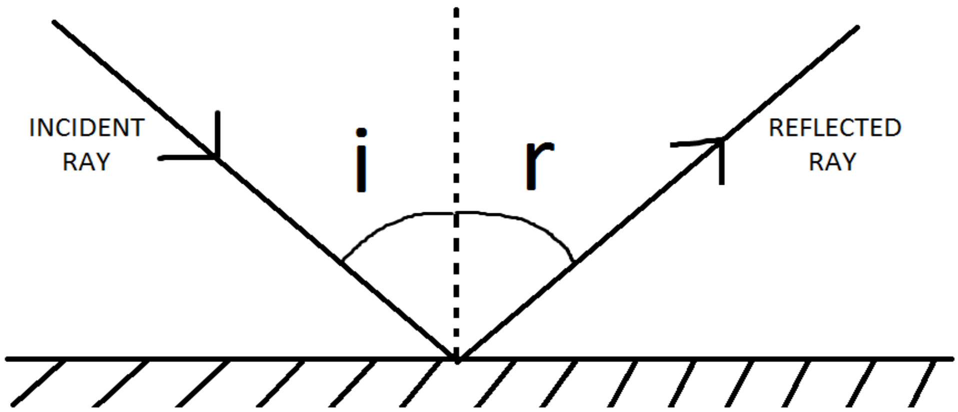
CHAPTER – 10

LIGHT – REFLECTION AND REFRACTION

REFLECTION

The phenomenon of bouncing back of light rays when it is incident on a surface (preferentially a mirror) is known as reflection of light.



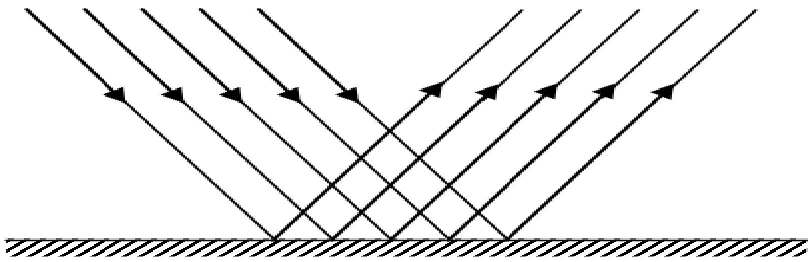
LAWS OF REFLECTION:

There are two Laws of Reflection:-

1) The angle of incidence is equal to the angle of reflection.
2) The incident ray, the normal to the mirror at the point of incidence and the reflected ray, all lie in the same plane.

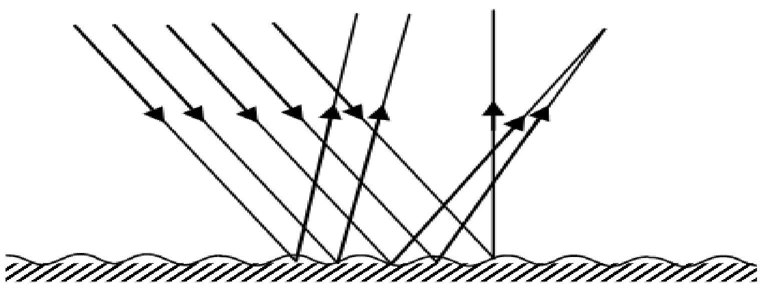
Types of Reflection:-

1) Regular Reflection: The regular reflection is the reflection of light rays when they fall on a smooth surface, where the reflected in one direction.



REGULAR REFLECTION

2) Irregular Reflection: The irregular reflection is the reflection of light rays when they fall on an irregular surface, where the reflected in more than one direction.



IRREGULAR REFLECTION

PROPERTIES OF IMAGE FORMED BY PLANE MIRROR:

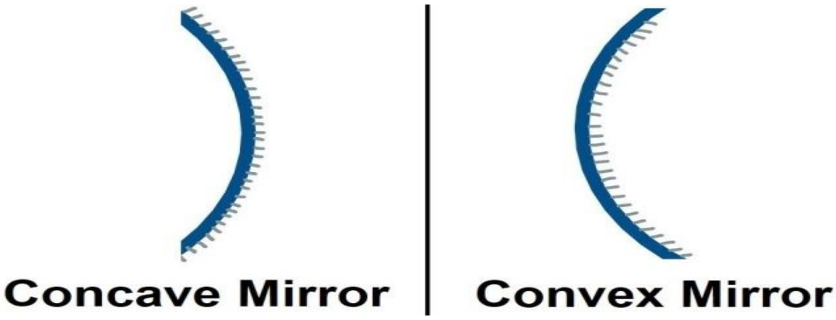
The image formed by a plane mirror has the following properties:

1) Virtual and Erect
2) Size of Image = Size of Object
3) The Distance of Object from the Mirror = The Distance of Image from the Mirror
4) Laterally Inverted

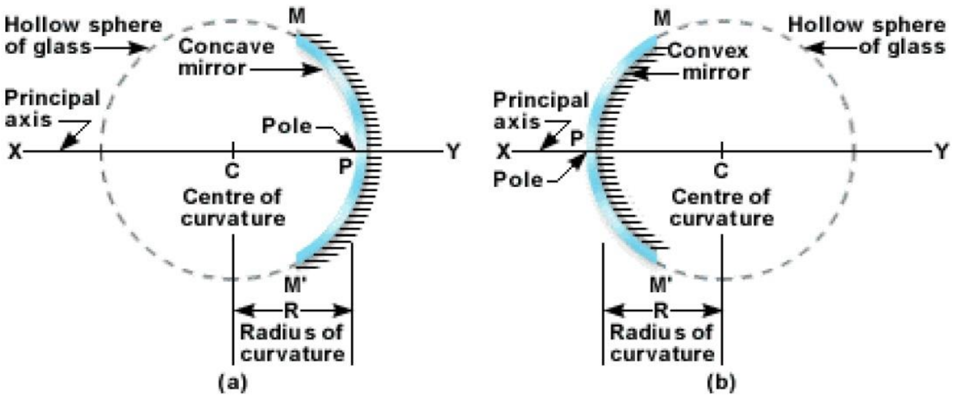
SPHERICAL MIRRORS

There are two types of spherical mirrors:

1) CONCAVE MIRRORS: A spherical mirror whose reflecting surface is curved inwards, that is, faces towards the centre of the sphere is called Concave Mirror.
2) CONVEX MIRRORS: A spherical mirror whose reflecting surface is curved outwards, that is, faces away from the centre of the sphere is called Convex Mirror.



SOME DEFINITIONS:

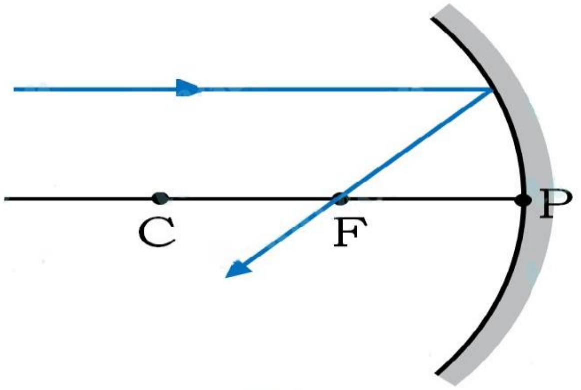


1) PRINCIPAL AXIS: The Imaginary Line Joining the Centre of Curvature and the Pole of the mirror is called the Principal Axis of the mirror.
2) PARAXIAL RAYS: A beam of light parallel to the principal axis of the mirror are called paraxial rays.
3) CENTRE OF CURVATURE: The centre of the imaginary sphere of which the mirror was part of, is called the centre of curvature of the mirror.
4) RADIUS OF CURVATURE: The radius of the imaginary sphere of which the mirror was part of, is called the radius of curvature.
5) FOCUS: The point at which the paraxial rays of light meet after reflection or appear to meet after reflection is called the focus of the mirror.
6) FOCAL LENGTH: The distance between the focus of the mirror and the pole of the mirror is called the focal length.
7) POLE: The centre of the reflecting surface of a spherical mirror is a point called the pole of the mirror.
8) APERTURE: The diameter of the reflecting surface of spherical mirror is called its aperture.

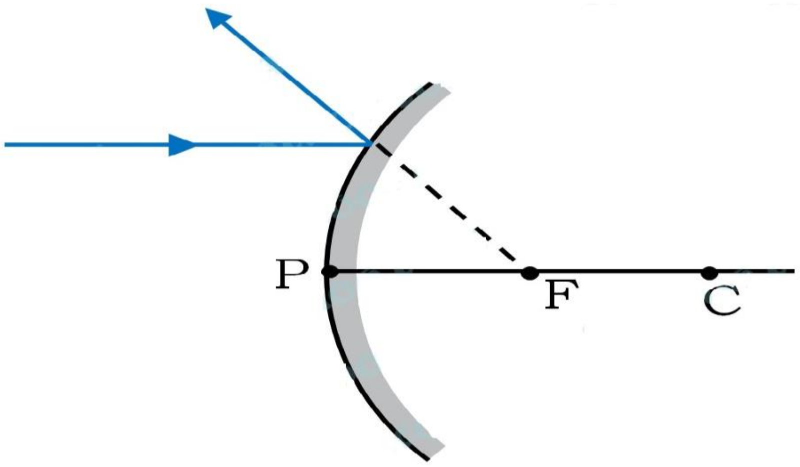
IMPORTANT FORMULA: **R = 2f**

IMAGE FORMATION RULES (FOR MIRORS):

1) A ray parallel to the Principal Axis (Paraxial Rays), after reflection, will pass throught the Focus or appear to pass through the Focus of the mirror.

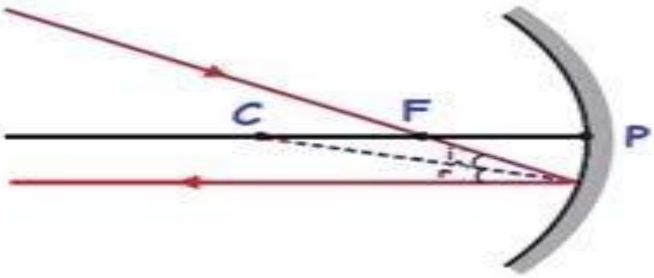


Concave Mirror

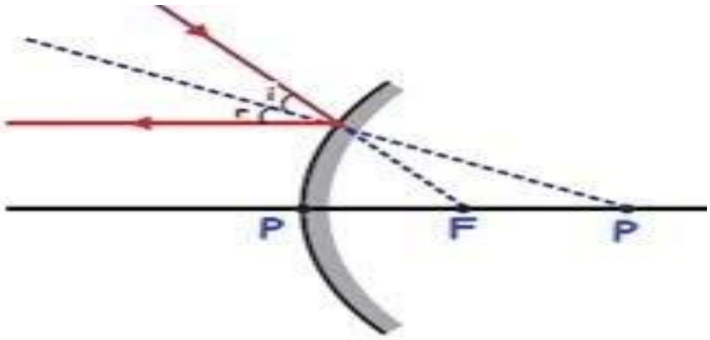


Convex Mirror

2) A ray passing through the Focus or appearing to pass through the focus of the mirror, after reflection, will become parallel to the Principal Axis (Paraxial Rays).

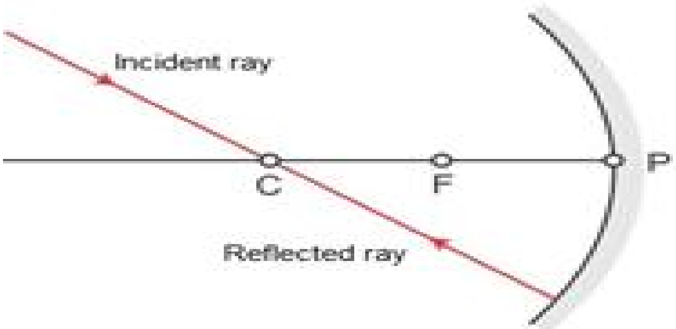


Concave Mirror

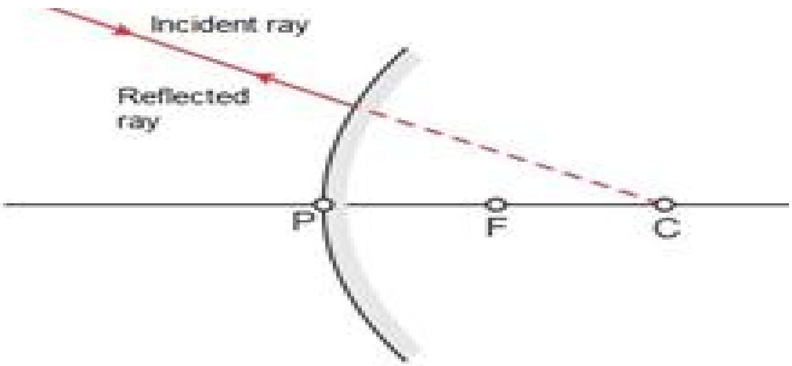


Convex Mirror

3) A ray passing through the centre of curvature or appears to pass through the centre of curvature of a mirror,after reflection, will retrace its path

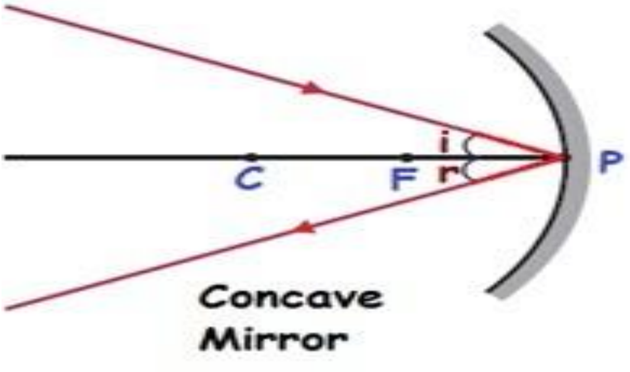


CONCAVE MIRROR



CONVEX MIRROR

4) A ray incident obliquely to the Principal Axis, towards a point P (pole of the mirror) is reflected obliquely. Here, the Principal Axis acts as the normal.



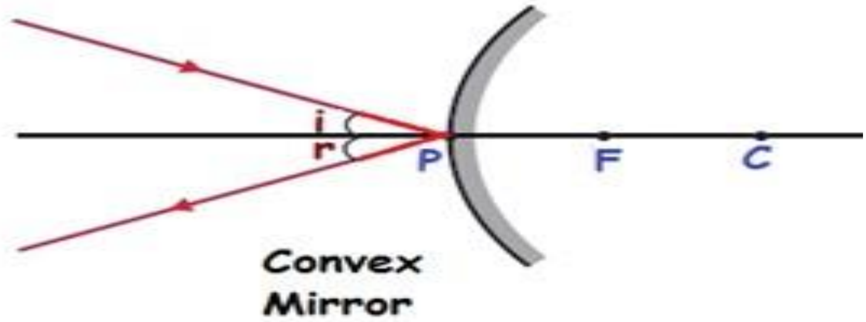


IMAGE FORMATION BY CONCAVE MIRROR:

TABLE OF POSITIONS AND NATURE OF IMAGE FORMED BY CONCAVE MIRROR:

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At focus F	Highly diminished, point sized	Real and inverted
Beyond C	Between F and C	Diminished	Real and inverted
At C	At C	Same size	Real and inverted
Between C and F	Beyond C	Enlarged	Real and inverted
At F	At infinity	Highly enlarged	Real and inverted
Between P and F	Behind the mirror	Enlarged	Virtual and erect

QUESTION: Does a concave mirror always form a real and inverted image?

ANSWER: NO. When the object is placed between the pole of the mirror (P) and the Focus of the mirror (F) the image formed is in front of the mirror and is VIRTUAL AND ERECT . Thus, a concave mirror does form a virtual and erect image.

QUESTION: Does a concave mirror always form a diminished image?

ANSWER: NO. There are many cases where if an object is placed in front of a concave mirror a magnified image is formed. As, if we place the object between F and C the image formed is magnified. Thus, a concave mirror can form a magnified image.

QUESTION: Does a convex mirror only form a virtual and erect image? (NOTE: See table after ray diagrams)

ANSWER: YES. No matter where the object is placed, the image formed is always virtual and erect because a convex mirror is a diverging type mirror. Due to this, the rays appear to meet at a point and never meet in reality.

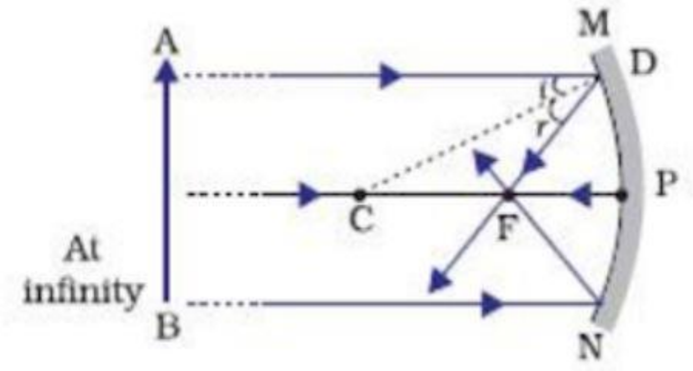
QUESTION: Does a convex mirror only forms a diminished image? (NOTE: See table after ray diagrams)

ANSWER: YES. No matter where the object is placed, the image formed is always diminished.

[**NOTE: ALSO DRAW BOTH THE RAY DIAGRAMS FOR THE LAST TWO QUESTIONS FOR CONVEX MIRROR**]

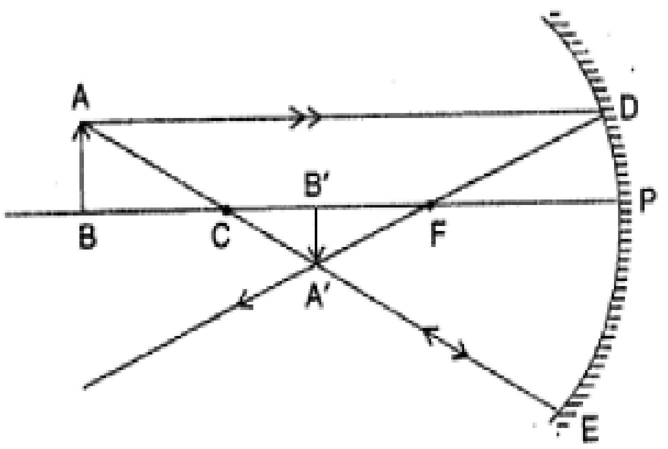
RAY DIAGRAMS:

1) WHEN OBJECT IS PLACED AT INFINITY



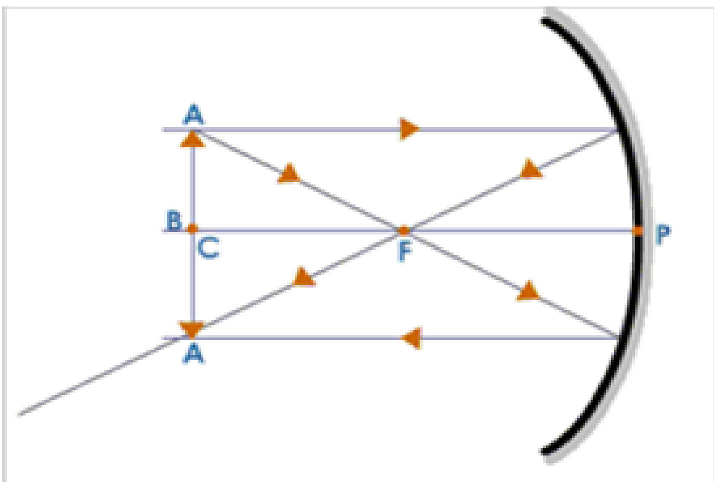
a) Position: At FOCUS (F) b) Nature: Real and inverted c) Magnified Image

2) BEYOND CENTRE OF CURVATURE



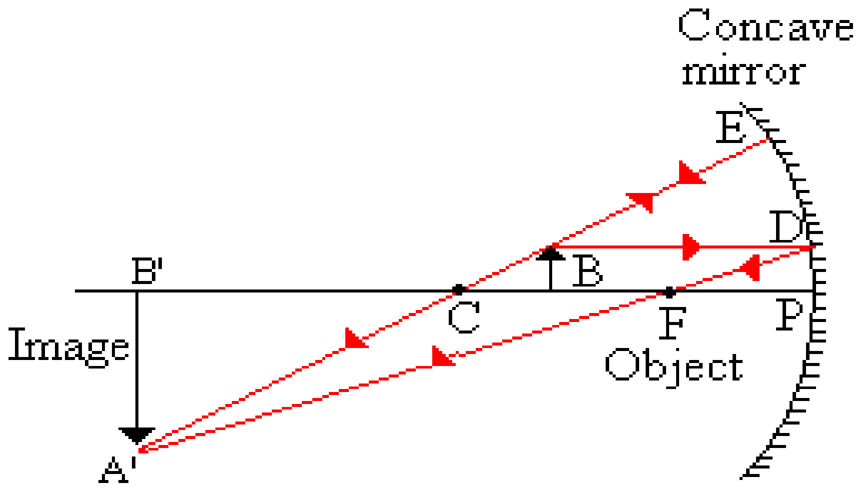
a) Position: Between the C and F b) Nature: Real and inverted c) Magnified Image

3) AT C



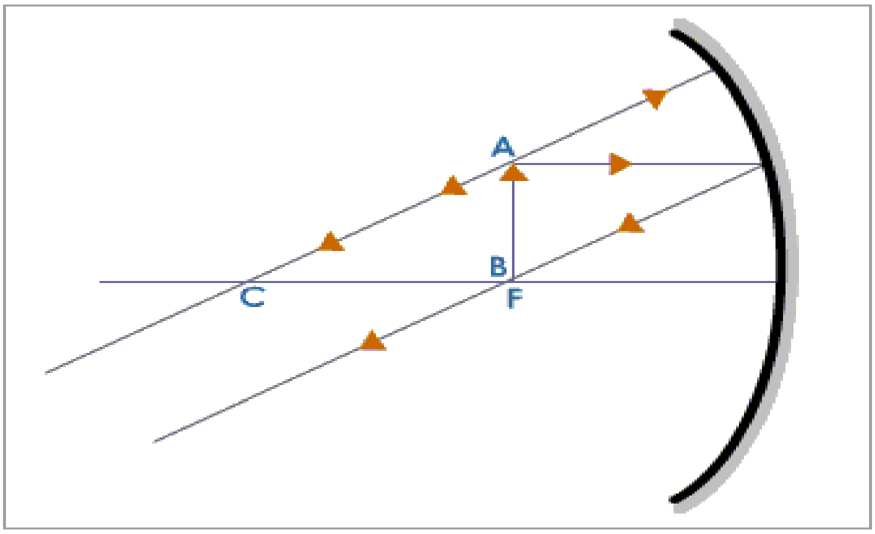
a) Position: At C b) Nature: Real and inverted c)Same SIze

4) BETWEEN C AND F



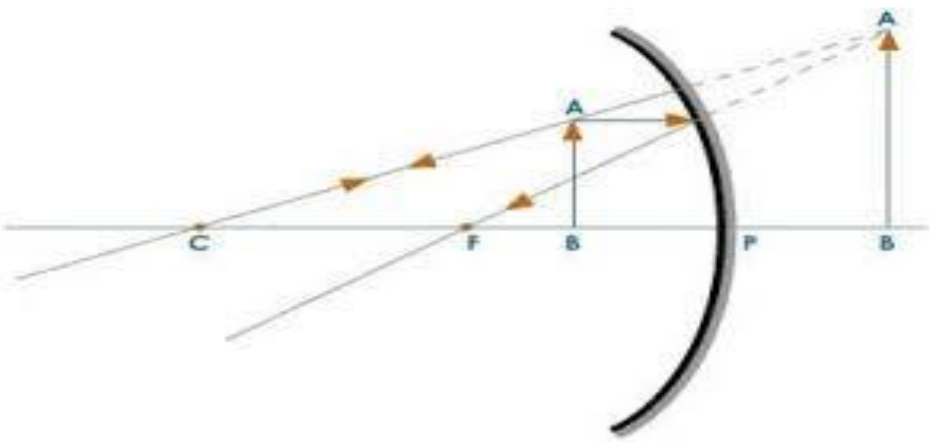
a) Position: Beyond C b) Nature: Real and inverted c) Magnified

5) AT F



a) Position: At infinity b) Nature: Real and inverted c) Highly Magnified

6) BETWEEN F AND P



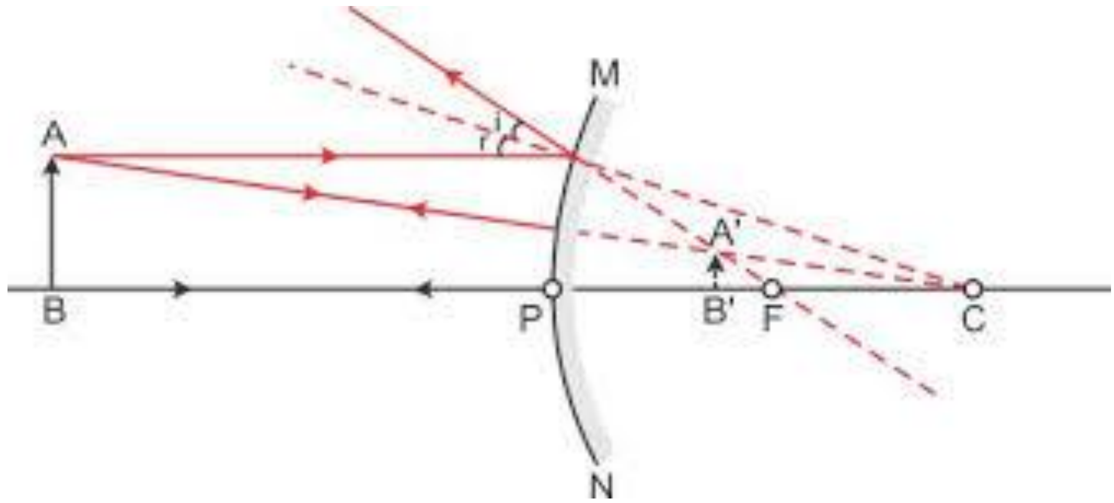
a) Position: Behind the mirror b) Nature: Virtual and erect c) Magnified

TABLE OF POSITIONS AND NATURE OF IMAGE FORMED BY CONCAVE MIRROR:

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F, behind the mirror	Highly diminished, point-sized	Virtual and erect
Between infinity and the pole P of the mirror	Between P and F, behind the mirror	Diminished	Virtual and erect

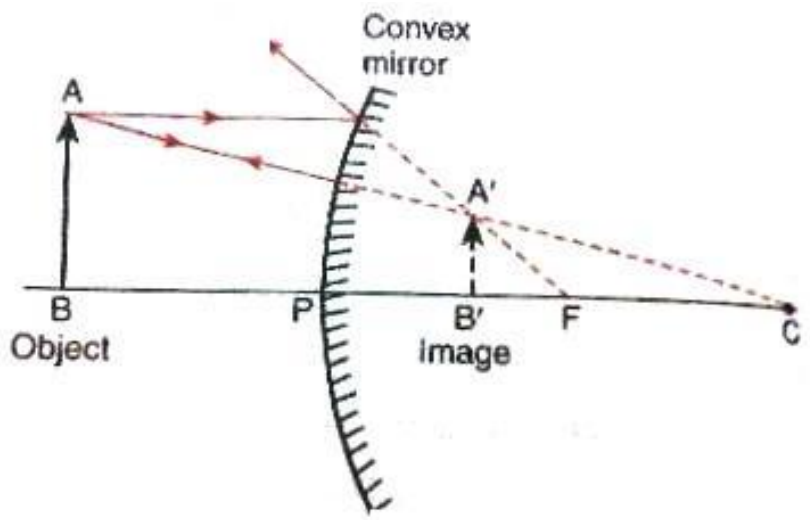
RAY DIAGRAMS:

1) AT INFINITY



a) Position: At Focus b) Nature: Virtual and erect c) Highly Diminished

2) ANYWHERE IN FRONT OF THE MIRROR



a) Position: Between P and F (Behind the mirror) b) Nature: Virtual and erect c) Diminished

NEW CARTESIAN SIGN CONVENTION

In this convention, the Pole of the mirror (P) is taken as ORIGIN. The Principal Axis of the mirror is taken as the x-axis (X`X) of the coordinate system.

1) The object is placed at the left of the mirror. Thus, light from the object falls on the mirror from left hand side.
2) All Distances parallel to the principal axis are measured from the pole of the mirror.
3) All the distances measured to the right of the origin (along + x-axis) are taken as positive, while those measured to the left of the origin (along – x-axis) are taken as negative.
4) Distances measured perpendicular to and above the principal axis (along + y-axis) are taken as positive.
5) Distances measured perpendicular to and below the principal axis (along - y-axis) are taken as negative.

MIRROR FORMULA

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

Where,

v = IMAGE DISTANCE

u = OBJECT DISTANCE

f = FOCAL LENGTH

[NOTE:ALL DISTANCES NEED TO BE SUBSTITUTED WITH SIGN, AS DISCUSSED IN NEW CARTESIAN SIGN CONVENTION]

MAGNIFICATION:

Magnification is defined as the ratio of Height of Image (H_I) to Height of the Object (H_O).

$$m = \frac{H\ image}{H\ object}$$

Through derivations we find that (derivation NOT IN SYLLABUS) :

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

$$m = \frac{H\ image}{H\ object} = \frac{-v}{u}$$

NOTE: 1) a) If m>0, then image is virtual

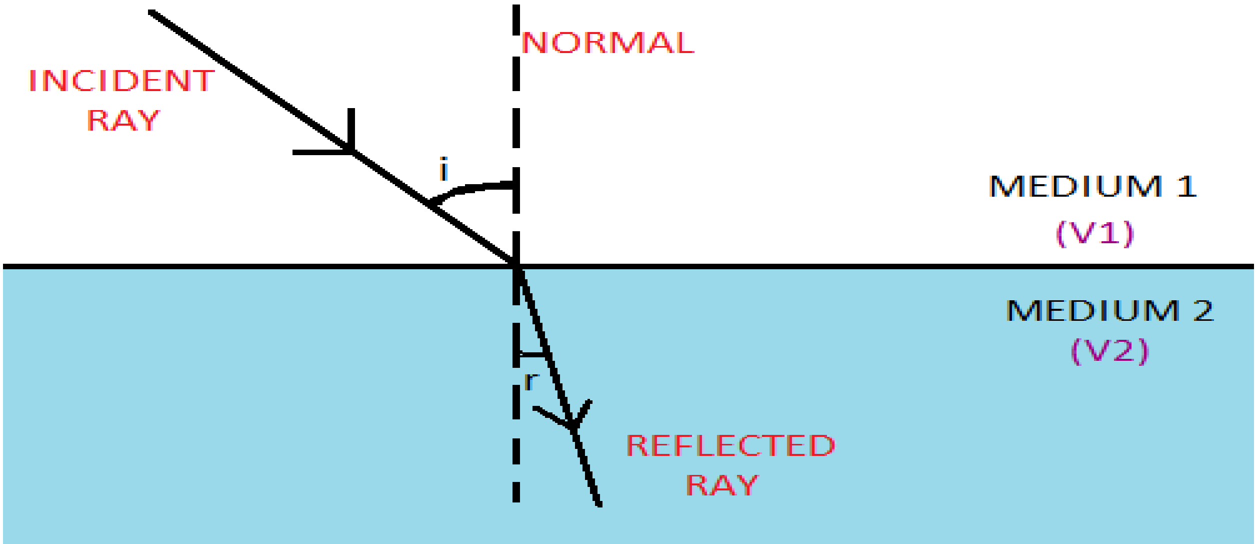
b) If m<0, then image is real

2) a) If |m| > 1, then image is magnified

b) If |m| < 1, then image is diminished

REFRACTION OF LIGHT

The phenomenon of bending of light when it passes from one medium to another is called refraction of light.



REASON FOR REFRACTION:

The speed of light is different in different media. When light enters from medium 1 to medium2 there is a change in the speed of light and thus the light bends.

LAWS OF REFRACTION:

There are two Laws of Refraction

1) The incident ray, reflected ray and the normal to the interface of two transparent media at the point of incidence, all lie in the same plane.
2) 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.

$$\frac{\sin i}{\sin r} = constant = refractive\ index$$

THE REFRACTIVE INDEX OF SECOND MEDIUM WITH RESPECT TO FIRST MEDIUM

REFRACTIVE INDEX

RELATIVE REFRACTIVE INDEX

The refractive index of medium 2 with respect to medium 1 is defined the ratio of speed of light in medium 1 to that in medium 2.

$$n_{21} = \frac{v1}{v2}$$

ABSOLUTE REFRACTIVE INDEX

The absolute refractive index of a medium is defined as the ratio of the speed of light in air/vacuum to that in the medium.

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

QUESTION: Write the SI Unit of refractive index.

ANSWER: We know that there are no SI Units for relative quantities. Since refractive index is a relative quantity so refractive index has no SI Unit.

NUMERICAL: Find the refractive index of water if the speed of light in water is 2.25 X 10^8 ms^{-1}.

ANSWER: We know that,

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

$$n = \frac{3\ X\ 10^8 m/s}{2.25\ X\ 10^8 m/s}$$

$$n = 1.33$$

Thus, the refractive index for water is 1.33.

NUMERICAL: The refractive index of water is 1.33 and that of glass is 1.5. Find

a) The refractive index of water w.r.t glass
b) The refractive index of glass w.r.t water

SOLUTION: We are given the following,

$$n\ (water) = \frac{c}{v\ (water)} \quad (1) \quad , \quad n(glass) = \frac{c}{v(glass)} \quad (2)$$

Since,

⇨ $$n\ (water\ w.r.t\ glass) = \frac{v\ (glass)}{v\ (water)}$$

Multiple and Divide c (speed of light) on RHS

⇨ $$n\ (water\ w.r.t\ glass) = \frac{v\ (glass)}{v\ (water)}\ X\ \frac{c}{c}$$

⇨ $$n\ (water\ w.r.t\ glass) = \frac{v\ (glass)}{c}\ X\ \frac{c}{v\ (water)}$$

⇨ $$n\ (water\ w.r.t\ glass) = \frac{1}{\frac{c}{v\ (glass)}}\ X\ \frac{c}{v\ (water)}$$

Using eq.(1) and eq.(2) ,we find that,

⇨ $$n\ (water\ w.r.t\ glass) = \frac{n\ (water)}{n\ (glass)}$$

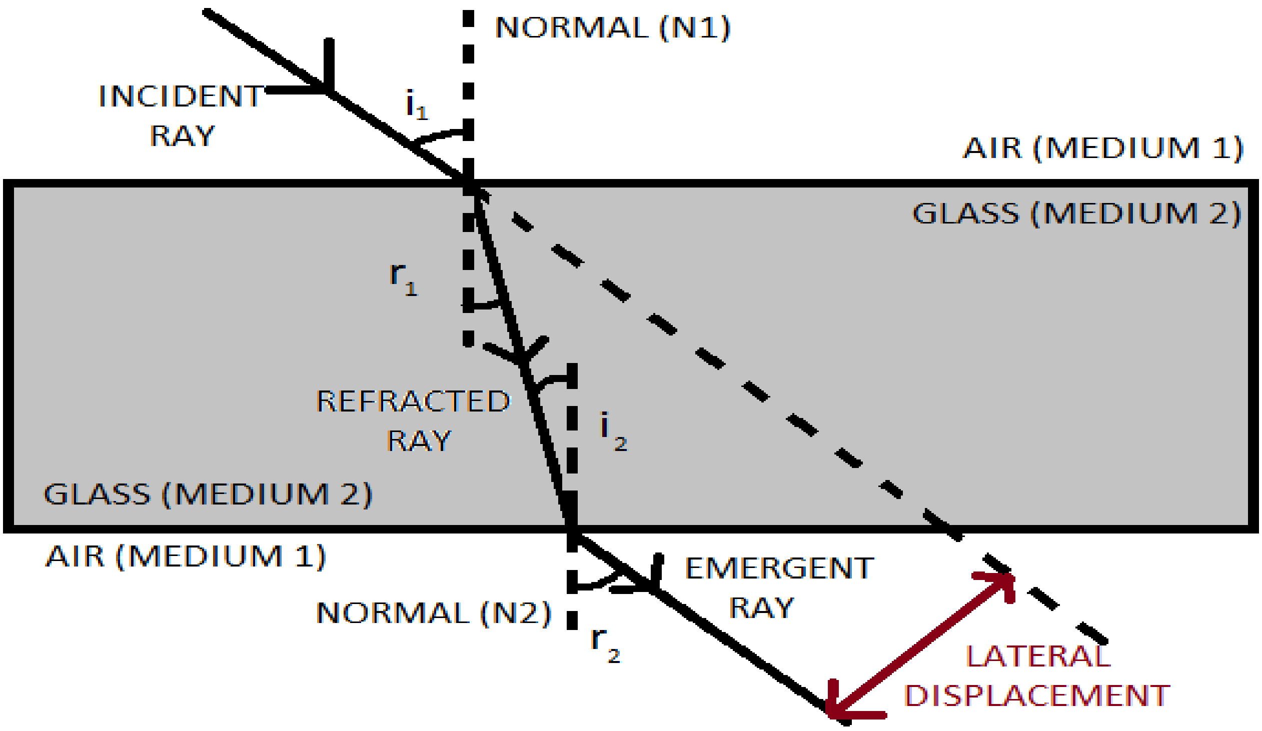
⇨ $$\boldsymbol{n\ (water\ w.r.t\ glass) = \frac{1.33}{1.50} = \frac{8}{9}}$$

Now,

$$\boldsymbol{n\ (glass\ w.r.t\ water) = \frac{1}{n\ (water\ w.r.t\ glass)} = \frac{9}{8}}$$

Answers: n(water w.r.t glass) = 0.89 and n (glass w.r.t water) = 1.125

REFRACTION THROUGH A RECTANGULAR GLASS SLAB



Some important results:

1) i1 = r2
2) r1 = i2
3) Emergent ray is parallel to incident ray

LENS

A Transparent material bound by two surfaces, of which one or both surfaces are spherical, forms a lens.

There are two types of lens:

1) CONVEX LENS: The lens which converges the incident rays of light.
2) CONCAVE LENS: The lens which diverges the incident rays of light.

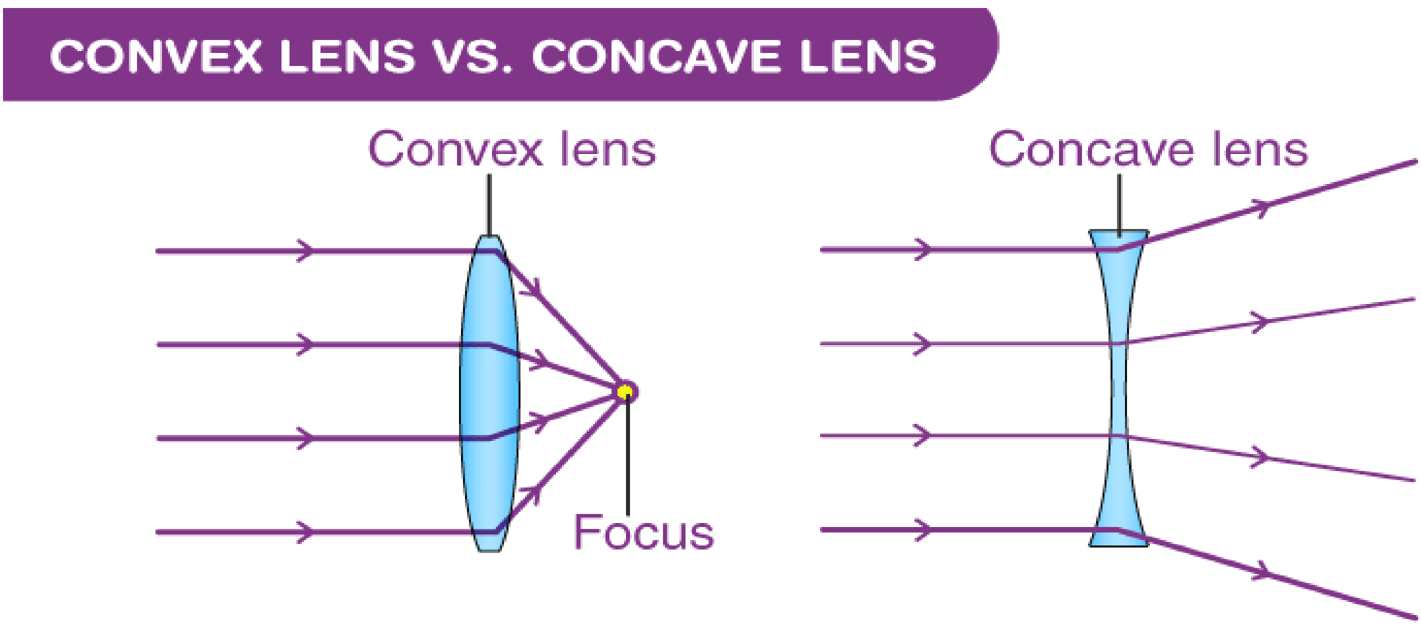
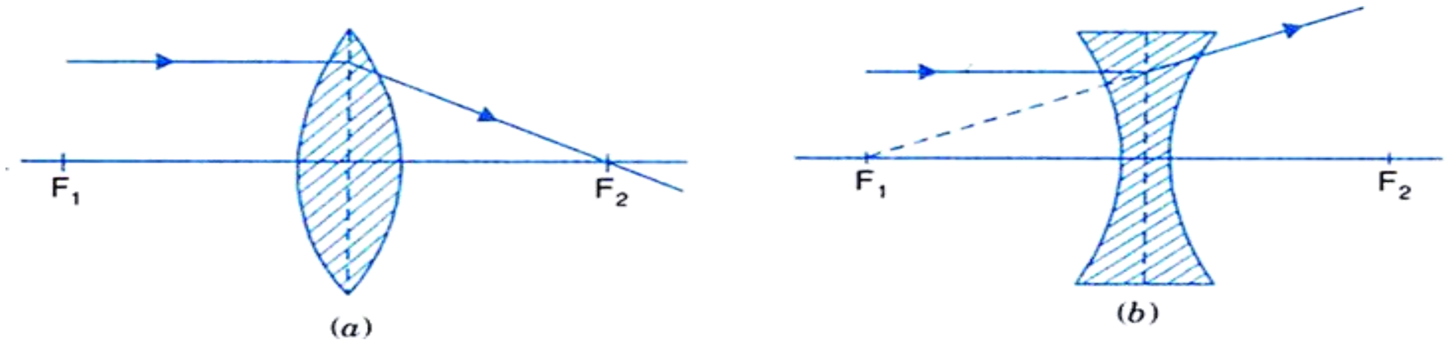
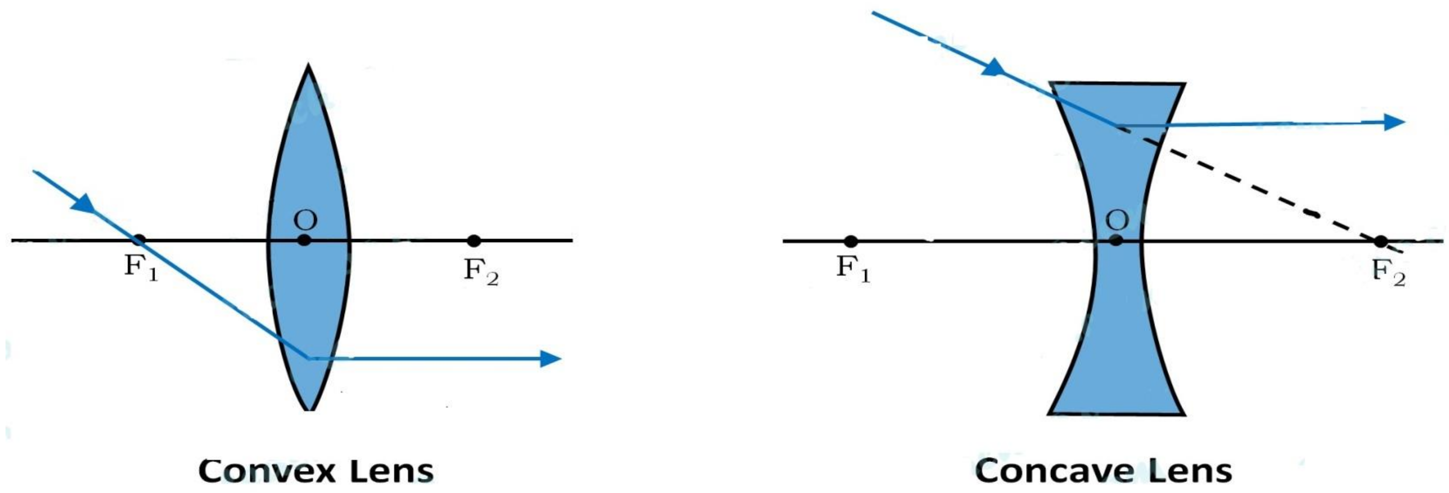


IMAGE FORMATION RULES FOR LENS:

1) A paraxial ray of light, after refraction, will pass through the focus or appear to pass through the focus of the lens.



2) A ray of light which passes through or appears to pass through the focus of the lens , after refraction, will emerge parallel to the principal axis of the lens.



3) A ray of light passing through the optical centre of a lens will emerge without any deviation.

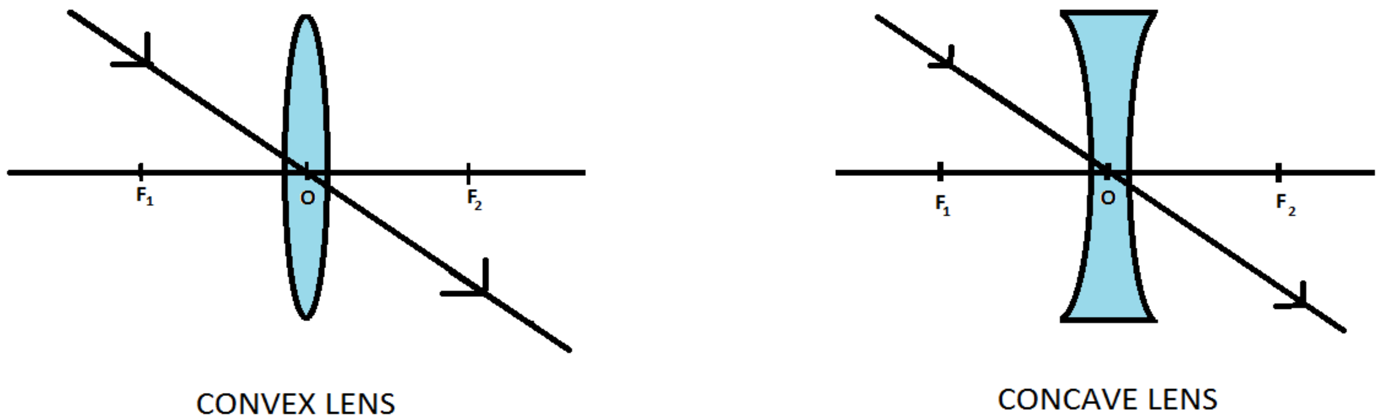


IMAGE FORMATION BY CONVEX LENS

QUESTION: Does a convex lens form a virtual and erect image??

ANSWER: Yes. When the object is placed between the focus and the optical centre of the convex lens, a virtual and erect image is formed.

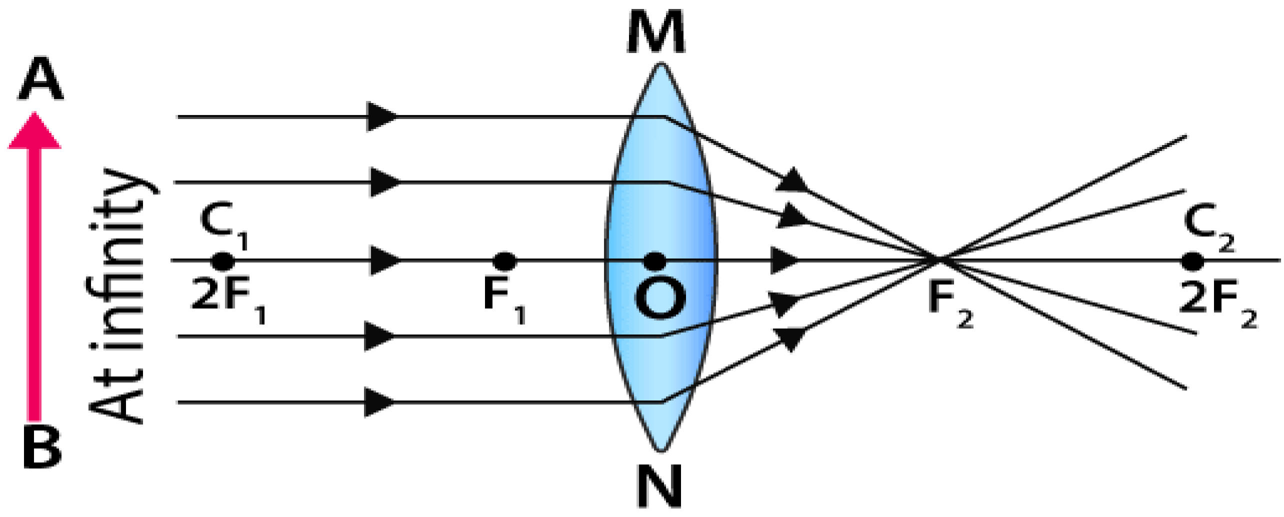
QUESTION: Does a concave lens from a real image??

ANSWER: No. A concave lens always forms a virtual image because it is a diverging lens. The rays of light diverges which can only meet virtually.

TABLE:

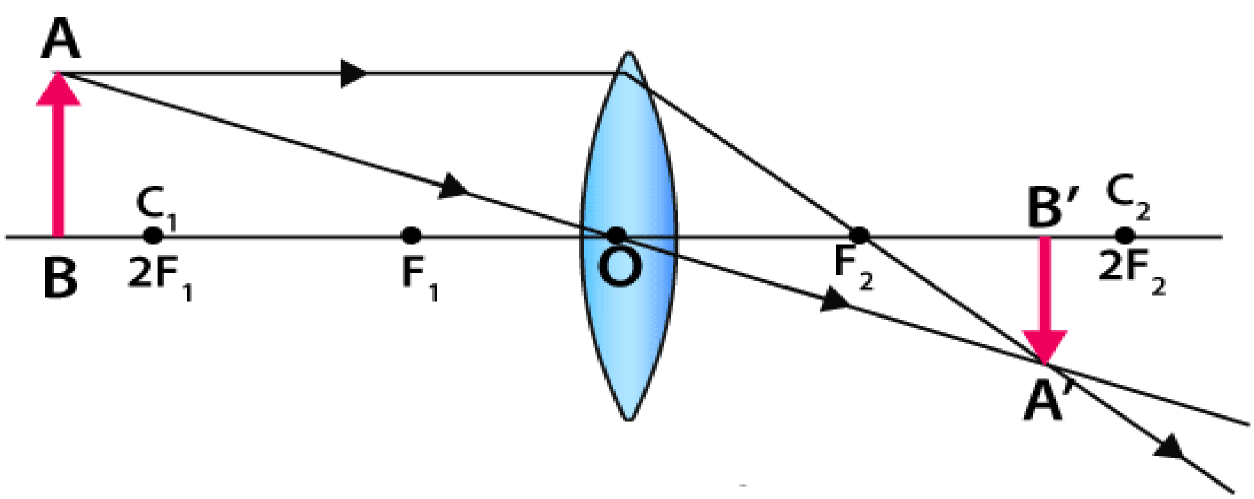
Image formation by Convex Lens			
Object location	**Image location**	**Image nature**	**Image size**
Infinity	At F2	Real and Inverted	Diminished
Beyond 2 F1	Between 2F2 and F2	Real and Inverted	Diminished
Between 2F1 and F1	Beyond 2F2	Real and Inverted	Enlarged
At F1	At infinity	Real and Inverted	Enlarged
At 2 F1	At 2F2	Real and Inverted	Same size
Between F1 and 0	On the same side as the object	Virtual and Erect	Enlarged

1) When object is at infinity



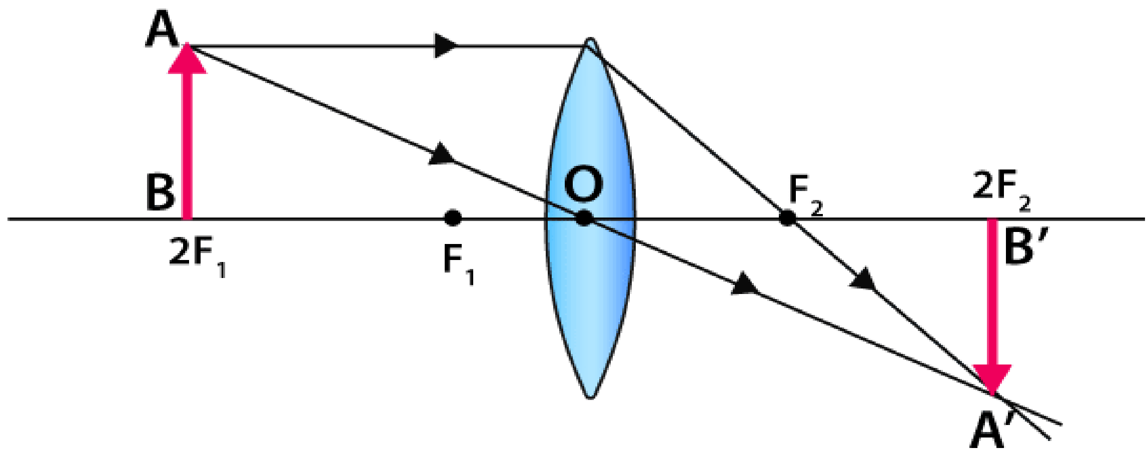
POSITION: At F2 REAL AND INVERTED HIGHLY DIMINISHED

2) When object is beyond 2F



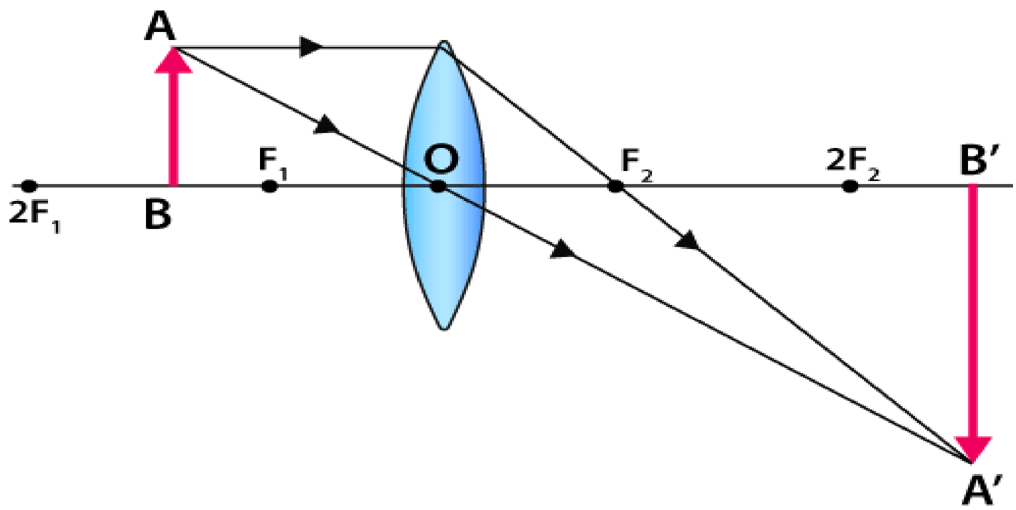
POSITION: Between F2 and 2F1 REAL AND INVERTED DIMINISHED

3) When object is at 2F



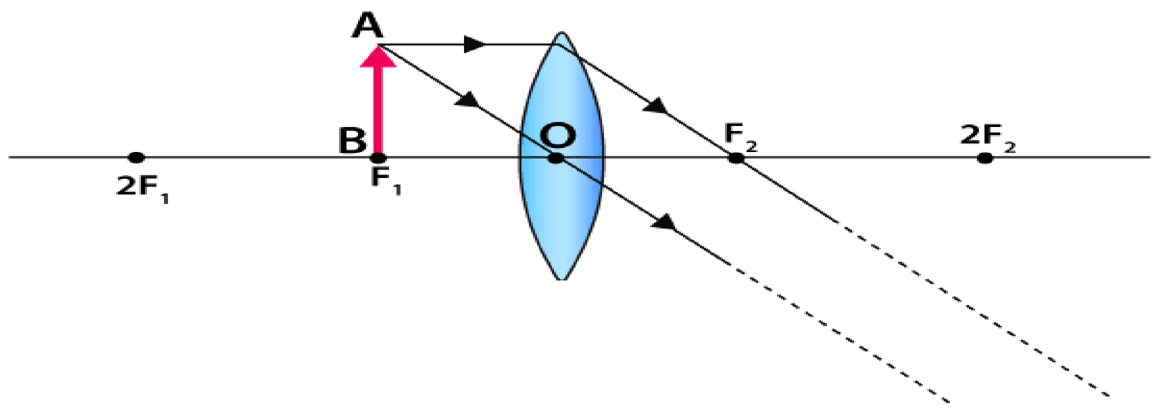
POSITION: At 2F2 REAL AND INVERTED SAME SIZE

4) When object is between 2F and F



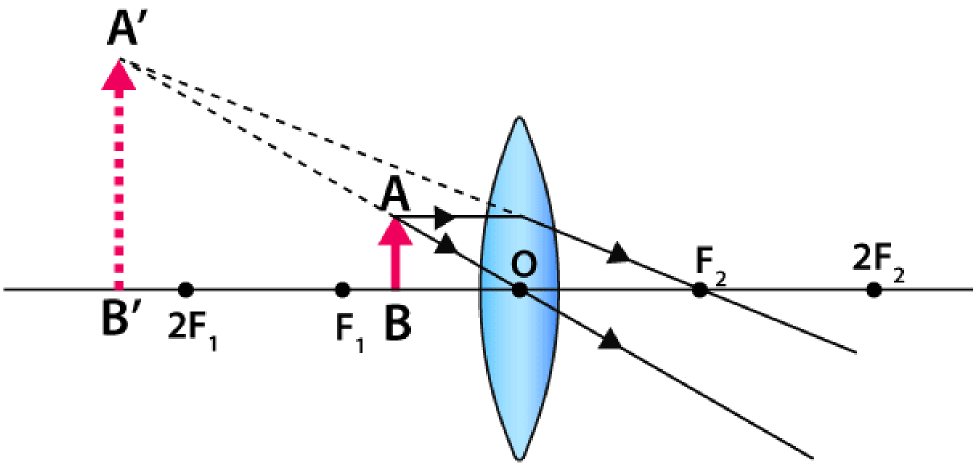
POSITION: BEYOND 2F2 REAL AND INVERTED MAGNIFIED

5) When object is at F



POSITION: AT INFINITY REAL AND INVERTED HIGHLY MAGNIFIED

6) When object is between F and O(Optical Centre)



POSITION: IN FRONT OF THE LENS

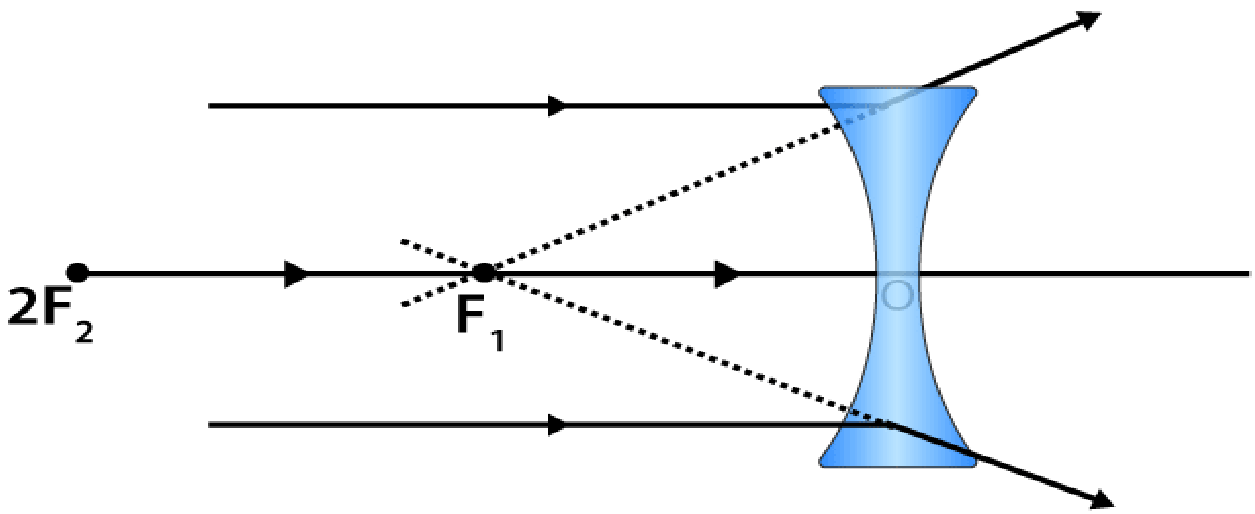
VIRTUAL AND MAGNIFIED

MAGNIFIED

IMAGE FORMATION BY CONCAVE LENS:

Image formation by Concave Lens			
Object Location	**Image Location**	**Image Nature**	**Image Size**
Infinity	At F2	Virtual and Erect	Highly Diminished
Beyond Infinity and Zero	Between F1 and Optical center	Virtual and Erect	Diminished

1) WHEN OBJECT IS AT INFINITY

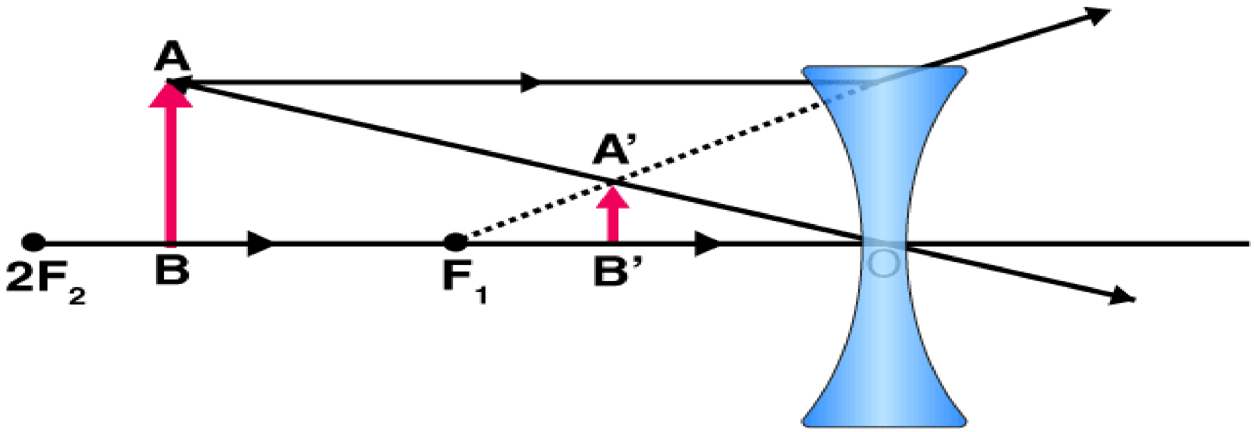


POSITION: AT F1

VIRTUAL AND ERECT

HIGHLY DIMINISHED

2) WHEN OBJECT IS FRONT OF LENS



POSITION: IN FRONT OF THE LENS

VIRTUAL AND ERECT

DIMINISHED

LENS FORMULA AND MAGIFICATION

LENS FORMULA:

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

MAGNIFICATION:

$$m = \frac{Height\ of\ Image}{Height\ of\ Object} = \frac{v}{u}$$

NOTE: v, u and f. All need to be put with signs in accordance with New Cartesian Sign Convention.

POWER OF A LENS

Power of a lens is defined as the reciprocal of the focal length of the lens.

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

SI UNITS: Dioptre (D) [One Dioptre is defined as the power of a lens whose focal length is one metre.]

NOTE: **f to be put in metre!!**

QUESTION: Find the power of a convex and concave lens, when each has a focal length equal to 1 m.

ANSWER: The focal length of a convex lens is positive and that of a concave lens is negative. Thus, the power of a convex lens is positive one and that of concave lens is negative one.

EXTRA INFORMATION:

If a number of lens are placed close to each other the there equivalent power and focal length is calculated as follows:

$$Pnet = P1 + P2 + P3 + \cdots + Pn \quad \&\& \quad \frac{1}{f(net)} = \frac{1}{f1} + \frac{1}{f2} + \frac{1}{f3} + \cdots + \frac{1}{fn}$$