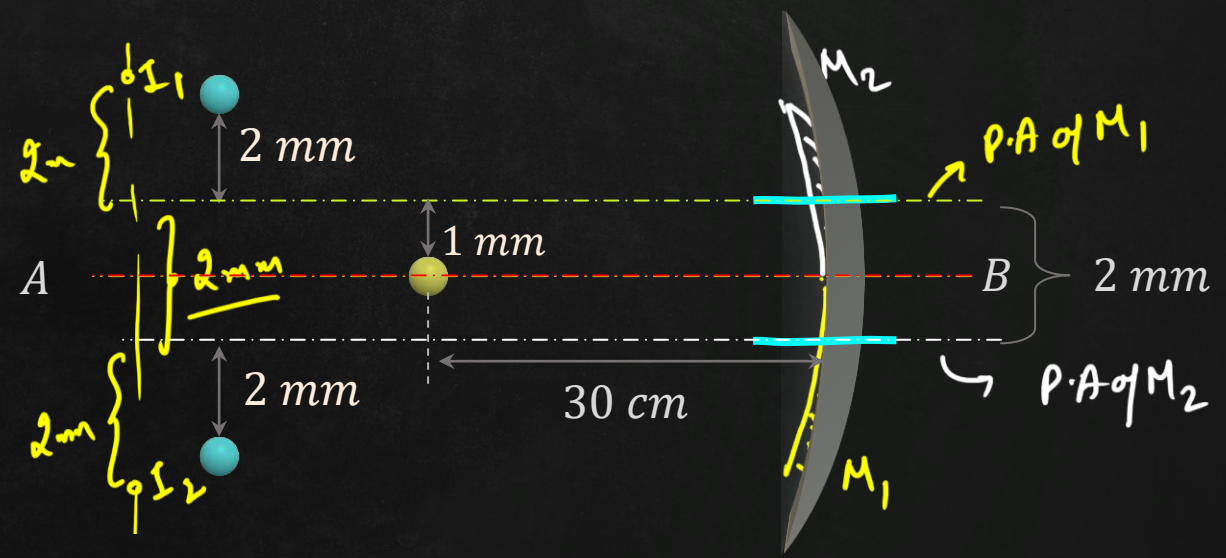
Distance of image,

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

$$= \frac{(-30)\times(-20)}{(-30)-(-20)} = -60\ cm$$

As the parts of mirror are moved by $1\ mm$, its principal axes also gets moved.

Thus, for M_1, $h_o = -1\ mm$



Height of the image due to M_1 :

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

$$h_i = -(-1) \times \frac{-60}{-20} = 2\ mm$$

B

Image by mirror M_2

Given,

$u = -30\ cm$

$f = -20\ cm$

Distance of image,

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

$$= \frac{(-30)\times(-20)}{(-30)-(-20)} = -60\ cm$$

For M_2, $h_o = 1\ mm$

Height of the image due to M_2 :

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

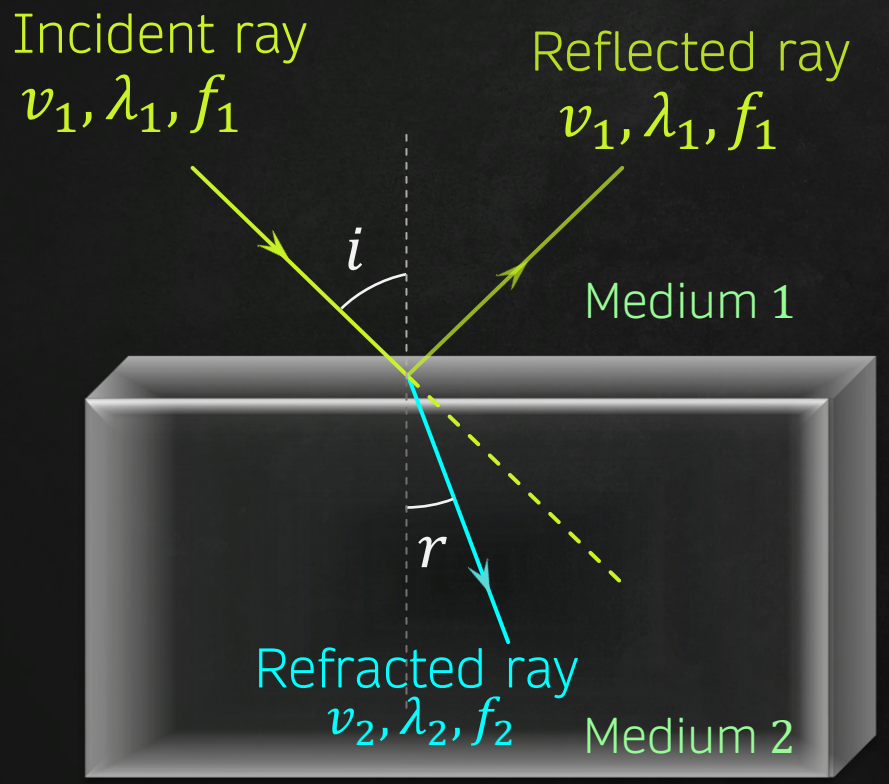
$$h_i = -(1) \times \frac{-60}{-20} = -2\ mm$$

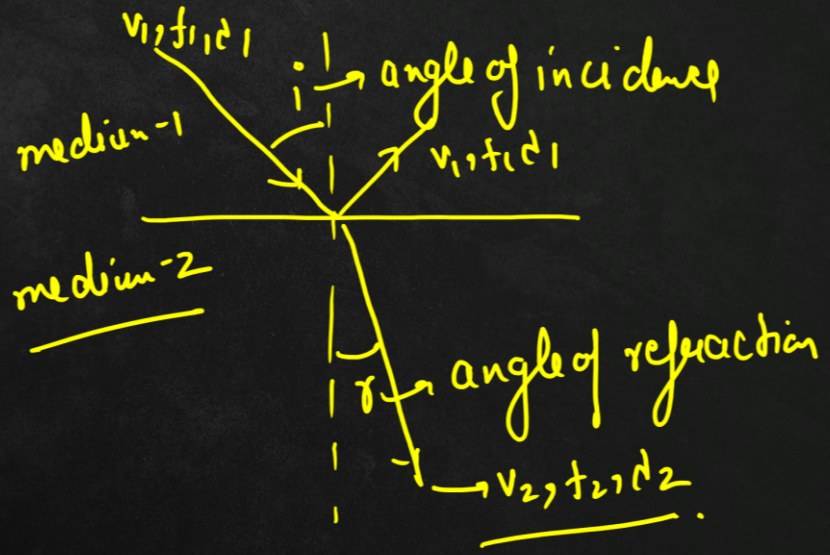
As the distance between principal axes of mirrors is $2\ mm$, the total distance between the two images is $6\ mm$.

$6\ mm$

REFRACTION

REFRACTION : Phenomenon of bending of light when it travels from one medium to another.





velocity depends on Medium → $V_2 \neq V_1$

frequency depends on Source. → $f_2 = f_1$ (bcoz Source is same)

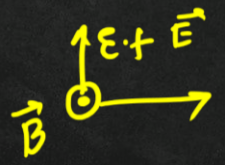
d depends on both → $d_2 \neq d_1$ {bcoz v changes}

When light travels from one medium to another medium, its velocity and wavelength changes but its frequency remains the same ($f_1 = f_2$).

REFRACTION

Refractive Index (n) (Medium Property)

Electromagnetic wave is a composition of electric and magnetic field. Intensity of electric and magnetic field is expressed in terms of permittivity and permeability of medium respectively.



ε_0: permittivity of free space (E.f)

8.85×10^{-12}

μ_0: permeability of free space (M.f)

$4\pi \times 10^{-7}$

μ_r = Relative permeability of Medium.

ε_r = Relative permittivity of Medium.

Speed of light in vacuum

$$c = 3 \times 10^8\ m/s = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

Speed of light in medium

$$\text{Speed} = \frac{1}{\sqrt{\mu_0 \mu_r \varepsilon_0 \varepsilon_r}}$$

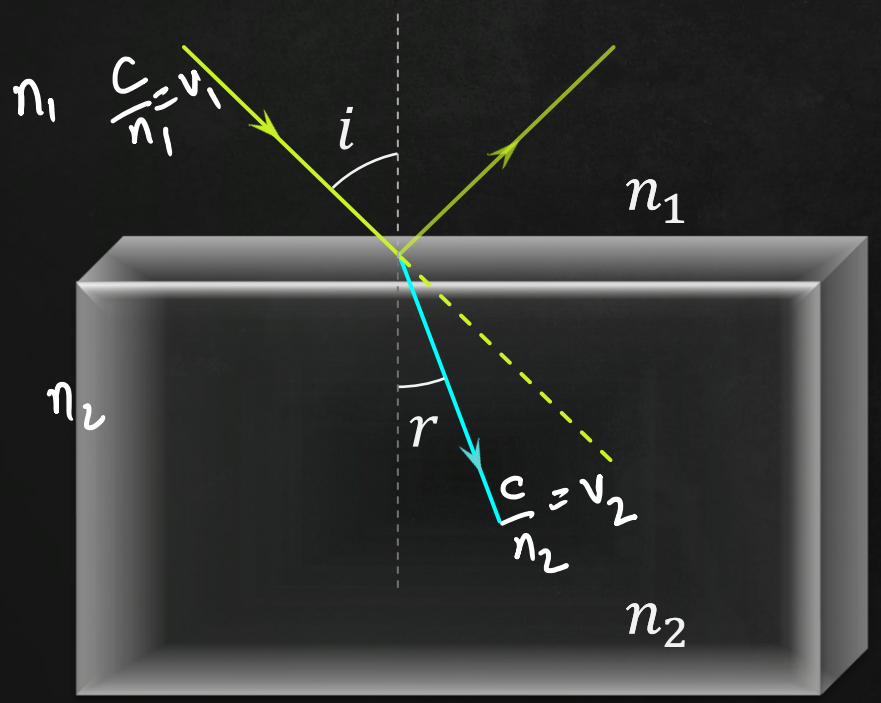
$$C_m = \frac{1}{\sqrt{\mu_0 \varepsilon_0}\sqrt{\mu_r \varepsilon_r}}$$

$$C_m = \frac{C}{\sqrt{\mu_r \varepsilon_r}} \rightarrow n = \text{Refractive Index}$$

$$n = \sqrt{\mu_r \varepsilon_r}$$

Refractive Index (n)

For a given medium, refractive index is defined as the ratio of speed of light in vacuum (c) to the speed of light in that medium (v).



$$\frac{n_1}{n_2} = \frac{v_2}{v_1} = \frac{\lambda_2}{\lambda_1}$$

$v_1 = c/n_1 \qquad v_2 = c/n_2$

$$\frac{v_1}{v_2} = \frac{n_2}{n_1} = \frac{d_1}{d_2}$$

Yaad Rakhein

$$n = \frac{c}{v}$$

$v_1 = f \cdot d_1$

$v_2 = f d_2$

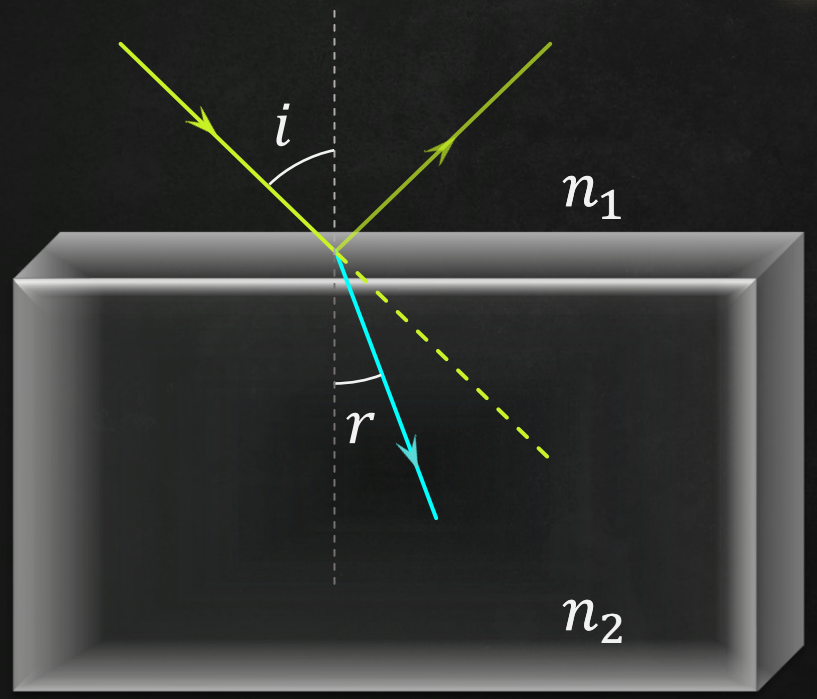
Medium	Refractive Index
Vacuum or air	1
Glass	1.5
Water	$\frac{4}{3}$

REFRACTION

Laws of Refraction

SNELL'S LAW

$$n_1 \sin i = n_2 \sin r$$



$$\frac{n_2}{n_1} = \frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

1st Law

$n_1 \cdot \sin i = n_2 \sin r$

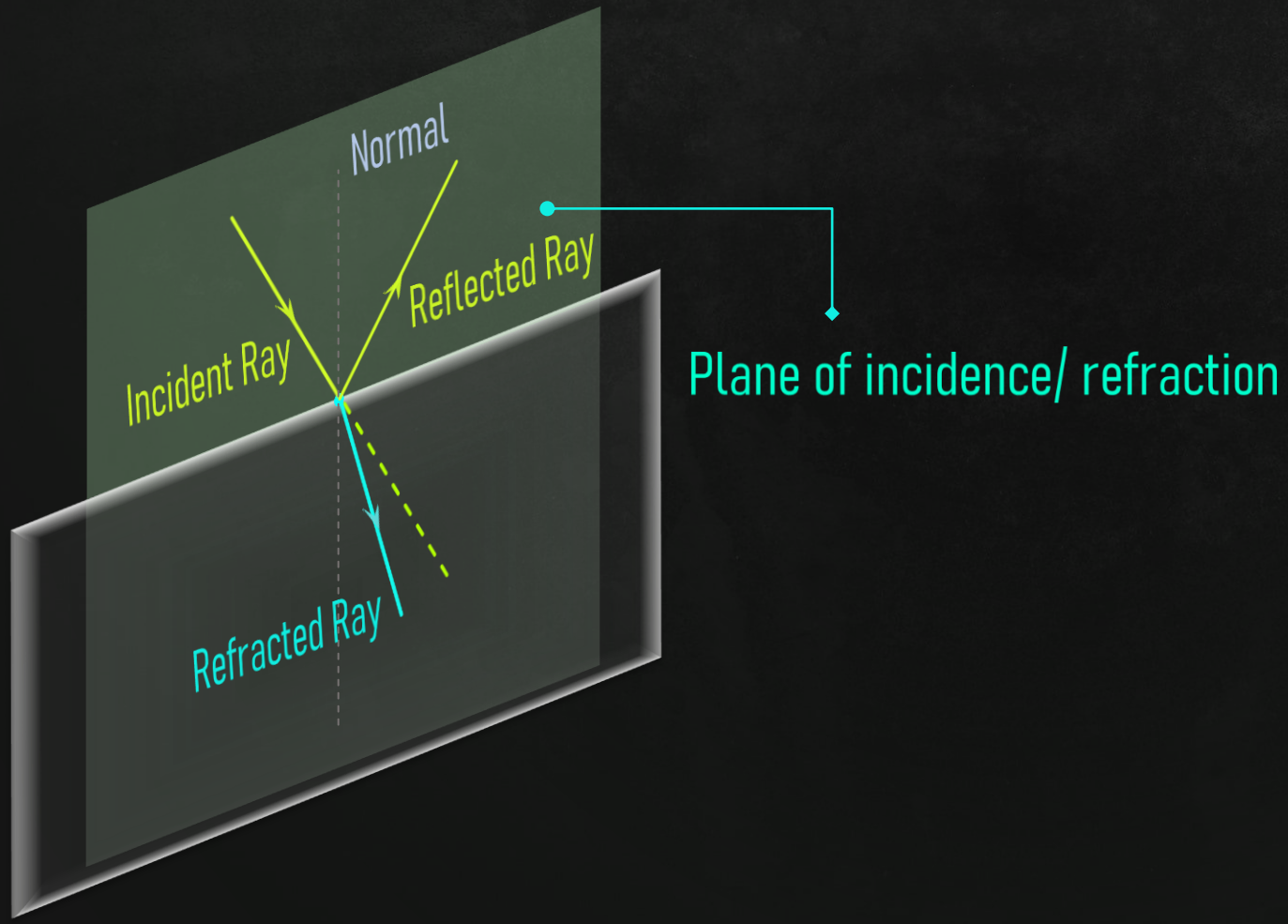
$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{d_1}{d_2}$

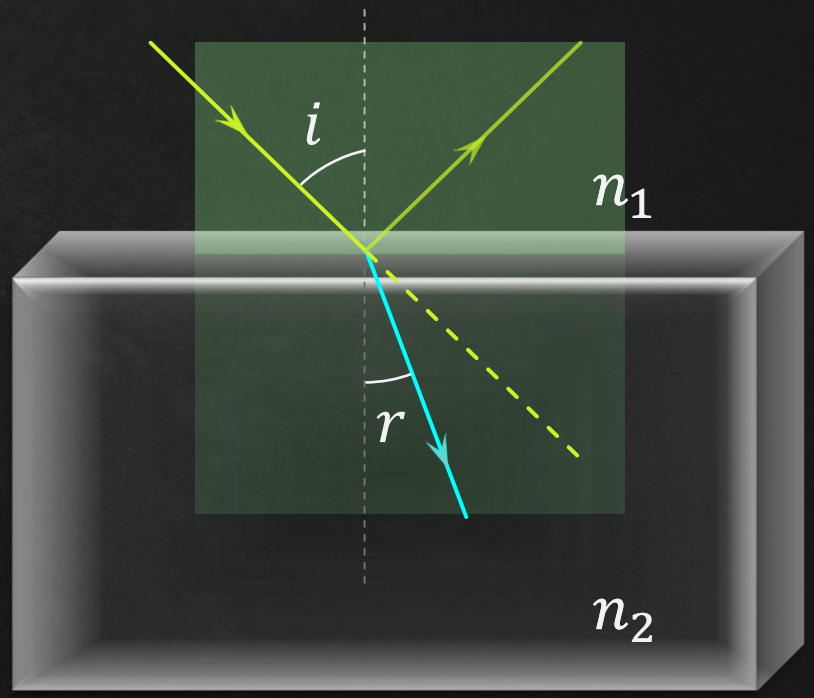
2nd law

Incident ray, refracted ray & the normal lie in the same plane.

Laws of Refraction

The incident ray, the reflected ray and the normal, all lie on the same plane.



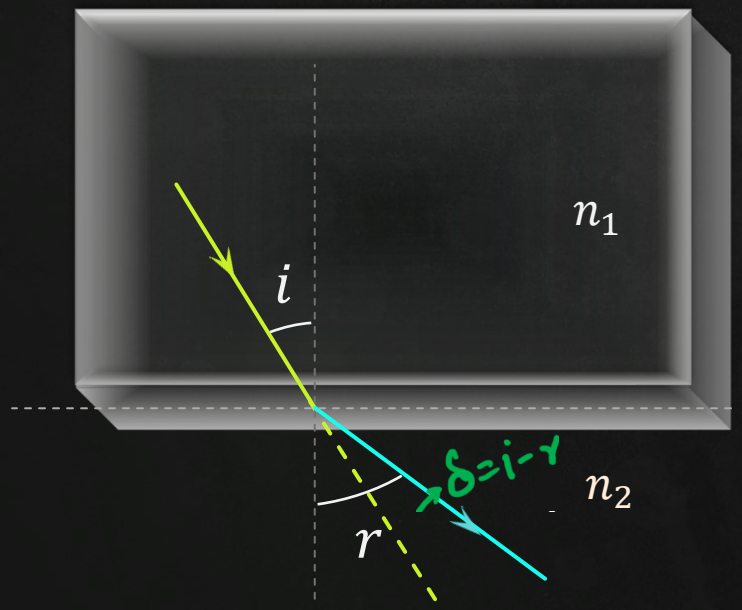


REFRACTION

Bending of Light Due to Refraction

Light is Moving from Denser Medium to the Rarer Medium $(n_1 > n_2)$

δ = angle of deviation $= |r - i|$



Denser & rarer
Ye Relative term hain.
Jiska n jyada ho wah Denser kaha kai.

$n_1 \sin i = n_2 \sin r$

$\sin r = \frac{n_1}{n_2} \cdot \sin i$

If $n_1 > n_2 \Rightarrow r > i$

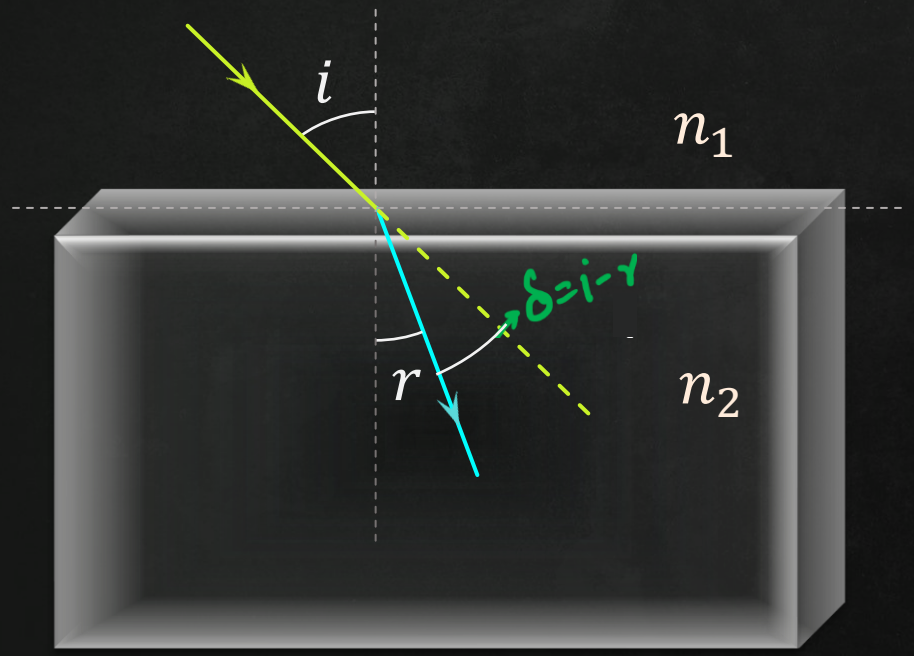
If a ray is moving from Denser to rarer then it shifts away from the normal.

- n_1 : Refractive Index of the medium where the rays are coming from.
- n_2 : Refractive Index of the medium where the rays are going to.

REFRACTION

Bending of Light Due to Refraction

Light is Moving from Rarer Medium to the Denser Medium



$n_1 < n_2$

If a Ray is moving from rarer to denser than it shifts towards the the normal.

$$n_1 \sin i = n_2 \sin r$$

$$\sin r = \frac{n_1}{n_2} \cdot \sin i$$

If $n_1 < n_2, r < i$

- n_1 : Refractive Index of the medium where the rays are coming from.
- n_2 : Refractive Index of the medium where the rays are going to.