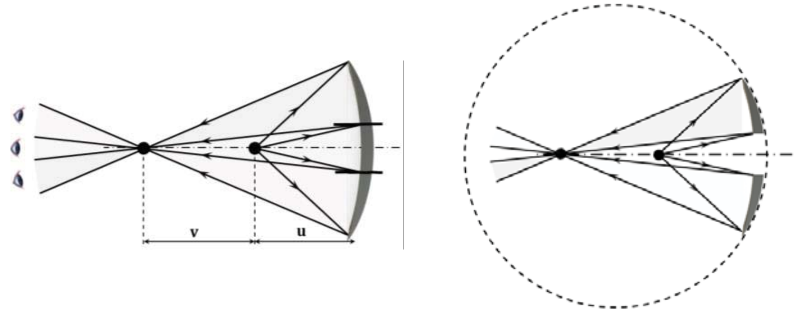
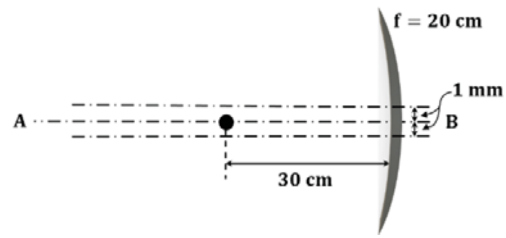
LAWS OF REFRACTION

Cutting of Mirror

If the sections resulting from cutting the mirror belong to the same sphere, the image remains unchanged. Cutting the mirror reduces the number of rays involved in forming the image. The intensity of the image varies depending on the observer's position.



Ex. A concave mirror with a focal length of 20 cm is bisected at its midpoint, and the two halves are displaced perpendicularly by 1 mm from the original principal axis AB. Given an object located 30 cm away, determine the distance between the images formed by the two mirror parts.



Sol. Image by mirror M_1.

Given, $u = -30$ cm; $f = -20$ cm

Distance of image, $v = \frac{uf}{u-f}$

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

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

Thus, for $M_1, h_o = -1\text{mm}$

Height of the image due to M_1 :

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

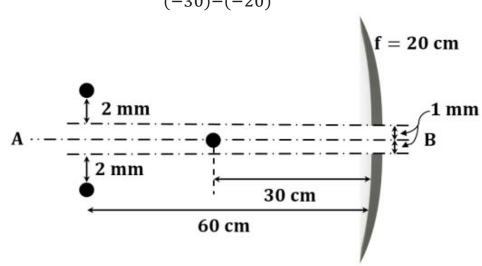
$$h_i = -(-1) \times \frac{-60}{-20} = 2\text{mm}$$

Image by mirror M_2.

Given, $u = -30$ cm; $f = -20$ cm

Distance of image, $v = \frac{uf}{u-f}$

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



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

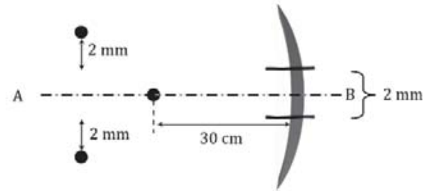
Thus, for $M_2, h_o = -1\text{mm}$

Height of the image due to M_1 : $\frac{h_i}{h_o} = -\frac{v}{u}$

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

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

Ex. 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

Sol. Image by mirror M_1.

Given, $u = -30$ cm; $f = -20$ cm

Distance of image, $v = \frac{uf}{u-f}$

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

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

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

Height of the image due to M_1 : $\frac{h_i}{h_o} = -\frac{v}{u}$

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

Image by mirror M_2.

Given, $u = -30$ cm; $f = -20$ cm

Distance of image, $v = \frac{uf}{u-f}$

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

Thus, for $M_2, h_o = -1$mm

Height of the image due to M_1 : $\frac{h_i}{h_o} = -\frac{v}{u}$

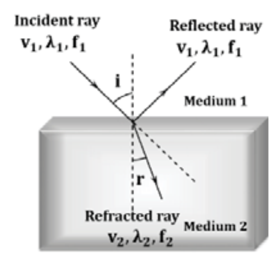
$$h_i = -(1) \times \frac{-60}{-20} = -2\text{mm}$$

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

Refraction

The phenomenon wherein light bends as it transitions from one medium to another.

As light moves from one medium to another, its speed and wavelength shift, while its frequency remains constant ($f_1 = f_2$).



Refractive Index (n)

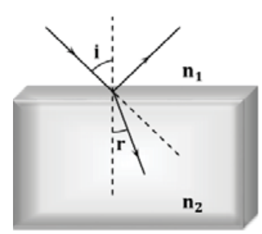
An electromagnetic wave consists of both electric and magnetic fields. The intensity of these fields is described in terms of the permittivity and permeability of the medium, respectively.

Speed of light in vacuum $c = 3 \times 10^8 \text{ m/s} = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$

ε_0: Permittivity of free space

μ_0: Permeability of free space

Speed of light in medium Speed $= \frac{1}{\sqrt{\mu_0 \mu_r \varepsilon_0 \varepsilon_r}}$



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

$$C_m = \frac{C}{\sqrt{\mu_1 \varepsilon_r}}$$

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

In a specified medium, the refractive index is characterized as the ratio of the speed of light in a vacuum (c) to its speed within that medium (v).

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

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

Laws of Refraction

Snell's Law $n_1 \sin i = n_2 \sin r$

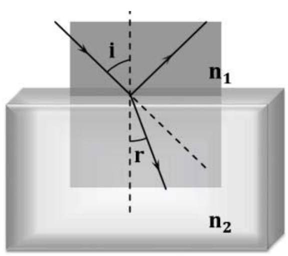
1st Law $n_1 \cdot \sin i = n_2 \sin r$

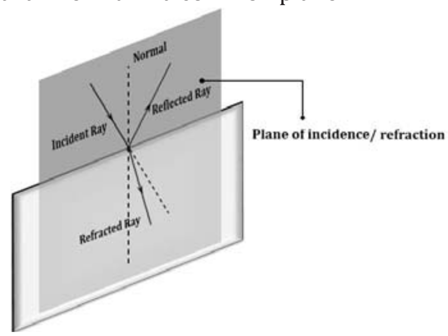
$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

2nd Law Incident ray and refracted ray & the normal lie in the same plane.

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

The incident ray, the reflected ray, and the normal all lie within a common plane.

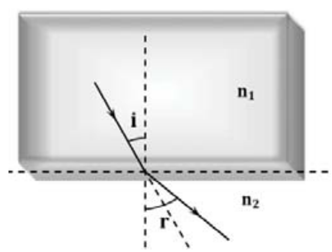


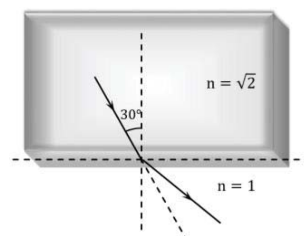


Bending of Light Due to Refraction

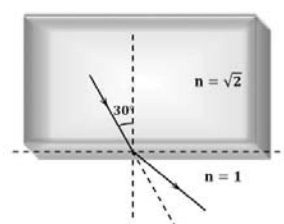
Light is transitioning from a denser medium to a less dense one ($n_1 > n_2$).
n_1: Refractive Index of the medium where the rays are coming from
n_2: Refractive Index of the medium where the rays are going to

Light is transitioning from a less dense medium to a denser one.
n_1: Refractive index of the medium from which the rays originate.
n_2: Refractive index of the medium toward which the rays are directed.





Ex. If a light ray goes from a medium having $n = \sqrt{2}$ to medium having $n = 1$ as shown, find the angle of deviation.



Sol. Here, the ray is going from denser to rarer medium hence, it is going away from the normal. We know that, if $n_1 > n_2, r > i$.

We have, $n_1 \sin i = n_2 \sin r$

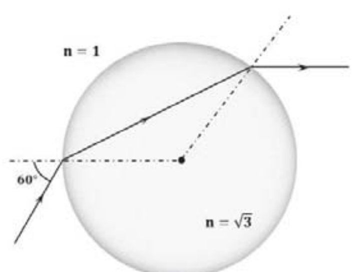
$$r = \sin^{-1}[\frac{\sqrt{2}}{1}\sin 30°]$$

$$r = \sin^{-1}(\frac{\sqrt{2}}{1}\frac{1}{2}) = \sin^{-1}(\frac{1}{\sqrt{2}}) = 45°$$

$$\delta = |\gamma - i| = 45° - 30° = 15°$$

$$15°(ACW)$$

Ex. If a light ray goes from a medium having $n = 1$ to medium having $n = \sqrt{3}$ as shown, find the angle of deviation.



Sol. Here, the ray is going from rarer to denser medium and then emerging out into rarer medium again.

We have, $n_1 \sin i = n_2 \sin r$

First refraction: $1 \cdot \text{Sin}60° = \sqrt{3} \cdot \text{Sin}r$

$$\frac{\sqrt{3}}{2} = \sqrt{3} \cdot \text{Sin}r r = 30°$$

Angle of deviation: $\delta_1 = |r - i| = 30° = (c \cdot \omega)$

Second refraction: $\sqrt{3} \cdot \sin 30° = 1 \cdot \sin r$

$$r = 60°$$

Angle of deviation: $\delta_2 = |\gamma - i| = 30^\circ = (c \cdot \omega)$

Net angle of deviation: $\delta_{net} = \delta_1 + \delta_2 = 30^\circ + 30^\circ = 60^\circ$

$$\delta_{net} = 60^\circ (c \cdot \omega)$$