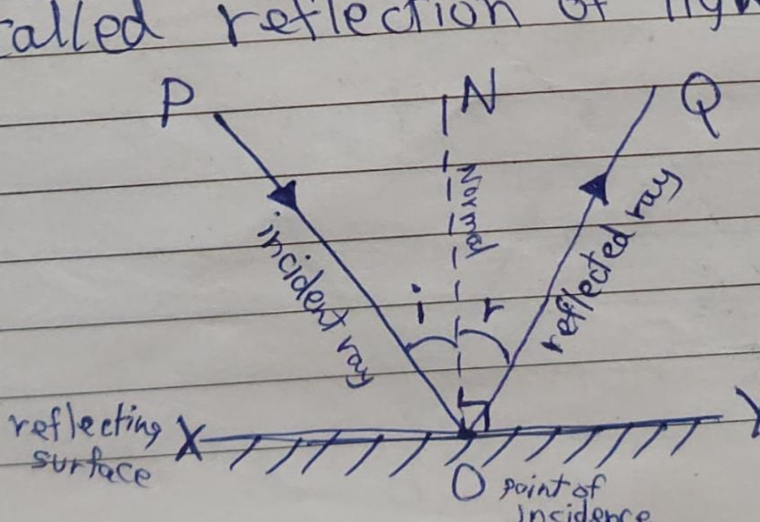
LIGHT - REFLECTION, REFRACTION

WHAT IS LIGHT?

- form of energy
- electromagnetic wave
- travels in a straight line
- transverse wave (non-mechanical wave)
- Speed = 3×10^8 m/s (c)
- gets reflected
- undergoes refraction (bending)
- Light = photons
- Several photons = "ray of light"
- Several rays = "beam of light"

REFLECTION OF LIGHT

- When a ray of light falls on a smooth polished surface and the light ray bounces back into the same medium then it is called reflection of light.



Incident ray = PO
Normal = ON
Reflected ray = OQ
Angle of incidence = ∠PO
Angle of reflection = ∠QO
$\angle i = \angle r$

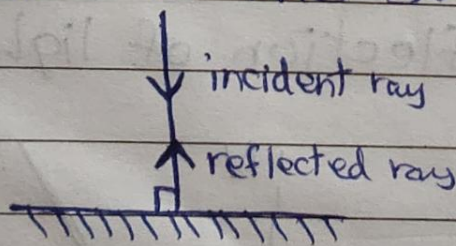
LAWS OF REFLECTION OF LIGHT

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

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

* Silver metal is one of the best reflectors of light.
* When a ray of light strikes at a surface normally (perpendicularly), then ~~the~~ $\angle i = 0°$. According to the law of reflection, $\angle r = 0°$ i.e., the reflected ray is also perpendicular to the surface.

$\angle i = \angle r = 0°$



Normal incidence

* IMAGE

1. Real image
2. Virtual image

u = object distance
v = image distance
hi = height of image
ho = height of object

Real image	Virtual image
Formed when two or more reflected rays actually meet at a point in front of the mirror.	Formed when two or more rays appear to meet at a point behind the mirror.
Can be obtained on a screen	Cannot be obtained on a screen
Real image is inverted with respect to objected.	Virtual image is erect (upright) with respect to the object.

PLANE MIRROR

» ~~plane~~ If the reflecting surface of a mirror is plane, then the mirror is called plane mirror.

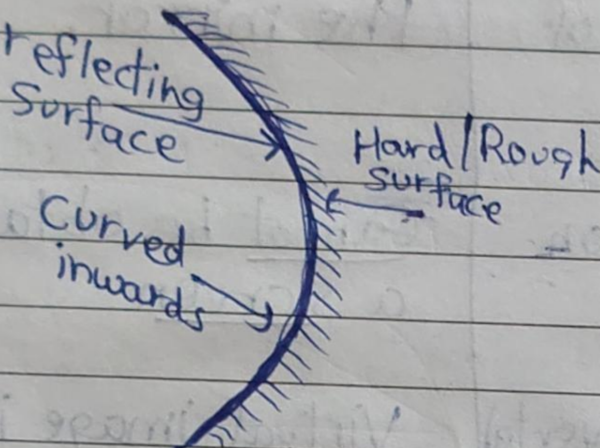
1. Virtual and erect
2. $h_i = h_o$
3. $u = v$
4. Left | Right Laterally inverted
   Right | Left
5. $f = \infty$ (focal length)

* R = radius of curvature
C = centre of curvature
F = Focus point
f = focal length
P = Pole

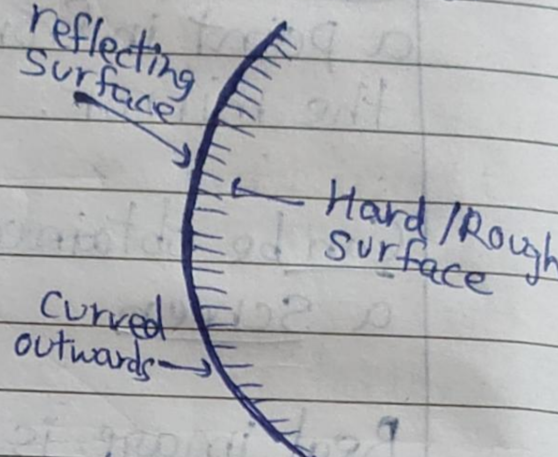
SPHERICAL MIRROR

Reflecting surface of the mirror is curved (inwards or outwards)

(i) Concave mirror

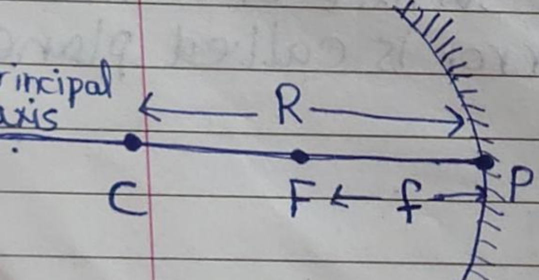


(ii) Convex mirror

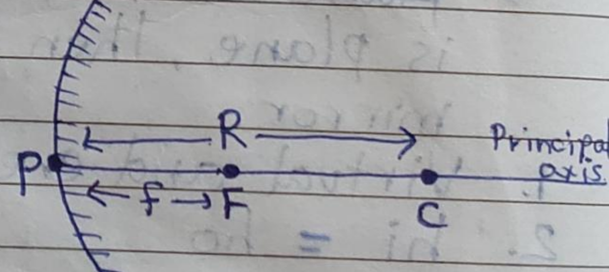


»» inward curved
»» rays meet at one point - "convergent mirror"

»» outward curved
»» rays diverge or go away - "divergent mirror"

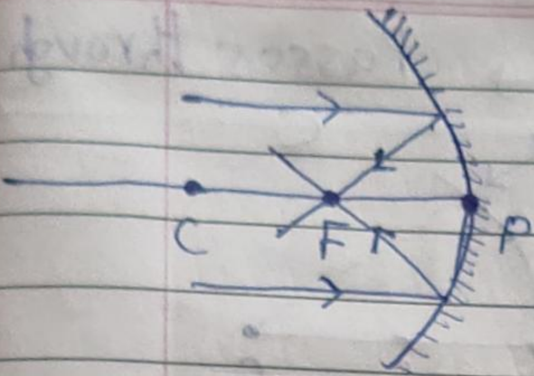


$f = \frac{-R}{2}$

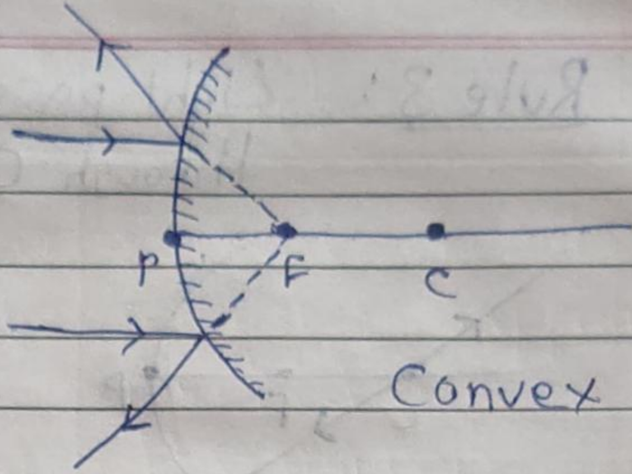


$f = \frac{R}{2}$

*



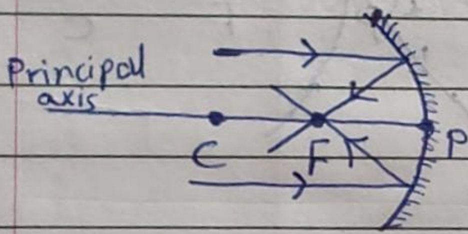
Concave

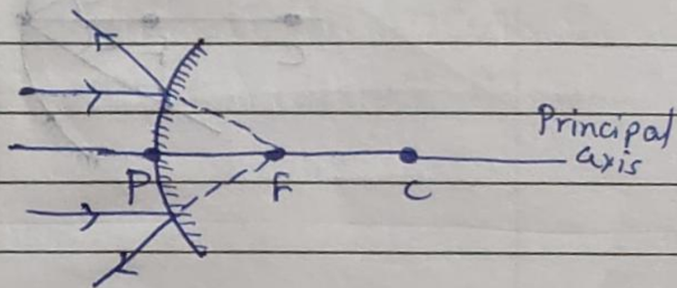


Convex

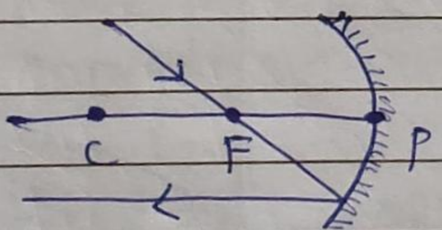
* Rules to draw ray diagrams (spherical mirror

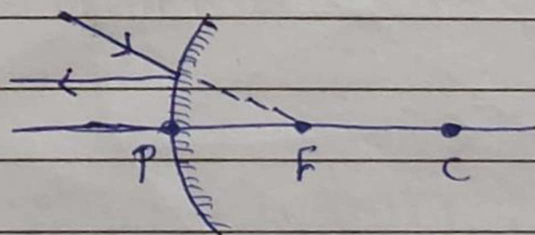
Rule 1: Light parallel to principal axis —passes through→ Focus (F)





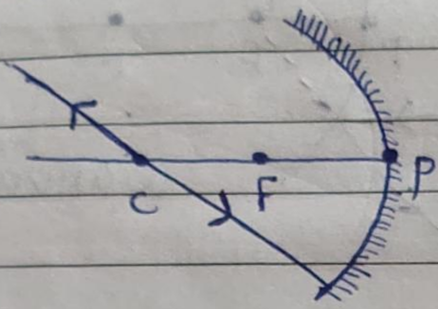
Rule 2: Light passes through Focus (F) ⟶ Parallel to Principal axis

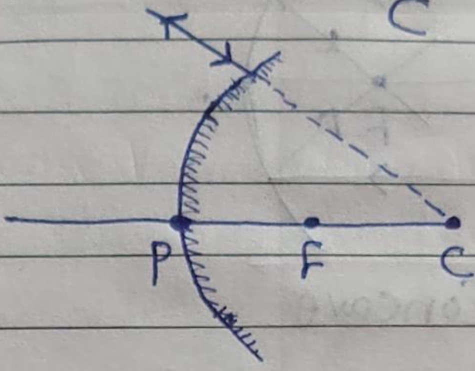




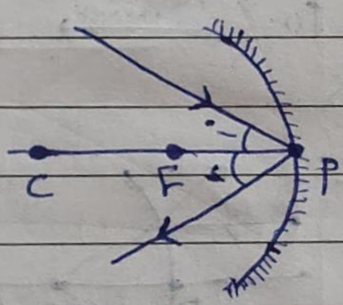
>>> CONTINUED

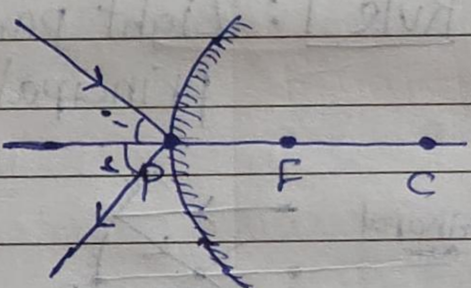
Rule 3: ∠Light passes through C → Passes through C





Rule 4: Passing at P at ∠i → Reflecting at P at ∠r





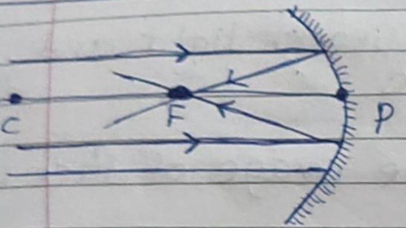
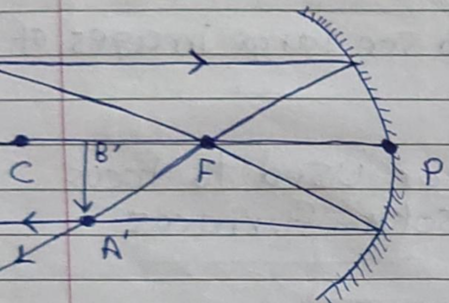
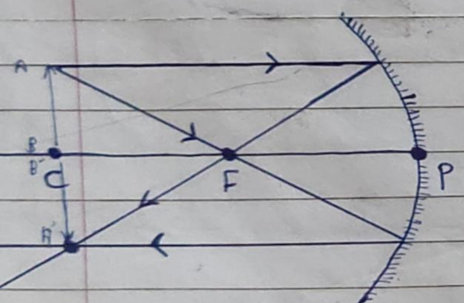
Uses of Concave Mirrors

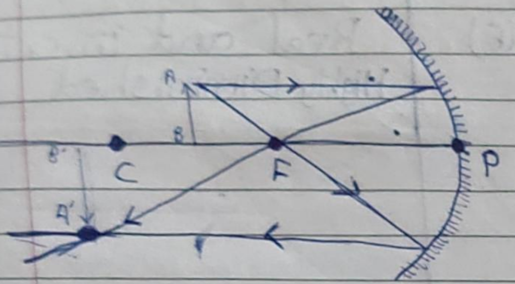
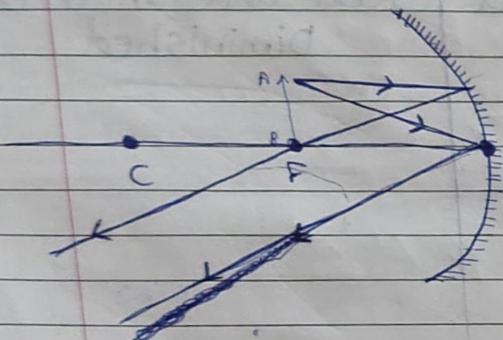
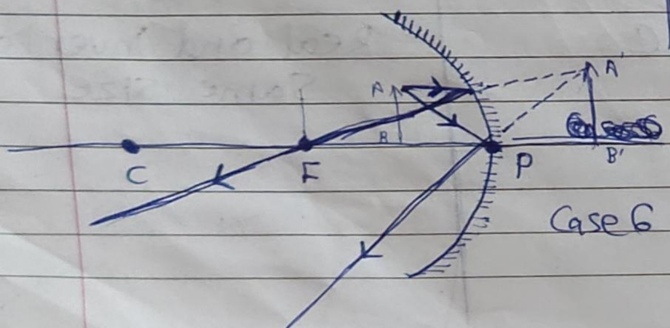
1. Used in torches, search light and headlight of vehicle
2. Used to see large image of face as shaving mirror.
3. Used by dentist to see large images of the teeth.
4. Large concave mirror used to focus sunlight (heat) in solar furnaces

- Uses of Convex Mirror

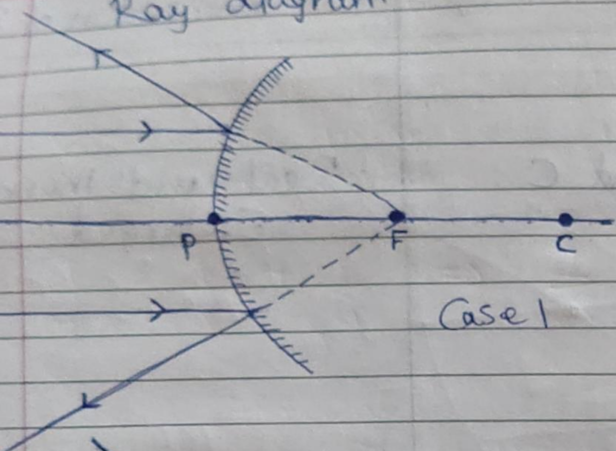
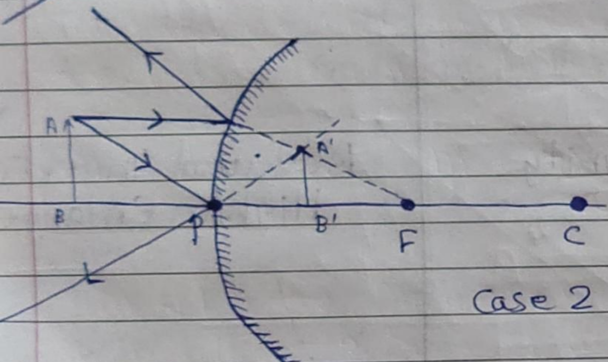
1. Used as rear-view mirror in vehicles.
2. Have a wider field of view as they are curved outwards.
3. Used in shops as security mirror.

Concave Mirror

Ray diagram	Position of object	Position of an image	Size and nature of an image
 Case 1	At Infinity	At Focus (F)	Real and inverted Highly Diminished
 Case 2	Beyond C	Between F and C	Real and Inverted Diminished
 Case 3	At C	At C	Real and inverted Same size

Ray diagram	Position of object	Position of image	Size and Nature of image
 Case 4	Between F and C	Beyond C	Real and inverted Enlarged
 Case 5	At F	At Infinity	Real and inverted Highly enlarged
 Case 6	Between F and P	Behind the mirron	Virtual and erect Enlarged

Convex Mirror

Ray diagram	Position of object	Position of image	Size and Nature of image
 Case 1	At Infinity	At Focus (F) Behind the mirror	Virtual and erect Highly diminished
 Case 2	Between Infinity ∞ and Pole (P)	Between Pole (P) and Focus (F) Behind the mirror	Virtual and erect Diminished

IMP

MIRROR FORMULA

f = focal length
v = Image distance
u = Object distance

h_i = Size of image
h_o = Size of object

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

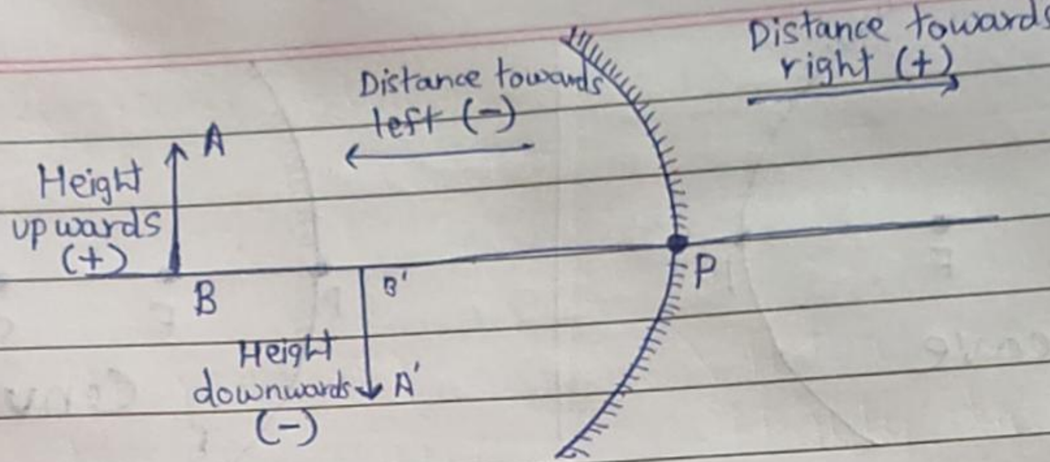
MAGNIFICATION

The ratio of size of image to the size object is called magnification.

$$m = \frac{h_i}{h_o}, \quad m = \frac{-v}{u}$$

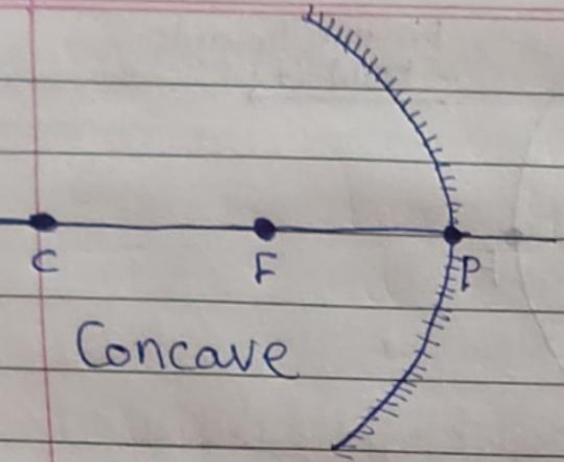
- $m < 1$ → Diminished
- $m = 1$ → Same size
- $m > 1$ → Enlarged
- $m = +ve$ → Virtual and Erect
- $m = -ve$ → Real and inverted

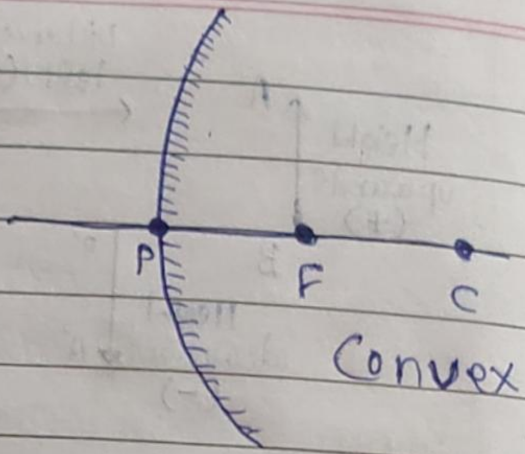
SIGN CONVENTION



»» The pole of the mirror is taken as the Origin and principal axis of the mirror is taken as x - axis.

1. The object is always placed to the left of the mirror.
2. All the distance parallel to the principal axis are measured from the pole of the mirror
3. All the distance measured to the right of the origin are taken positive and left of the origin are taken negative.
4. Distance measured perpendicular and above the principal axis are taken as positive, and below the principal axis are taken as negative.





Concave

$u = -ve$

$v =$ Case 1-5 $-ve$

Case 6 $+ve$

$f = -ve$

$R = -ve$

$h_o = +ve$

$h_i =$ 1-5 $-ve$

6 $+ve$

$m < 1$ ✓

$m = 1$ ✓

$m > 1$ ✓

$m =$ (1-5) $-ve$

(6) $+ve$

Convex

$u = -ve$

$v = +ve$

$f = +ve$

$R = +ve$

$h_o = +ve$

$h_i = +ve$

$m < 1$ ✓

$m = 1$ ✗

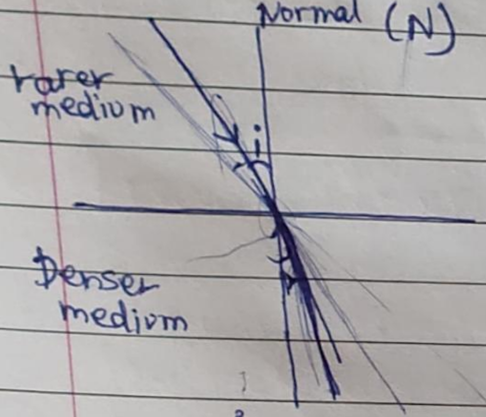
$m > 1$ ✗

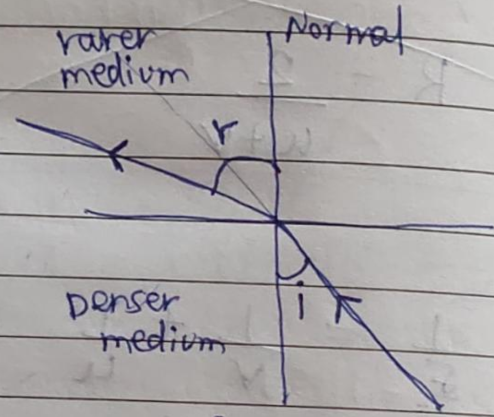
$m = +ve$

REFRACTION

When light rays pass from one transparent medium to another transparent medium, it changes its path.

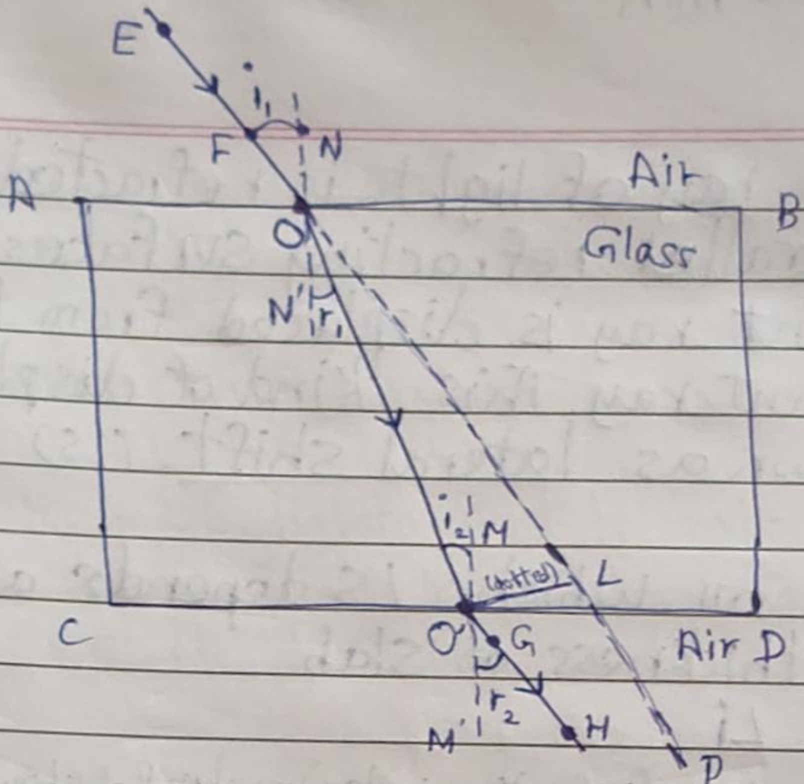
> When light travels from a rarer medium to a denser one, it bends towards the normal (i>r) and when travels from a denser medium to a rarer one, it bends away from the normal (i<r).





CAUSES OF REFRACTION

- >>> Speed of light is different in different medium
- >>> Speed of light more in rarer medium
- >>> Speed of light is less in denser medium.
- >>> Denser medium — speed reduce, bend towards N.
- >>> Rarer medium — speed increase, bends away from Normal.



ABCD = Glass Slab
EO = Incident ray
OO' = Refracted ray
O'H = Emergent ray
NN' = Normal at surface AB at point O
MM' = Normal at surface CD at point O
i_1 = Angle of incidence at surface AB at point O
r_1 = Angle of refraction at surface AB at point O
i_2 = Angle of incidence at surface CD at point O
r_2 = Angle of refraction at surface CD at point O.

Red λ → max
Violet λ → min

» When a ray of light is refracted from two parallel refracting surfaces, the emergent ray is displaced from the direct of incident ray. This kind of displacement is known as lateral shift. (LS)

» Factors on which LS depends are:

(i) LS $\propto$ thickness of slab
(ii) LS $\propto$ $\angle i$
(iii) LS $\propto$ n (refractive index) = value that shows bending)
(iv) LS $\propto$ $\frac{1}{\lambda}$

* Laws of Refraction

(i) The incident ray, the refracted ray and the normal to the interface of two transparent media 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 a constant, for the light of a given colour and for the given pair of media. This law is also known as Snell's law of refraction.

$$\frac{\sin i}{\sin r} = \text{constant} = n \text{ (refractive index)}$$

* Refractive Index

>>> A ray of light that travels obliquely from one transparent medium into another will change its direction in the second medium.

>>> The extent of change in direction that takes place in a given pair of media may be expressed in terms of the refractive index.

$$\boxed{n_{21}} = \frac{\text{Speed of light in medium 1}}{\text{Speed of light in medium 2}} = \boxed{\frac{v_1}{v_2}}$$

$$\boxed{n_{12}} = \frac{\text{Speed of light in medium 2}}{\text{Speed of light in medium 1}} = \boxed{\frac{v_2}{v_1}}$$

How to read:

n_{21} = Refractive index of medium 2 with respect to medium 1

$$n_{gw} = \frac{v_w}{v_g} \quad \Big| \quad n_{wg} = \frac{v_g}{v_w}$$

$$n_{12} = \frac{V_2}{V_1} \quad --- (1)$$

$$n_{21} = \frac{V_1}{V_2} \quad --- (2)$$

Multiply eqⁿ (1) and (2)

$$n_{12} \times n_{21} = \frac{V_2}{V_1} \times \frac{V_1}{V_2}$$

$$\boxed{n_{12} \times n_{21} = 1}$$

* **Absolute refractive index**

⋙ n_1 - Refractive index of medium 1 with respect to air

$$n_1 = \frac{c}{V_1} \longrightarrow (1)$$

$$n_2 = \frac{c}{V_2} \longrightarrow (2)$$

Divide eqⁿ (1) and (2)

c = speed of light

$$\frac{n_1}{n_2} = \frac{\frac{c}{v_1}}{\frac{c}{v_2}}$$

$$\frac{n_1}{n_2} = \frac{c \times v_2}{c \times v_1}$$

$$\boxed{\frac{n_1}{n_2} = \frac{v_2}{v_1}}$$

$$n_{gw} = \frac{n_g}{n_w} = \frac{v_w}{v_g}$$

$$n_{21} = \frac{n_2}{n_1} = \frac{v_1}{v_2}$$

$$\boxed{n_{12} = \frac{n_1}{n_2} = \frac{v_2}{v_1}}$$

Refractive Index

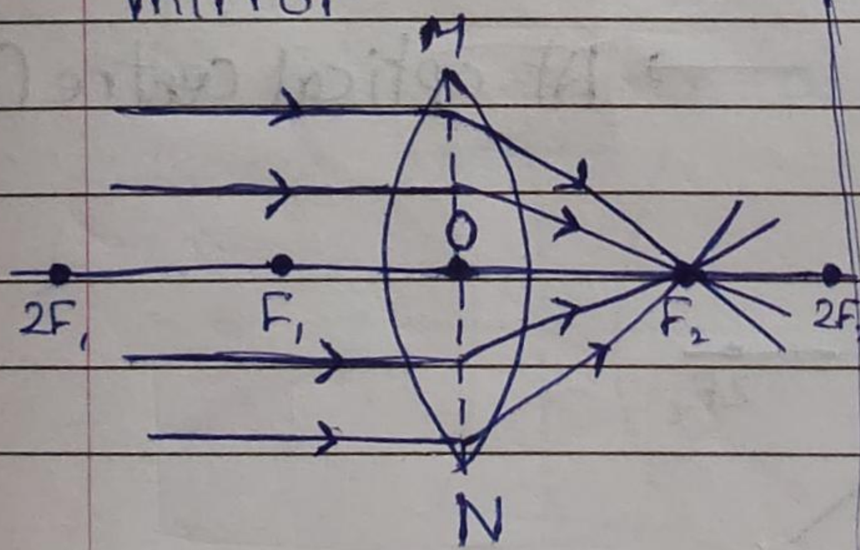
Air - 1.0003
Water = 1.33
Glass - 1.52
Diamond = 2.42

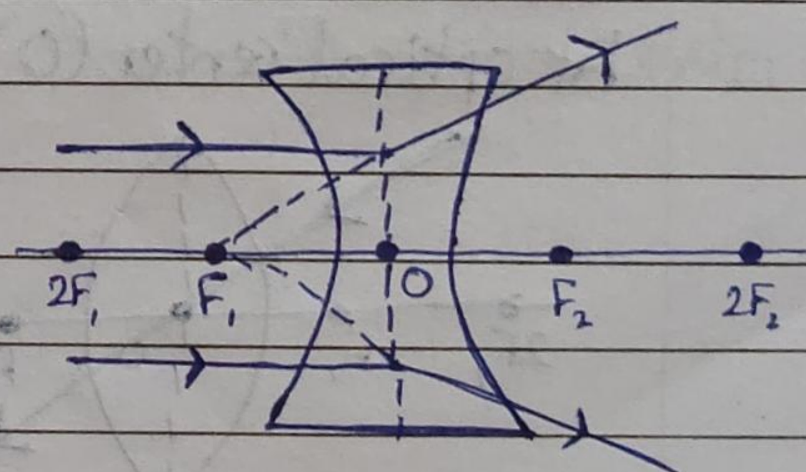
>>>>

REFRACTION BY SPHERICAL LENSES

>>> A transparent material bound by two ~~Spherical~~ surfaces, of which one or both surfaces are spherical, forms a lens

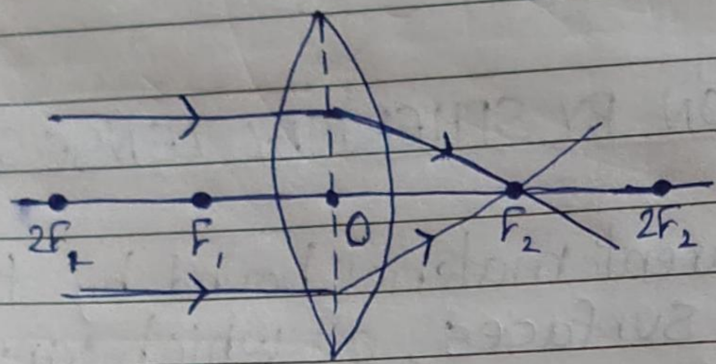
Convex (double)	Concave (double)
>>> Curved outwards	>>> curved inwards
>>> thick at middle, thin at edges	>>> thick at edges, thin at middle
>>> converges light	>>> diverges light
>>> Known as "converging" mirror	>>> Known as "divering mirror"



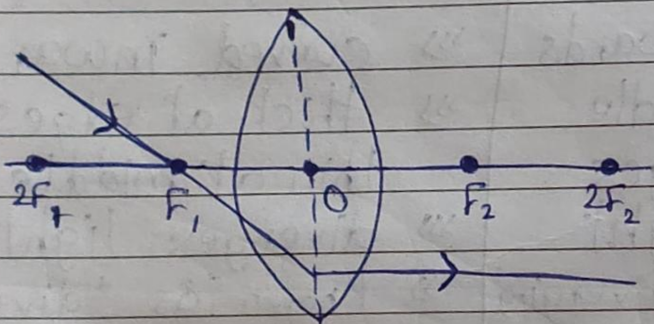


Convex lens

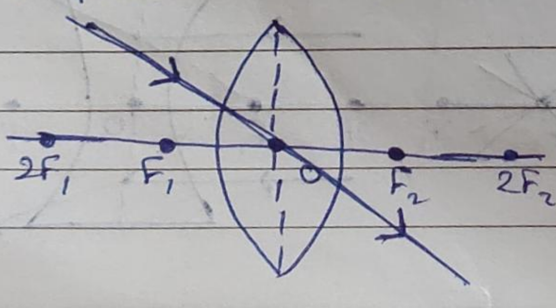
Rule 1:
Parallel ⟶ At Focus



Rule 2:
At Focus ⟶ Parallel

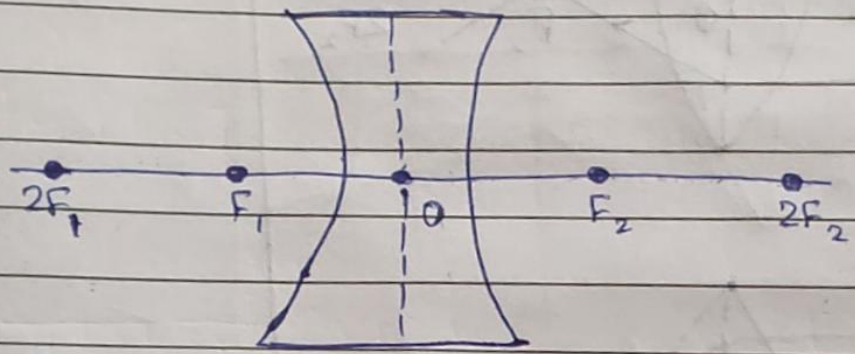


Rule 3:
At optical center (O) ⟶ At optical centre (O)



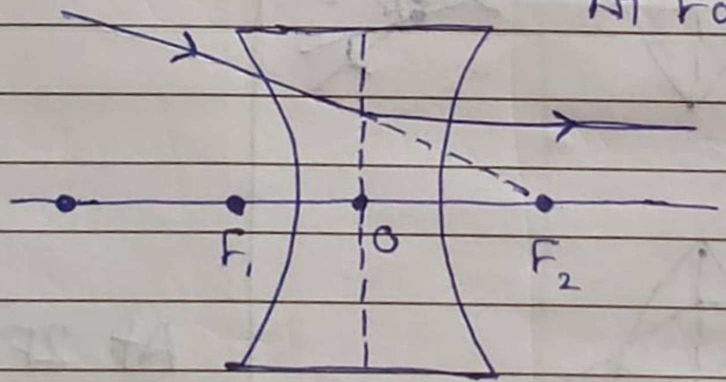
Concave lens

Rule 1:
Parallel ⟶ At Focus

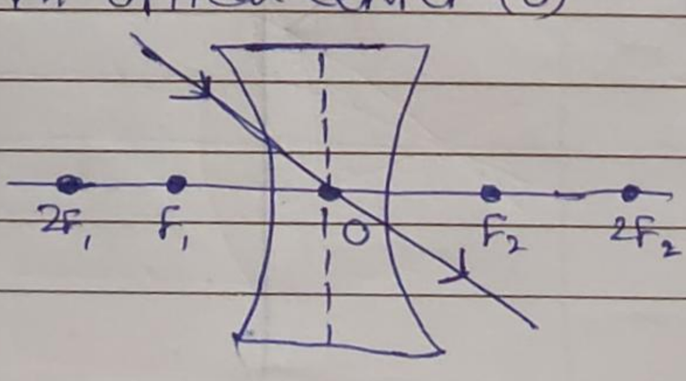


Rule 2:

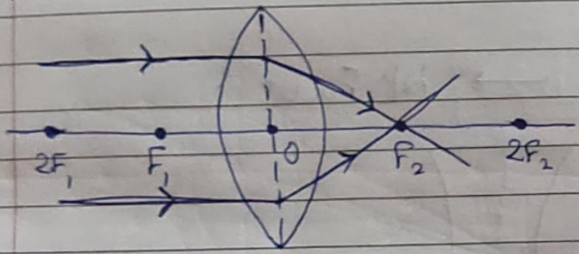
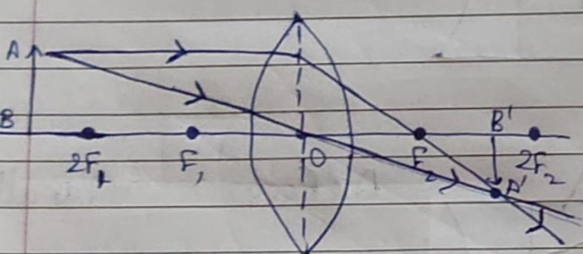
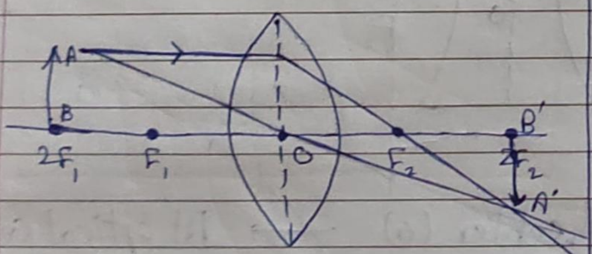
At Focus ⟶ Parallel

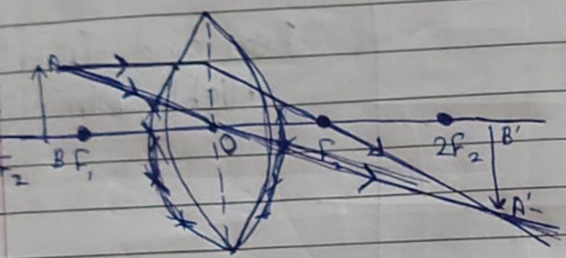
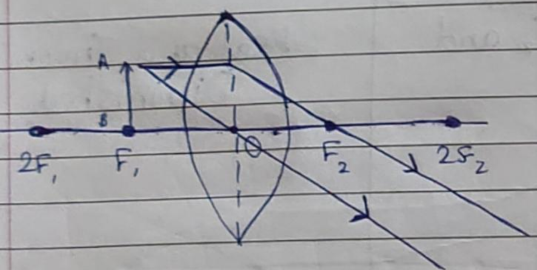
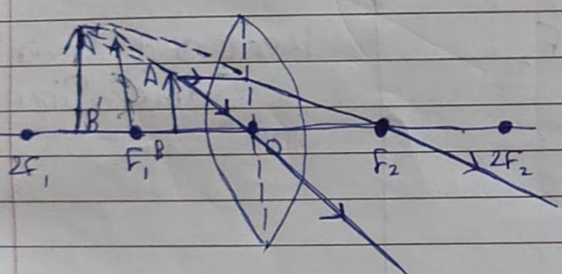


Rule 3:
At optical center (O) ⟶ At optical center (O)

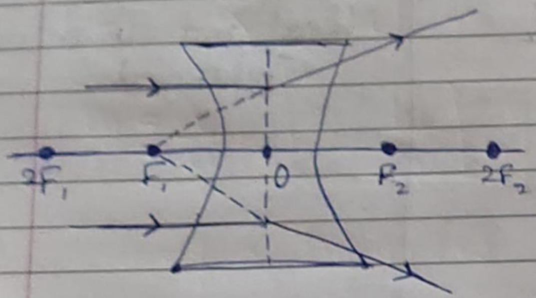
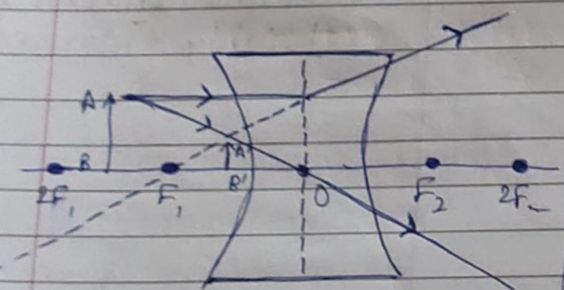


RAY DIAGRAMS OF CONVEX LENS

Ray diagram	Position of object	Position of image	Size and Nature of imag
	At Infinity ∞	At F_2	Real and Inverted Highly Diminished
	Beyond $2F_1$	Between F_2 and $2F_2$	Real and Inverted Diminished
	At $2F_1$	At $2F_2$	Real and Inverted Same Size

Ray diagram	Position of object	Postition of image	Size and Nature of image
	Between $2F_1$ and F_1	Beyond $2F_2$	Real and Inverted Enlarged
	At F_1	At Infinite ∞	Real and Inverted Highly Enlarged
	Between F_1 and O	On the same side of the lens as the object	Virtual and Erect Enlarged

Ray Diagrams of Concave lens

Ray Diagram	Position of object	Position of image	Size and Nature of Image
	At Infinity ∞	At F_1	Virual and Erect Highly Diminished
	Between Infinite ∞ and O.	Between F and O	Virtual and Erect Diminished

LENS FORMULA

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

f = focal length
v = Image distance
u = object distance
h_i = height of image
h_o = height of object

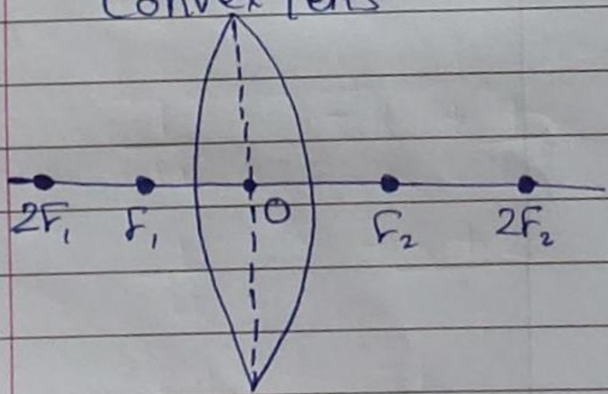
$$m = \frac{v}{u}$$ $$m = \frac{h_i}{h_o}$$

$m < 1$: Diminished
$m = 1$ Same size
$m > 1$ Enlarged

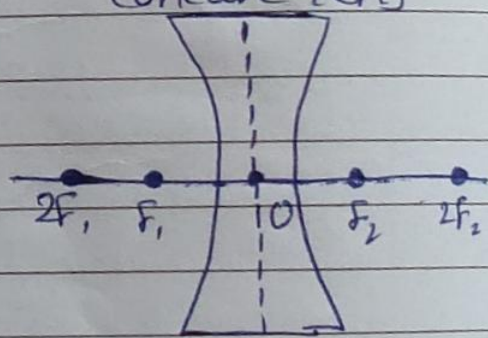
m = +ve Virtual and erect
m = -ve Real and Inverted

SIGN CONVENTION

Convex lens



Concave lens



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Convex lens	Concave lens
u = -ve	u = -ve
v = +ve [Case 1-5] -ve [Case 6]	v = -ve
f = +ve	f = -ve
hi = -ve [Case 1-5] = +ve [Case 6]	hi = +ve
ho = +ve	ho = +ve
m < 1 ✓ m = 1 ✓ m > 1 ✓	m < 1 ✓ m = 1 ✗ m > 1 ✗
m = -ve [Case 1-5] +ve [Case 6]	m = +ve

POWER OF LENS

- The degree of convergence or divergence of light rays achieved by a lens is expressed in terms of its power.

- The power of a lens is defined as the reciprocal of its focal length.

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

- The SI unit of power of a lens is 'dioptre'. It is denoted by the letter D.

- Note: f must be expressed in metre (m).

$$1D = 1m^{-1}$$

- Power of convex lens is positive (+ve).
- Power of concave lens is negative (-ve).