Ch-1

Light

Optics

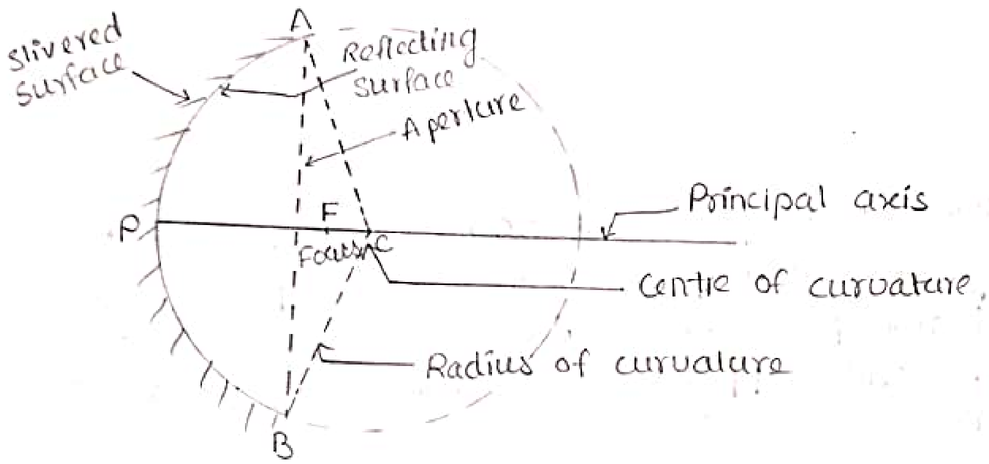
It is the branch of physics which deals with the study of nature, production and propagation of light.

Laws of Reflection

i) The angle of incidence is equal to the angle of reflection.
i.e $\angle i = \angle r$.

ii) The incident ray, the reflected ray and the normal at the point of incidence all lie in the same plane.

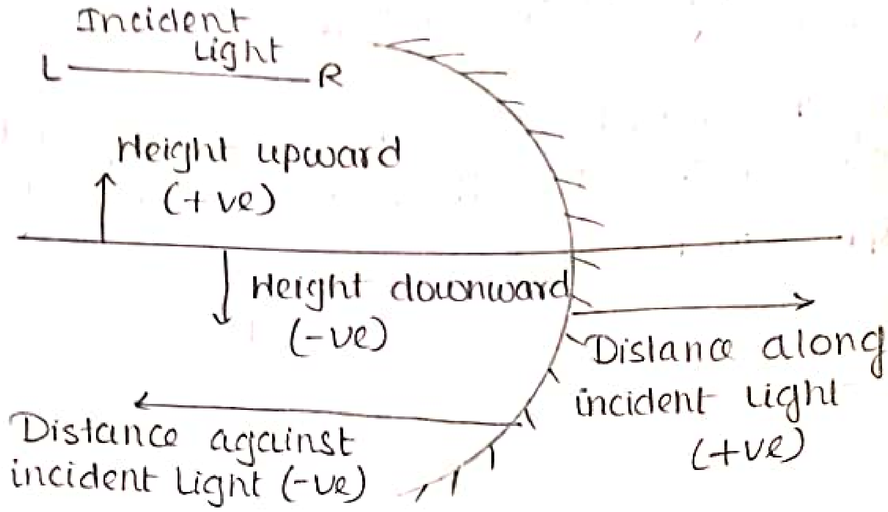
Spherical mirror



1. Pole: It is the middle point P of the spherical surface.
2. Centre of curvature :- It is the centre C of the sphere of which the mirror forms a part.
3. Radius of Curvature :- It is the radius ($R = AC$ or BC) of the sphere of which the mirror forms a part.
4. Principal axis :- The line PC passing through the pole and the centre of curvature of the mirror is called its principal axis.
5. Linear aperture :- It is the diameter AB of the circular boundary of the spherical mirror.
6. Angular aperture :- It is the angle ACB subtended by the boundary of the spherical mirror at its centre of curvature C.
7. Principal focus :- A narrow beam of light parallel to the principal axis either actually converges to or appears to diverge from a point F on the principal axis after reflection from the spherical mirror. This point is called the principal focus of the mirror.

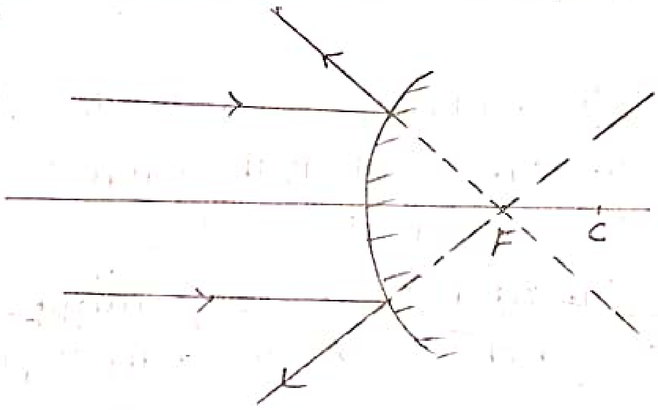
8. ~~F~~ Focal length :- It is the distance ($f = PF$) between the focus and the pole of the mirror.

9. Focal plane :- The vertical plane passing through the principal focus and perpendicular to the principal ~~axis~~ axis is called focal plane.

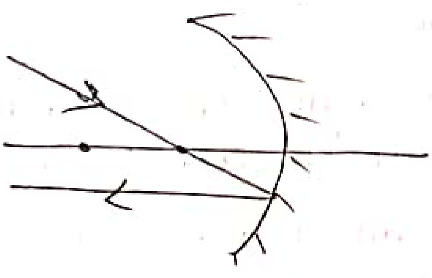


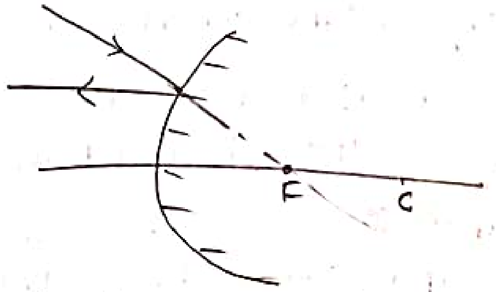
Rules for drawing images formed by spherical mirror

(i) A ray proceeding parallel to the principle axis will after reflection pass through the focus in case of a concave mirror, and will appear to come from focus in case of convex mirror.



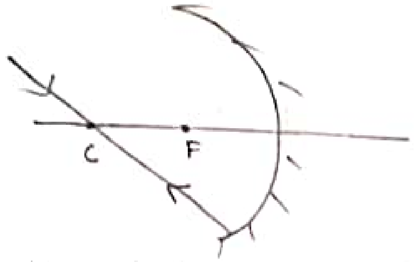
(ii) A ray passing through the principal focus in the case of a concave mirror, and directed towards the ~~principal~~ principle focus in case of a convex mirror will after reflection become parallel to the principle axis.

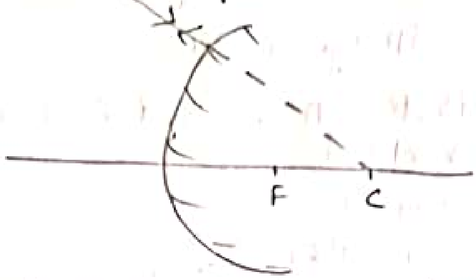




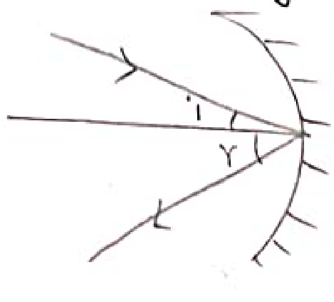
(iii) A ray passing through the centre of curvature in case of a concave mirror and directed towards the centre of curvature in case of a convex mirror falls normally ($\angle i = \angle r$)

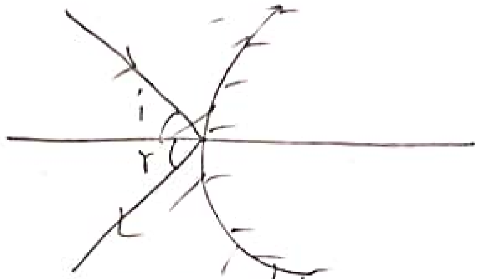
and is reflected back alone the same part.





iv) For the ray incident at any angle at the pole, the reflected ray follows the laws of reflection.

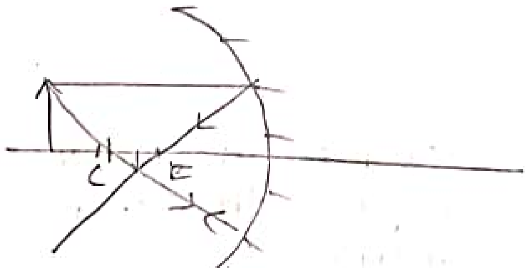




Formation of images by concave mirror

① object beyond C

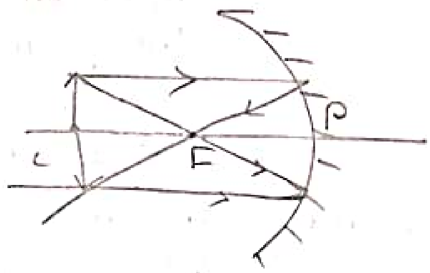
Image is obtained



ⓐ Between C and F
ⓑ Real
ⓒ Inverted
ⓓ Smaller than O.

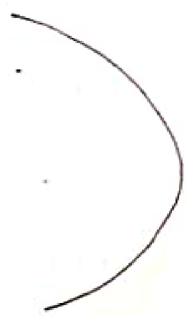
② Object at C

Image is obtained



a. Image form in Centre
b. Real
c. Inverted
d. O and Image is equal

③ Object beth F and C



a. behind Centre
b. Real, Inverted
c. larger than O

④ Object beth F and P

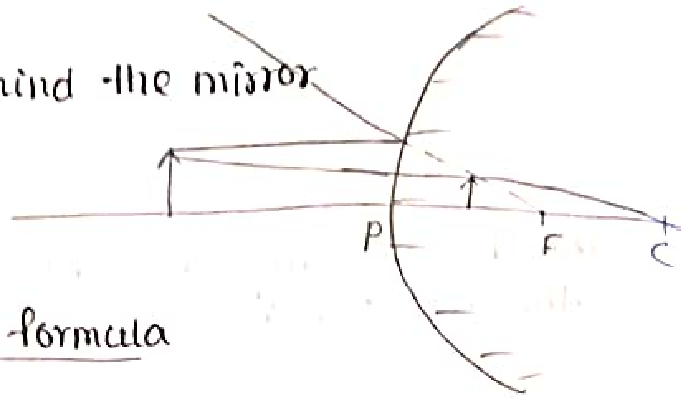
Image obtained

ⓐ behind the mirror
b. Virtual
c. Errect (upright)
d. larger size than O.

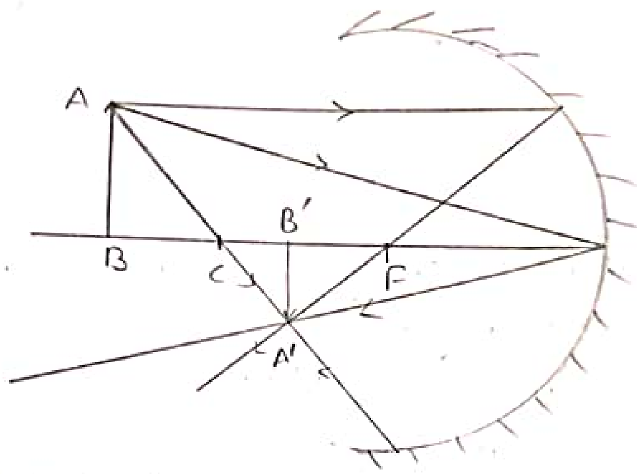
Formation of images by convex mirror

Image obtained

a. Between P and F behind the mirror
b. Virtual
c. Erect
d. Smaller size



Magnification and mirror formula



Consider an object AB placed on the principle axis beyond the centre of curvature (C) of a concave mirror.

Now using sign convention,

object distance $= -u$
Imag " $= -v$
focal length $= -f$
Radius of curvature $= -R = -2f$

$\Delta A'B'C$ and ΔABC are similar –

$$\therefore \frac{A'B'}{AB} = \frac{CB'}{BC} = \frac{CP - B'P}{BP - CP} = \frac{-R+v}{-u+R} \quad \text{— (i)}$$

As, $\angle A'PB' = \angle APB$

$\therefore \Delta A'B'P \sim \Delta APB$

$$\therefore \frac{AB'}{AB} = \frac{B'P}{BP} = \frac{-v}{-u} = \frac{v}{u} \quad \text{— (ii)}$$

From eqn (i) and (ii)

$$\frac{-R+v}{-u+R} = \frac{v}{u}$$

$\Rightarrow -uR + uv = -uv + vR$

$\Rightarrow vR + uR = 2uv$

Dividing both sides by uvR

$$\frac{vR}{uvR} + \frac{uR}{uvR} = \frac{2uv}{uvR}$$

$$\Rightarrow \frac{1}{u} + \frac{1}{v} = \frac{2}{R}$$

$$\Rightarrow \frac{1}{u} + \frac{1}{v} = \frac{2}{2f}$$

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

Linear magnification – The ratio of the height of the image to that of the object is called linear magnification.

$$m = \frac{\text{height of image}}{\text{height of object}}$$

For concave mirror,

$$\Delta APB \sim \Delta A'PB'$$

$$\therefore \frac{A'B'}{AB} = \frac{B'P'}{BP}$$

$$\Rightarrow \frac{-h_2}{h_1} = \frac{+v}{+u}$$

$$\Rightarrow \frac{h_2}{h_1} = -\frac{v}{u}$$

$$\therefore \boxed{m = \frac{h_2}{h_1} = -\frac{v}{u}}$$

Note

i) If $|m| > 1$, the image is magnified.
ii) If $|m| < 1$, the image is diminished.
iii) If $|m| = 1$, the image is the same size as the object.
iv) If m is (+ve), or v is (+ve), the image is virtual and erect.
v) If m is (−ve) or v is (−ve) the image is real and inverted.

Q. An object is placed (i) 10cm (ii) 5cm in front of a concave mirror of radius of curvature 15cm. Find the position, nature and magnification the image in each case.

Ans– Given, (i) $u = -10$ cm
$R = -15$ cm
$v = ?$
$m = ?$

$\therefore R = 2f \Rightarrow f = R/2 = -15/2$

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

$\Rightarrow \frac{1}{-10} + \frac{1}{v} = \frac{1}{f} - \frac{1}{u}$

$\Rightarrow \frac{1}{v} = \cancel{\frac{-15}{2}} - \frac{2}{15} + \frac{1}{10}$

$\Rightarrow \frac{1}{v} = \frac{-4+3}{30}$

$= \frac{-1}{30}$

$\Rightarrow v = -30\ cm$

$m = \frac{-v}{u} = -\left(\frac{-30}{-10}\right) = -3$

As v is (-ve), a real image is formed 30cm from the mirror on the same side of the object.

The image is magnified, real and inverted.

(ii) $u = -5cm$

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

$\Rightarrow \frac{1}{v} = \frac{1}{f} - \frac{1}{u}$

$= -\frac{2}{15} + \frac{1}{5}$

$= \frac{-2+3}{15}$

$= \frac{+1}{15}$

$\Rightarrow v = 15\ cm$

$m = -\frac{v}{u} = -\frac{15}{(-5)} = 3$

The image is virtual and erect and magnified.

Q. An object 0.05 m height is placed at a distance of 0.5 m from a concave mirror of radius of curvature 0.2 m. Find the position, nature and size of the image formed.

Ans– Given, $u = -0.5m = -50cm$

$R = -0.2m = -20cm$

$h_1 = 0.05m = 5cm$

$\therefore f = \frac{R}{2} = \frac{-20}{2} = -10\text{ cm}$

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

$\Rightarrow \frac{1}{v} = \frac{1}{f} - \frac{1}{u}$

$= -\frac{1}{10} + \frac{1}{50}$

$= \frac{-5+1}{50}$

$= \frac{-4}{50}$

$\Rightarrow v = -\frac{50}{4} = 12.5\text{ cm}$

$\therefore \frac{h_2}{h_1} = -\frac{v}{u}$

$\Rightarrow \frac{h_2}{5} = -\frac{12.5}{50}$

$\Rightarrow 50h_2 = -62.5$

$\Rightarrow h_2 = \frac{-62.5}{50}$

$= -1.25\text{ cm}$

The image is real, inverted and magnified.

Q. An object is placed at a distance of 40 cm on the principal axis of a concave mirror of radius of curvature 30 cm by how much does the image move if the object is ~~tt~~ shifted towards the mirror through 15 cm?

Sol:- Given, $R = -30\text{ cm}$

$f = -15\text{ cm}$

Case I $u_1 = -40\text{ cm}$

$\frac{1}{u_1} + \frac{1}{v_1} = \frac{1}{f}$

$5 \,|\, 15, 40$
$\quad 3, 8$

$\Rightarrow \frac{1}{v_1} = \frac{1}{f} - \frac{1}{u_1}$

$15 \times 8 = 120$

$= \cancel{\frac{1}{40} - \frac{1}{15}}$ $\quad -\frac{1}{15} + \frac{1}{40}$

$= \cancel{\frac{-8+3}{120}}$ $\quad \frac{-8+3}{120}$

$= \cancel{\frac{-5}{120}}$ $\quad \frac{-5}{120}$

$\Rightarrow \frac{1}{v_1} = -\frac{1}{24} \Rightarrow v_1 = -24\text{ cm}$

Case II

$u_1 = (40-15)\text{ cm} = -25\text{ cm}$

$$\Rightarrow \frac{1}{v_2} = \frac{1}{f} - \frac{1}{u}$$

$5 \,|\, 25, 15$
$\quad 5, 3$

$$= -\frac{1}{15} + \frac{1}{25}$$

$$= \frac{-5+3}{75}$$

$$= \frac{-2}{75}$$

$$\Rightarrow v_2 = -\frac{75}{2}$$

$$= -37.5\text{ cm}$$

$\therefore$ Shift in image $= v_2 - v_1$

$$= -37.5 + 24$$

$$= -13.5$$

37.5
-24.0
13.5

Difference betn a Real image and Virtual image

Real image	Virtual image
(i) Rays of light coming from a point after reflection actually converges at a second point, which is called the real image of the first point.	(i) Rays of light coming from a point after reflection appears to diverge from a second point, which is called the virtual image of the first point.
(ii) Real image has real existence.	(ii) Virtual image has no real existence.
(iii) Real image is formed due to real or actual inter-section of the reflected or refracted rays.	(iii) Virtual image is formed due to imaginary intersaction of the reflected or refracted rays.
(iv) Real image has real existence and hence it can be touched or received on the screen.	(iv) Virtual image has no real existence and hence cannot be touched or received on the screen
(v) Real image is always inverted or upside down.	(v) Virtual image is always erect or upside up.
(vi) Real image is produced infront of the mirror.	(vi) Virtual image is produced behind the mirror.

Distinction beth three types of mirror

Type of mirror	Nature of image form
i) Plane mirror	Virtual, erect, laterally inverted image of same size formed as far behind the mirror as the object is in front of the mirror.
ii) Concave mirror	An inverted real image when the object is beyond the focus and an erect, virtual magnified image when object is within the focus of the mirror.
iii) Convex mirror	Always a diminished virtual, erect image formed behind the mirror between focus and pole of the mirror.

Refraction —

The phenomenon of change in path (or bending of light) as it travels from one medium to another medium is known as refraction of light.

laws of refraction

i) The incident ray, the reflected ray and the normal at the point of incidence all lie in the same plane.

ii) The ratio of sine of angle of incidence to the sine of angle of refraction is const for a given pair of media,

$$ {}^{1}\mu_2 = \frac{\sin i}{\sin r}, \quad {}^{1}\mu_2 = \text{Const} $$ (${}^{1}\mu_2$ is called refractive index of 2nd medium with respect to 1st medium)

Refractive index :-

The refractive index of a medium for a light of given wavelength may be defined as the ratio of the speed of light in vaccum to each speed in that medium.

$$\text{Refractive index} = \frac{\text{Speed of light in vaccum}}{\text{speed of light in medium}}$$

$$\boxed{\mu = \frac{c}{v}}$$

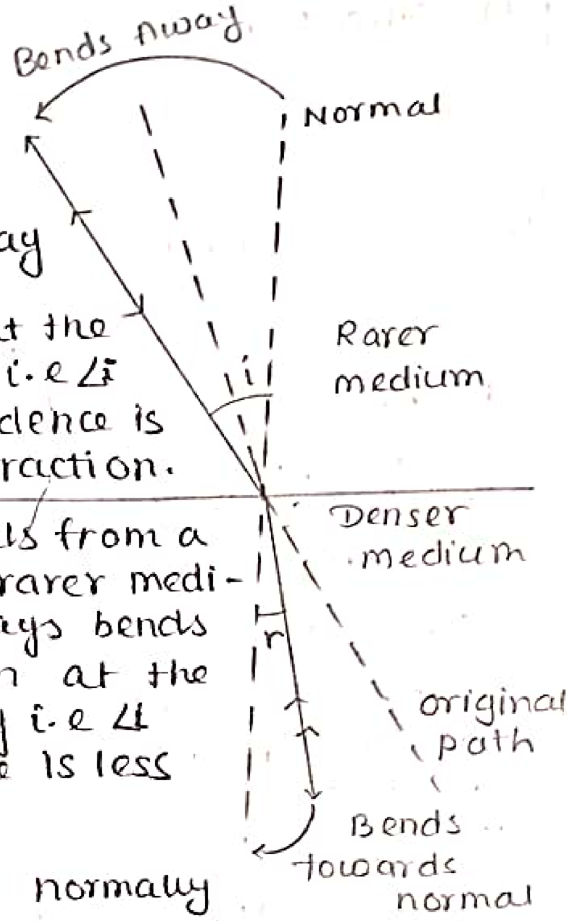
Refractive index of a medium with respect to vaccum is called absolute refractive index.

Relative refractive index –

The relative refractive index of medium 2 with respect to medium 1 is defined as the ratio of speed of light in medium 1 (v_1) to the speed of light in medium 2 (v_2).

$$\boxed{{}^1\mu_2 = \frac{v_1}{v_2}}$$

Direction of bending light



a. When a ray of light travels from a optically rarer medium to a denser medium (say air to glass), it always bends towards the normal drawn at the point of incidence of the ray i.e $\angle i$ greater than $\angle r$, angle of incidence is greater than the angle of refraction.

b. When a ray of light travels from a optically denser medium to a rarer medium (say air to glass), it always bends away from the normal drawn at the point of incidence of the ray i.e $\angle i$ less than angle $\angle r$ of incidence is less than the angle of refraction.

Fig-

The ray which is incident normally on the surface seperating the two media, passes undeviated (i.e no bending at the surface, $\angle i = 0$ and hence, $\angle r = 0$).

Principle of reversibility of light.

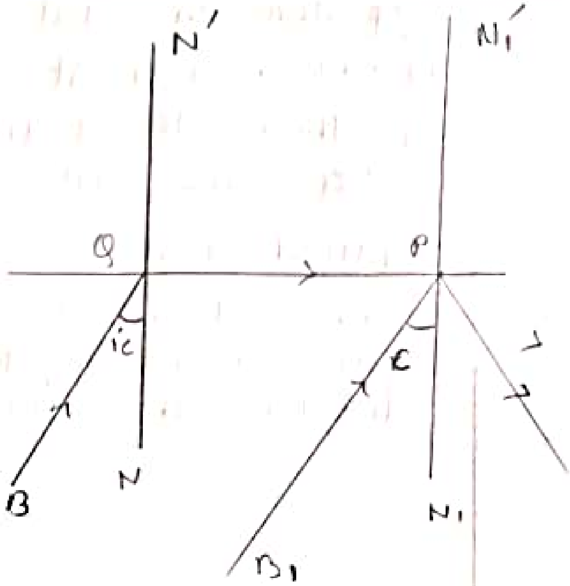
If the final path of a ray of light after it has suffered from several ~~refraction and~~ reflection and refraction in reverse, it retraces its path exactly.

$$\boxed{{}^1\mu_2 = \frac{1}{{}^2\mu_1}} \quad \text{or} \quad \boxed{{}^a\mu_g = \frac{1}{{}^g\mu_a}}$$

Relation betn critical angle and refractive index

Let us consider a ray of light BQ travelling from a denser medium to a rarer medium and refracted as QP.

Now, $\angle BQN$ is the angle of incidence for which angle of refraction $\angle N'QP = 90°$.



If μ is the refractive index of the denser medium, then according to snell's law,

$$\mu = \frac{\sin i}{\sin r}$$

In Critical Condition,

$i = i_c$ and $r = 90°$

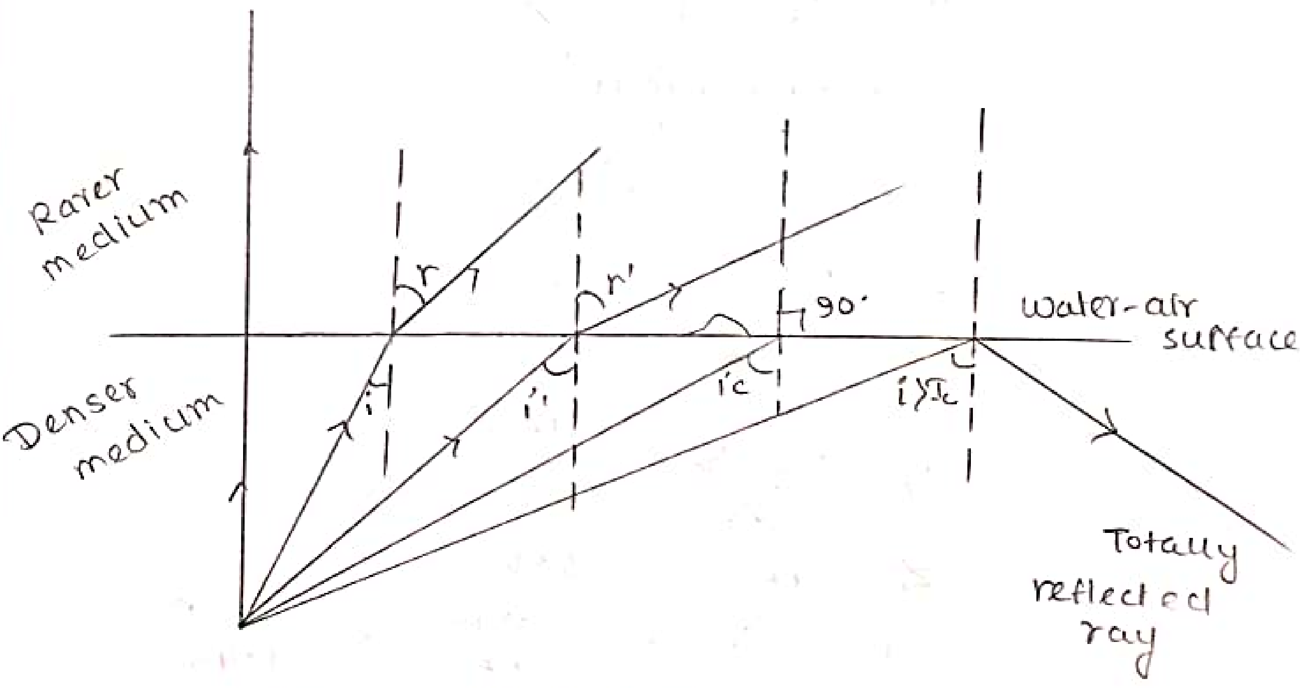
$$\mu = \frac{\sin i}{\sin r} = \frac{\sin 90°}{\sin i_c} = \frac{1}{\sin i_c}$$

$$\boxed{i_c = \sin^{-1}\left(\frac{1}{\mu}\right)}$$

<u>Critical Angle</u>- Critical angle is the angle of incidence in a denser medium for which angle of refraction in rarer medium is 90°.

<u>Total internal reflection</u>

When a ray of light travelling from denser to rarer medium is incident at the interface of two media at an angle greater than critical angle for the two media, the incident ray is totally reflected back to denser medium. This phenomena is called total internal reflection.



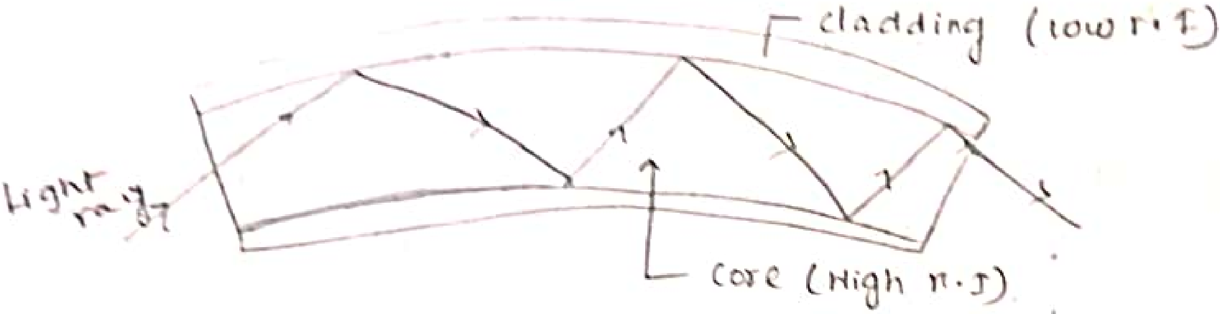
Conditions for total internal reflection

i) The ray must travel from denser to rarer medium.

ii) The angle of incidence must be greater than than the critical angle for those two medium.

Optical fibre :-

An optical fibre is a tube of transparent material that allows light to pass through, without being refracted into the air or another external medium.



Q. Find the value of critical angle of a material of refractive index $\sqrt{3}$.

Soln : Given, $\mu = \sqrt{3}$

we know that,

$$i_c = \sin^{-1}\left(\frac{1}{\mu}\right)$$

$$= \sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$$

$$= 35.26.$$

Q. Calculate the speed of light in a medium, whose critical angle is 45°.

Ans:- Given, $i_c = 45°$

we know that,

$$\mu = \frac{1}{\sin i_c}$$

$$\Rightarrow \frac{c}{v} = \frac{1}{\sin 45°}$$

$$\Rightarrow \frac{3\times10^8}{v} = \frac{1}{\frac{1}{\sqrt{2}}}$$

$$\Rightarrow \frac{3\times10^8}{v} = \frac{\sqrt{2}}{1}$$

$$\Rightarrow \sqrt{2}v = 3\times10^8$$

$$\Rightarrow v = \frac{3\times10^8}{\sqrt{2}} = \frac{3\times10^8}{1.43}$$

$$\Rightarrow$$

$$\Rightarrow v = \frac{3 \times 10^8 \times 10^{-2}}{143}$$

$$= 0.020 \times 10^6$$

$$= 2 \times 10^4 \ m/s$$

Formation of images by spherical lenses

① Convex lens

a. Beyond 2F

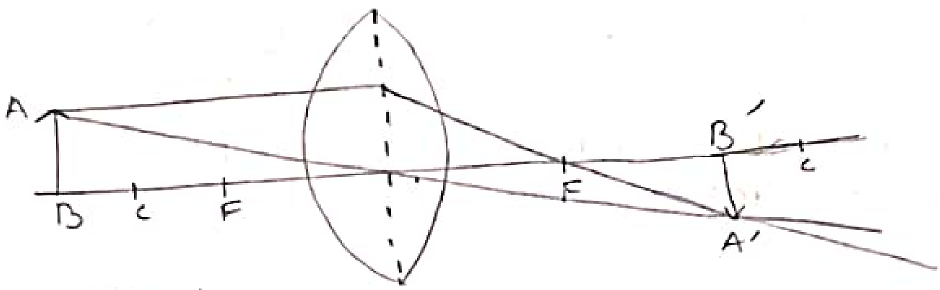


Image obtained

→ Betn F and C

→ Real

→ Inverted

→ Smaller than the object

b. At 2F

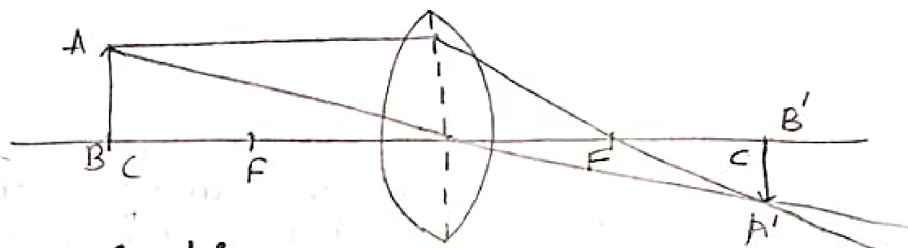


Image obtained:

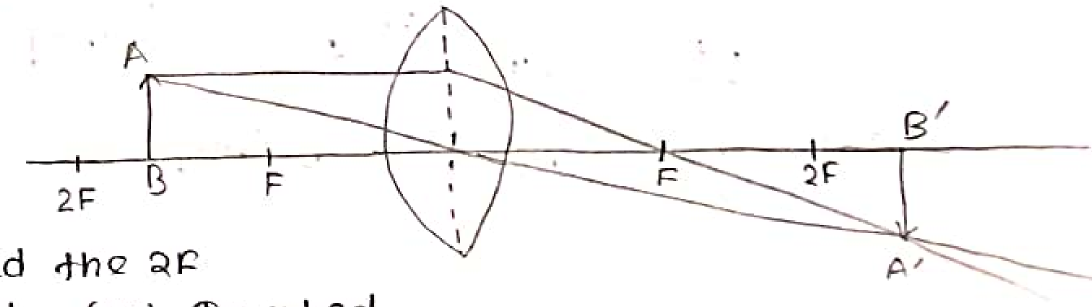
① At the C

(ii) Real

(iii) inverted

(iv) Same size to the object

c. Object betn the 2F & F

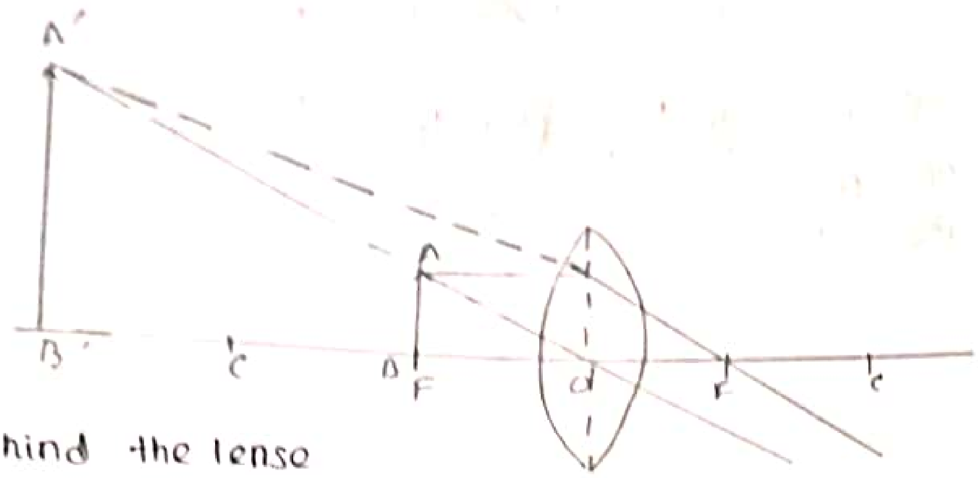


(i) Beyond the 2F

(ii) Real (iii) Inverted

(iv) larger than the object

d. object betn P & O



(i) Behind the lense

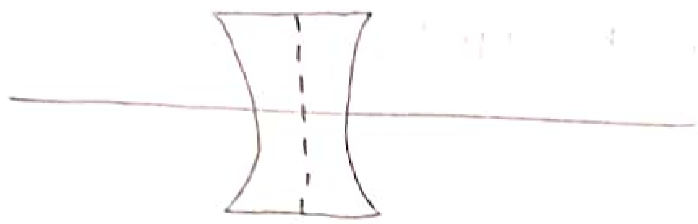
(ii) Vertual

(iii) Erect

(iv) larger than the object

2. Concave lense

Any position



lens formula

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

$$m = \frac{v}{u} = \frac{h_2}{h_2}$$

v - image distance
u - object distance
f - focal length

Power of a lens

Power of a lens is defined as the ability of the lens to converge a beam of light falling on the lens. It is measured as the reciprocal of focal length of the lens.

$$\boxed{P = \frac{1}{f(m)}} \quad \text{or} \quad \boxed{P = \frac{100}{f\,(cm)}}$$

S.I unit of power is D (Dioptre)

$P = \frac{1}{f}$

$\Rightarrow 1D = \frac{1}{1m}$ $(f = 1m)$

when $f = 1m$

$P = 1D$

One dioptre is the power of a lens of focal length 1 m.

Q. Find the power of a convex lens of focal length 50 cm.

Ans:- Given,

$100\,cm = 1\,m$

$1\,cm = \frac{1}{100}\,m$

$f = 50cm$

$= \frac{5\cancel{0}}{10\cancel{0}}\ m$

$\therefore P = \frac{1}{f}$

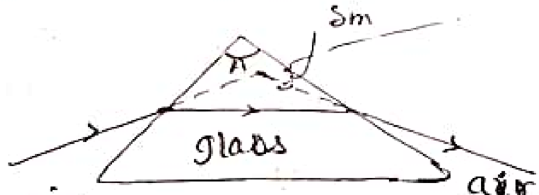
$= \frac{1}{\frac{5}{10}}$

$= \frac{10}{5}$

$= 2\,D$

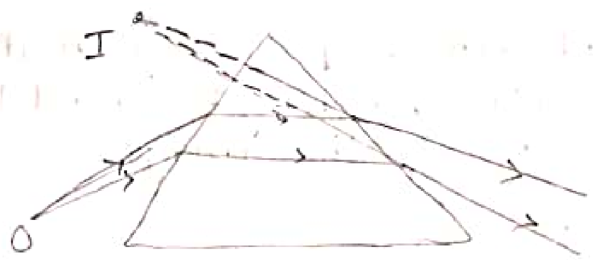
Prism :-

A prism is a wedge-shaped transparent medium bounded by three surfaces inclined to each other at an angle.



δm = Angle of minimum deviation

Formation of image by prism



Reln betn Refractive Index and angle of minm deviation

$$\mu = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{\delta m + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Q. A needle 5 cm in length is placed 45 cm from a lens and forms an image on a screen placed 90 cm on the other side of the lens. Identify the type of lens and find the focal length and size of the image formed.

Ans- Given, $u = -45\text{cm}$

$h_1 = 5\text{ cm}$

$v = 90\text{cm}$

| focal length (+) — convex

f (−) — concave

$$
\begin{array}{r|l}
5 & 45, 90 \\
3 & 9, 18 \\
3 & 3, 6 \\
 & 1, 2
\end{array}
$$

$18 \times 5 = 90$ 4

$$\therefore \frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\Rightarrow \frac{1}{90} + \frac{1}{45} = \frac{1}{f}$$

$$\Rightarrow \frac{1+2}{90} = \frac{1}{f}$$

$$\Rightarrow \frac{3}{90} = \frac{1}{f}$$

$$\Rightarrow 90 = 3f$$

$$\Rightarrow f = \frac{90}{3}$$

$$= 30\text{ cm}$$

Now, $\frac{h_2}{h_1} = \frac{v}{u}$

$$\Rightarrow \frac{h_2}{5} = -\frac{90}{45}$$

$$\Rightarrow 45 h_2 = -450$$

$$\Rightarrow h_2 = -10\text{ cm}$$

The lens is convex.

Q. An object of height 2 cm is placed 4 cm infront of a convex lens of 5 cm focal length. Find the position, size and nature of the image.

Ans- Given, $h_1 = 2\text{cm}$

$u = -4\text{cm}$

$f = 5\text{cm}$

$$\therefore \frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

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

$$\Rightarrow \frac{1}{v} = \frac{1}{5} \cancel{+p} - \frac{1}{4}$$

$$= \frac{4-5}{20}$$

$$= -\frac{1}{20}$$

$$\Rightarrow v = -20 \text{ cm}$$

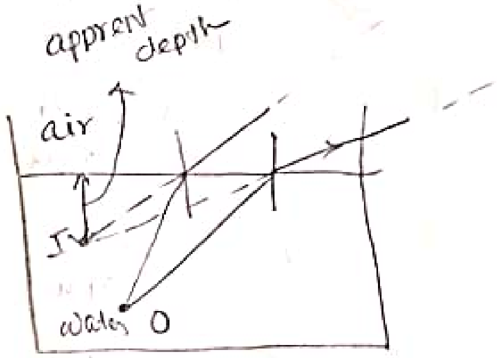
$$\frac{h_2}{h_1} = \frac{v}{u}$$

$$\Rightarrow \frac{h_2}{2} = \frac{-\cancel{20}\,5}{-\cancel{4}\,1}$$

$$\Rightarrow h_2 = 10 \text{ cm}$$

nature of the image is virtual and erect.

__Apparent depth__



Q. A convex lens has a focal length of 16 cm. At what distance should an object be placed to ~~p~~ obtain an image 4 times magnified.

__Ans-__ Given, $f = 16$ cm

$m = 4$

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

$$\Rightarrow 4 = \frac{v}{u}$$

$$\Rightarrow v = 4u$$

$$\therefore \frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\Rightarrow \frac{1}{4u} - \frac{1}{u} = \frac{1}{16}$$

$$\Rightarrow \frac{4\cancel{u} - 4}{4u} = \frac{1}{16}$$

$$\Rightarrow \frac{1\,\cancel{3u}}{4u} = \frac{1}{16} \Rightarrow 4u = 16 - 16u$$

$$\Rightarrow 20u = 16 \Rightarrow u = \frac{\cancel{20}\,\cancel{10}\,5}{\cancel{16}\,\cancel{8}\,4} = 1.2$$

Case I

$$\therefore \frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\Rightarrow \frac{1}{4u} - \frac{1}{u} = \frac{1}{16}$$

$$\Rightarrow \frac{1-4}{4u} = \frac{1}{16}$$

$$\Rightarrow \frac{-3}{4u} = \frac{1}{16}$$

$$\Rightarrow -48 = 4u$$

$$\Rightarrow u = -12 \text{ cm}$$

Case II

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

$$\Rightarrow \frac{1}{-4u} - \frac{1}{u} = \frac{1}{16}$$

$$\Rightarrow -\frac{1-4}{4u} = \frac{1}{16}$$

$$\Rightarrow \frac{-5}{4u} = \frac{1}{16}$$

$$\Rightarrow 4u = -80$$

$$\Rightarrow u = -20 \text{ cm}$$

Magnetism

A magnet~~ism~~ is a material that ~~can~~ has both attractive and directive properties.

Magnetic field :-

A magnetic field is a space around a magnetic pole where the magnetic force of attraction or repulsion exists.

~~mg~~ **Magnetic lines of force :-**

The path along which a unit north pole would move under the action of a magnetic fields is called magnetic lines of force.

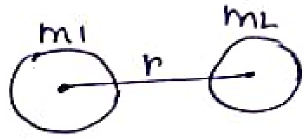
Magnetic lines of force may be defined as continuous curve lines drawn in a magnetic field.

such that the tangent drawn at any point on it gives the resultant magnetic field at that point.

Inverse square law of magnetism (Coulombs law of magnetic force):-

The force of attraction or repulsion betn two magnetic poles varies directly as the product of their pole strengths and inversely as the square of the distance betn them.

Mathematically,



$$F \propto m_1 m_2 \quad \text{--- (i)}$$

$$F \propto r^2 \quad \text{--- (ii)}$$

From eqn (i) and (ii)

$$F \propto \frac{m_1 m_2}{r^2}$$

$$\Rightarrow \boxed{F = \frac{1}{4\pi\mu_m}\left(\frac{m_1 m_2}{r^2}\right)} \quad \text{In S.I}$$

In CGS system,

$$\boxed{K = \frac{1}{\mu}\left(\frac{m_1 m_2}{r^2}\right)}$$

where, $\boxed{\mu = \mu_0 \mu_r}$

μ — Absolute ~~permittivity~~ permeability

μ_0 — Permeability of free space

μ_r — Relative permeability of the medium.