CHAPTER 10

Light

Acknowledgment

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- Some images and video clips have been modified according to the syllabus.

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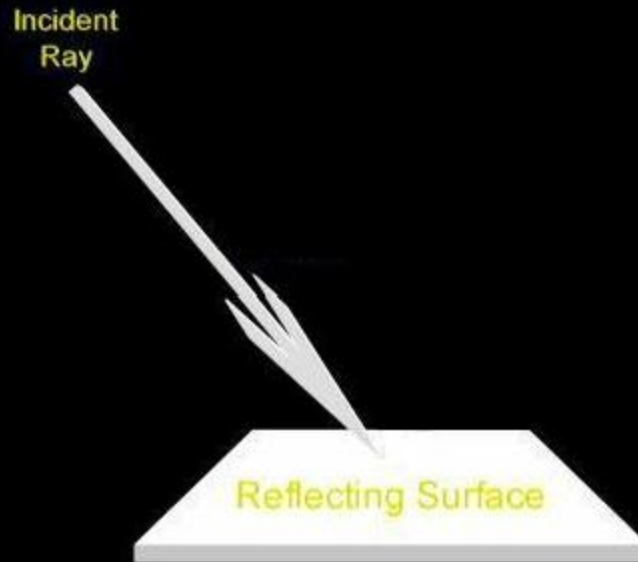
Contents

Reflection of light

Reflection of light

The process through which light rays falling on the surface on an object are sent back is called reflection of light.
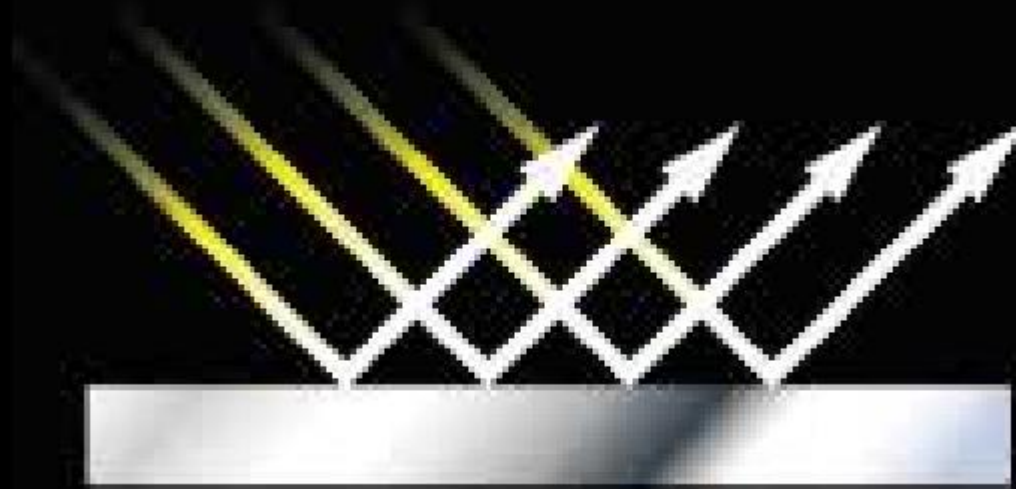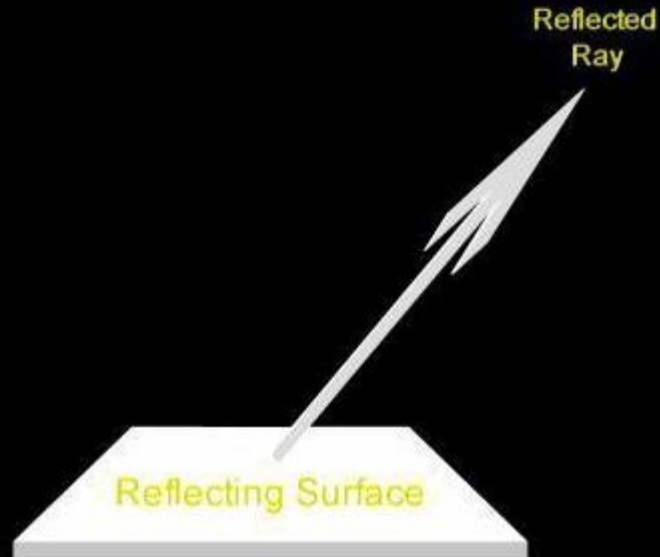
Incident ray

An incident ray is a ray of light that strikes a reflecting surface.

Incident
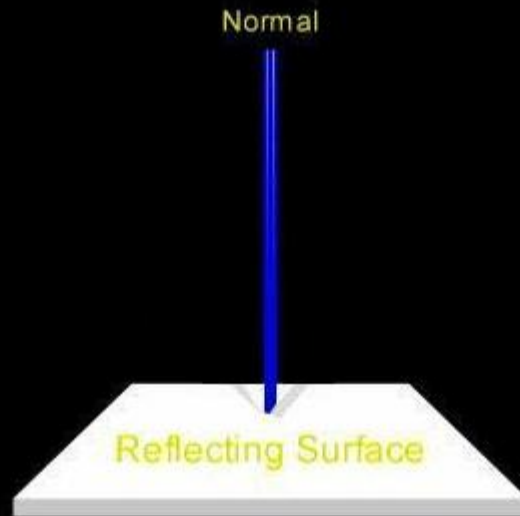Ray

Reflecting Surface

Reflected ray

The ray that represents the light reflected by the reflecting surface.

Normal ray

A ray that is incident at 90 degrees to a surface.

Normal

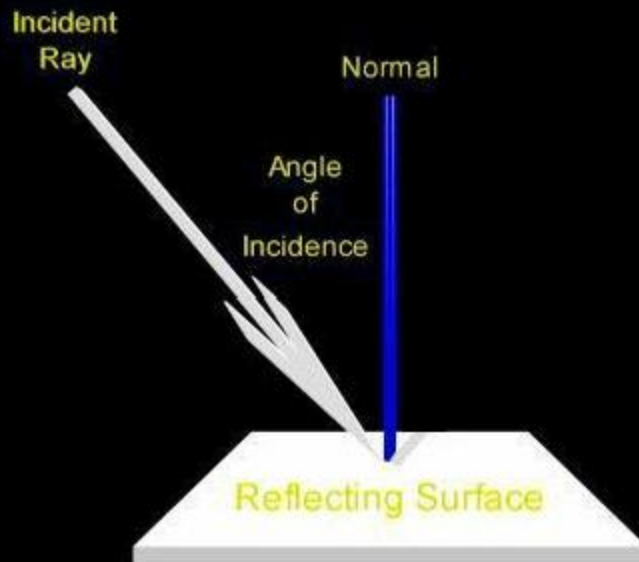Reflecting Surface

Angle of incidence

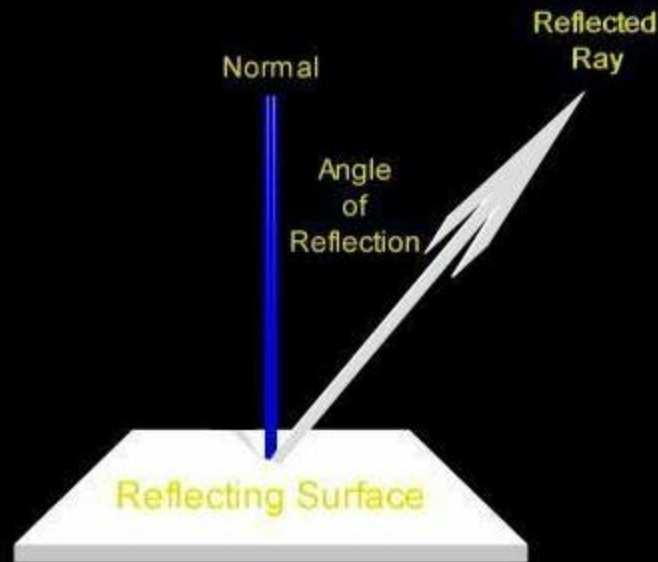The angle which an incident ray makes with normal at point of incidence.

Angle of Reflection

The angle which a reflected ray makes with normal at point of incidence.

Laws of reflection of light

The angle of incidence is equal to the angle of reflection.
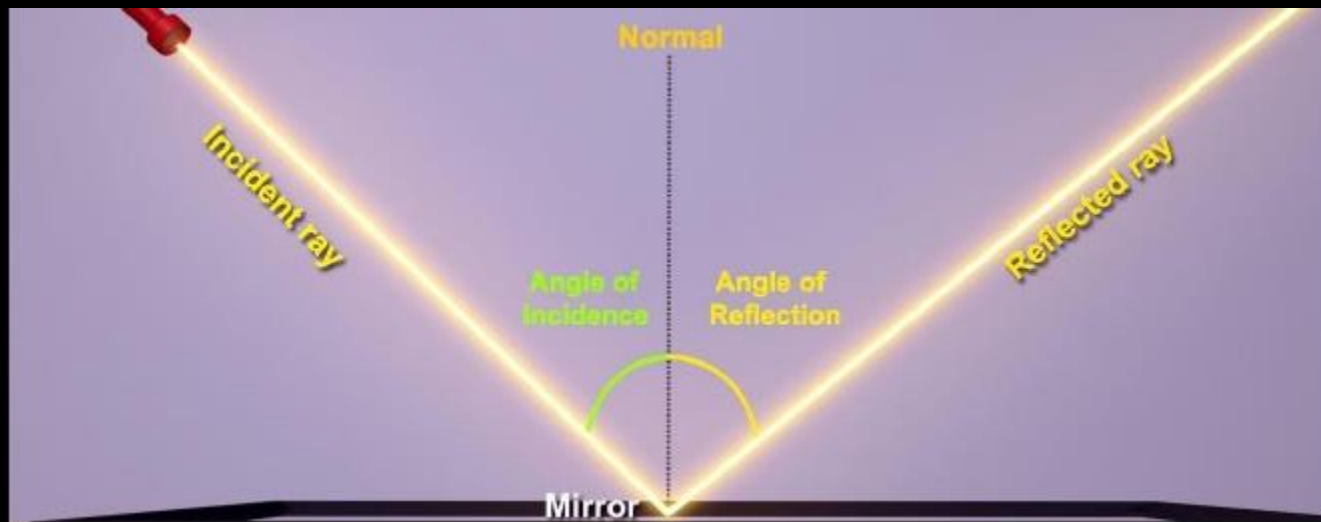
Laws of reflection of light

The incident ray, the normal to the mirror at the point of incidence and the reflected ray, all lie on the same plane.
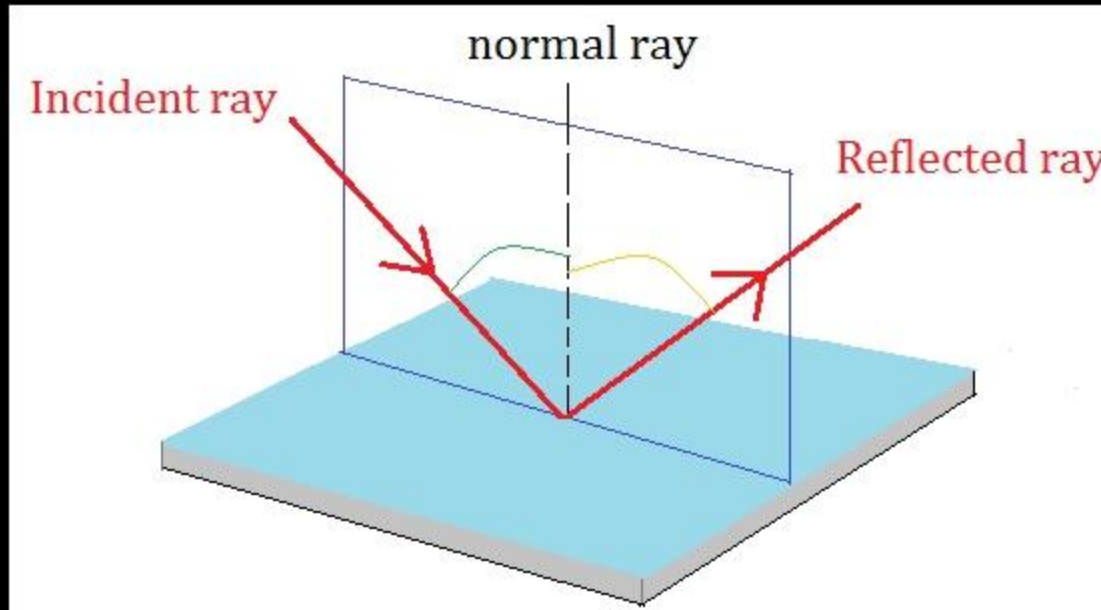
Characteristics of image formed by a plane mirror

a) The image formed by the plane mirror is always virtual and erect.
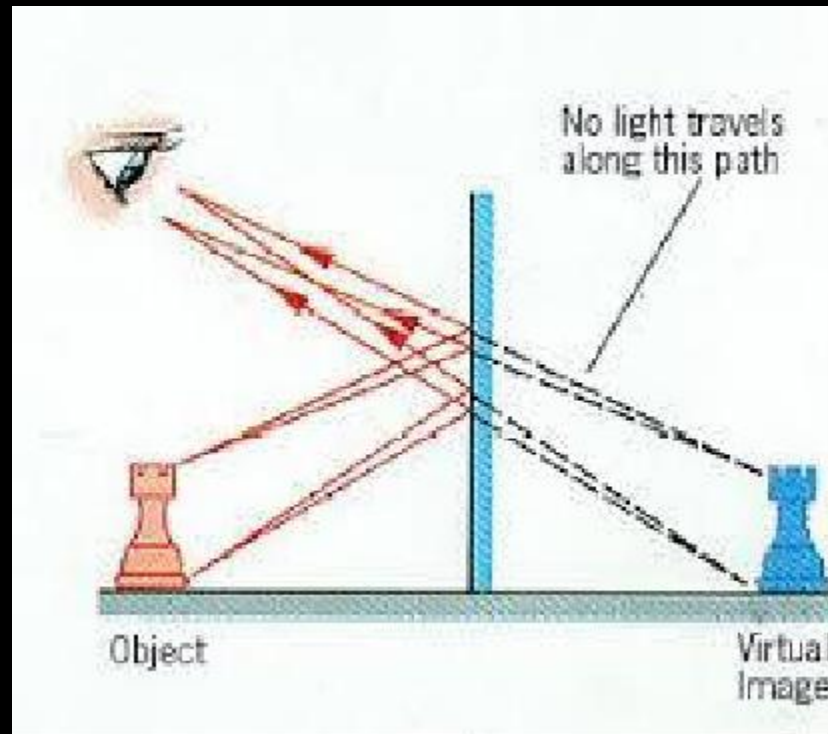
Characteristics of image formed by a plane mirror

b) The size of the image is equal to that of the object.
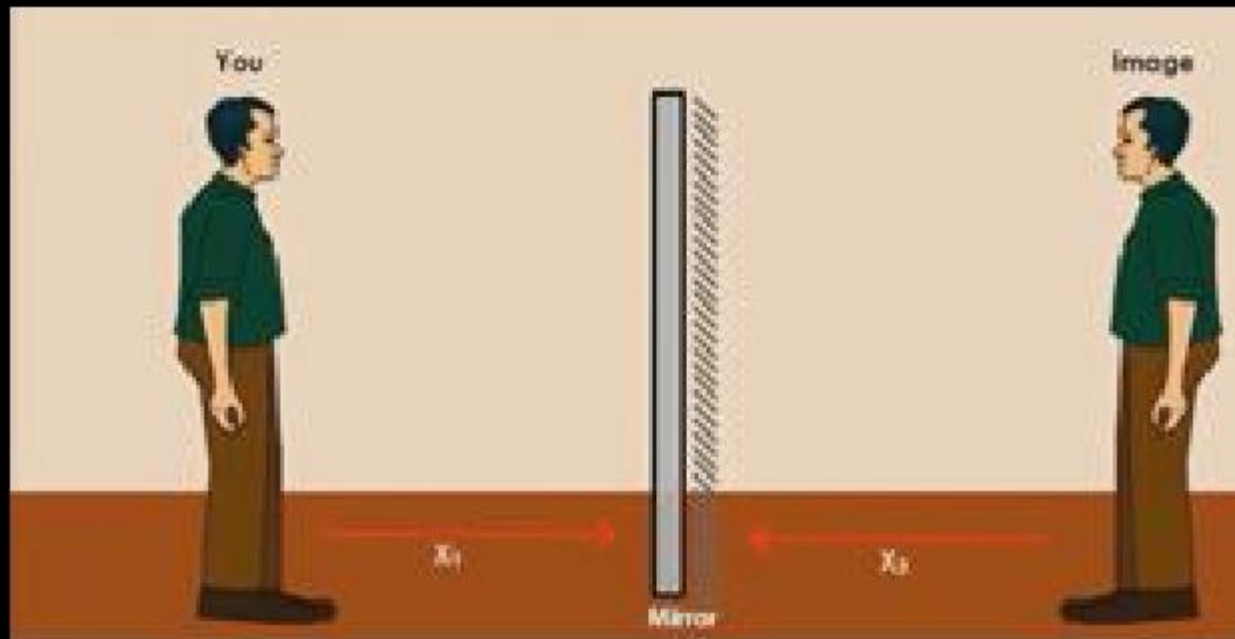
Characteristics of image formed by a plane mirror

c) The image formed is as far behind the mirror as the object is in front of it.

Flat mirror

d_o

d_i
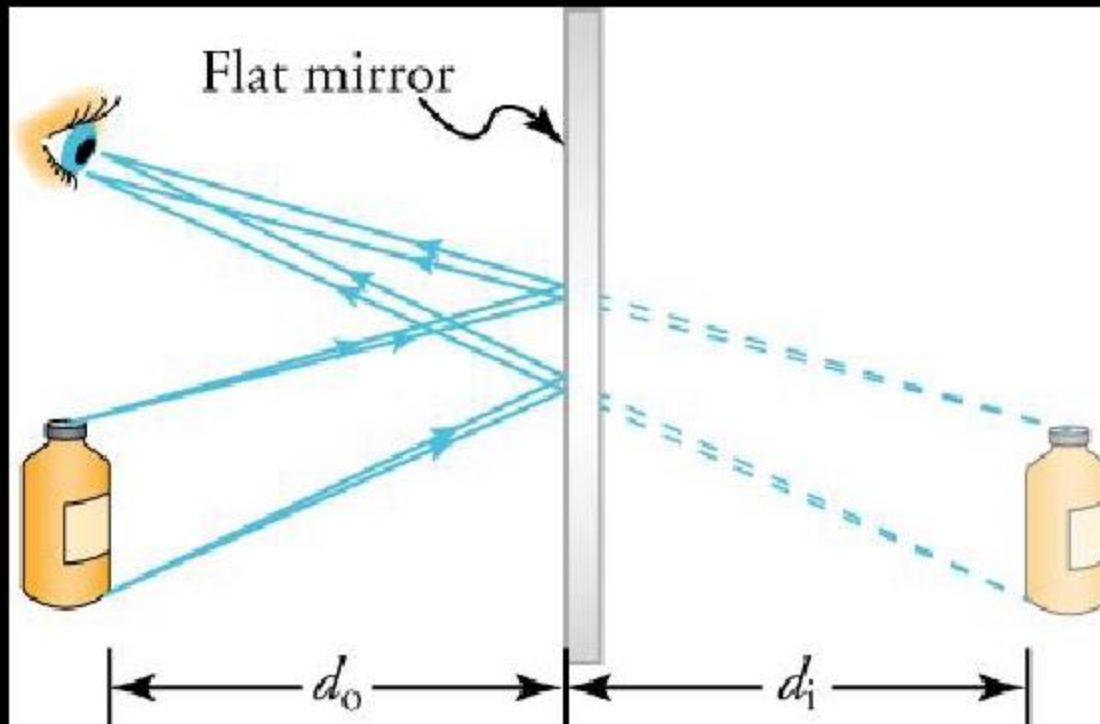
Characteristics of image formed by a plane mirror

d) The image is laterally inverted.
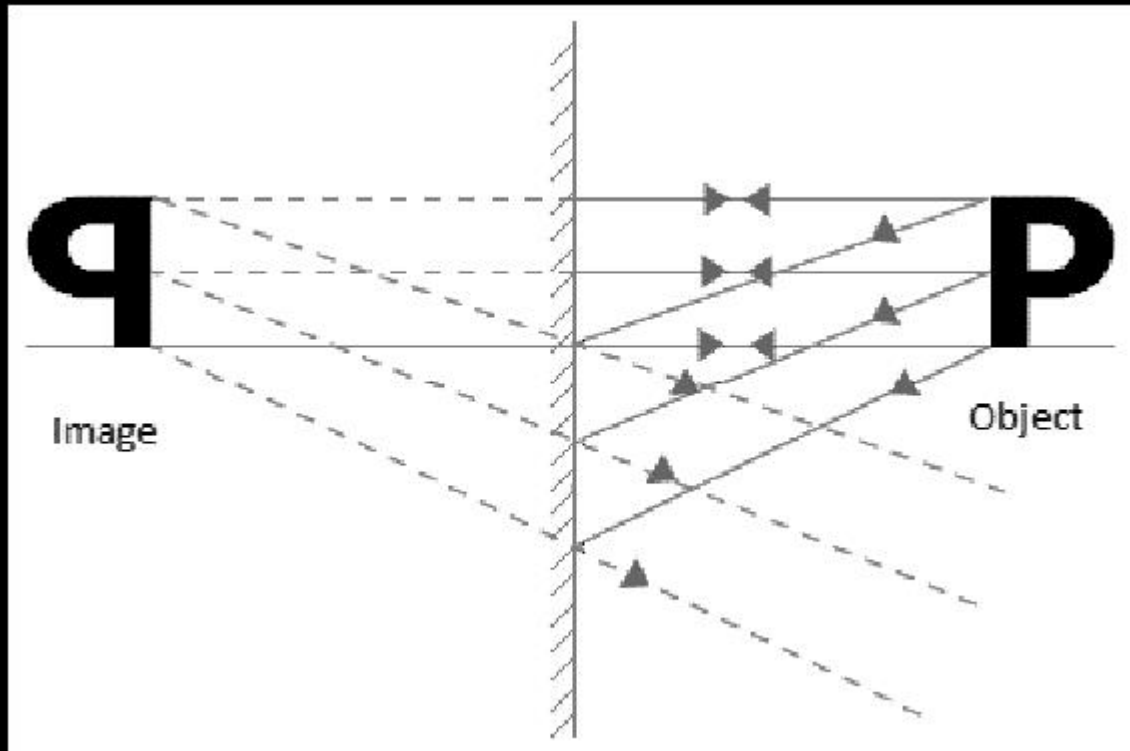
Real image Vs Virtual image

RealImage	Virtualimage
1.Theraysactually meetattheimage point. 2.Itcanbetakenona screen. 3.Itisalwaysinverted.	1.Theraysappearto divergefromthe imagepoint. 2.Itcannotbetaken onthescreen. 3.Itisalwayserect.

Lateral inversion

The inversion of the left hand side of the object into the right hand side in the image and vice-versa is called lateral inversion.
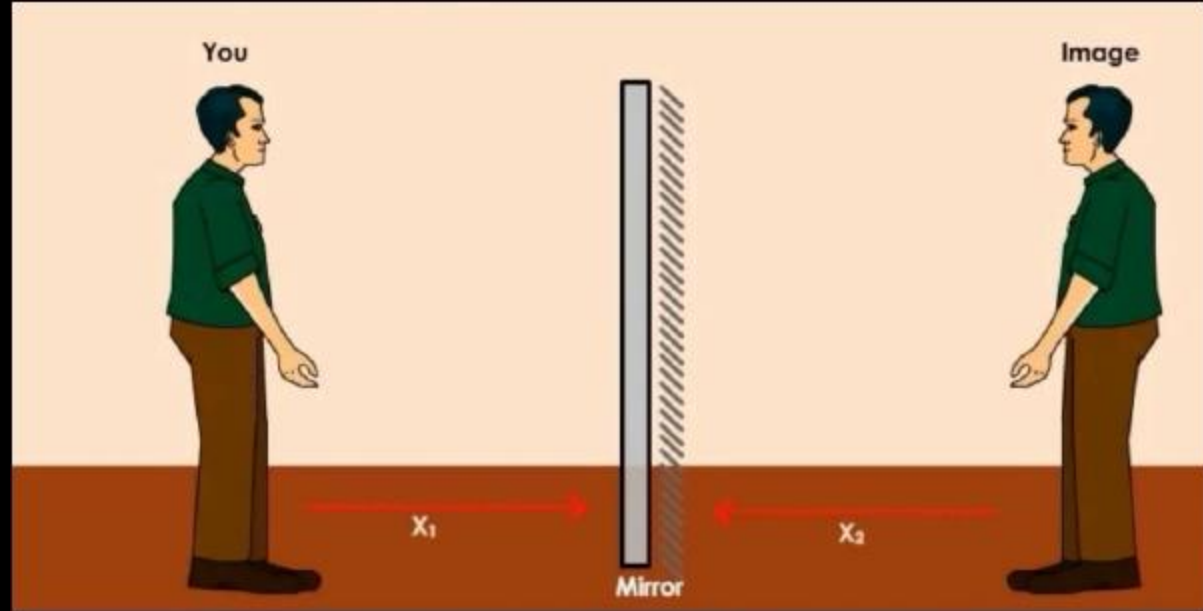
(Activity 10.1) Take a large shining spoon. Try to view your face in its curved surface. Do you get the image? Is it smaller or larger?

Yes, the image of the face formed on outer curved surface is smaller in size.

(Activity 10.1) Take a large shining spoon. Try to view your face in its curved surface. Do you get the image? Is it smaller or larger?

Move the spoon slowly away from your face. Observe the image.

The size of image gradually decreases with an increase in field of view.

How does it change? Reverse the spoon and repeat the Activity.

Earlier, when the spoon was close the image formed on the inner curved surface was erect and magnified and as we moved the spoon slowly away from our face, the image transitioned to an inverted image with gradual decrease in its size.

Compare the characteristics of the image on the two surfaces.

Outersurface	Innersurface
(i)Imageisalwayserect.	(i)Theimageiserectwhen spooniscloseandinverted whenspoonisaway
(ii)Imagesizeisgradually decreasesaswemoveaway thespoon	(ii)Imagesizeislargerwhen spooniscloseanditis smallerwhenspoonismoved away

Spherical mirrors

Spherical mirror

A Mirror in which reflecting surfaces are spherical are called spherical mirror.

Concave mirror

A spherical mirror, whose reflecting surface is curved inwards (faces towards the centre of the sphere) is called a concave mirror.

Concave Mirror

Reflecting surface
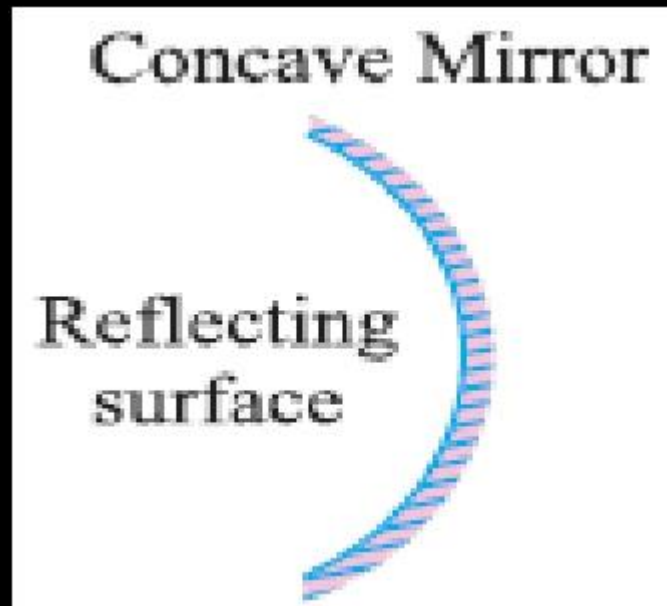
Convex mirror

A spherical mirror whose reflecting surface is curved outwards, is called a convex mirror.

Convex Mirror

Reflecting surface
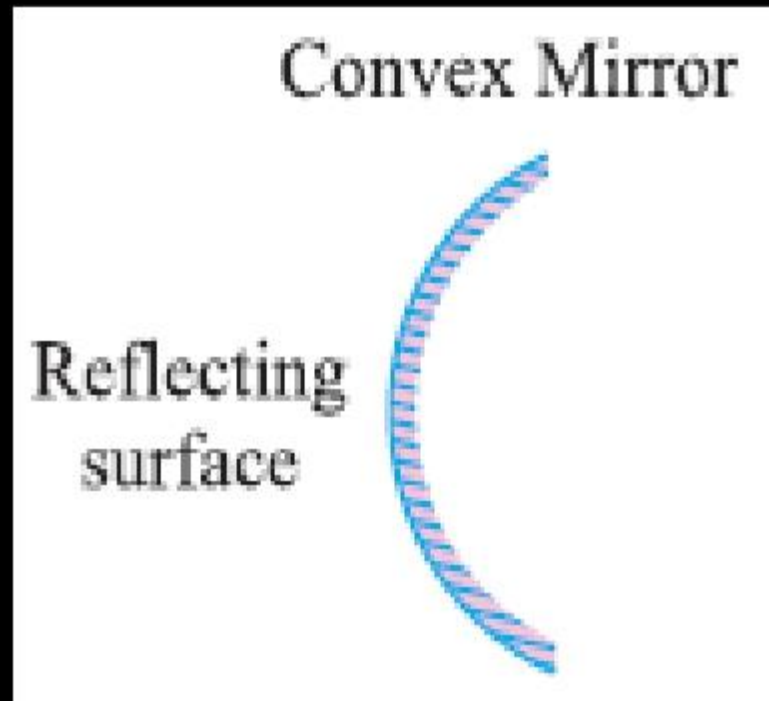
Pole of the mirror

The centre of the reflecting surface of a spherical mirror is a point called the pole.

Pole

Pole | F | C | Pole

Convex mirror | Concave mirror
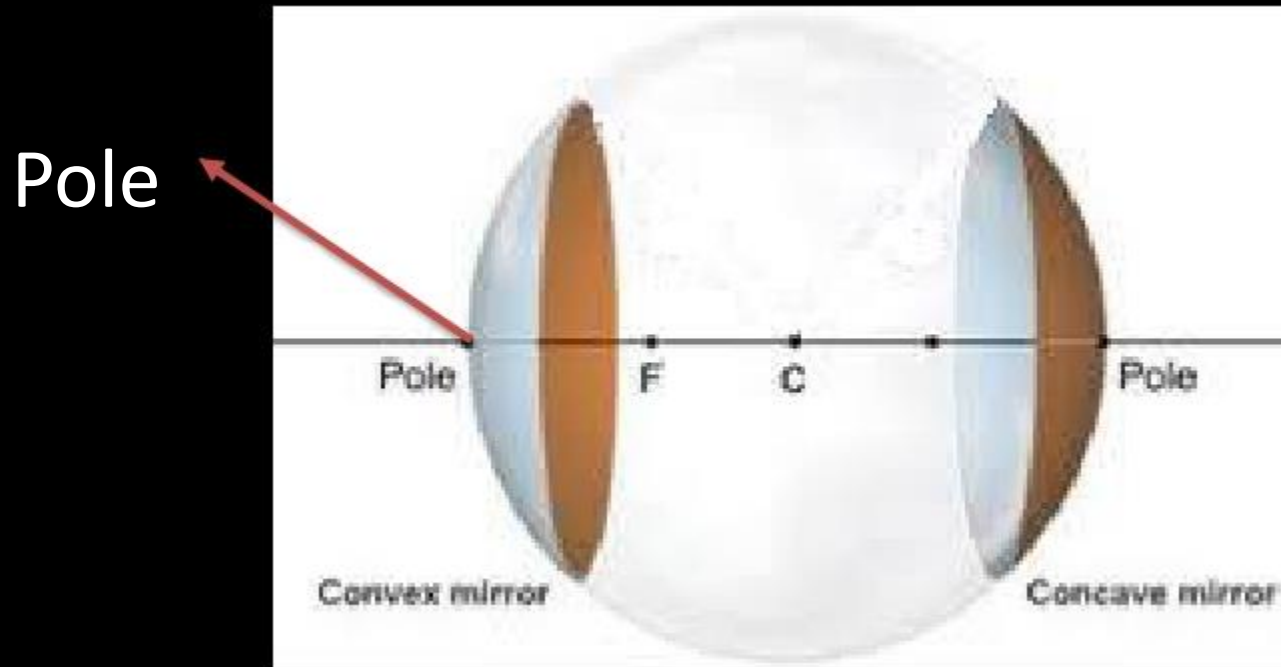
Centre of curvature

The centre of the sphere of which the reflecting surface of a spherical mirror forms a part of a sphere.
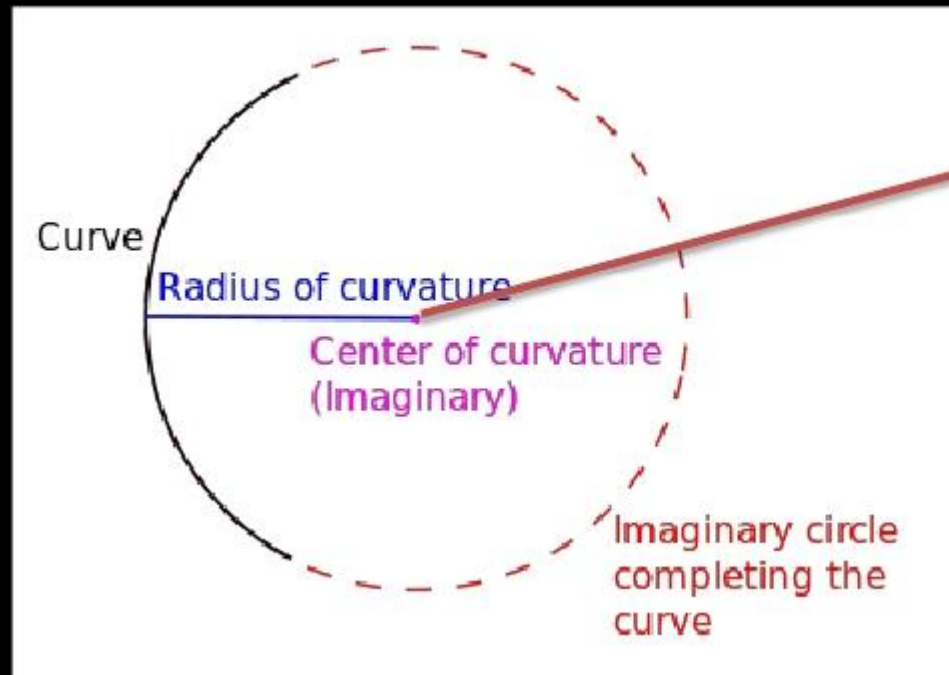
Curve

Radius of curvature

Center of curvature (Imaginary)

Imaginary circle completing the curve

Centre of curvature

Radius of curvature

The radius of the sphere of which the reflecting surface of a spherical mirror forms a part, is called the radius of curvature of the mirror.

Radius Of curvature

Curve

Radius of curvature

Center of curvature (Imaginary)

Imaginary circle completing the curve
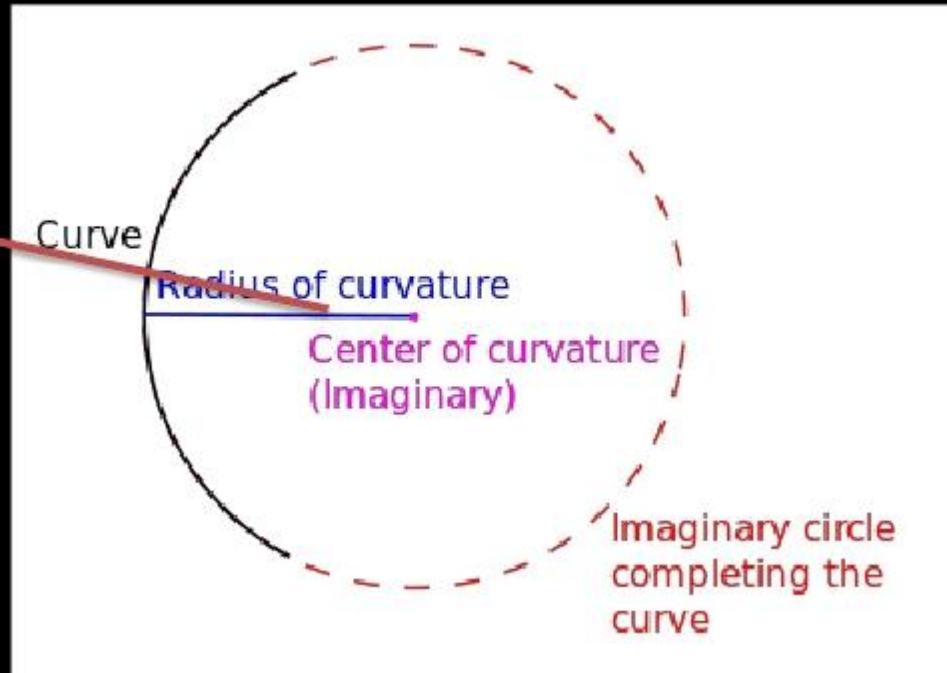
Principal axis

The straight line passing through the centre of curvature and pole of the spherical mirror, produced on both sides.

Principal Axis   P
C
Concave Mirror

Principal Axis   P
C
Convex Mirror
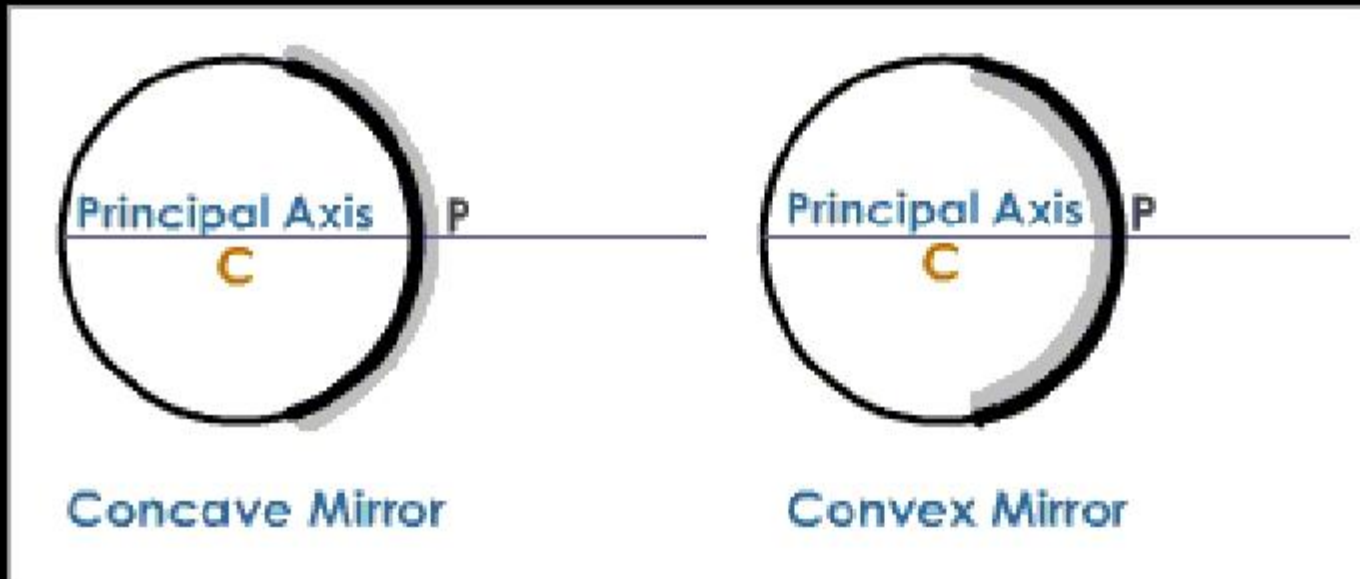
Focus of concave mirror

The point on principal axis where all the parallel light rays after reflection actually meet at a point called focus (F).
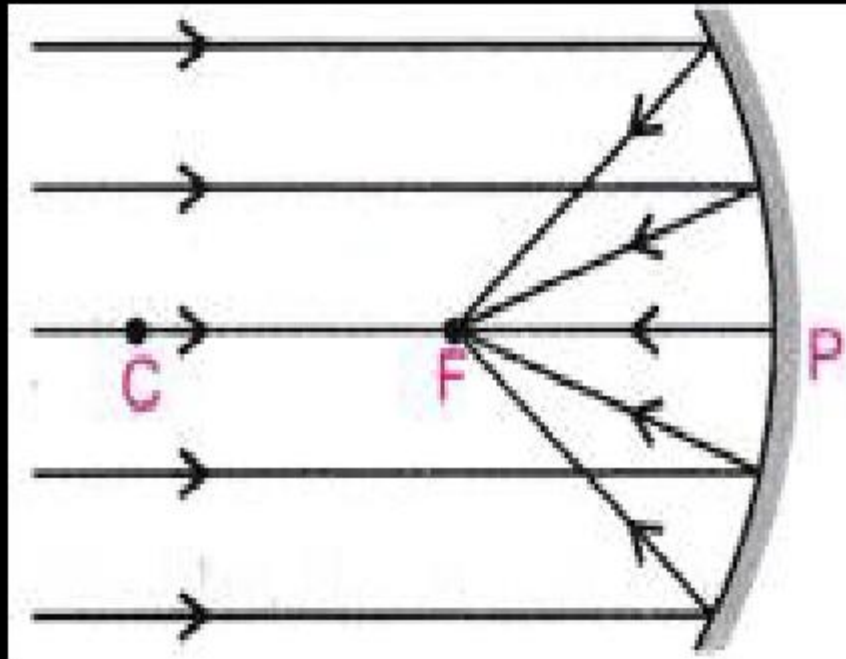
Focus of convex mirror

The point on principal axis where all the parallel light rays after reflection appear to meet at a point called focus (F).

Focal length

The distance between the pole of the mirror and principal focus.
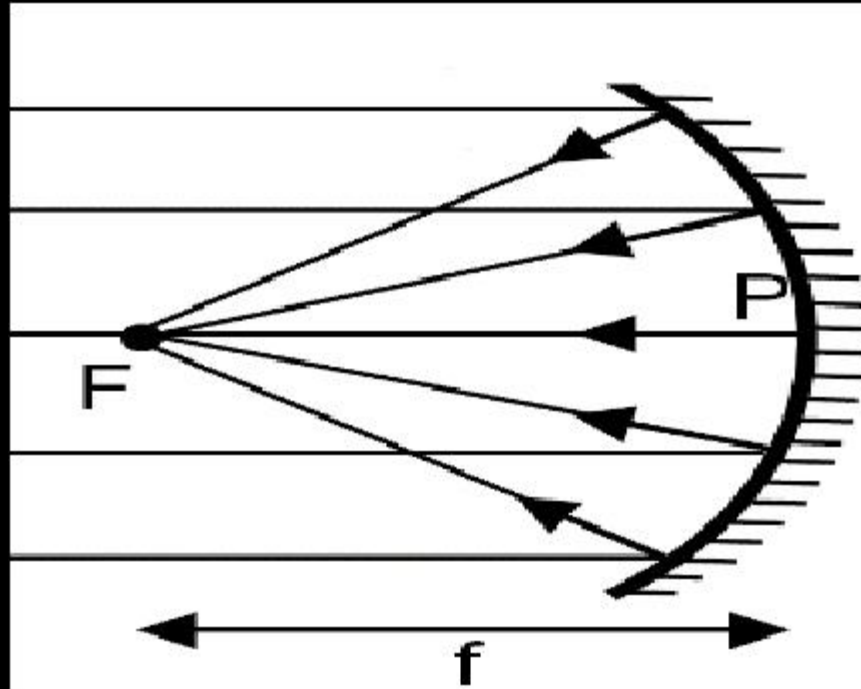
The radius of curvature of a spherical mirror is twice the focal length. R=2f

(Activity 10.2) Hold a concave mirror in your hand and direct it's reflecting surface towards the Sun. Direct the light reflected by the mirror on to a sheet of paper held close to the mirror. Move the sheet of paper back and forth gradually until you find on the paper sheet a bright, sharp spot of light.
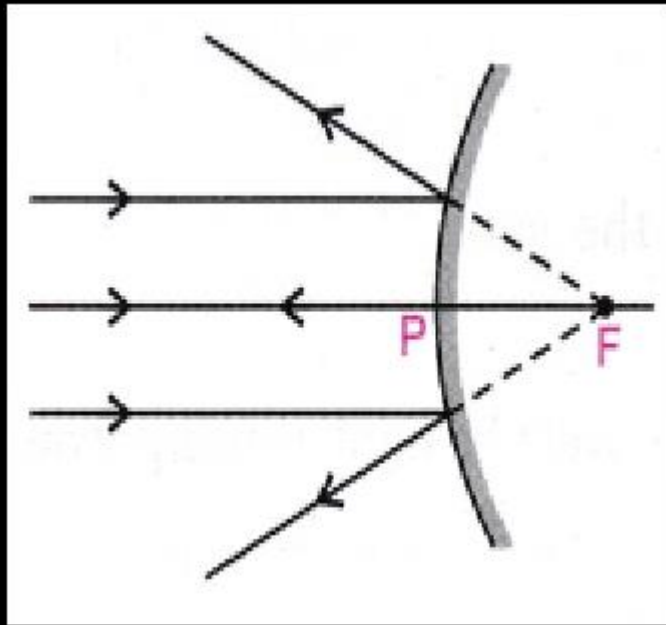
Hold the mirror and the paper in the same position for a few minutes. What do you observe? Why?
The light rays from the Sun, are concentrated at focus, and form a sharp spot of light on the sheet. Paper starts burning after some time due to increase intensity of reflected sun light from the mirror

(Activity 10.2) Hold a concave mirror in your hand and direct it's reflecting surface towards the Sun. Direct the light reflected by the mirror on to a sheet of paper held close to the mirror. Move the sheet of paper back and forth gradually until you find on the paper sheet a bright, sharp spot of light.

Why, we should not look at the Sun directly or even into a mirror reflecting sunlight?

Because the intense heat resulting from the concentrated sun light through eye lens may burn the retina wall with dark spots. This may result in partial or complete vision impairment.

Image formation in a concave mirror & nature of the image when the object is placed:

At infinity

When the Object is at Infinity
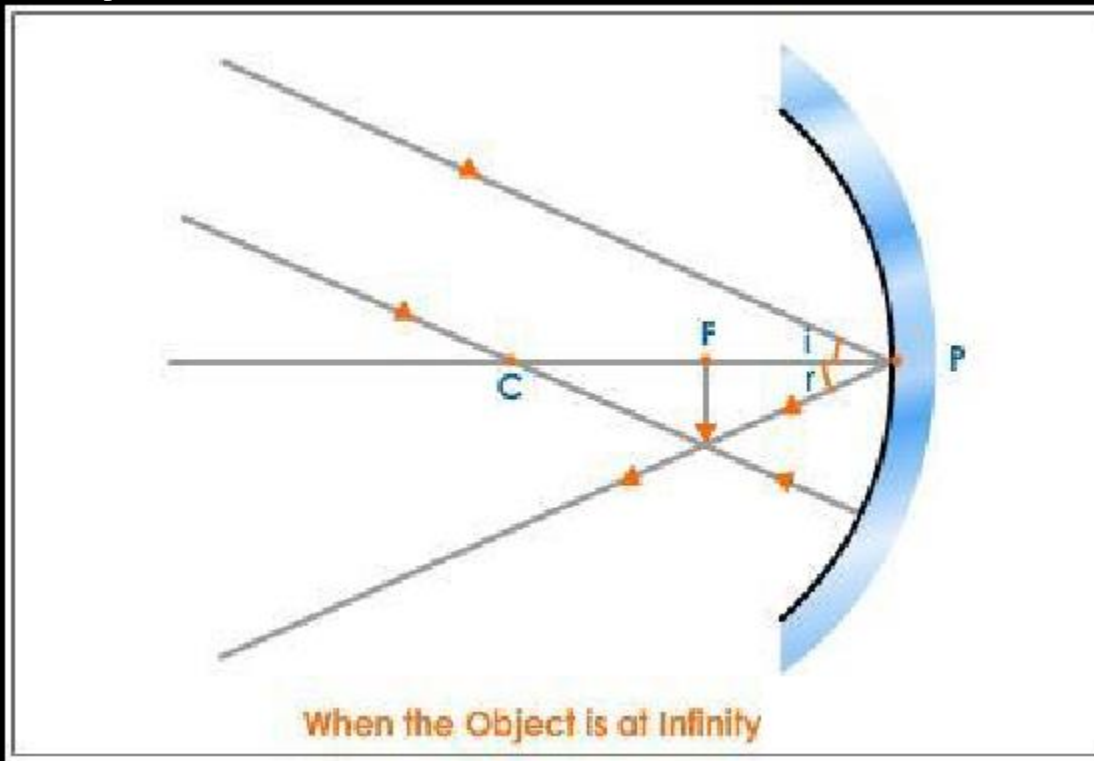
Nature: Real, inverted, highly diminished, point-sized image is formed at focus (F)

Image formation in a concave mirror & nature of the image when the object is placed:

Beyond C

When the Object is Placed Beyond C
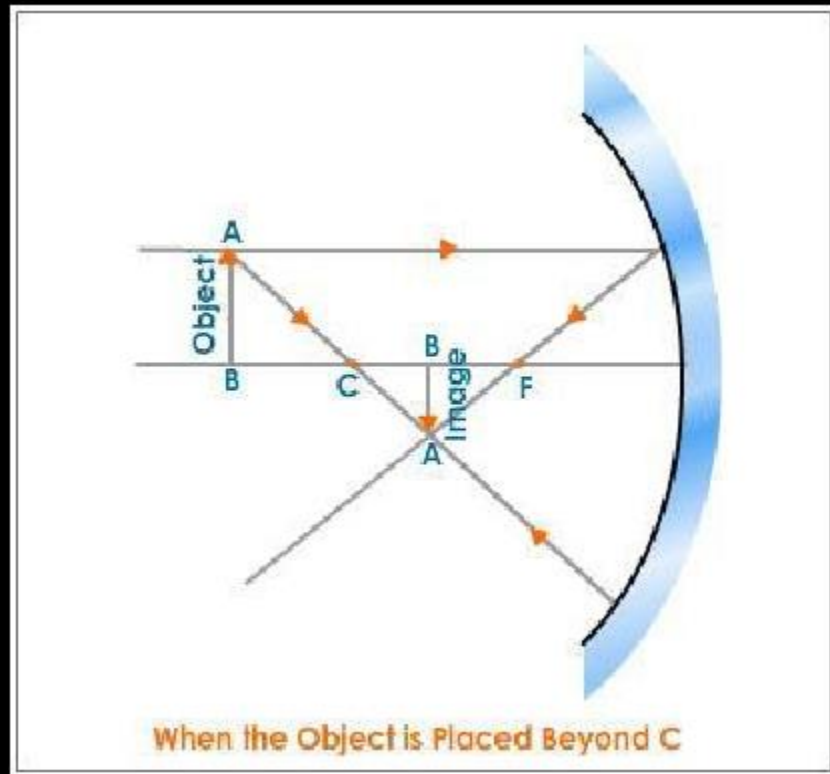
Nature: Real, inverted, diminished, image is formed between C and F

Image formation in a concave mirror & nature of the image when the object is placed:

At C

When the Object is Placed at the Centre of Curvature

Nature: Real, inverted, same size image is formed at C

Image formation in a concave mirror & nature of the image when the object is placed:

Between C and F

When the Object is Between C and F
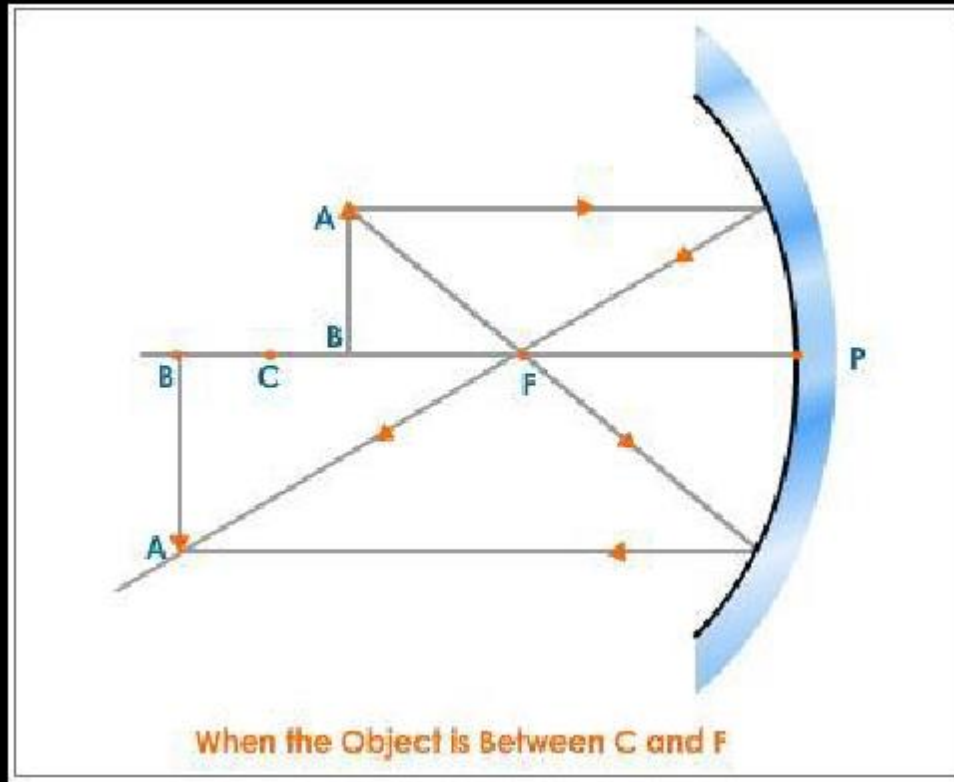
Nature: Real, inverted, enlarged image is formed beyond C

Image formation in a concave mirror & nature of the image when the object is placed:

At F

When the Object is at the Focus
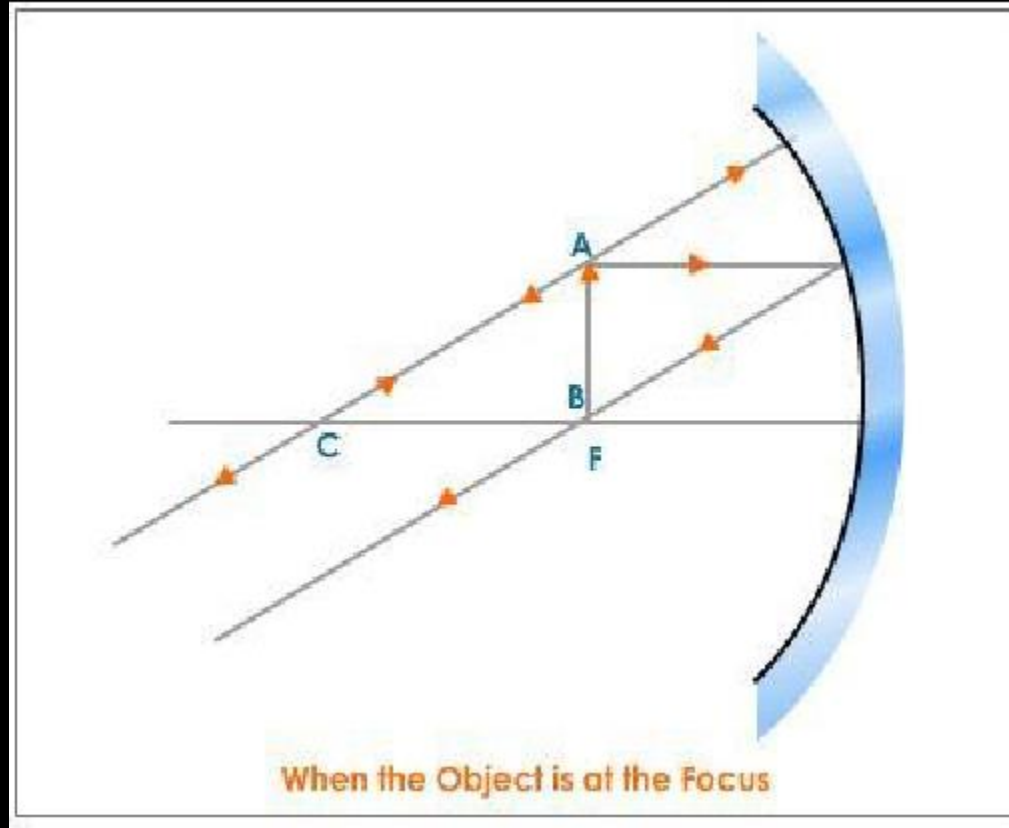
Nature: Real, inverted, highly enlarged image at infinity

Image formation in a concave mirror & nature of the image when the object is placed:

Between F and P

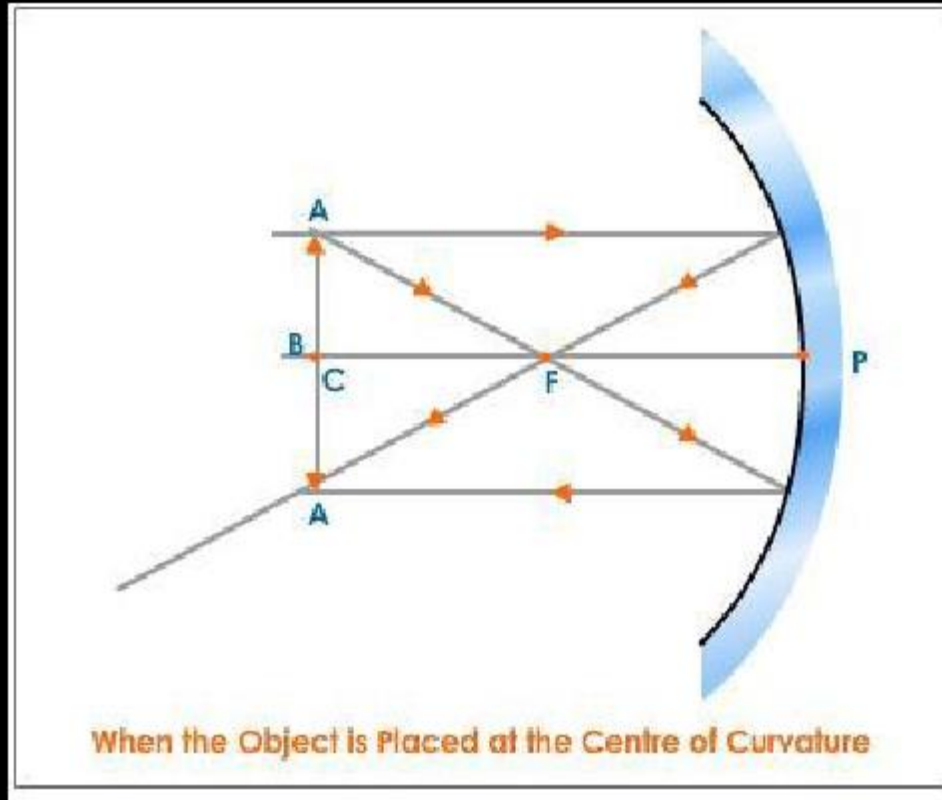When the Object is Between the Pole and the Focus
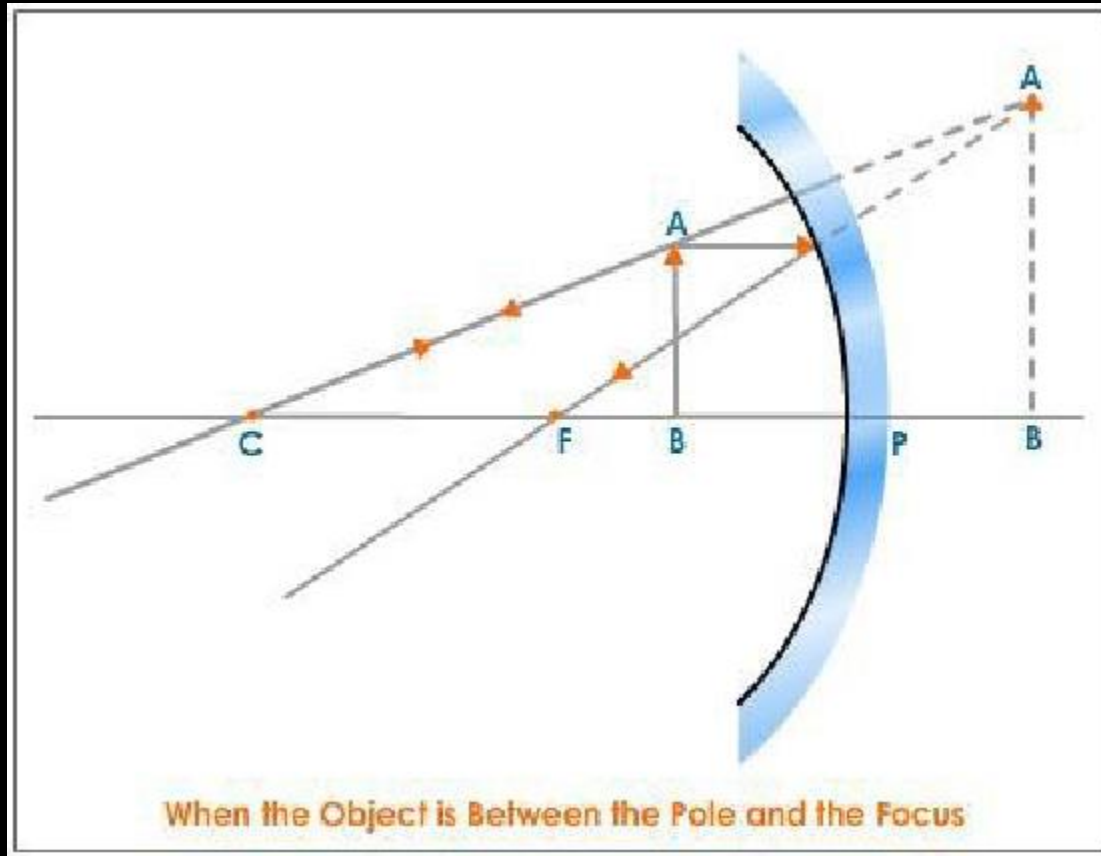
Nature: Virtual, erect, enlarged image is formed behind the mirror

Uses of concave mirror

a) Concave mirror is used in torches, search lights and vehicle headlights to get powerful parallel beam of light.

Uses of concave mirror

b) They are used in shaving mirrors to see a larger image of the face.

Uses of concave mirror

c) Dentists use concave mirrors to see large images of the teeth of patients.

Uses of concave mirror

d) Large concave mirrors are used to concentrate sunlight to produce heat in solar furnace.

Convex mirror

(Activity 10.5) Take a convex mirror. Hold it in one hand. Hold a pencil in the upright position in the other hand. Observe the image of the pencil in the mirror.

Is the image erect or inverted? Is it diminished or enlarged?

The image is erect and diminished
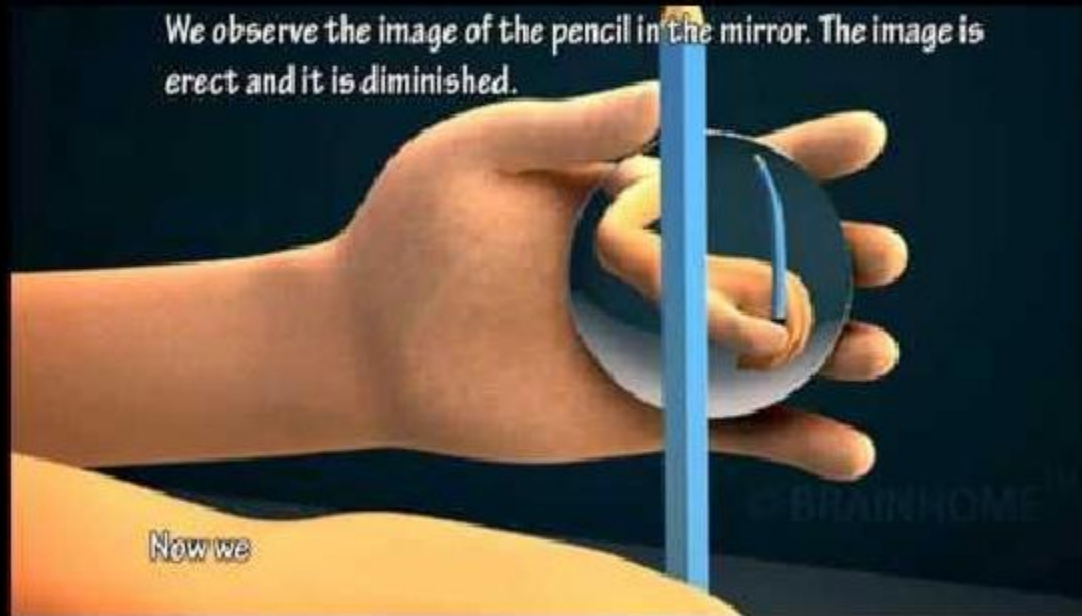
We observe the image of the pencil in the mirror. The image is erect and it is diminished.

(Activity 10.5) Take a convex mirror. Hold it in one hand. Hold a pencil in the upright position in the other hand. Observe the image of the pencil in the mirror.

Move the pencil away from the mirror slowly. Does the image become smaller or larger?

The image becomes smaller.

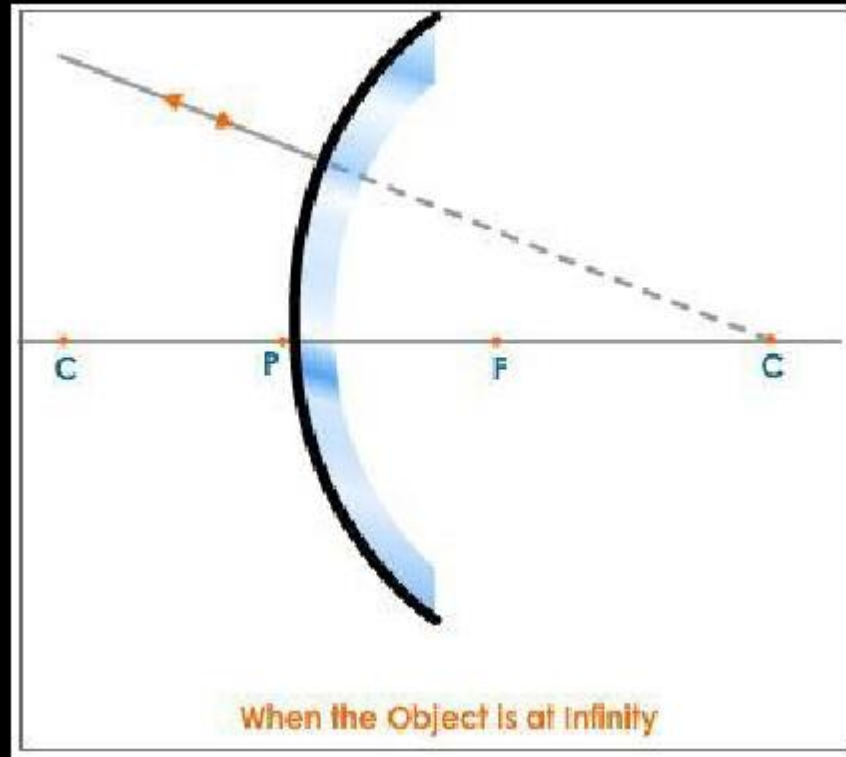State whether the image will move closer to or farther away from the focus as the object is moved away from the mirror?

The image will move closer to the focus.

Image formation in a convex mirror & nature of the image when the object is placed:

At infinity

When the Object is at Infinity

Nature: Virtual, erect, highly diminished point sized image is formed at focus F behind the mirror.

Image formation in a convex mirror & nature of the image when the object is placed:

Between infinity and the pole P the mirror

Reflected ray

Parallel ray of light

C   P   F

Convex mirror

When the Object is Placed Between Infinity and the Pole of the Mirror
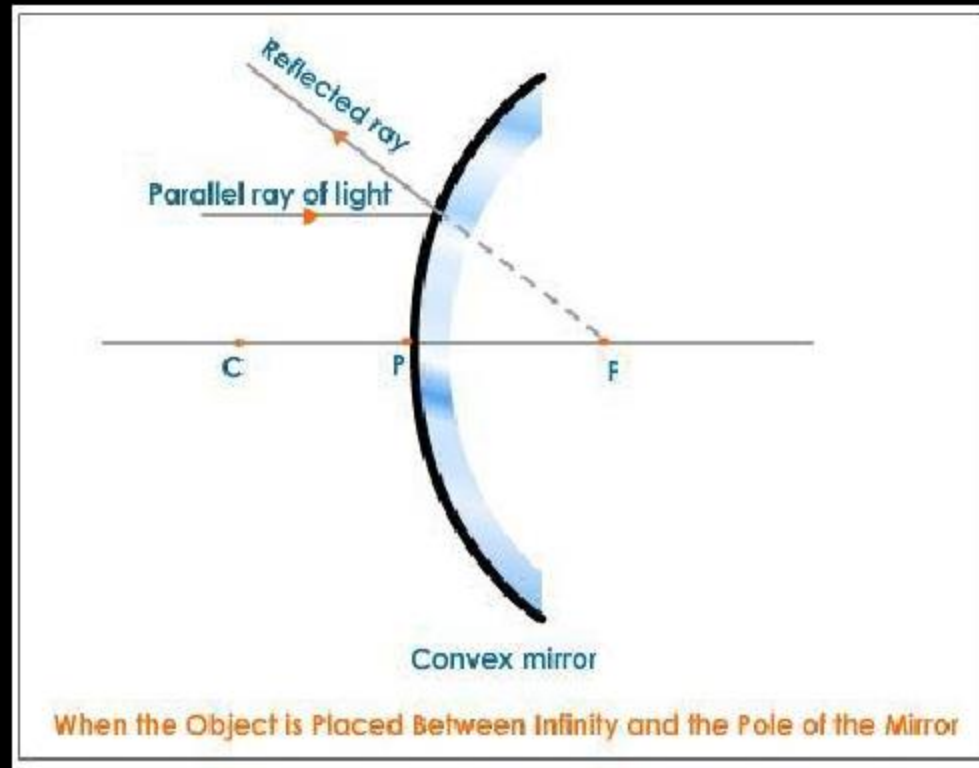
Nature: Virtual, erect, diminished image is formed between F and P behind the mirror.

(Activity 10.6) Observe the image of a distant object, say a distant tree, in a plane mirror.

Could you see a full-length image?

No, we cannot see a full-length image of a distant object in a plain mirror.

Try with plane mirrors of different sizes. Did you see the entire object in the image?

No, we cannot see a full-length image of the distant object in a plain mirror.

(Activity 10.6) Observe the image of a distant object, say a distant tree, in a plane mirror.

Repeat this Activity with a concave mirror. Did the mirror show full length image of the object?

No, we cannot see a full length image in concave mirror.

Now try using a convex mirror. Did you succeed? Explain your observations with reason.

Yes, now we could see full length image of distant object with wider field of view. The image formed was diminished, erect and virtual.
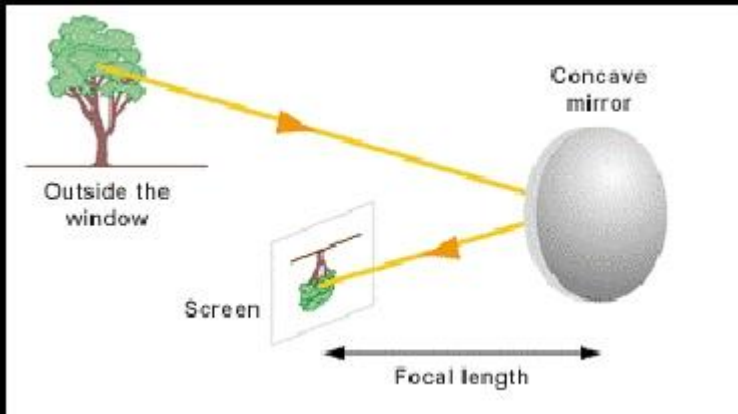
Uses of convex mirror

Convex mirror is used as rear-view mirror in vehicles.

Uses of convex mirror

Convex mirror is used as rear-view mirror in vehicles.

# Why do we prefer a convex mirror as a rear-view mirror in vehicles?

Convex mirrors are commonly used as rear-view (wing) mirrors in vehicles because they give an ~~erect, virtual, full size~~ diminished <u>image</u> of distant objects with a wider field of view. Convex mirrors enable the driver to view much larger area than would be possible with a plane mirror.

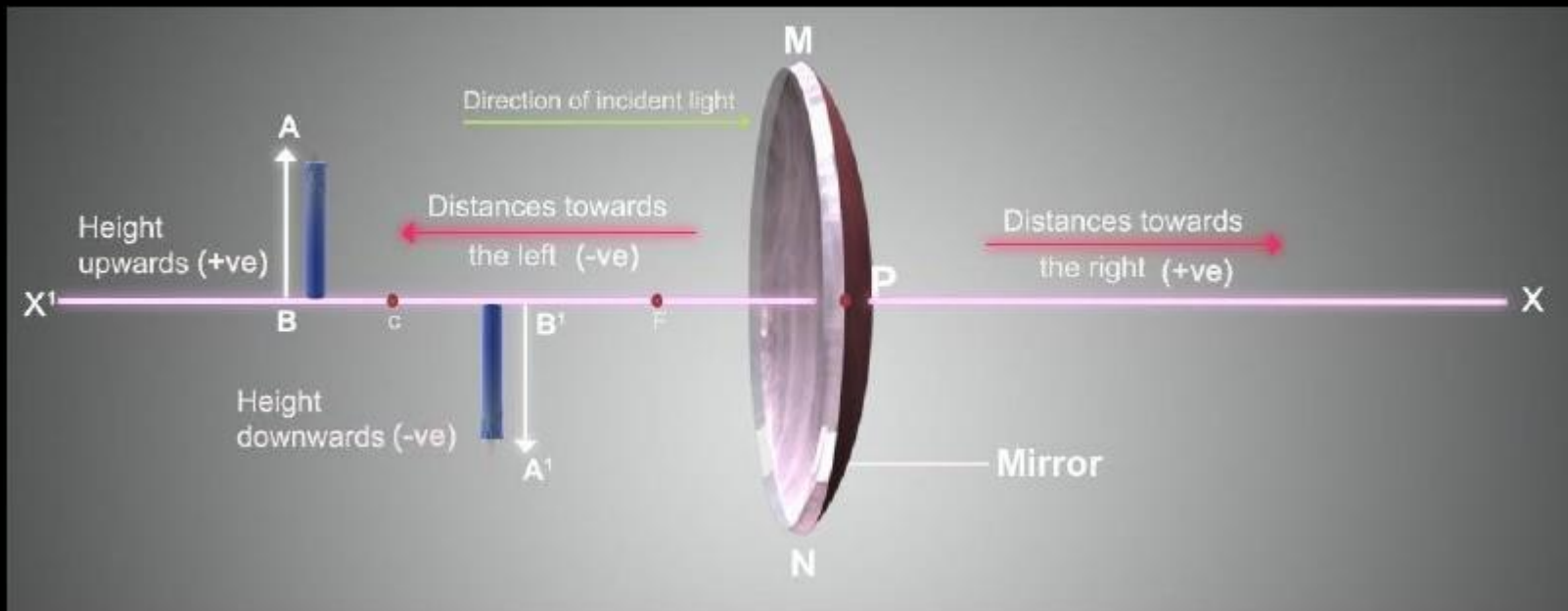# Sign Convention for Reflection by Spherical Mirror Or New Cartesian Sign Convention

a) The object is placed to the left of the mirror.
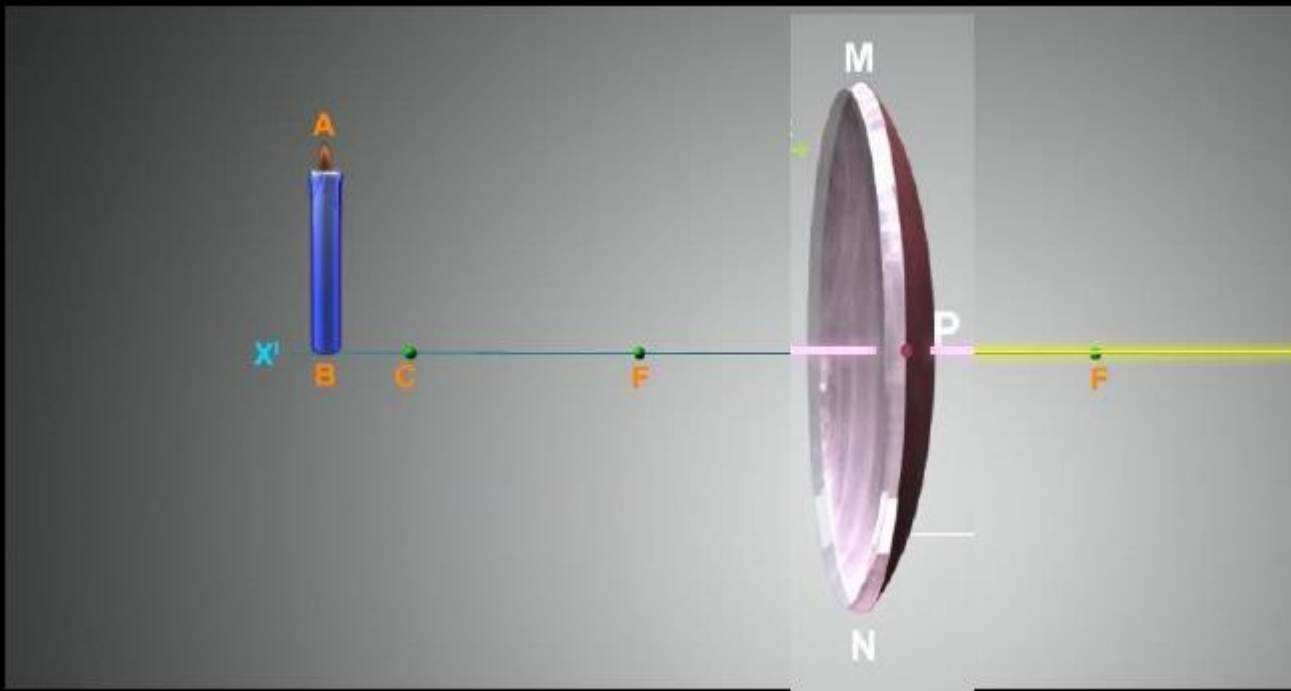
Sign Convention for Reflection by Spherical Mirror Or New Cartesian Sign Convention

b) All distances parallel to the principal axis are measured from the pole of the mirror.

Sign Convention for Reflection by Spherical Mirror Or New Cartesian Sign Convention

c) All distances measured in the direction of incident ray (along + X-axis) are taken as positive and those measured against the direction of incident ray (along – X-axis) are taken as negative.
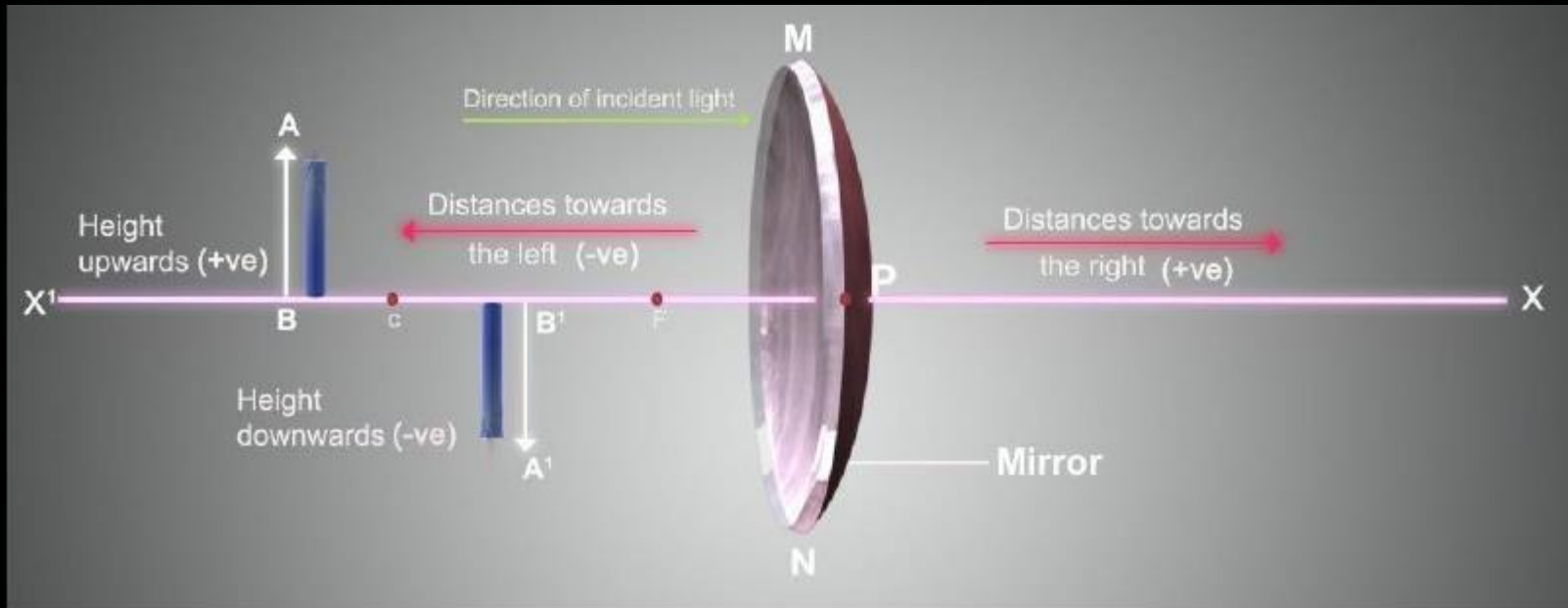
Sign Convention for Reflection by Spherical Mirror Or New Cartesian Sign Convention

d) Distance measured perpendicular to and above the principal axis are taken as positive.
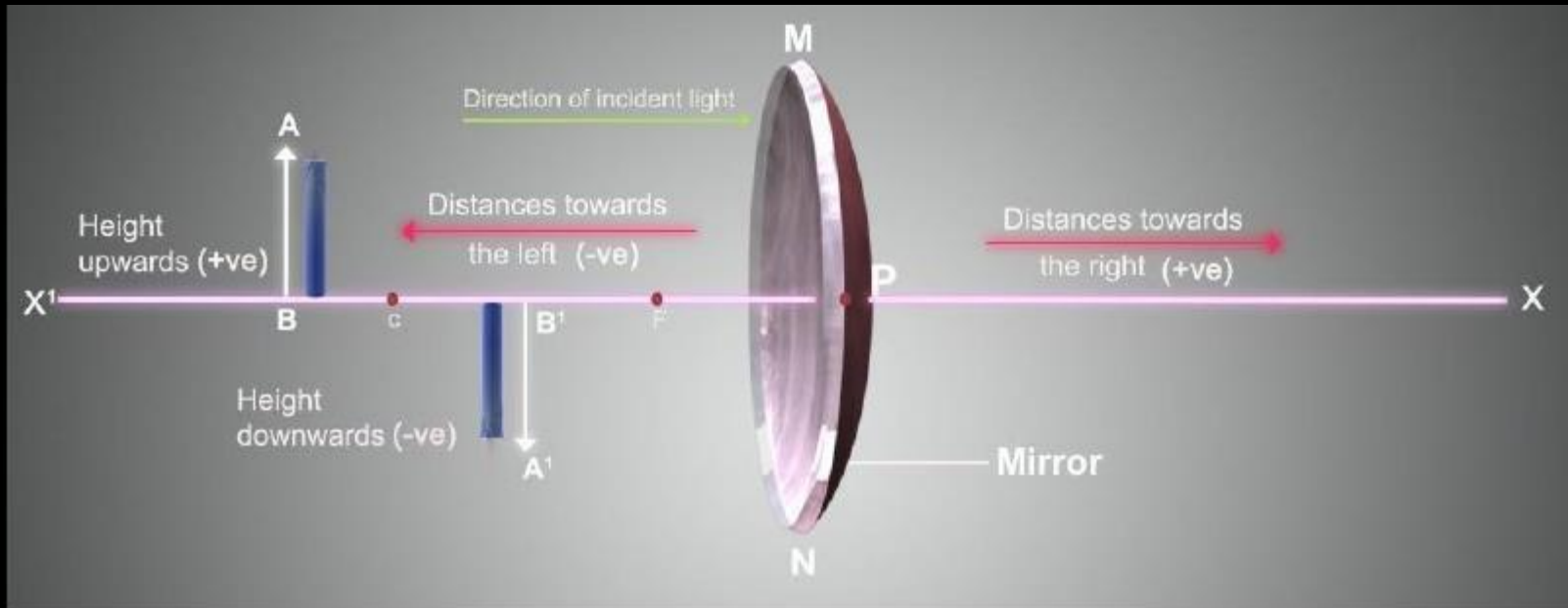
Sign Convention for Reflection by Spherical Mirror Or New Cartesian Sign Convention

e) Distances measured perpendicular to and below the principal axis are taken as negative.
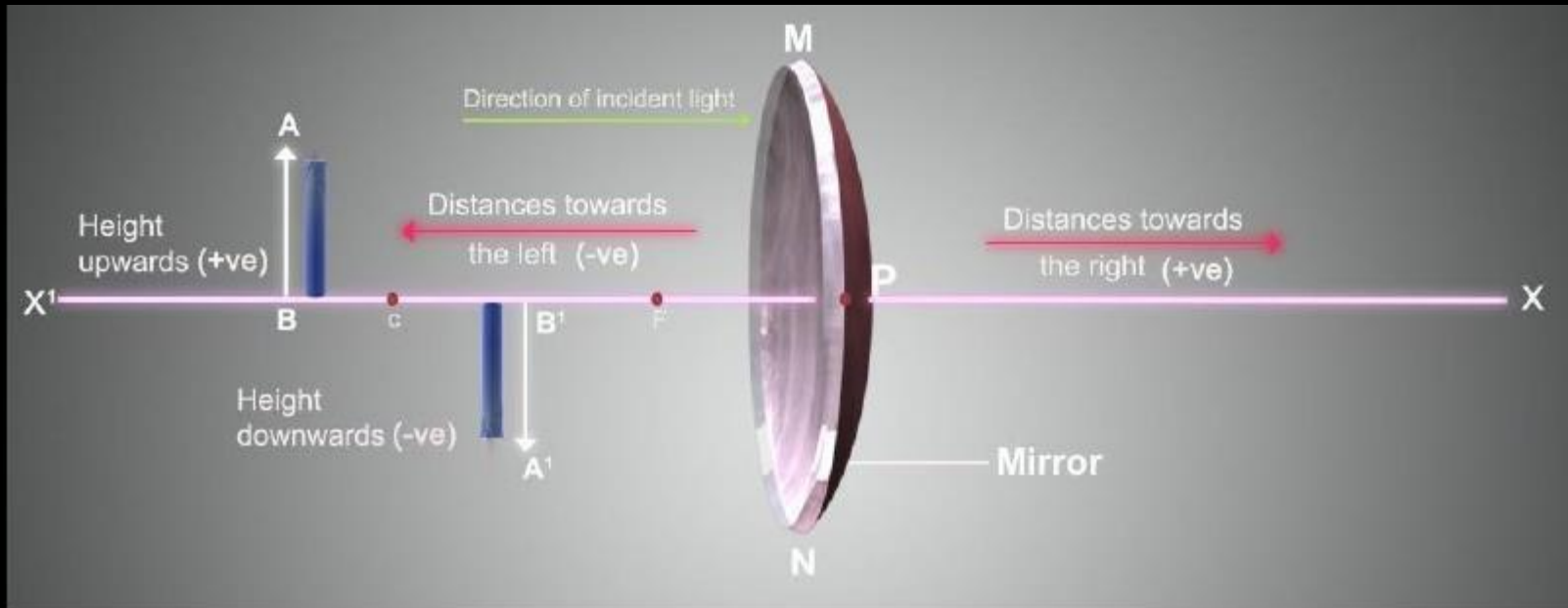
Object distance

The distance of the object from its pole is called object distance (u).
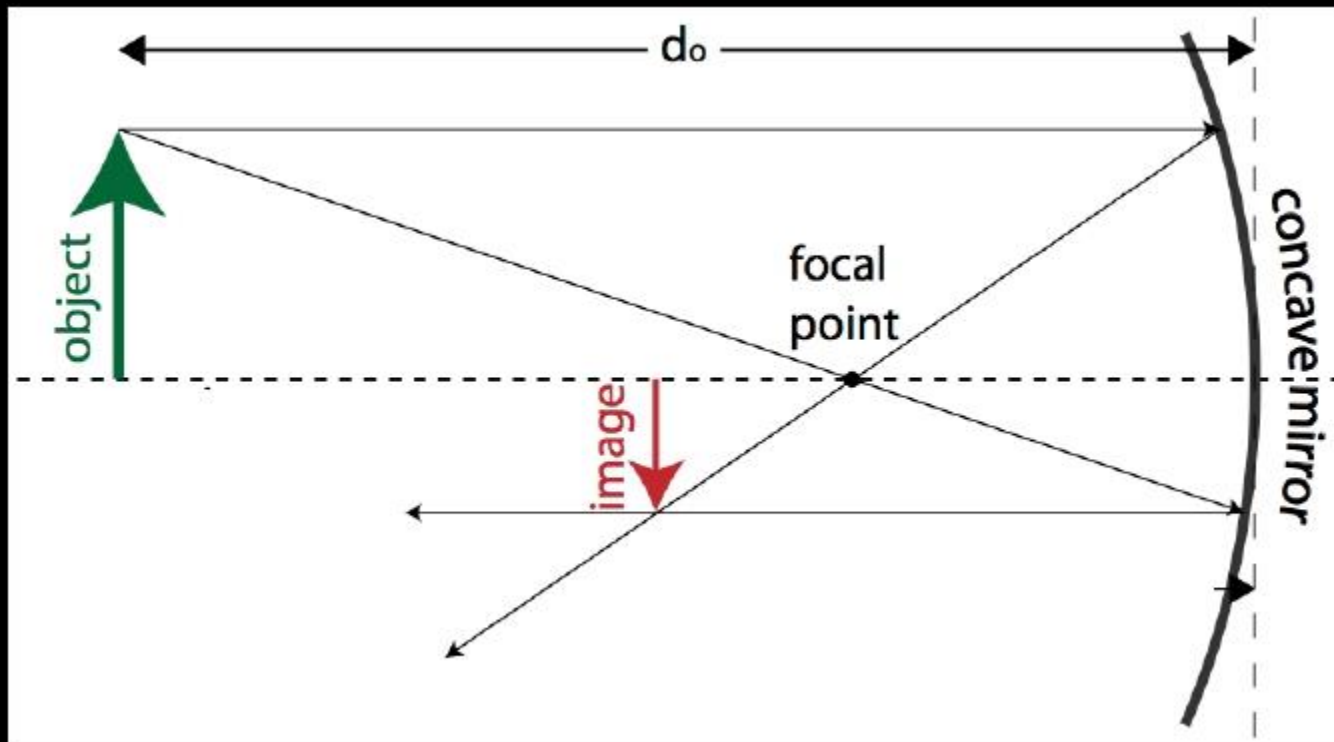
Image distance

The distance of the object from its pole is called object distance (u).
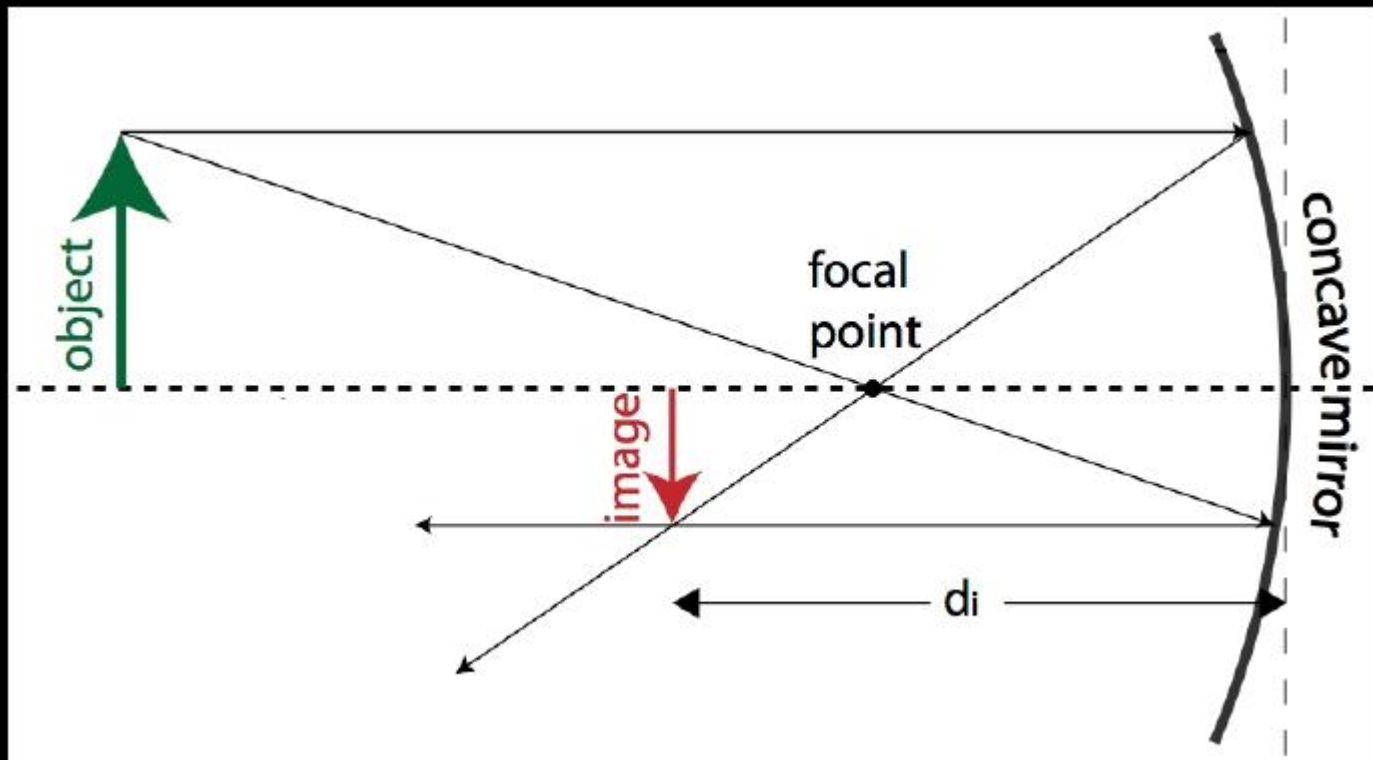
Mirror formula

$$\frac{1}{v} \quad \frac{1}{u} \quad \frac{1}{f}$$

Magnification

Magnification is the ratio of the height of the image to the height of the object.

$$m = \frac{\text{Height of the image}}{\text{Height of the object (h)}} = \frac{-v}{\text{Object distance}(u)}$$

$$\frac{h_I}{h} \qquad \frac{-v}{u}$$
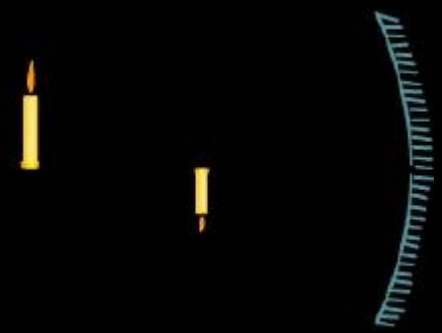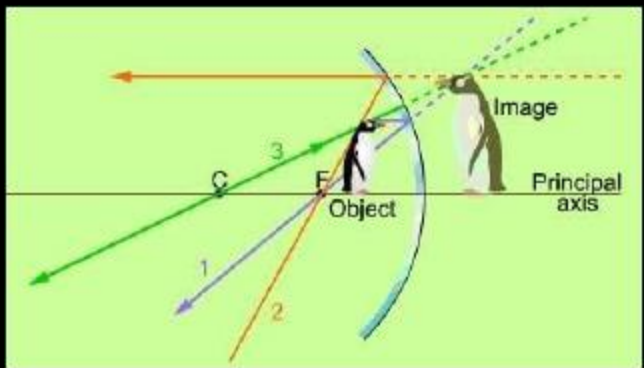
Refraction of light

What happens when light enters from one transparent medium to another?

When light travels from one transparent medium to another medium, it tends to change its directions.
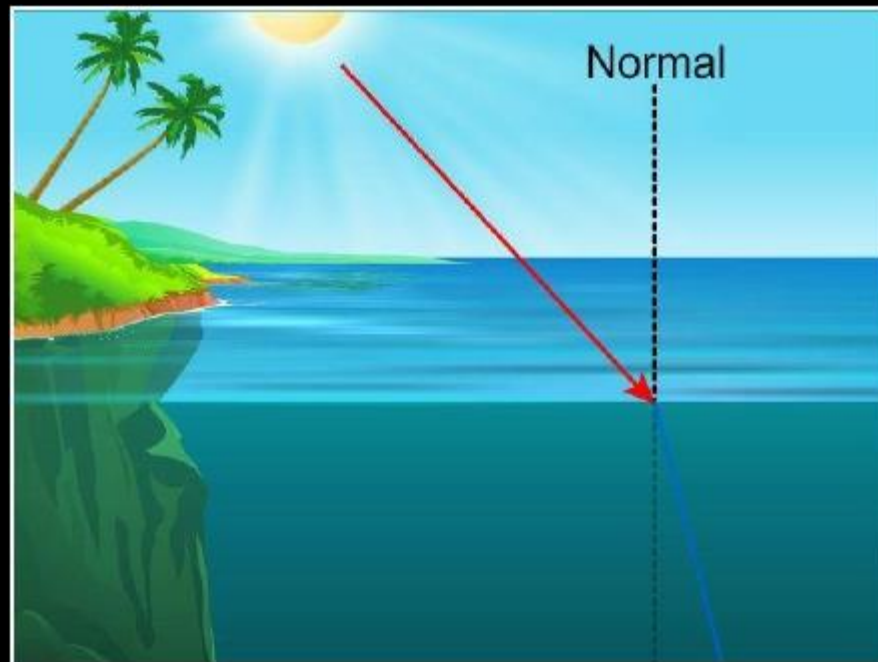
Why does the bottom of a tank or a pond containing water appears to be raised?

This is due to the refraction. The light rays pass through the air-water interface, they get bent due to refraction. The light rays are bent away from the normal making us perceive the bottom of the pond or tank as shallow or raised.
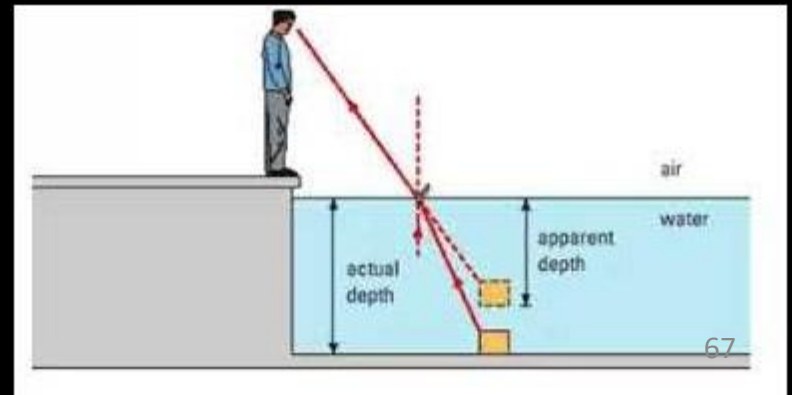
Why does a thick glass slab placed over some printed matter, the letters appear raised when viewed through the glass slab?

The letters appear raised because of a phenomenon known as refraction. When light travels from one medium to another, it bends (either towards or away from the normal). This happens because different media have different densities and thus, the speed of light is different in each one of them. This causes the light to slow down or speed up, depending on the medium.

Why does a lemon kept in water in a glass tumbler appears to be bigger than its actual size, when viewed from the sides.

Light is refracted as it passes from water into air. Tumbler with water acts as convex lens which curves outward in the middle and can focus light rays to magnify object.

A pencil partly immersed in water in a glass tumbler appears to be displaced at the interface of air and water.

The light reaching the eye from the portion of the pencil inside water seems to come from a different direction, compared to the part above water. This makes the pencil appear to be displaced at the interface.

Refraction of light

The change in direction of light when it passes from one medium to another obliquely is called refraction of light.

(Activity 10.7) Place a coin at the bottom of a bucket filled with water. With your eye to a side above water, try to pick up the coin in one go.

Did you succeed in picking up the coin?

No

Repeat the Activity. Why did you not succeed in doing it in one go?
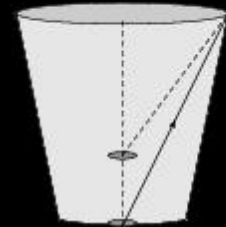
Because on seeing, the coin appeared to be closer than its actual distance, so we are likely to miss the coin. Reflected light coming from the submerged coin in denser medium of water, on entering air which is a rarer medium, bend away from the normal due to refraction of light and image size becomes larger than its actual size, thus submerged object apparently seem closer.

(Activity 10.8) Place a large shallow bowl on a Table and put a coin in it. Move away slowly from the bowl. Stop when the coin just disappears from your sight. Ask a friend to pour water gently into the bowl without disturbing the coin. Keep looking for the coin from your position. Does the coin becomes visible again from your position? How could this happen?

Yes, on pouring water into the bowl, the coin becomes visible again because due to refraction of light, for our eyes, the submerged coin apparently seems raised above its actual level and thus becomes visible on seeing from the same side and distance.

(Activity 10.9) Draw a thick straight line in ink, over a sheet of white paper placed on a Table. Place a glass slab over the line in such a way that one of its edges makes an angle with the line.

Look at the portion of the line under the slab from the sides. What do you observe? Does the line under the glass slab appear to be bent at the edges?

Yes, due to the refraction of light, the line under the glass slab appear to be bent at the edges

(Activity 10.9) Draw a thick straight line in ink, over a sheet of white paper placed on a Table. Place a glass slab over the line in such a way that one of its edges makes an angle with the line.

Next, place the glass slab such that it is normal to the line. What do you observe now? Does the part of the line under the glass slab appear bent?

No, now the part of the line under the glass slab appear in a straight line. Because a ray of light, which is perpendicular to the plain of a refracting medium, does not change its angle due to refraction.

(Activity 10.9) Draw a thick straight line in ink, over a sheet of white paper placed on a Table. Place a glass slab over the line in such a way that one of its edges makes an angle with the line.

Look at the line from the top of the glass slab. Does the part of the line, beneath the slab, appear to be raised? Why does this happen?

Yes, the part of the line, beneath the slab, appear to be raised. Due to refraction of light, apparent position of image of object seems nearer than its actual position.

Fix a sheet of white paper on a drawing board using drawing pins. Place a rectangular glass slab over the sheet in the middle. Draw the outline of the slab with a pencil. Let us name the outline as ABCD. Take four identical pins.

Fix two pins, say E and F, vertically such that the line joining the pins is inclined to the edge AB. Look for the images of the pins E and F through the opposite edge. Fix two other pins, say G and H, such that these pins and the images of E and F lie on a straight line. Remove the pins and the slab. Join the positions of tip of the pins E and F and produce the line up to AB. Let EF meet AB at O. Similarly, join the positions of tip of the pins G and H and produce it up to the edge CD. Let HG meet CD at O'. Join O and O'. Also produce EF up to P

Fix a sheet of white paper on a drawing board using drawing pins. Place a rectangular glass slab over the sheet in the middle. Draw the outline of the slab with a pencil. Let us name the outline as ABCD. Take four identical pins.

Question 1. What happens to incident ray as it enters the glass slab?

The incident ray as it enters from a rarer medium of air to a denser medium of glass, bends towards the normal, due to refraction of light. The refraction is caused by change in the speed of light as it enters from one transparent medium to another.

Fix a sheet of white paper on a drawing board using drawing pins. Place a rectangular glass slab over the sheet in the middle. Draw the outline of the slab with a pencil. Let us name the outline as ABCD. Take four identical pins.

Question 2. What happens to emergent ray as it leaves the glass slab?

The emergent ray as it leaves the denser medium of glass and enters into a rarer medium of air, bends away from the normal, due to refraction of light. The refraction is caused by change in the speed of light as it enters from one transparent medium to another.

Fix a sheet of white paper on a drawing board using drawing pins. Place a rectangular glass slab over the sheet in the middle. Draw the outline of the slab with a pencil. Let us name the outline as ABCD. Take four identical pins.

Question 3. What is the perpendicular distance between directions of incident and emergent rays?

Lateral displacement. This gives a measure of path deviation of refracted rays due to refraction.

Fix a sheet of white paper on a drawing board using drawing pins. Place a rectangular glass slab over the sheet in the middle. Draw the outline of the slab with a pencil. Let us name the outline as ABCD. Take four identical pins.

Question 4. As given in the activity above, the medium of incidence and emergent ray is same (air), what could be the possible observations for angle of incidence and angle of emergence?

When the medium of incidence and emergent ray is same (air), angle of incidence is equal to angle of emergence.

Laws of Refraction of light

(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.
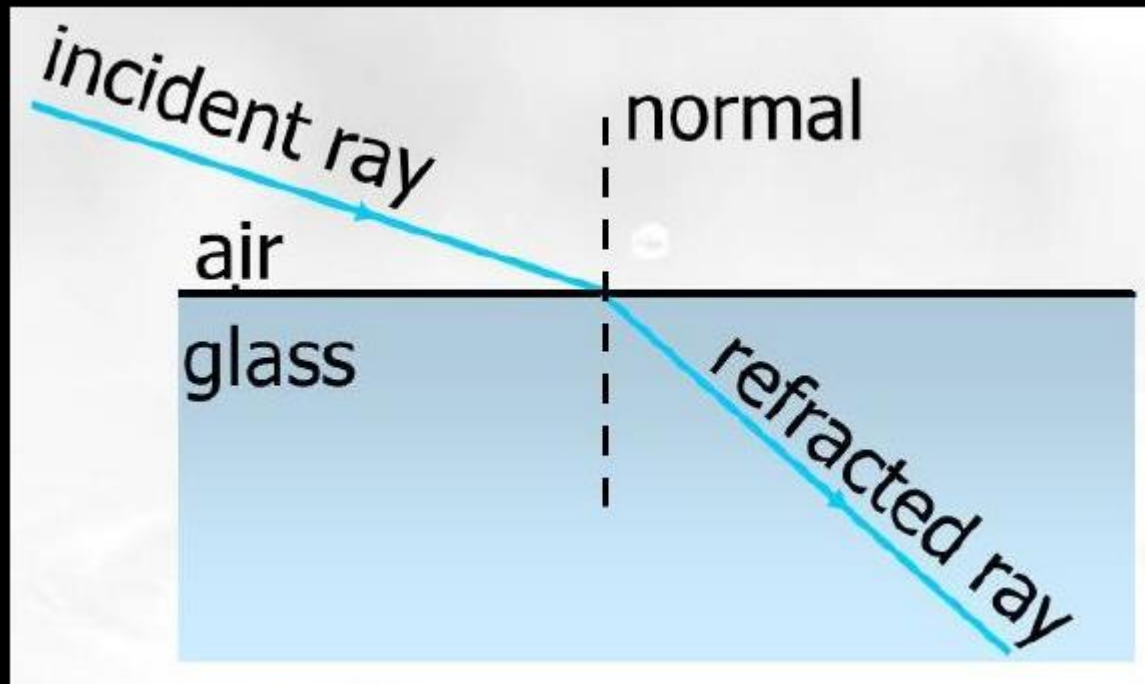
Laws of Refraction of light

(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.
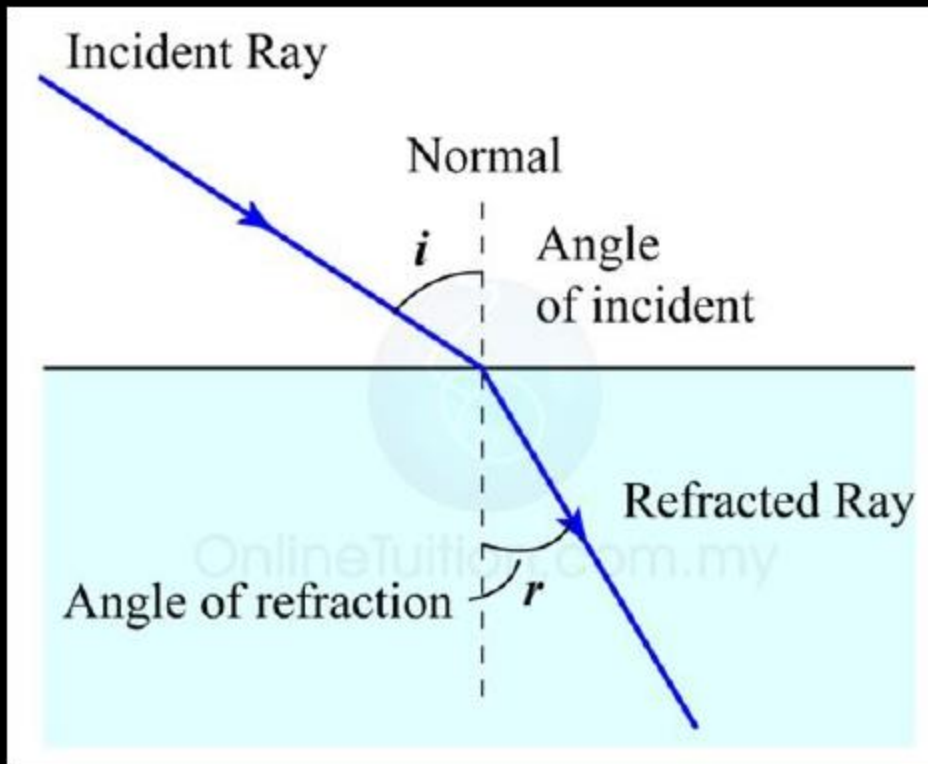
$$n = \frac{\sin i}{\sin r}$$

n = refractive Index
i = angle of incident
r = angle of refraction

Refractive index

The refractive index of a medium is defined as the ratio of speed of light in vacuum to the speed of light in the medium. It is represented by n.

Absolute Refractive index

Refractive index of a medium with respect to vacuum or air.

Refractive index of water is 1.33 – Write the meaning of the statement.

This means that the ratio of the speed of light in air and the speed of light in water is equal to 1.33.

When is a medium said to be optically denser?

The medium with the larger refractive index is optically denser medium.

When is a medium said to be optically rarer?

The medium with the lower refractive index is optically rarer medium.

Lateral shift

The perpendicular distance between the direction of the incident ray and emergent ray is called lateral shift.
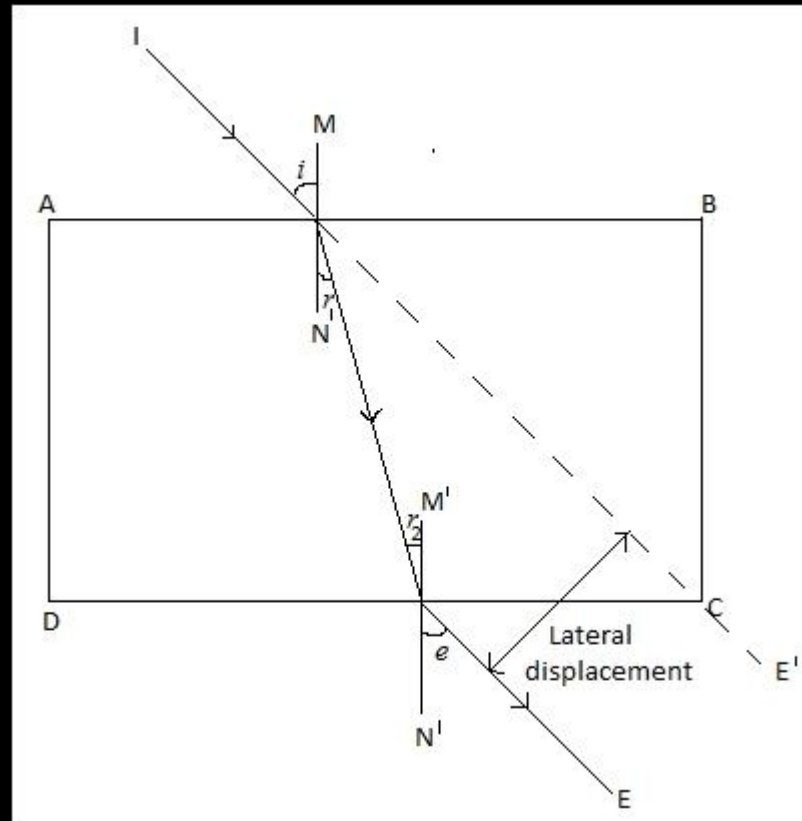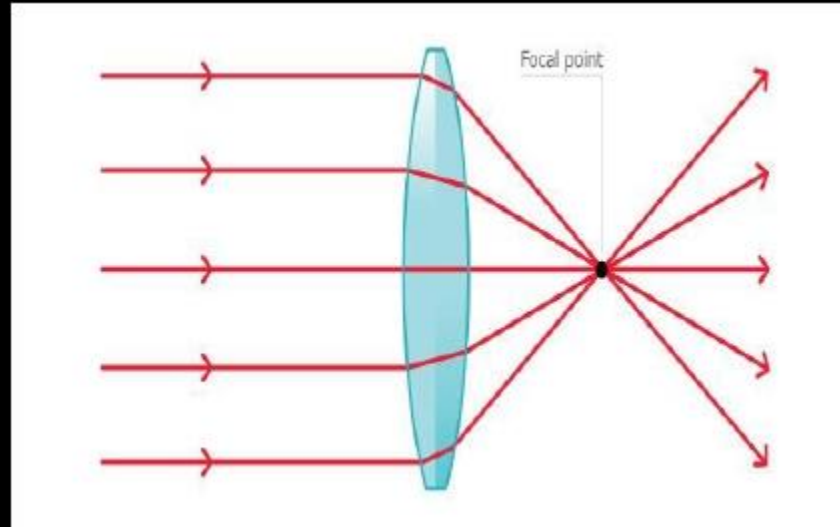
Lens

Lens

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

Biconvex   Plano-convex   Convex-concave   Meniscus   Plano-concave   Biconcave
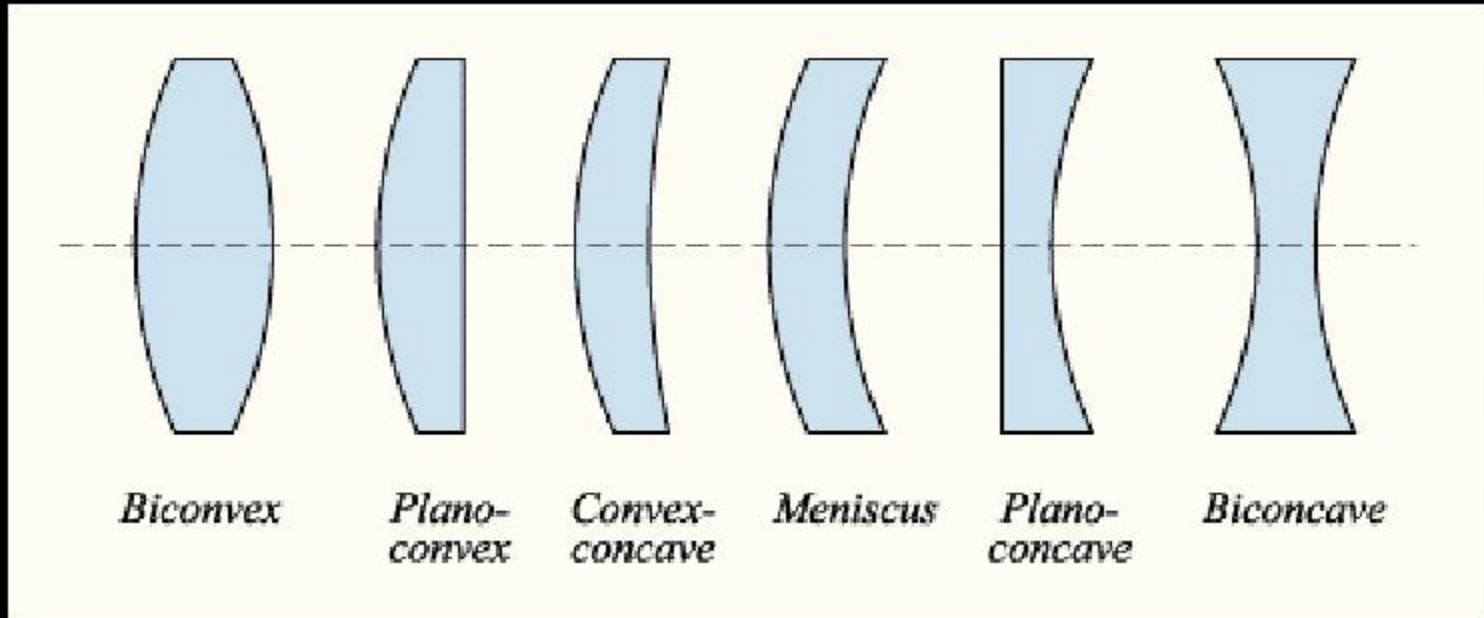
Convex Lens

A lens having two spherical surfaces, bulging outwards is called a double convex lens or a convex lens. It is thicker at the middle and thinner at the edges. It is also called as converging lens.
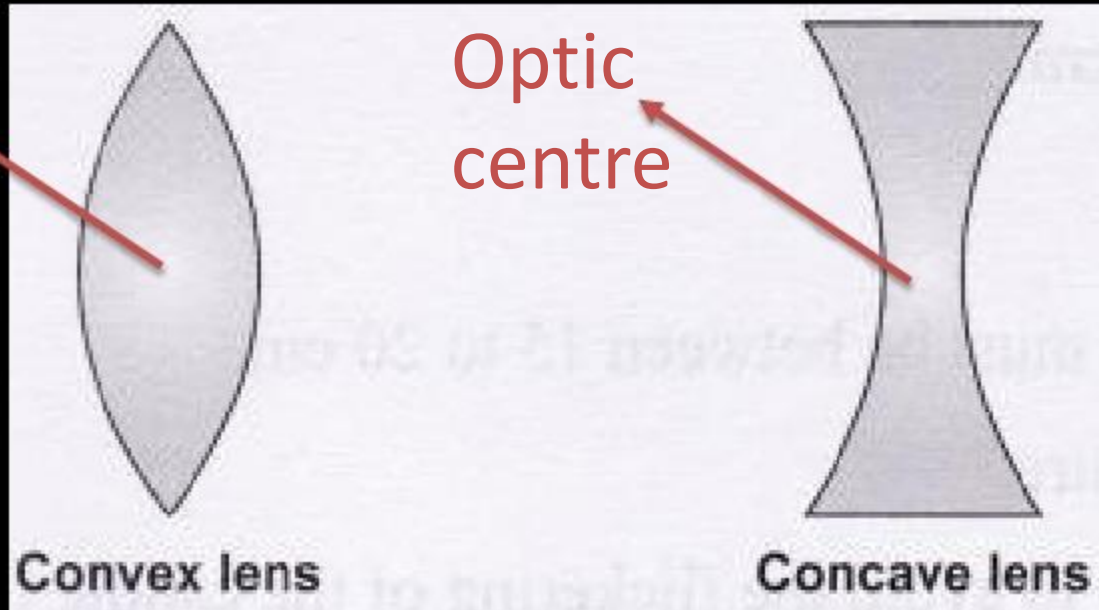
Concave Lens

A lens which is bounded by two spherical surfaces, curved inwards is called concave lens. It is thicker in the edges and thinner in the middle. It is also called diverging lens.

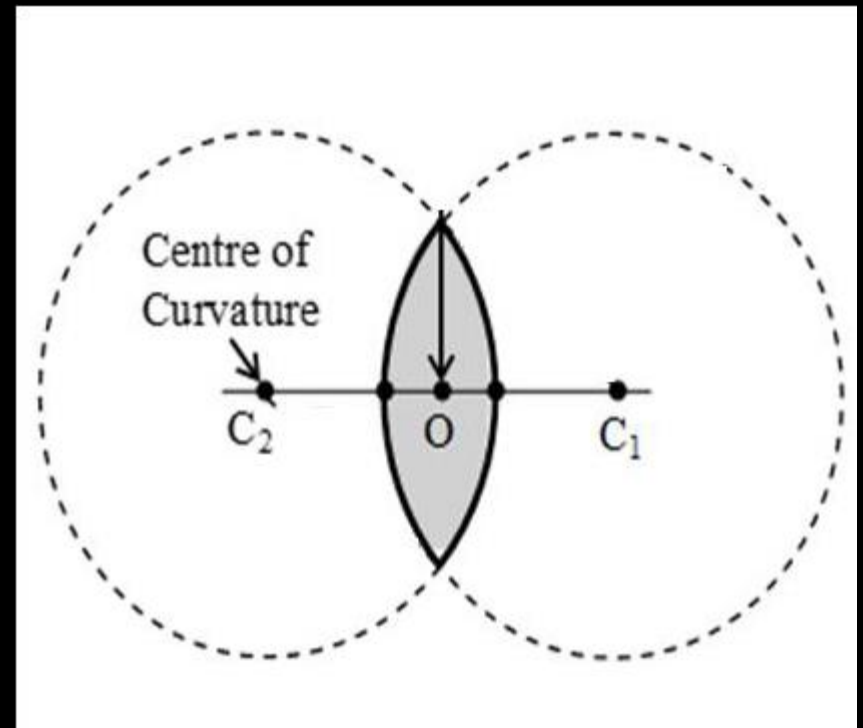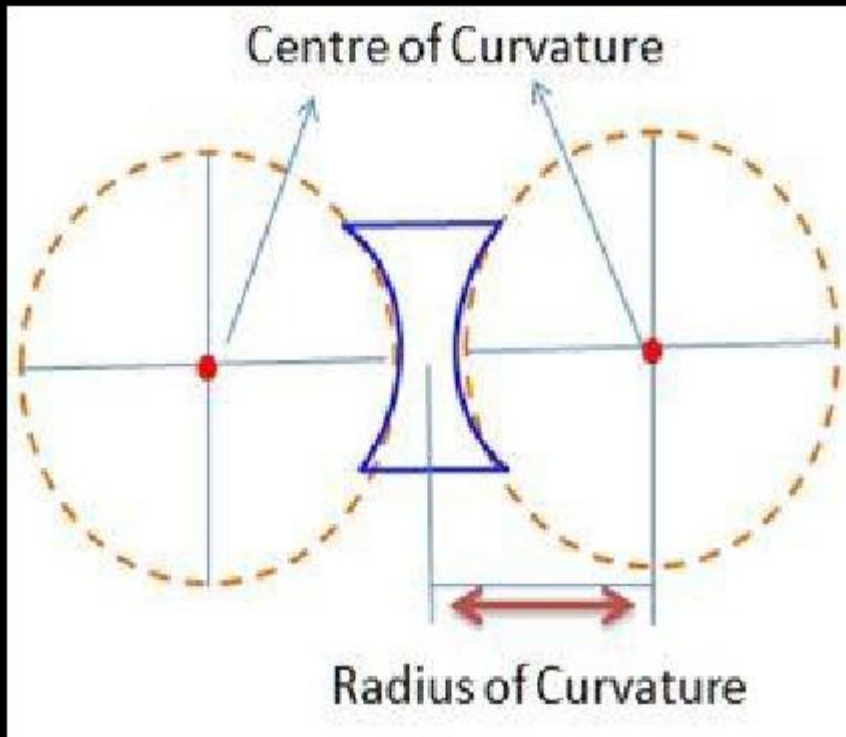Concave lens
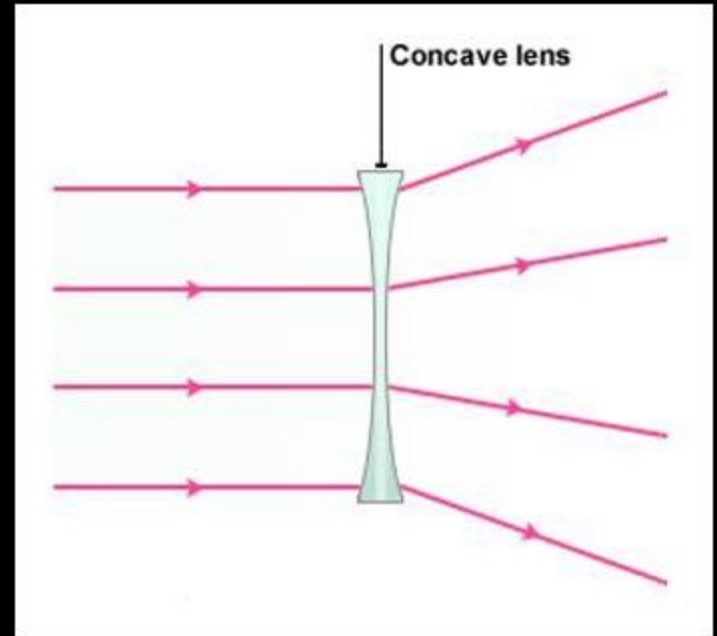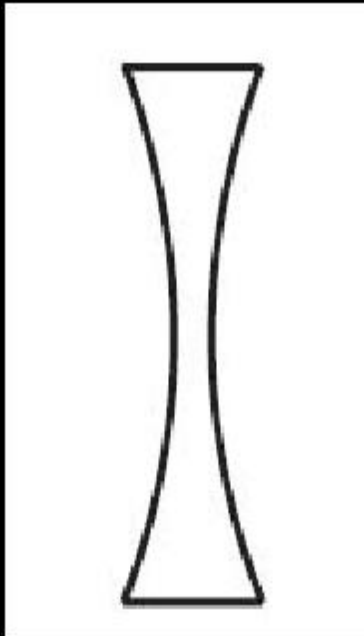
Optic centre of the lens

The centre point of a lens is called the optic centre.

Optic centre

Optic centre

Convex lens

Concave lens

Centre of curvature

The centre of the spheres of which the lens forms a part.

Centre of Curvature
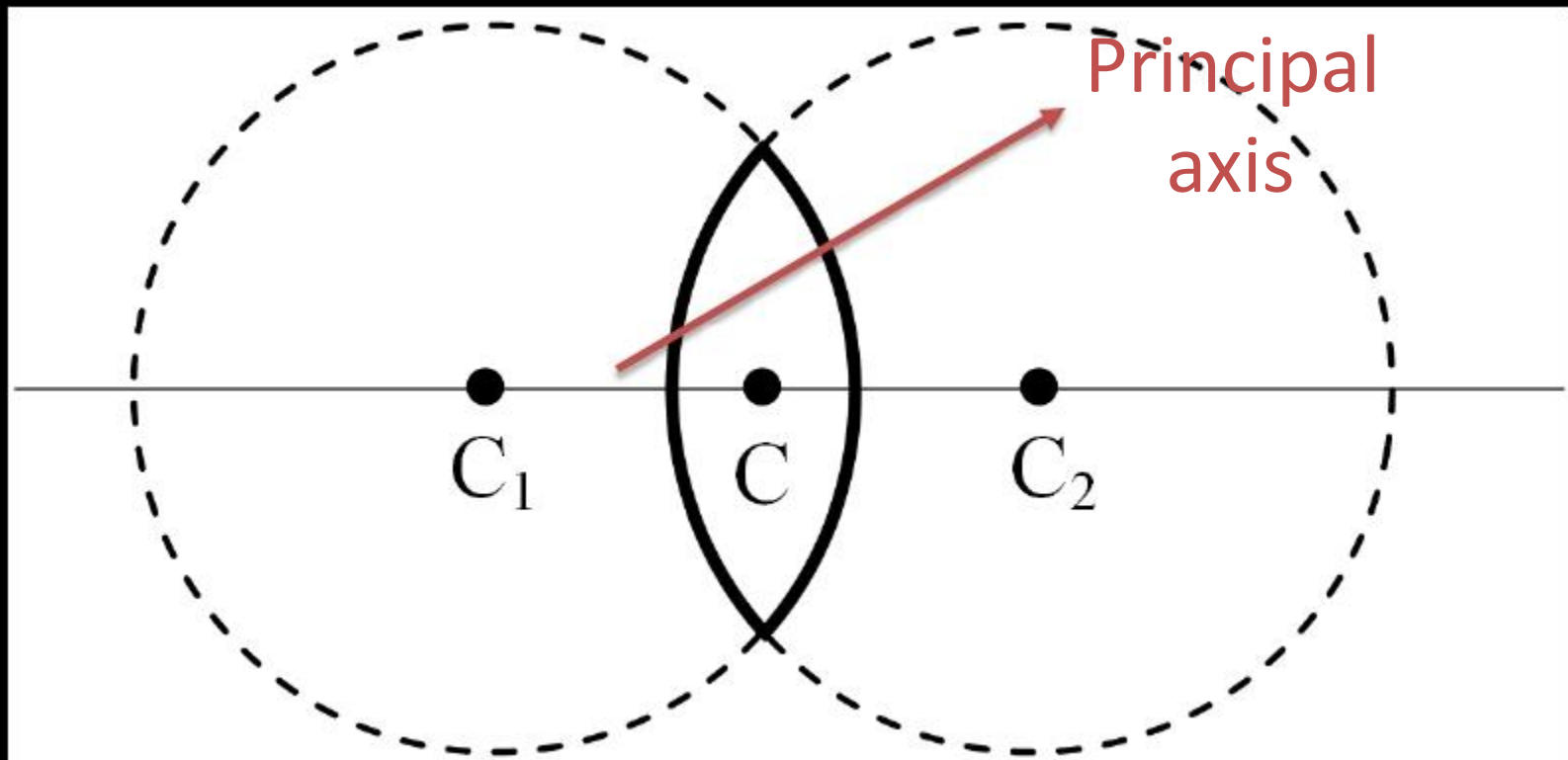
Radius of Curvature

Centre of
Curvature

C_2 O C_1

Radius of curvature

The radius of the sphere of which lens forms a part is called the radius of curvature of the lens.

Radius of curvature
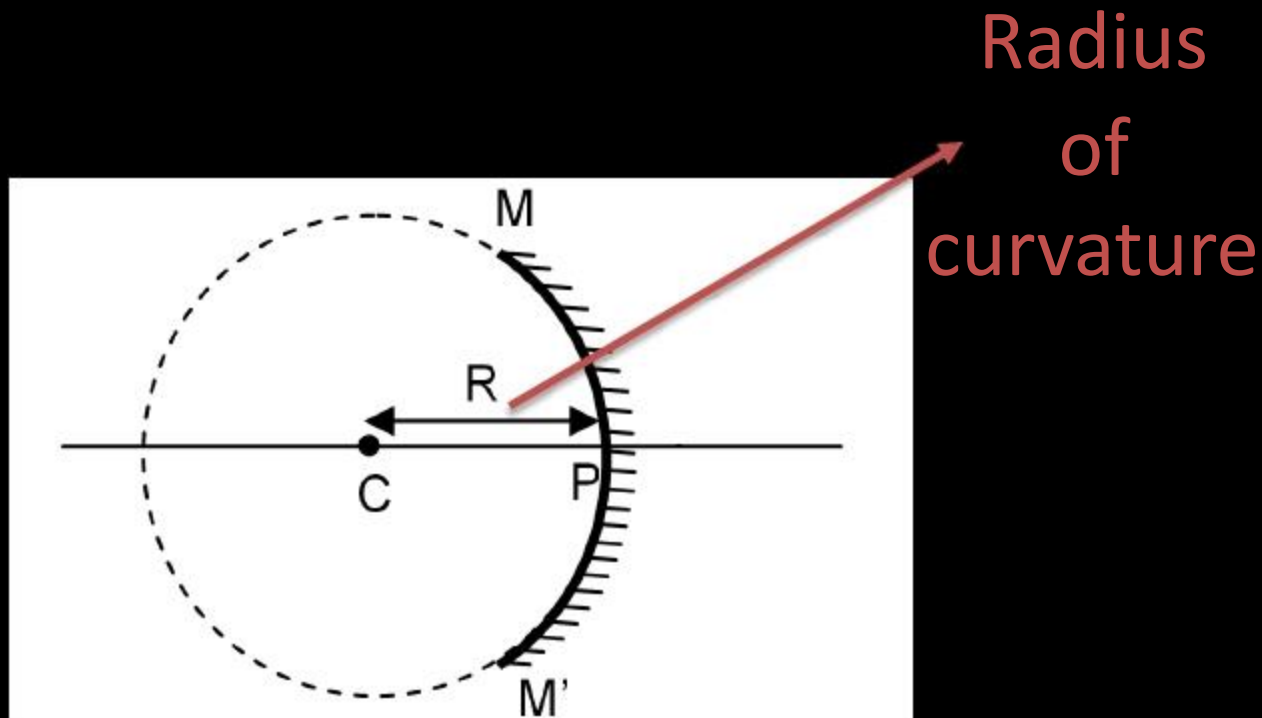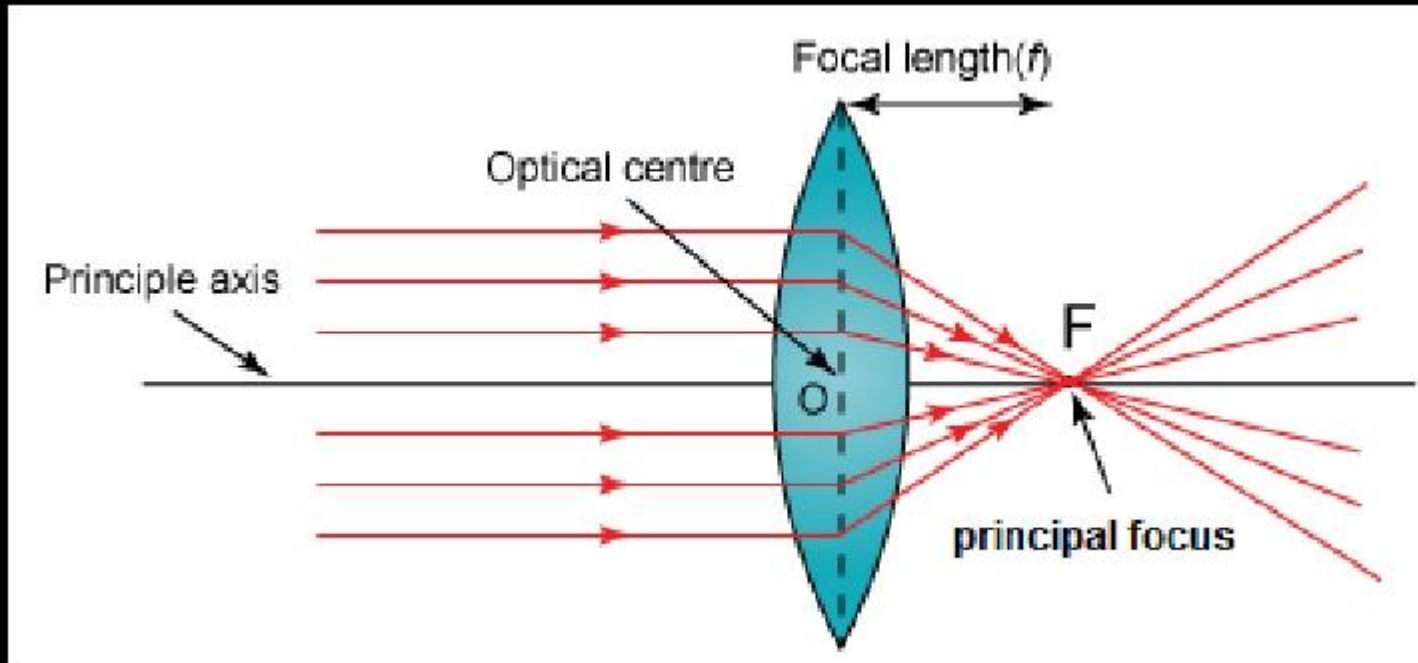
Principal axis

The imaginary straight line passing through the two centres of curvature is called principal axis.
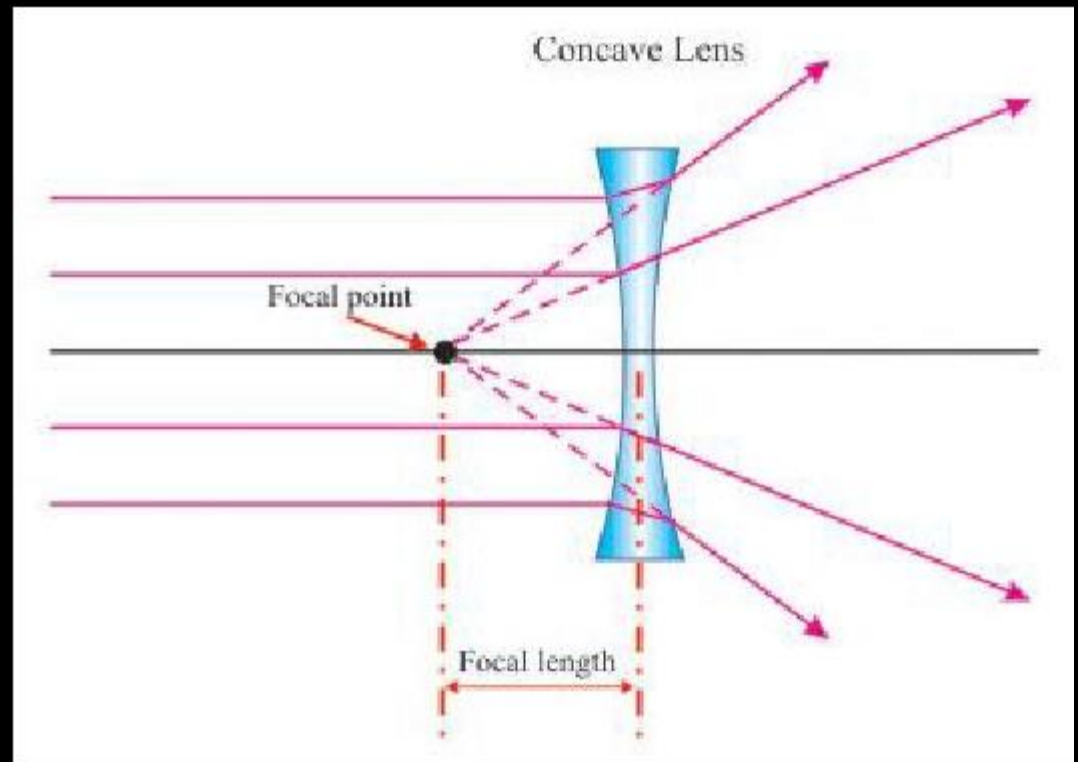

Principal axis

Principal focus of convex lens

The point on principal axis where all the parallel light rays after refraction actually meet at a point called focus (F).
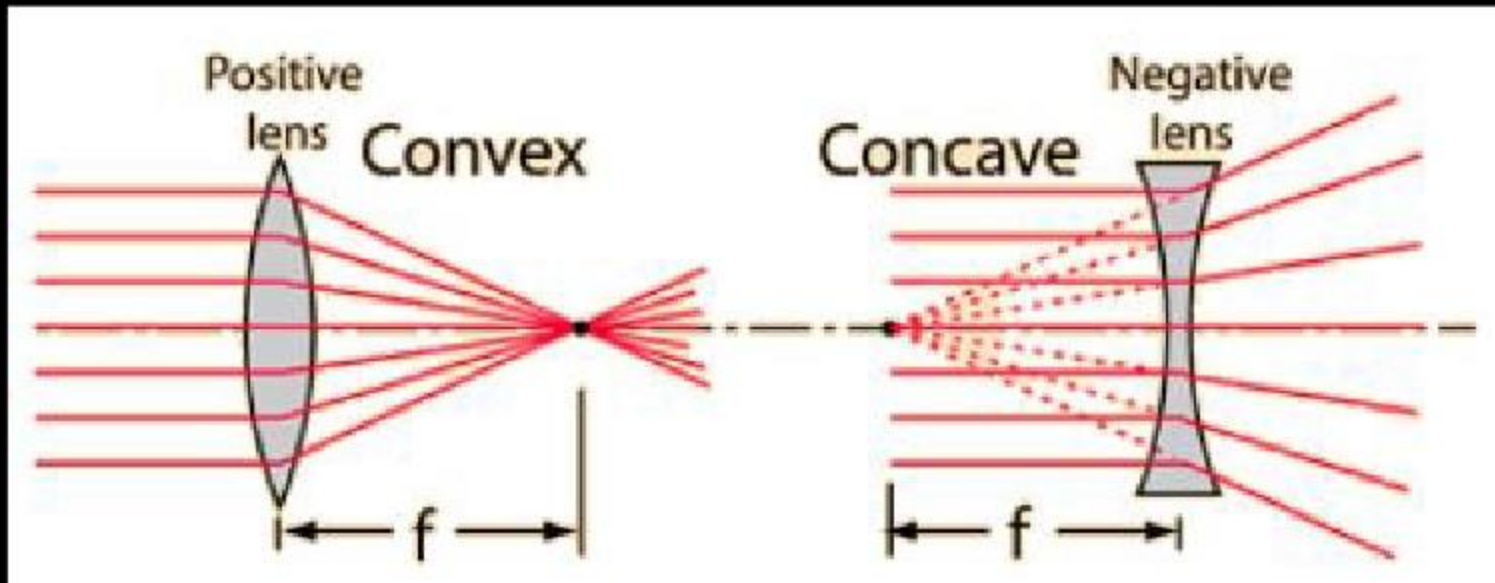
Principal focus of concave lens

The point on principal axis where all the parallel light rays after refraction appear to meet at a point called focus(F).
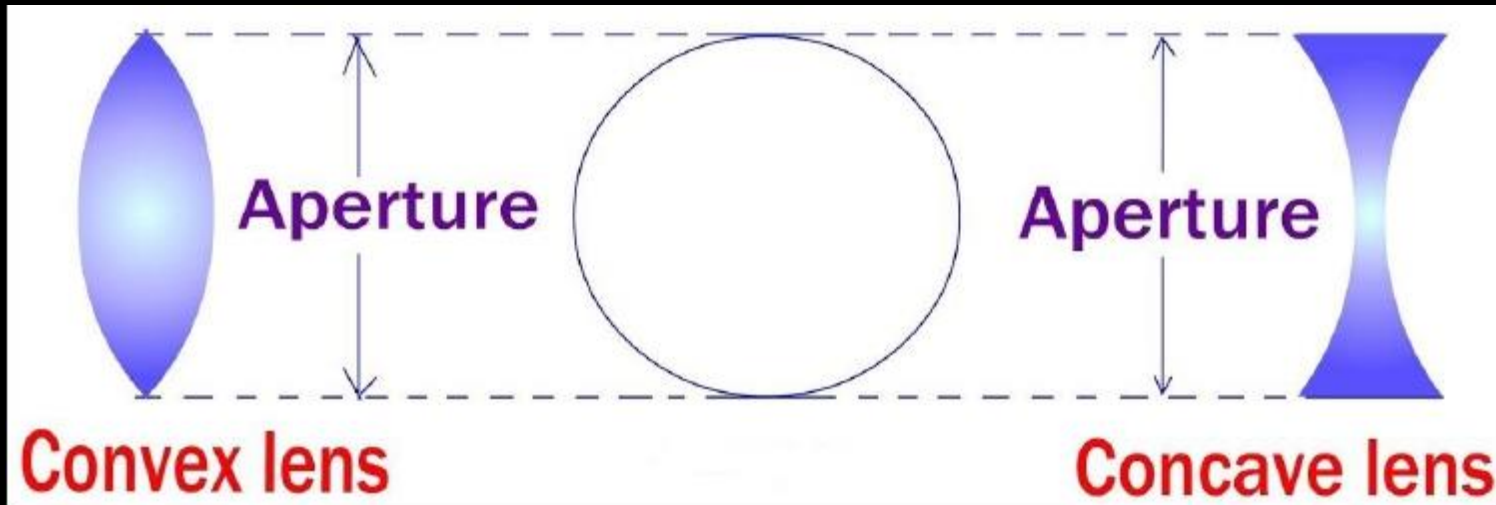

Concave Lens

Focal point

Focal length

Focal length

The distance of the principal focus from the optical centre of the lens is called focal length (f).

Aperture

The diameter of the circular outline of a lens is called aperture.

(Activity 10.11) Hold a convex lens in your hand. Direct it towards the Sun. Focus the light from the Sun on a sheet of paper. Obtain a sharp bright image of the Sun. Hold the paper and the lens in the same position for a while. Keep observing the paper. What happened? Why?

The paper begins to burn producing smoke. If we still hold the paper and the lens in the same position for some more time, the paper may even catch fire.

The parallel rays of light from the sun are converged by the lens at the sharp bright spot formed on the paper. The concentration of the sunlight at a point generated heat. The bright spot is the real image of the sun.

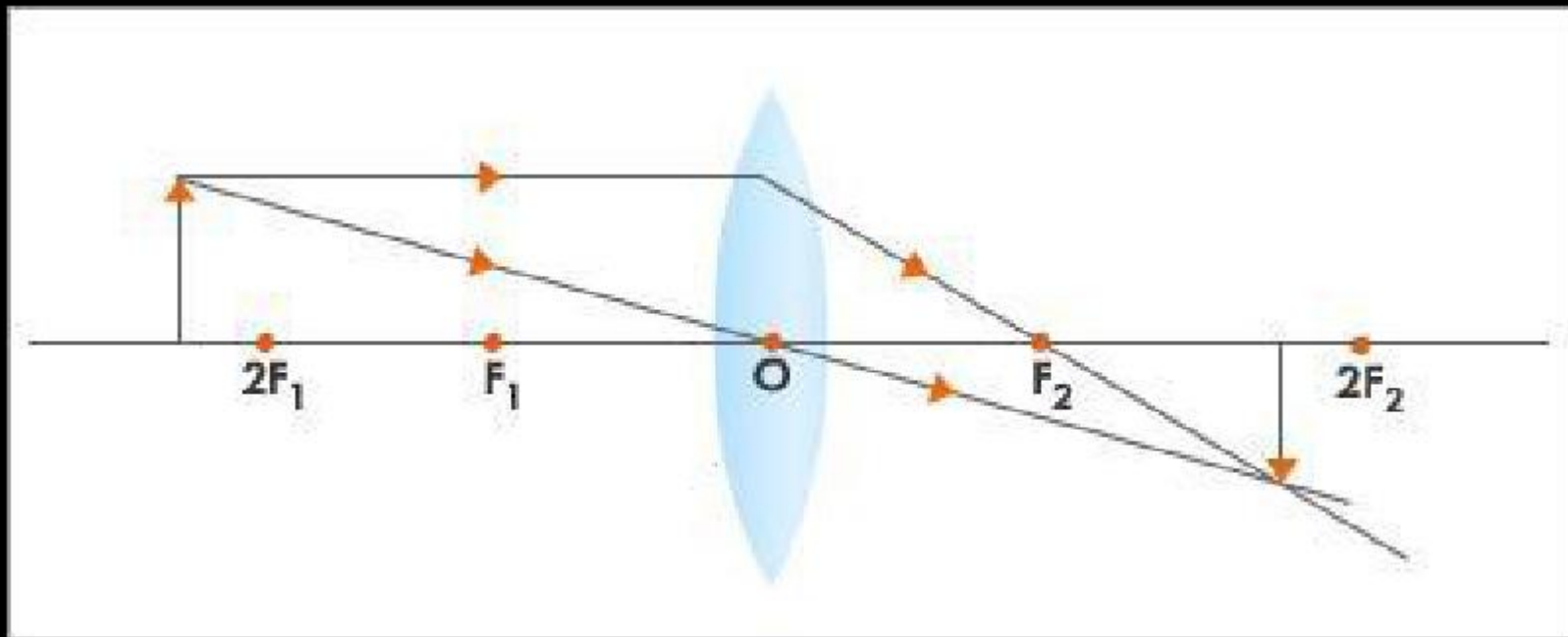# Image formation in a convex lens & nature of the image when the object is placed:

At infinity
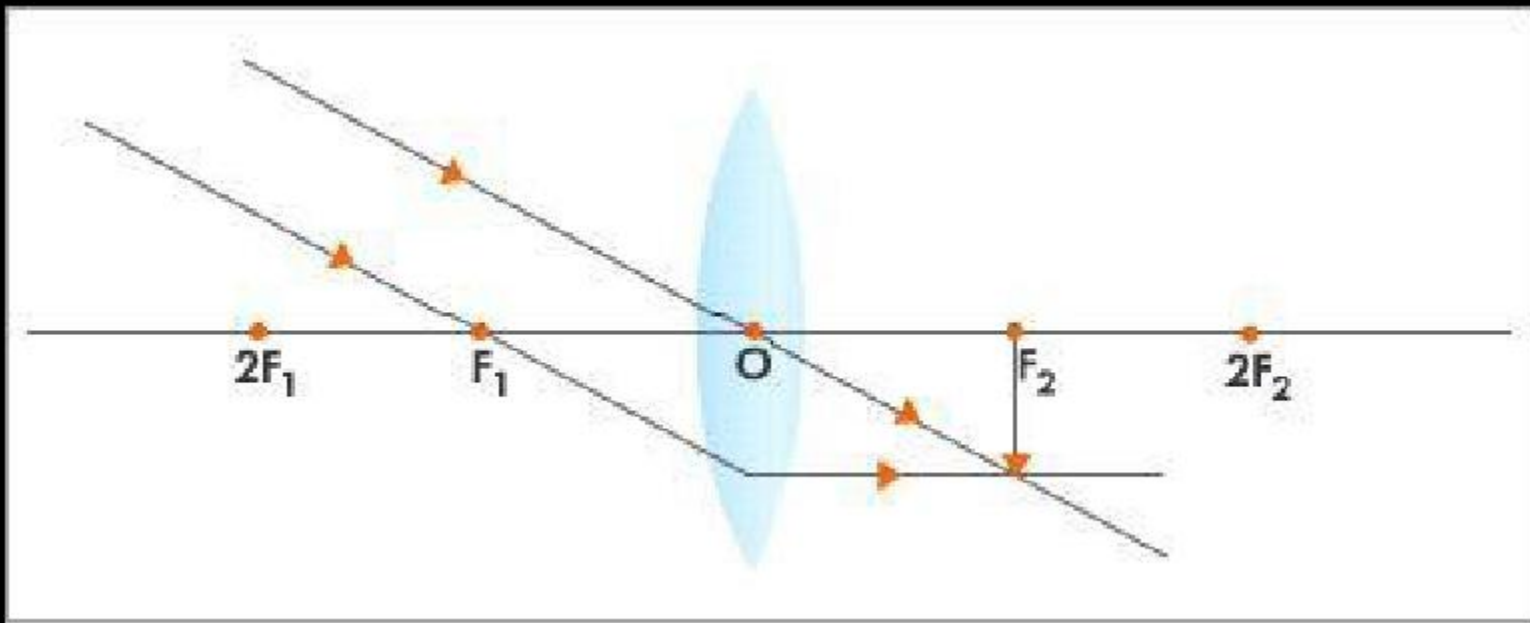
Nature: Real, inverted, highly diminished image is formed at F2.

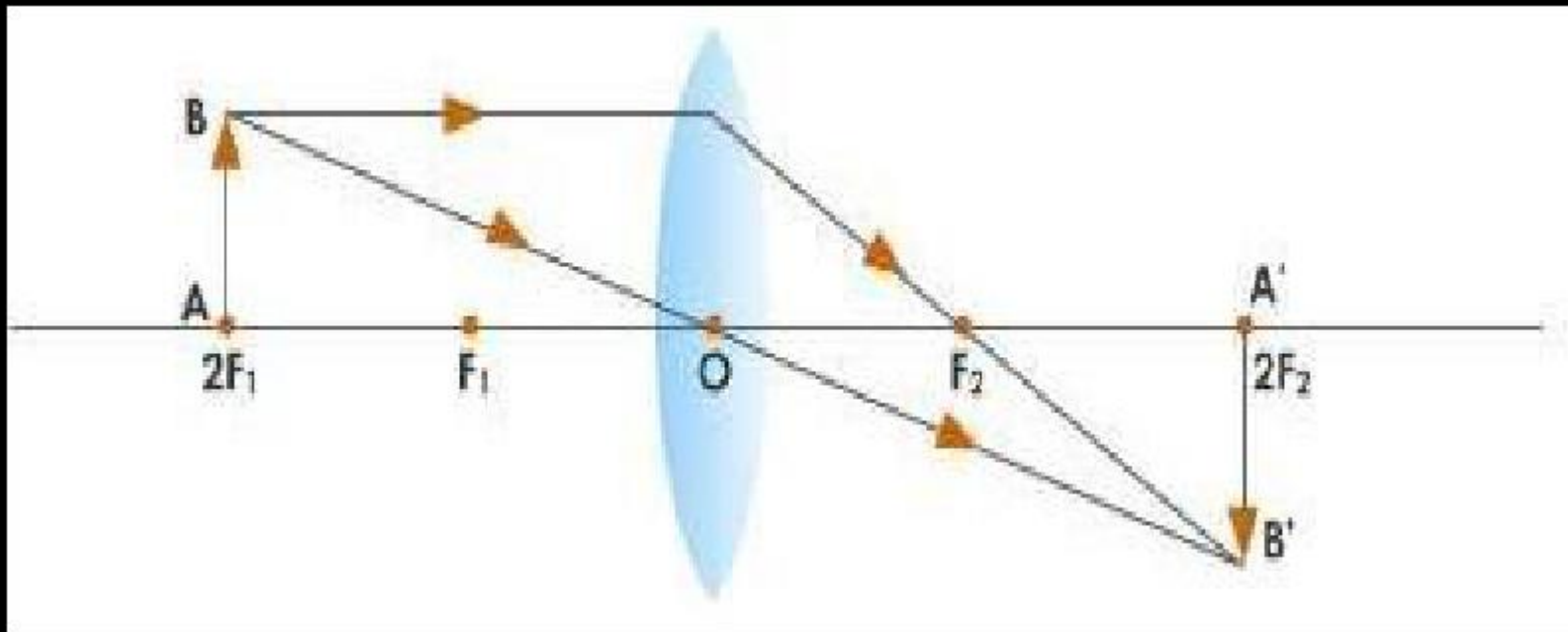# Image formation in a convex lens & nature of the image when the object is placed:

Beyond 2F1

Nature: Real, inverted, diminished image is formed between F2 and 2F2.

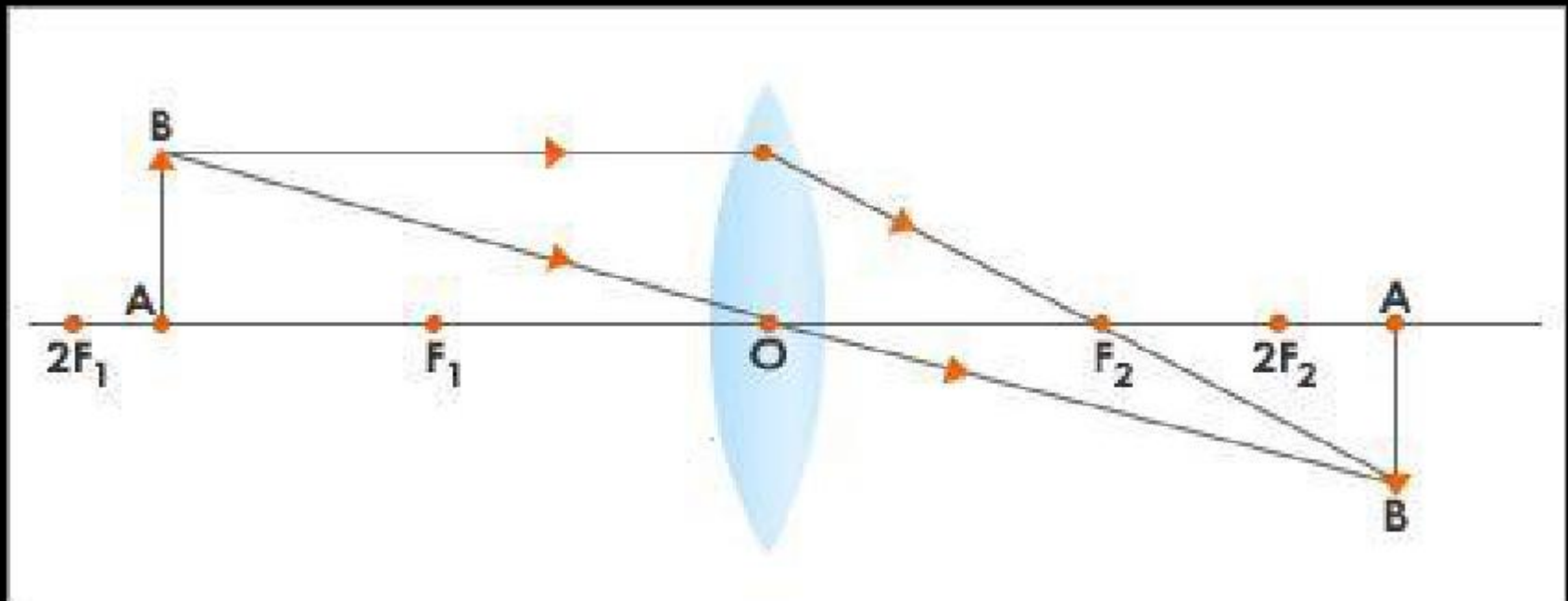# Image formation in a convex lens & nature of the image when the object is placed:

At 2F1

Nature: Real, inverted, same size image is formed at 2F2.

Image formation in a convex lens & nature of the image when the object is placed:

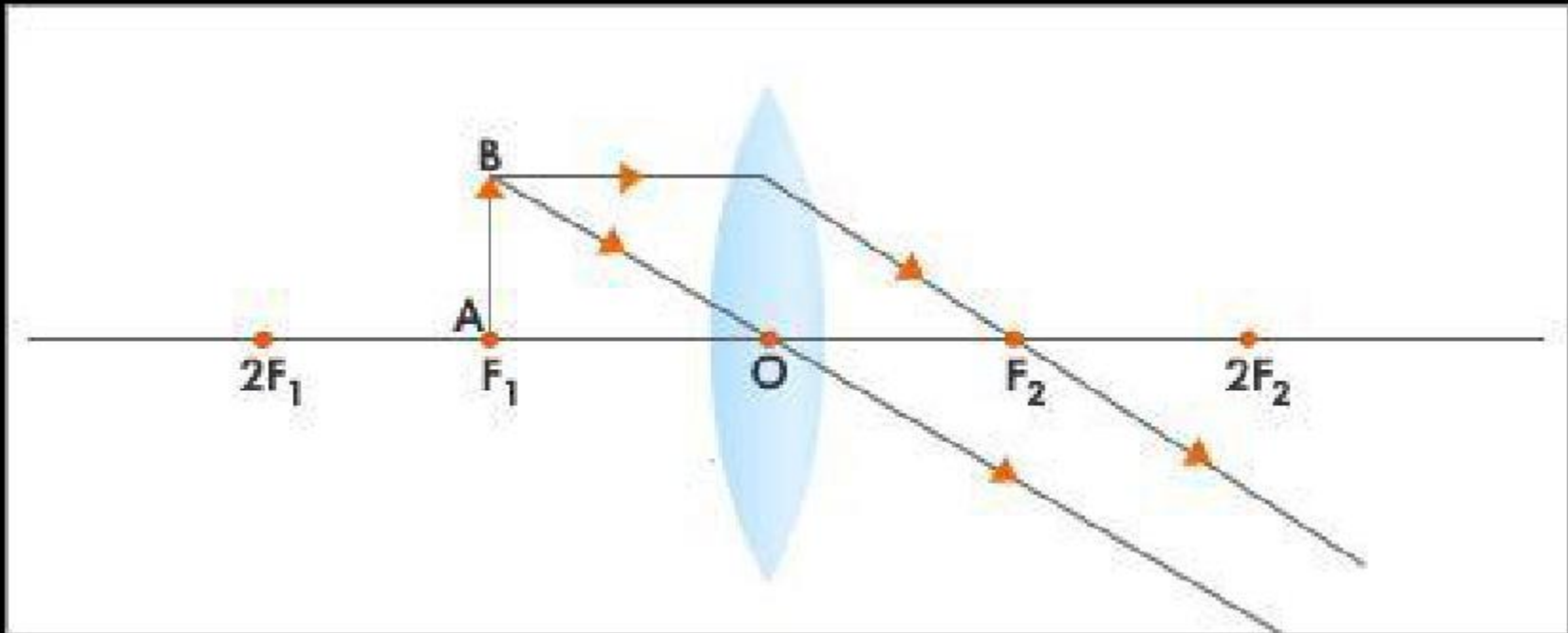## Between 2F1 and F1

Nature: Real, inverted, enlarged image is formed at beyond 2F2.

Image formation in a convex lens & nature of the image when the object is placed:

At F1

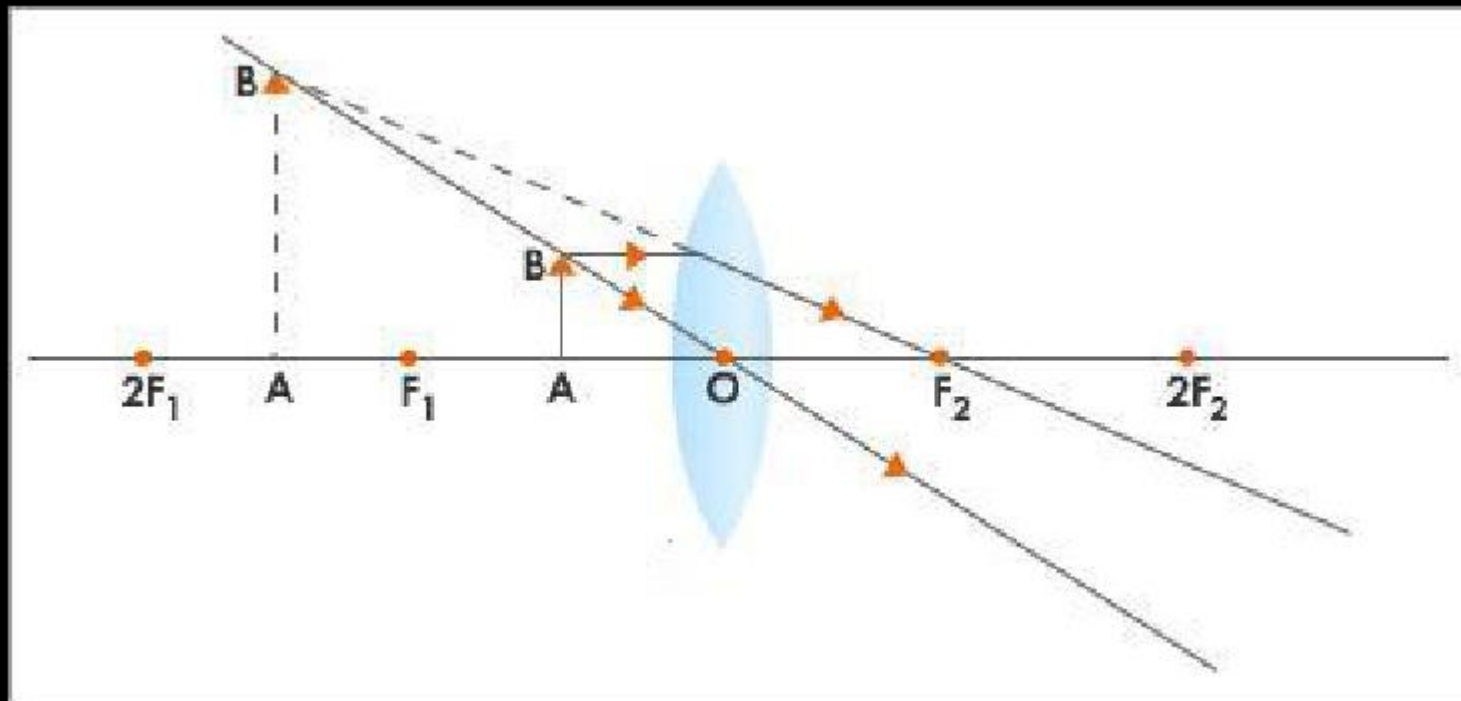Nature: Real, inverted, enlarged image is formed at infinity.

Image formation in a convex lens & nature of the image when the object is placed:

Between F1 and O

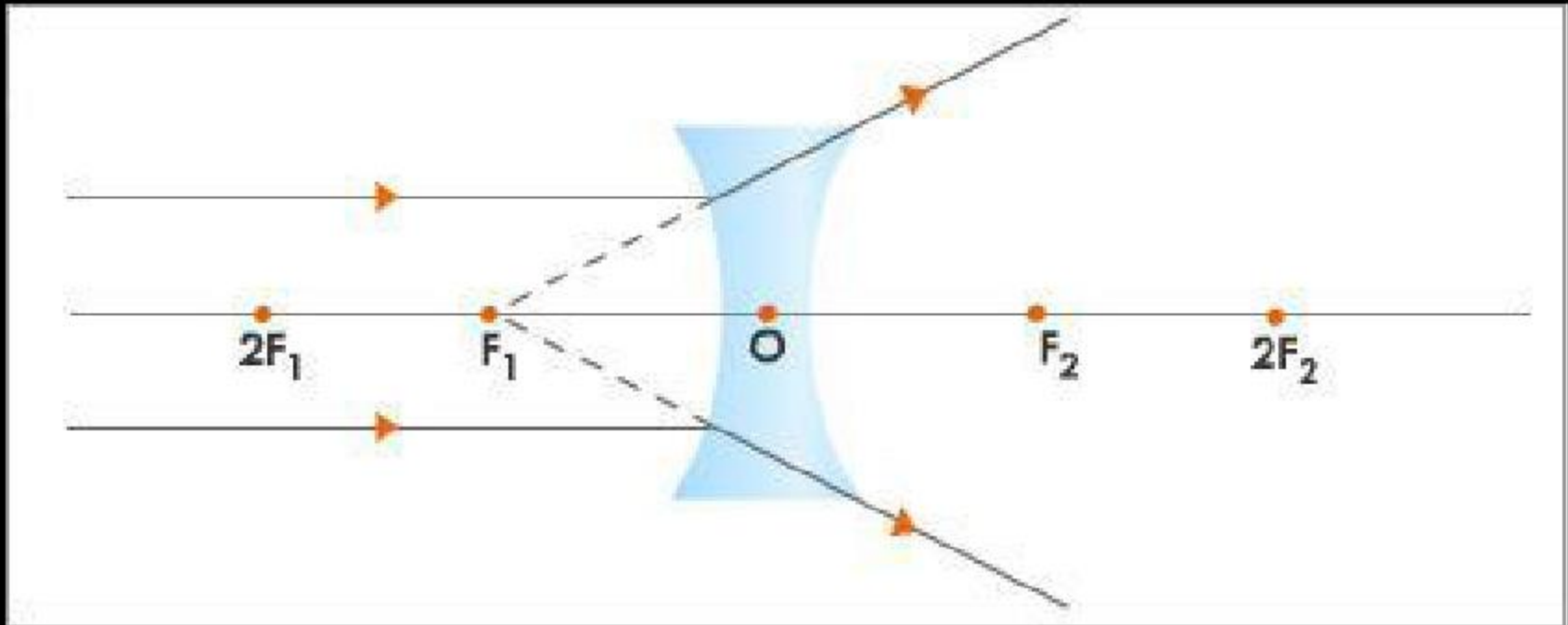Nature: Virtual, erect, enlarged image is formed behind the lens.

Image formation in a concave lens & nature of the image when the object is placed:

At infinity

Nature: Virtual, erect, diminished image is formed at F1.

Image formation in a concave lens & nature of the image when the object is placed:

Between F and O
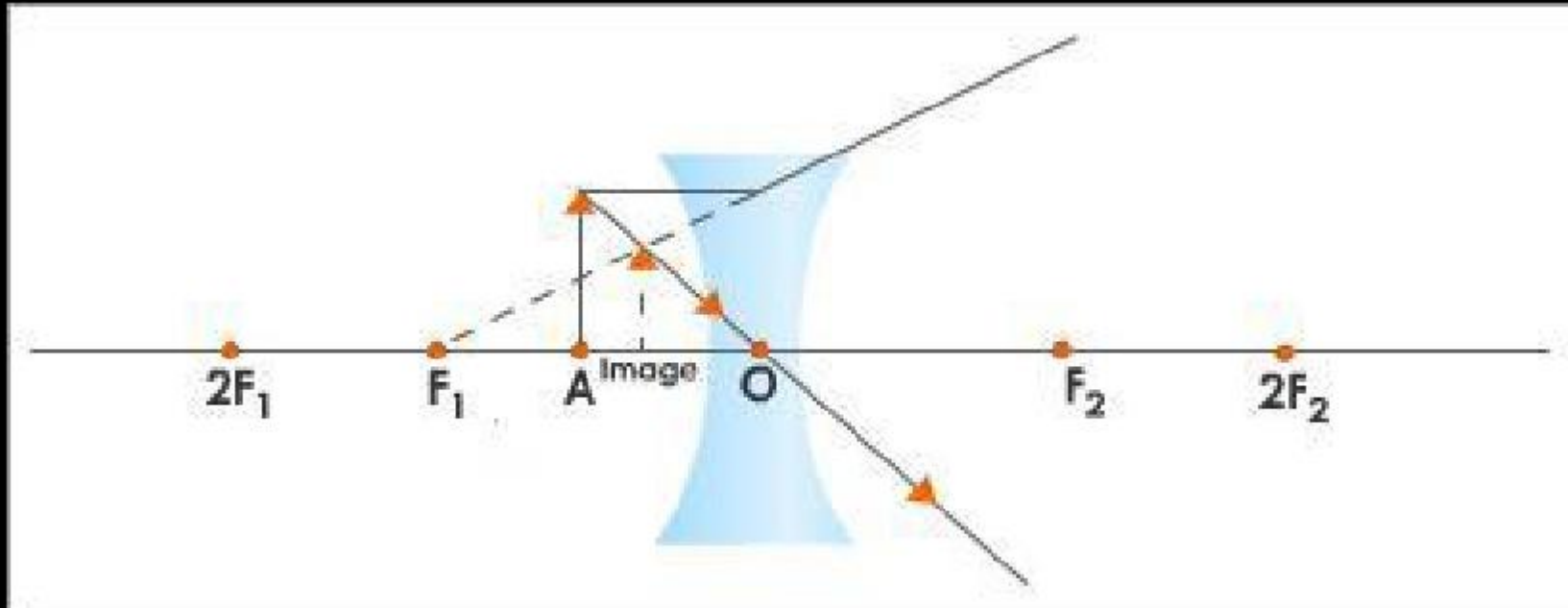
Nature: Virtual, erect, diminished image is formed between F1 and O.

Convex lens Vs Concave lens

ConvexLens	Concavelens
1.Itisthickeratthe centrethanatthe edges. 2.Itconvergesparallel beamoflighton refractionthroughit. 3.Ithasarealfocus.	1.Itisthinneratthe centrethanatthe edges. 2.Itdivergesaparallel beamoflighton refractionthroughit. 3.Ithasavirtual focus.

Lens formula

$$\frac{1}{v} \quad \frac{1}{u} \quad \frac{1}{f}$$

Magnification of lens

Magnification is the ratio of the height of the image to the height of the object.

$$m = \frac{}{\text{Height of theobject}} \quad \frac{|}{h} = \frac{}{u}$$

Power of lens

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

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

Power of lens

SI unit of power of lens is Dioptre (D)

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

-1

Why do we use lens combinations in various optical instruments?

i) To increase the magnification of the image.

ii) To increase the sharpness of the image

iii) To erect the final image

iv) To minimise certain defects or aberrations in the image formed by a single lens.

Exercise (MCQ)

1. Which one of the following materials cannot be used to make a lens?

(a) Water
(b) Glass
(c) Plastic
(d) Clay

2.   The image formed by a concave mirror is observed to be virtual, erect and larger than the object. Where should be the position of the object?

(a) Between the principal focus and the centre of curvature
(b) At the centre of curvature
(c) Beyond the centre of curvature
(d) Between the pole of the mirror and its principal focus.

3. Where should an object be placed in front of a convex lens to get a real image of the size of the object?

(a) At the principal focus of the lens
(b) At twice the focal length
(c) At infinity
(d) Between the optical centre of the lens and its principal focus.

4. **A spherical mirror and a thin spherical lens have each a focal length of −15 cm. The mirror and the lens are likely to be**

(a) both concave.
(b) both convex.
(c) the mirror is concave and the lens is convex.
(d) the mirror is convex, but the lens is concave.

5.   No matter how far you stand from a mirror, your image appears erect. The mirror is likely to be

(a) plane.
(b) concave.
(c) convex.
(d) either plane or convex.

END