CHAPTER

5

Lenses

We all are familiar with the use of lenses in our daily life through spectacles and other resources. The shape of lenses is responsible for their applications in a particular area. On the basis of shape mainly there are two types of lenses: convex and concave. In this chapter, we will explore these two types of lenses with their related aspects.

Chapter Objectives

- Lens
- Refraction Through Equi-convex Lens and Equi-concave Lens
- Image
- Ray Diagram for Principal or Construction Rays
- Image Formation of Lenses
- Lens Formula
- Linear Magnification
- Power of a Lens
- Magnifying Glass or Simple Microscope
- Applications of Lenses

Lens

It is a transparent refracting medium bounded by two surfaces of which, one or both surfaces are spherical.

Lenses are of two types

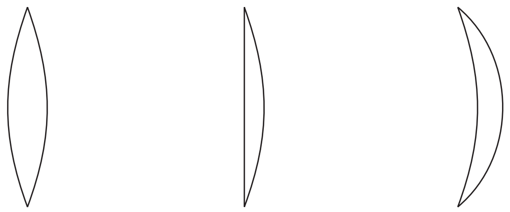
(i) Convex or converging lens

(ii) Concave or diverging lens

(i) Convex or Converging Lens

A lens which is thicker at the centre and thinner at its end is called convex lens. It is also known as converging lens because it converges a parallel beam of light rays passing through it.

Convex lenses are of three types as shown below



(a) Double-convex lens (b) Plano-convex lens (c) Concave-convex lens

(a) A double-convex lens has two outward curving sides and is simply called convex lens.

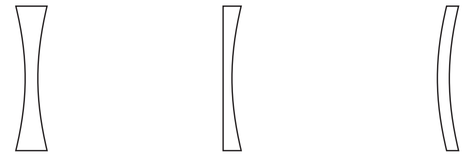
(b) The plano-convex lens is flat on one side and curved outward on the other side.

(c) The concave-convex lens has an inward curved from one side and has a more outward curve on the other side in the same direction.

(ii) Concave or Diverging Lens

A lens which is thinner at the centre and thicker at its ends is called a concave lens. It is also known as diverging lens because it diverges a parallel beam of light rays passing through it.

Concave lenses are of three types as shown below



(a) Double-concave lens (b) Plano-concave lens (c) Convex-concave lens

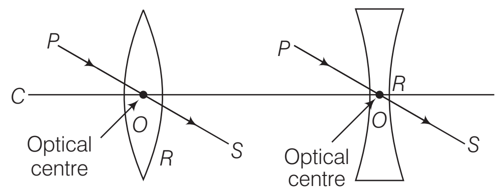
(a) A double-concave lens has two inward curving sides and is simply called concave lens.
(b) Plano-concave lens has a flat surface and one inward curving side.
(c) Convex-concave lens has one outward curving side with one greater inward curving side in the same direction.

Some Definitions Related to Lenses

Some of definitions related to lenses are discussed as follow.

Optical Centre

The centre point of a lens is known as its optical centre. It is a point of the lens, directed to which the incident rays refract without any deviation in the path.



Optical centres of convex lens and concave lens

Centres of Curvature

The centres of the two imaginary spheres of which the lens is a part are called centres of curvature of the lens. A lens has two centres of curvature with respect to its two curved surfaces.

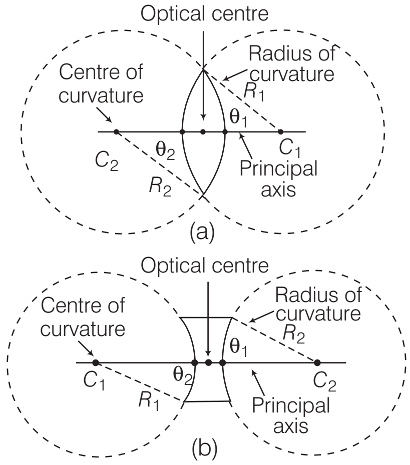
Radii of Curvature

The radii of the two imaginary spheres of which the lens is a part are called radii of curvature of the lens. A lens has two radii of curvature. These may or may not be equal.

Note A plane surface can be considered as to be a spherical surface of infinite ratii of curvature.

Principal Axis

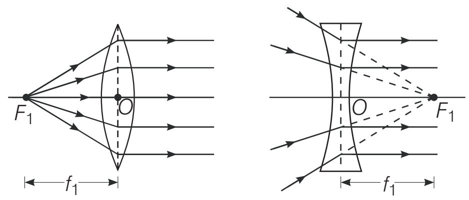
The imaginary line joining the two centre of curvature is called principal axis of lens. It also passes through the optical centre.



Principal Focus

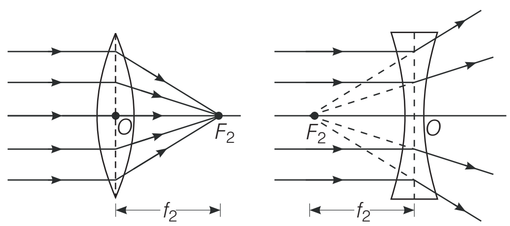
Rays of light can pass through any side of the lens in any direction. Hence, there will be two principal foci on either side of the lens. They are referred to as the first principal focus and the second principal focus of a lens.

(i) **First Principal Focus** The point on the principal axis such that the rays starting from this point (in convex lens) or appearing to go towards this point (in concave lens), after refraction through the lens become parallel to the principal axis, is called first principal focus.



First principal focus on convex and concave lenses

(ii) **Second Principal Focus** It is the point on the principal axis at which the rays coming parallel to the principal axis converge (in convex lens) or passing through it appear to diverge (from concave lens) after refraction from the lens.



Second principal focus on convex and concave lenses

Both the foci of convex lens are real while that of concave lens are virtual.

Focal Length of Lens

The distance between the focus and optical centre of a lens is called focal length of lens.

Note
- Focal length of a lens implies the second focal length.
- If the medium on both sides of the lens is same, the first and second focal lengths are equal.
- Focal length of a lens depends on the refractive index of material of lens.
- If a lens is placed in water instead of air, its focal length increases.
- A thick lens has less focal length than a thin lens of same material.

Focal Plane

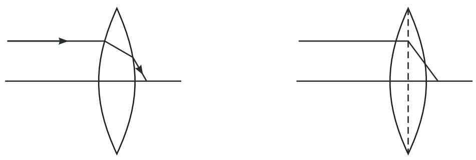
The plane passing through the focus and perpendicular to the principal axis is called focal plane.

Aperture

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

Refractive Axis

It is an imaginary axis, passing through the optical centre and perpendicular to the principal axis of the lens.



(a) Real path of ray

(b) Path of ray as shown with reference to refraction axis

CHECK POINT 01

1. What do you mean by concave-convex lens?
2. Why and which lens is called diverging lens?
3. Define principal focus of convex lens.
4. What type of lens is an air bubble inside the water?
5. Draw a diagram to represent the refractive and principal axis of a concave lens.

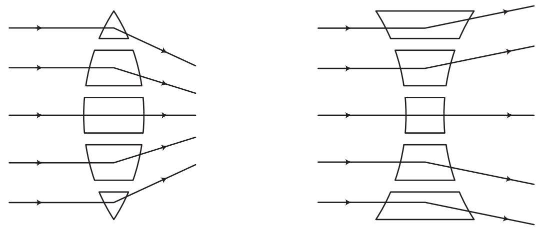
Converging and Diverging Action of Lenses

The converging and diverging action of lenses can be explained by considering a lens made up of large number of different small angles prisms.

A converging lens can be supposed to be made up of a number of prisms with the base of each prism **towards** the centre of the lens.

A diverging lens can be supposed to be made up of a number of prisms with the base of each prism **away from** the centre of the lens.

A prism has a tendency to bend a light ray towards its base, on this basis converging and diverging action can be explained.

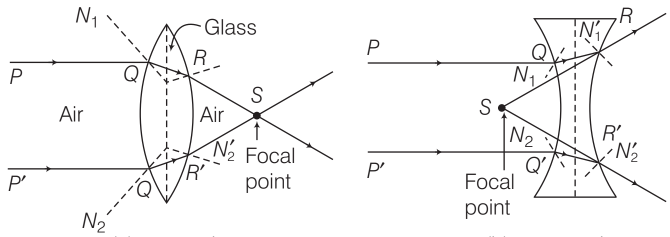


Converging action of convex lens

Diverging action of concave lens

Refraction Through Equi-convex Lens and Equi-concave Lens

Figure given below, shows the refraction of a ray of light at the two surfaces of an equi-convex lens and an equi-concave lens.



(a) convex lens

(b) concave lens

It is clear from the figure, that a convex lens bends the ray of light towards its middle i.e., it converges the light. While a concave lens bends a ray of light towards its edges (or away from its middle) i.e., it diverges the light.

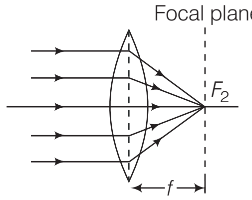
Image

The point where the rays meet or appear to meet after refraction from the lens is called image of that point of the object.

There are two types of images

Real Image

If the rays from a point of an object after refraction through the lens actually meet at a point, the image formed is called real image.

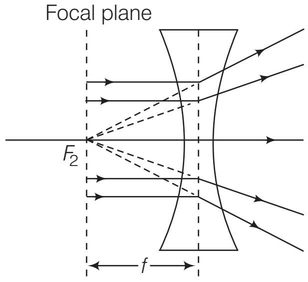


Real Image

Virtual Image

If the rays from a point of an object after refraction through the lens do not actually meet at a point, but they appear to diverge or converge from to a point, the image formed is called virtual image.

Focal plane

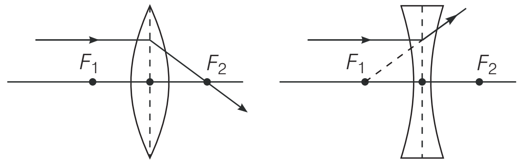


Virtual Image

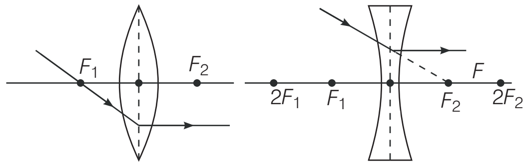
Ray Diagram for Principal or Construction Rays

We can represent image formations by lenses using ray diagrams. By drawing these diagrams, we can determine the position, size and nature of the image formed by a lens. The figures given below show the path through a concave lens and convex lens separately each for the three principal rays generally used for the construction of the ray diagrams.

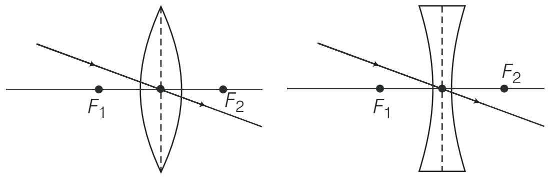
(i) Rays which are **parallel to the principal axis** after refraction, will pass through principal focus in case of convex lens and will appear to be coming from principal focus in case of concave lens.



(ii) Ray **passing through or directed to the focus** will emerge parallel to the principal axis.



(iii) Ray **directed to optical centre** will emerge out undeviated.



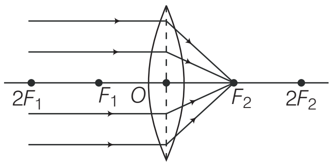
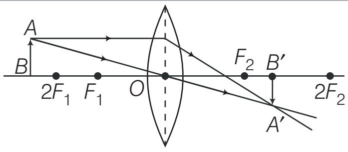
CHECK POINT 02

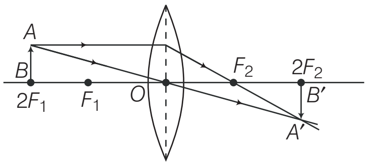
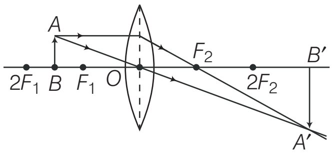
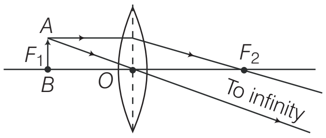
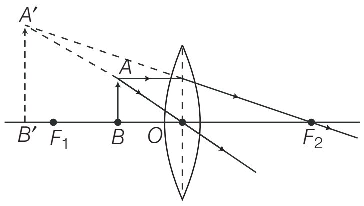
1. How many times does a ray incident on a lens gets refracted after being deviated from its path?
2. Write one difference between real and virtual image.
3. Draw a ray diagram to show a ray passing through the focus convex lens.
4. Give the position from which a ray passes undeviated through optical centre of the lens.
5. Which lens always forms a virtual of an object?

Image Formation of Lenses

Formation of Image by a Convex Lens

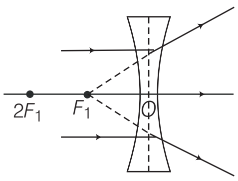
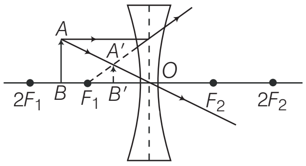
The table given below illustrates the ray diagrams along with the position and nature of an image, formed by convex lens for various positions of an object.

Position of Object	Ray Diagram	Position of Image	Nature and Size of Image
At infinity		At F_2	Real, inverted and extremely diminished
Beyond $2F_1$ (at finite distance)		Between F_2 and $2\ F_2$	Real, inverted and diminished

Position of Object	Ray Diagram	Position of Image	Nature and Size of Image
At $2F_1$		At $2F_2$	Real, inverted and of same size as that of object
Between F_1 and $2F_1$		Beyond $2F_2$	Real, inverted and magnified
At F_1		At infinity	Real, inverted and highly magnified
Between lens and F_1		On same side of the lens as the object	Virtual, erect and magnified

Formation of Image by a Concave Lens

For studying the image formation by concave lens, there are only two positions of an object that are considered. Firstly, when the object is at infinity and the second position is when the object is at finite distance from the lens. The table given below illustrates the ray diagrams along with the position and nature of image, formed by concave lens for the above two positions of the object.

Position of Object	Ray Diagram	Position of Image	Nature and Size of Image
At infinity		At focus on same side of lens as object	Virtual, erect and highly diminished
At finite distance		Between focus and optical centre on the same side of lens as object	Virtual, erect and diminished

To Differentiate Between a Convex and a Concave Lens

(i) **By Touching** If the lens is thick in the middle and thin at the edges, the lens is convex and if the lens is thin in the middle and thick at the edges, the lens is concave.

(ii) **By Seeing the Image**

(a) On keeping the lens near a printed page, if letters appear magnified, the lens is convex and if the letters appear diminished, the lens is concave.

(b) On seeing a distant object through the lens, if its inverted image is seen, the lens is convex and if the upright image is seen, the lens is concave.

Lens Formula

It is a relation between focal length of a lens and distance of object and image from optical centre of the lens.

If u = object distance, v = image distance and f = focal length, then

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

This is called the lens formula.

Linear Magnification

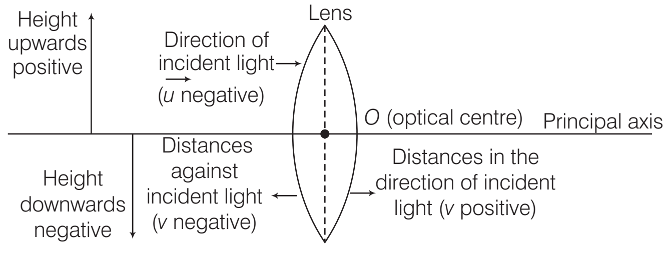
The ratio of height of image to the height of object is called linear magnification (m).

Linear magnification, $\boxed{m=\frac{h_i}{h_o} \quad \text{or} \quad m=\frac{v}{u}}$

It is **positive**, when image formed is **virtual** and is **negative**, when image formed is **real.**

Sign Convention for Spherical Lenses

To derive the relevant formulae for refraction by spherical lenses, we must first adopt a sign convention for measuring distances.



According to the cartesian sign convention,

(i) all the distances are measured from the optical centre (O) of the lens.

(ii) the principal axis of the lens is taken as X-axis and the optical centre as origin.

(iii) distances measured in the direction of the incident light are taken as positive and opposite to the direction of incident light as negative.

(iv) the heights measured upwards with respect to X-axis and normal to the principal axis of the mirror or lens are taken as positive and the heights measured downwards are taken as negative.

Example 1. A convergent beam of light passes through the diverging lens of focal length 0.2 m and comes to focus 0.3 m behind the lens. Find the position of the point at which the beam would converge in the absence of the lens.

Sol. Given, focal length, $f = 0.2\,\text{m}$

Image distance, $v = -0.3\,\text{m}$

Object distance, $u = ?$

According to lens formula,

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \Rightarrow \frac{1}{u}=\frac{1}{v}-\frac{1}{f} \Rightarrow \frac{1}{-0.3}-\frac{1}{0.2}=\frac{-0.5}{0.06}$$

$$u=\frac{-0.06}{0.5}$$

Object distance, $u = -0.12\,\text{m}$

Example 2. A concave lens has a focal length 15 cm. At what distance should an object be placed from the lens so that it forms an image at 10 cm from the lens? What is the nature of the image?

Sol. Given, focal length, $f = -15\,\text{cm}$

Image distance, $v = -10\,\text{cm}$

Object distance, $u = ?$

According to lens formula, $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

i.e., $$\frac{1}{-10}-\frac{1}{u}=\frac{1}{-15}$$

$\therefore$ $$\frac{1}{u}=\frac{-1}{10}+\frac{1}{15}=\frac{-1}{30} \Rightarrow u=-30\,\text{cm}$$

As, it is a concave lens, the image is virtual erect and diminished.

Example 3. A 5 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 20 cm. The distance of the object from lens is 30 cm. Determine the

(i) position (ii) nature

(iii) size of image formed.

Sol. Given, object size, $h_o = 5\,\text{cm}$

Object distance, $u = -30\,\text{cm}$

Focal length, $f = +20\,\text{cm}$

Using lens formula, $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

$$\Rightarrow \frac{1}{v}=\frac{1}{u}+\frac{1}{f} \Rightarrow \frac{1}{v}=-\frac{1}{30}+\frac{1}{20}=\frac{1}{60} \Rightarrow v=60\text{ cm}$$

Since, magnification, $m=\frac{h_i}{h_o}=\frac{v}{u}$

$$\Rightarrow m=\frac{h_i}{5}=\frac{60}{-30} \Rightarrow h_i=-10\,\text{cm}$$

Therefore, the image is real, inverted and magnified.

Power of a Lens

The ability of a lens to deviate light rays towards or away from its principal axis is called power of lens. It is defined as the reciprocal of the focal length in metres. It is expressed as

$$\text{Power, } P=\frac{1}{f\text{ (in metre)}}$$

Its SI unit is dioptre (D). The power of convex lens is positive and that of concave lens is negative.

If many thin lenses are in contact with each other, then the total power is the algebraic sum of powers of individual lenses.

i.e., $P = P_1 + P_2 + P_3 + \ldots$

Example 4. **Calculate the power of a convex lens having the focal length of 50 cm.**

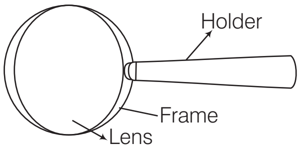
Sol. Given, focal length, $f = 50\,\text{cm} = 0.5\text{ m}$

Power, $P = \dfrac{1}{\text{Focal length}} = \dfrac{1}{0.5} = 2\,\text{D}$

Magnifying Glass or Simple Microscope

Principle

It is based on the principle that when an object is placed between the first principal focus and the optical centre of a convex lens, it forms an erect, virtual and enlarged image on the same side of the object.



Magnifying glass (or simple microscope)

Construction

Magnifying glass is a kind of convex lens of short focal length mounted in a metallic frame with a holder.

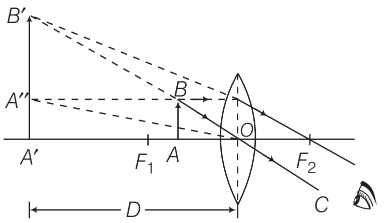
Way of Using the Microscope

The lens is placed near the eye and the object is at such a distance from the lens such that the image is formed at the least distance of distinct vision $(D) = 25$ cm from the lens.

Note The minimum distance, at which an object can be seen most distinctly without any strain is called the least distance of distinct vision (D). For a healthy normal eye of an adult, it is 25 cm.

Ray Diagram and Magnification

Consider a ray diagram for location of image $(A'B')$ of an object *(AB)* due to a simple microscope. The object *AB* is placed between focus F_1 and optical centre O of the lens.



Ray diagram for location of image and magnification

Magnified and erect image $A'B'$ is formed atleast distance of distinct vision *(D)* from O. The magnifying power of the microscope is defined as the ratio of the $\angle B'OA'$ subtended by the image $A'B'$ at the eye to the $\angle A''OA'$ subtended by *AB* at the eye.

It is expressed as

$$m = \frac{A'B'}{AB}$$

Applications of Lenses

Some of applications of lenses are discussed as follows

(i) We usually use spectacles when our eyesight weakens. They either consist of convex lens or concave lens or both.

A person suffering from long sightedness, i.e., hypermetropia, use convex lens while a person suffering from short sightedness, i.e., myopia, uses concave lens.

(ii) They are used in a spectroscope which uses convex lens for obtaining pure spectrum.

(iii) In telescope, camera, slide projector, etc, convex lens is used which forms a real and inverted image of an object.

(iv) In galilean telescope, a concave lens is used as an eyelens to obtain an erect final image of the object.

(v) Convex lens of short focal length fitted in a steel frame with a handle, is used as a magnifying glass.

Note
- In order to photograph a distant object, the lens is moved closer to the film and for near object, the lens is moved away from the film. This adjustment of the lens is called focussing.
- The maximum variation in the power of the lens for focussing near or far objects clearly at retina is called power of accomodation.
- The time for which impression or sensation of an object continues in the eye is called persistance of vision. It is about (1/16)th of a second.

CHECK POINT 03

1. Name the lens which acts as magnifying glass.
2. Which type of lens produce
   (i) diminished neutral image
   (ii) magnified vertical image?
3. What is the minimum distance between an object and its real image formed by a convex lens?
4. What happens to the image formed by a convex lens if its lower part is blackened?
5. Two lens of power – 3 D and + 2.5 D are placed in contact. Find the total power of combination of Lens. Calculate the focal length of this combination.

SUMMARY

- Lens is a transparent medium bounded by two surfaces in which, one or both surfaces are spherical.
- Convex lens is a lens which is thicker at the centre and thinner at its end.
- Concave lens is a lens which is thinner at the centre and thicker at its end.
- The centre point of a lens is known as its optical centre.
- The centre of the two imaginary spheres of which the lens is a part is known as centre of curvature of lens.
- The radii of the two imaginary spheres of which the lens is a part are called radii of curvature of lens.
- The imaginary line joining the two centres of curvature is called principal axis of lens.
- The distance between focus and optical centre of a lens is known as focal length of lens.
- The plane passing through the focus and perpendicular to the principal axis is known as focal plane.
- The effective diameter of the circular outline of a spherical lens is known as aperture of lens.
- An imaginary axis, passing through the optical centre and perpendicular to the principal axis of the lens is called refractive axis.
- The converging and diverging action of lenses can be explained by considering a lens made up of large number of different small angled prisms.
- Image formation by convex lens for different positions of object

Position of Object	Position of Image	Relative Size of Image	Nature of Image
At infinity	At focus F_2	Highly diminished, point-sized	Real and inverted
Beyond $2F_1$	Between F_2 and $2F_2$	Diminished	Real and inverted
At $2F_1$	At $2F_2$	Same size	Real and inverted
Between focus F_1 and $2F_1$	Beyond $2F_2$	Enlarged	Real and inverted
At focus F_1	At infinity	Highly magnified	Real and inverted
Between focus F_1 and optical centre O.	On the same side of the lens as the object	Enlarged	Virtual and erect

- Image formation by concave lens for different positions of object

Position of Object	Position of the Image	Relative Size of Image	Nature of Image
At infinity	At focus F_1	Highly diminished, point-sized	Virtual and erect
At finite distance	Between focus F_1 and optical centre O	Diminished	Virtual and erect

- Lens Formula

  It is given by, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

where, v = distance of image from the optical centre of lens,

u = distance of object from the optical centre of lens

and f = focal length of lens.

- Linear Magnification

$$m = \frac{\text{Height of image } (h_i)}{\text{Height of object } (h_o)} \quad \text{or} \quad m = \frac{\text{Image distance } (v)}{\text{Object distance } (u)}$$

  If m is positive, image is virtual and if m is negative, image is real.
- The ability of a lens to converge or diverge light rays is known as power of lens. It is denoted by P.
- The SI unit of power is dioptre (D).

$$\text{Power, } P = \frac{100}{\text{Focal length } f \text{ (in cm)}}$$

- For concave lens, power and focal length are negative.
  For convex lens, power and focal length are positive.
- Magnifying glass is a kind of convex lens of short focal length mounted in a metallic frame with a holder.

EXAM PRACTICE

a 2 Marks Questions

1. Define convex lens and give its nature of refraction.

Sol. A lens which is thicker at the centre and thinner at its end is called convex lens. ***[1]***

It is also called converging lens as it converges the light rays passing through it. ***[1]***

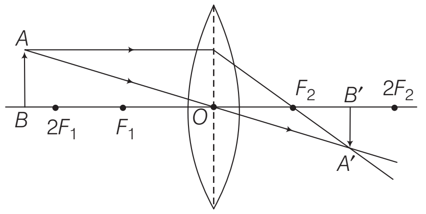
2. What is the difference between double convex and a bi-convex lens?

Sol. In double convex lens, the two surfaces may have any values for the two radii of curvature of the two surfaces while the bi-convex lens, the radii of curvature of the two surfaces have the same value. So, all double convex lens may not be bi-convex, but every bi-convex lens is a double convex lens. ***[2]***

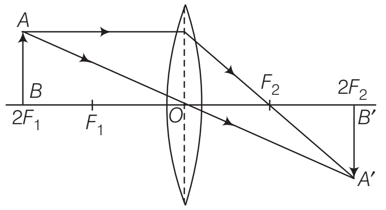
3. (i) An object is placed infront of a converging lens at a distance greater than twice the focal length of the lens. Draw a ray diagram to the formation of the image. ***[2007]***

(ii) An object is placed infront of a convex lens such that the image formed has the same size as that of the object. Draw a ray diagram to illustrate this. ***[2006]***

Sol. (i) *The ray diagram to show the formation of the image is shown below* ***[1]***

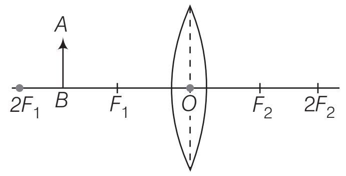


(ii) *The ray diagram to show the formation of the image is shown below*



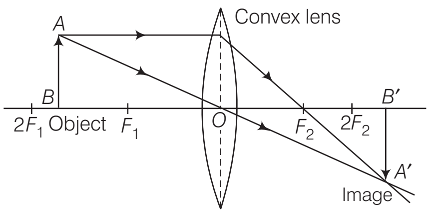
[1]

4. An object AB is placed between $2F_1$ and F_1 on the principal axis of a convex lens as shown in the diagram.



Copy the diagram and using these rays starting from point A, obtain the image of the object formed by the lens.

Sol. *The formation of image is shown below*



[2]

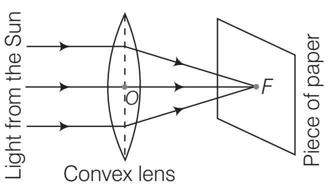
5. We can burn a piece of paper by focusing the sun rays by using a particular type of lens. ***[2010]***

(i) Name the type of lens used for the above purpose.

(ii) Draw a ray diagram to support your answer.

Sol. (i) To collect all Sun's rays to a particular point (called focus) we use a converging lens, i.e., convex lens. ***[1]***

(ii) *The ray diagram is shown below*



[1]

6. State two characteristics of the image of an extended source, formed by a concave lens.

Sol. The two characteristics of the image of an extended source formed by a concave lens are

(i) virtual and ***[1]***

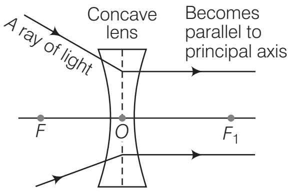
(ii) highly diminished, if the object is at infinity/ diminished, if the object is between optical centre and infinity. ***[1]***

7. State the position of the object in front of a converging lens if
(i) it produces a real and same size image of the object.
(ii) it is used as a magnifying lens. ***[2018]***

Sol. (i) To get real and same size image, object is placed at '$2F$'. ***[1]***
(ii) To use a converging lens as magnifying lens object must be placed between lens and first focus. ***[1]***

8. A ray of light, after refraction through a concave lens, emerges parallel to the principal axis. Draw a ray diagram to show the incident ray and its corresponding emergent ray. Can we obtain a real image with the help of a concave lens?

Sol. *The ray diagram to show the incident ray and its corresponding emergent ray is shown below*



[1]

When a concave lens is kept in front of a convex lens (additional) it produces real image. ***[1]***

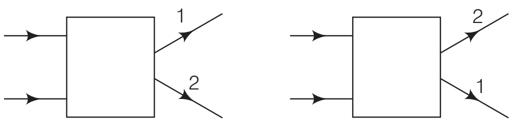
9. (i) When does a ray of light falling on a lens pass through it undeviated? ***[2011]***
(ii) Which lens can produce a real and inverted image of an object?

Sol. (i) A ray of light parallel to the principal axis of convex lens when passes through the optical centre, then the ray coming out from the lens will be undeviated. ***[1]***
(ii) A real and inverted image of an object can be produced by using convex lens or converging lens. ***[1]***

10. You are provided with a printed piece of paper. Using this paper, how will you differentiate between a convex lens and concave lens? ***[2012]***

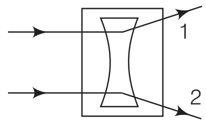
Sol. When the printed piece of paper is moved near to both the lenses and the letters appear as
(i) erect and diminished, then the lens is concave lens. ***[1]***
(ii) erect and magnified, then the lens is convex lens. ***[1]***

11. Figs. (a) and (b) are shown below, the incident and transmitted rays through lens kept in a box in each case. Draw the lens and complete the path of rays through it.



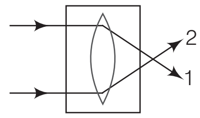
(a) (b)

Sol. *The ray diagram is as follows*
(i) From fig. (a) we see after passing through a box, rays are diverses, hence a concave lens will be there inside the box.



(a) ***[1]***

(ii) From fig. (b) we see after passing through a box, rays are converses, hence a convex lens will be there inside the box.



(b) ***[1]***

12. The power of a lens is -5D.
(i) Find its focal length.
(ii) Name the type of lens. ***[2018]***

Sol. Given, power of lens $= -5$ D
(i) We know that,

$$\text{Power of lens } (P) = \frac{1}{f\,(\text{focal length})} \quad \text{or} \quad f = \frac{1}{P}$$

$$\Rightarrow \quad f = \frac{1}{-5} = -0.2 \text{ m}$$

$$= -20 \text{ cm}$$ ***[1]***

(ii) The power of lens is negative, therefore lens is concave. ***[1]***

b 3 Marks Questions

13. State the changes in the position, size and nature of the image of an object when brought from infinity upto a concave lens. Illustrate your answer by drawing diagrams.

Sol. When an object is brought from infinity upto a concave lens, then position of image is shifted from focus toward optical centre of concave lens, size of image increases, while nature of image is same (i.e., virtual). ***[1]***
When object is placed at infinity.

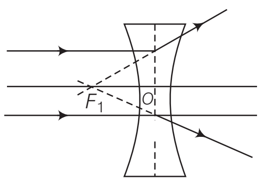


Image is formed at focus. ***[1]***

When object is placed at finite distance.

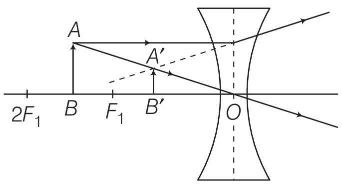
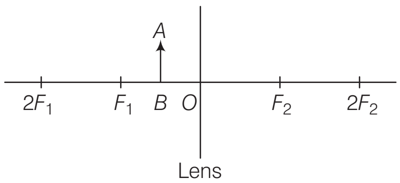


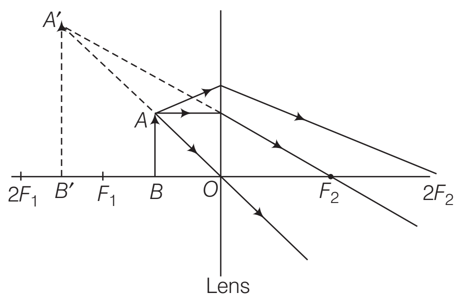
Image is formed between focus and optical centre **[1]**

14. An object AB is placed between O and F_1 on the principal axis of a converging lens as shown in the diagram.



Copy the diagram and by using three standard rays starting from point A, obtain an image of the object AB. **[2018]**

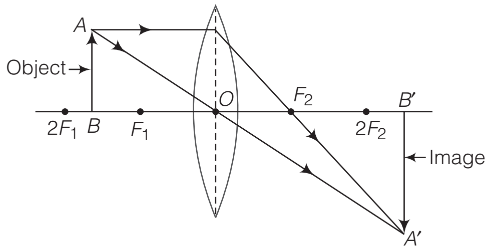
Sol.



[3]

15. Draw a labelled diagram showing how an image of a small slide can be projected on large screen. State two characteristics of the image.

Sol. *The ray diagram is shown below*



[1]

Characteristics of an image are

(i) image is real and inverted

(ii) image is enlarged. **[1+1]**

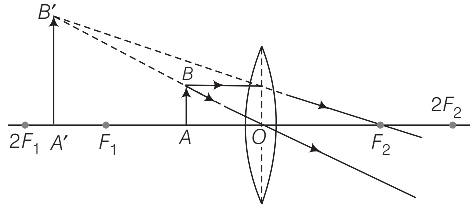
16. A lens forms an erect, magnified and virtual image of an object.

(i) Name the lens.

(ii) Draw a labelled ray diagram to show the image formation. **[2014]**

Sol. (i) A convex lens forms an erect, magnified and virtual image of an object. **[1]**

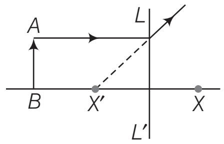
(ii) *The ray diagram showing the formation of image is shown below*



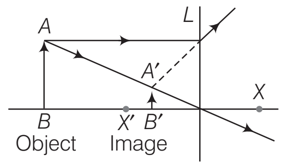
In this case, object is between optical centre (O) and focus (F_1) of lens. **[2]**

17. (i) Copy and complete the diagram to show the formation of the image of an object AB.

(ii) What is the name given to X? **[2009]**



Sol. (i) The ray diagram showing the formation of the image ($A' B'$) of the object AB is shown below



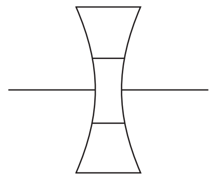
[2]

(ii) X is the principal focus. **[1]**

18. Figure below shows a lens treated as a combination of two prisms and a glass block.

(i) Name the lens formed by the combination.

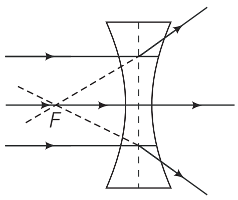
(ii) Draw the refraction of two incident rays to illustrate the property of the lens mentioned by you in part (ii).



Sol. (i) The lens is formed by the combination is a concave lens. **[1]**

(ii) The lens is a diverging lens. **[1]**

(iii) *The ray diagram is shown as below*



[1]

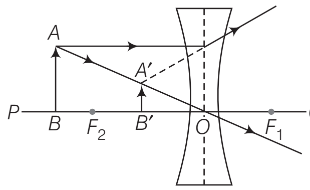
19. A linear object is placed on the axis of a lens. An image is formed by refraction in the lens. For all positions of the object on the axis of the lens, the positions of the image are always between the lens and the object.

(i) Name the lens.

(ii) Draw a ray diagram to show the formation of the image of an object placed in front of the lens at any position of your choice except infinity. **[2008]**

Sol. (i) The lens is concave lens. **[1]**

(ii) *The ray diagram showing the formation of image is shown below*



AB = object, *A′B′* = image

The object is placed between focus (f) and $2f$. **[2]**

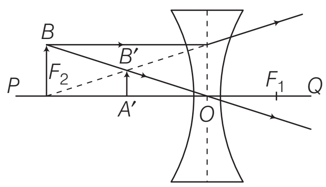
20. A lens forms an upright and diminished image of an object when the object is placed at the focal point of the given lens.

(i) Name the lens.

(ii) Draw a ray diagram to show the image formation. **(2017)**

Sol. (i) The lens is concave lens. **[1]**

(ii) *The ray diagram is shown below*



AB = object, *A′ B′* = image **[2]**

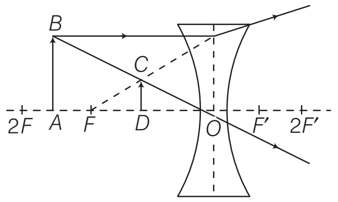
21. A lens produces a virtual image between the object and the lens.

(i) Name the lens.

(ii) Draw a ray diagram to show the formation of this image. **(2016)**

Sol. (i) Concave lens is the lens which produces a virtual image between the object and the lens. **[1]**

(ii) *The ray diagram is given below*



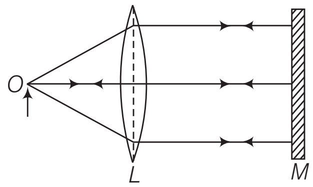
[2]

22. The given ray diagram illustrates the experimental set up for the determination of the focal length of a converging lens using a plane mirror.

(i) State the magnification of the image formed.

(ii) Write two characteristics of the image formed.

(iii) What is the name given to the distance between the object and optical centre of the lens in the given diagram? **[2005]**



Sol. (i) As, the distance of image from lens is same as that of object, therefore its magnification is equal to one.

(ii) The image formed is real, inverted and of same size as that of object.

(iii) The distance between the object and optical centre of the lens is named as focal length of the lens. **[1 × 3]**

23. Define the power of a lens. Write its formula expression and its SI unit.

Sol. It is defined as the ability of a lens to converge or diverge light rays. It is the reciprocal of focal length in metre. **[1]**

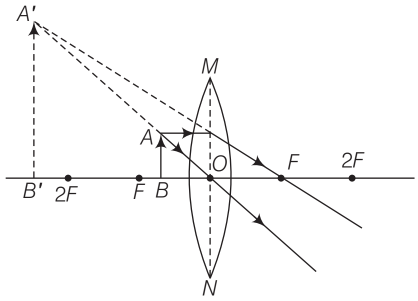
$$P = \frac{1}{f\ (\text{in metre})}$$ **[1]**

Its SI unit is diopter (D). **[1]**

C 4 Marks Questions

24. Draw a ray diagram to illustrate the action of a convergent lens as a reading lens or a magnifying glass.

Sol. A convex lens of small focal length can be used as a reading glass or a magnifying glass.



When an object is placed within the focal length of the lens, then a virtual, erect and magnified image is formed.

[2 + 2]

25. Draw ray diagrams showing the image formation by a convex lens when an object is placed

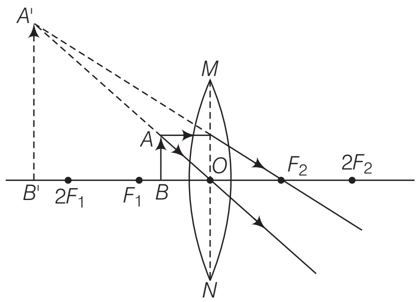
(i) between optical centre and focus of the lens.

(ii) between focus and twice the focal length of the lens.

(iii) at twice the focal length of the lens.

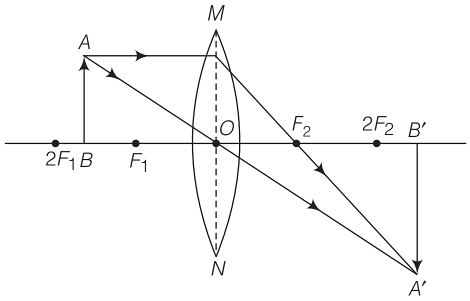
(iv) at infinity.

Sol. (i) An enlarged, virtual and erect image of an object forms beyond F on the same side as that of object.



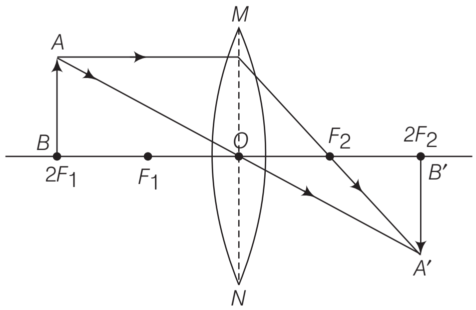
[1]

(ii) An enlarged, real and inverted image of an object forms beyond $2F$ on the other side of the lens.



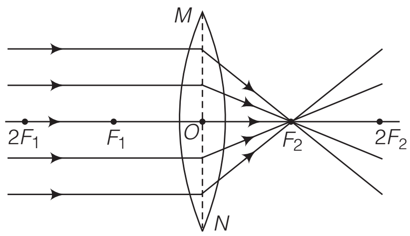
[1]

(iii) An real and inverted image of an object an equal to the size of the object, forms at $2F$ on the other side of the lens.



[1]

(iv) The real, inverted and highly diminished image of the object forms at focus F on the other side of the lens.



[1]

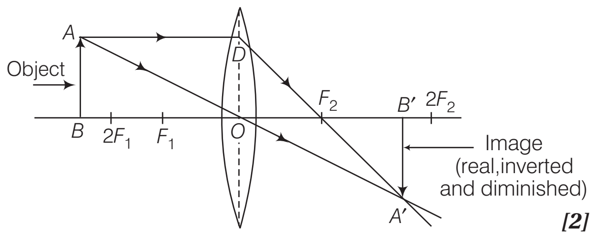
26. A converging lens is used to obtain an image of an object placed in front of it. The inverted image is formed between F_2 and $2F_2$ of the lens.

(i) Where is the object placed?

(ii) Draw a ray diagram to illustrate the formation of the image obtained. ***[2012]***

Sol. (i) The object is placed beyond $2F_1$. ***[2]***

(ii) *The ray diagram to illustrate the formation of the image is shown below*



[2]

27. A thin converging lens form a real magnified image and a virtual magnified image of an object in front of it.

(i) Write the positions the objects in each case.

(ii) Draw ray diagrams to show the image formation in each part.

(iii) How will the following be affected on cutting this lens into two halves along the principal axis?

(a) Focal length

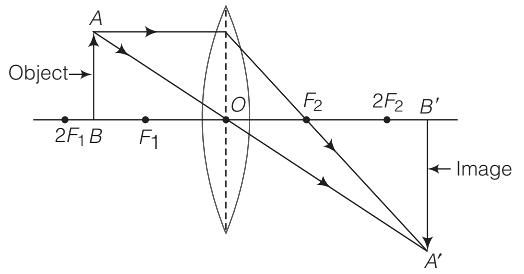
(b) Intensity of the image formed by half lens

Sol. (i) (a) Object is placed between F and $2F$.

(b) Object is placed between optical centre and F. ***[1]***

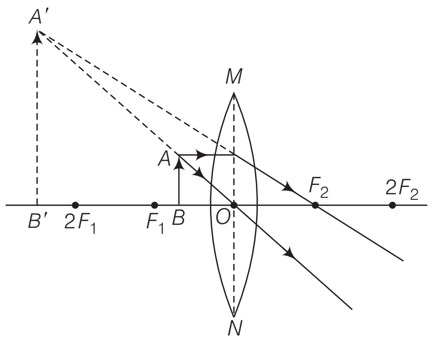
(ii) *The ray diagrams are as shown below*

Part (a)



[1]

Part (b)



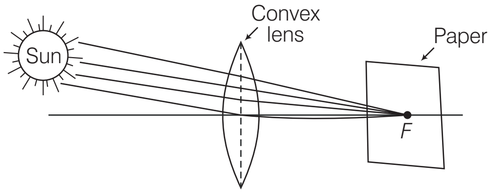
[1]

(iii) (a) There will be no change in focal length.

(b) Intensity will become one-fourth. ***[1]***

28. A student wants to burn a piece of paper using a convex lens in day light, rather than using match stick or any direct flame. Will he be able to, if yes justify your answer with a ray diagram?

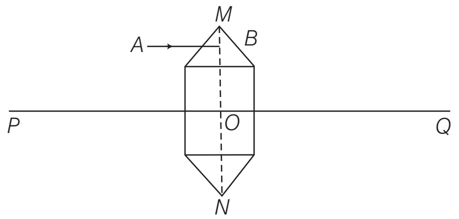
Sol. Yes, he will be able to burn a piece of paper using a convex lens in day light without using match sticks or any flame. When the sun rays coming from infinity passes through the convex lens and the paper being kept at the focus of the lens. Then, rays after passing the lens would converge at the focus as shown in figure below.



[2]

When the paper and the lens are held in the same position for sometime, then the paper will burn out. This is because of the heat produced by the Sun's rays as they are concentrated on the spot, where these rays are bring to focus at lens focal point. ***[2]***

29. A ray is directed towards a lens as shown in the figure below. The lens is being depicted as a combination of a glass slab and two prisms.



Answer the following questions.

(i) Name the lens which is formed by this combination.

(ii) What is PQ line called?

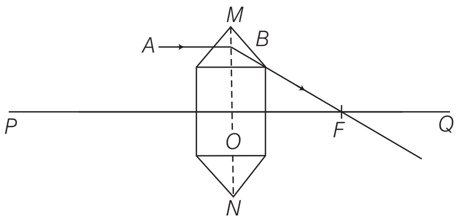
(iii) Complete the ray diagram.

(iv) The incident ray after refraction actually meet or appears to meet line PQ at a point. What is this point called?

Sol. (i) The lens is convex. ***[1]***

(ii) The line PQ is called principal axis. ***[1]***

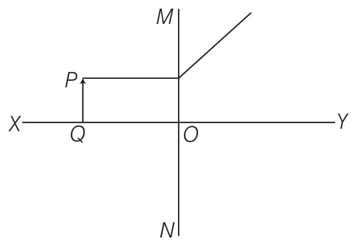
(iii) **Ray diagram**



[1]

(iv) When a incident ray parallel to the principal axis falls on a convex lens, then after refraction the emergent ray actually meet at a point on PQ. This point is known as focal point of the lens. ***[1]***

30. The figure given below shows a ray directed towards a lens MN.



Study the above ray diagram and answer the following questions.

(i) Name the lens.

(ii) What is line XY called?

(iii) The image of the object PQ is formed between which points.

(iv) Write the nature of the image.

Sol. (i) The lens is concave. **[1]**

(ii) The line XY is called principal axis. **[1]**

(iii) The image of the object PQ is formed between points Q and O. **[1]**

(iv) The image will be virtual and erect. **[1]**

Numerical Based Questions

31. The focal length of a convex lens is 25 cm. Calculate the power of the lens. **[2014]**

Sol. Given, focal length, $f = 25\text{cm} = 0.25$ m

Power, $P = ? \quad \Rightarrow \quad P = \frac{1}{f} = \frac{1}{0.25} = 4\text{D}$ **[2]**

32. Express the power of a concave lens of focal length 20 cm with its sign.

Sol. Power, $P = \frac{1}{f}$, where f is focal length.

As, $\quad f = -20$ cm

$\Rightarrow \quad P = -\frac{1}{20} = -\frac{100}{20} = -5$ D

Hence, power of a concave lens is -5 D. **[2]**

33. Two lenses have power of (i) + 2 D (ii) – 4 D. What is the nature and focal length of each lens?

Sol. (i) Given, $P = +2$ D

Since, power is positive, so the lens is convex lens.

Focal length, $f = \frac{1}{P} = \frac{1}{2} = 0.5$ m

$= 50\text{cm} \quad (\because P = \text{power of lens})$ **[1]**

(ii) Given, $P = -4\text{D}$

Since, power is negative, so the lens is concave lens.

Focal length, $f = \frac{1}{P} = \frac{1}{-4} = -0.25\text{ m} = -25\text{cm}$ **[1]**

34. Rohit while playing with an old lens discovers that, if he holds the lens 20 cm away from a wall opposite to a window, he can see sharp but inverted images of outside world on the wall. What is the power of the old lens holded by him?

Sol. Since, the rays from far away objects in outside world get focussed at principal focus, the distance between lens and wall is equal to focal length 20 cm. **[1]**

$\therefore \quad$ Power of lens, $P = \frac{100}{f(\text{ in cm})} = \frac{100}{20} = 5$ D **[1]**

35. A convex lens has focal length of 20 cm. At what distance from the lens should the object be placed, so that the image is formed at 40 cm on the other side of the lens? Also, state the nature of the image formed.

Sol. Given, $f = 20$ cm, $v = 40$ cm, $u = ?$

Now by using, $-\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

We have, $\quad -\frac{1}{u} = \frac{1}{f} - \frac{1}{v} = \frac{1}{20} - \frac{1}{40}$

or $\quad -\frac{1}{u} = \frac{1}{40}$

or $\quad u = -40$ cm **[1]**

Thus, the object should be placed at a distance of 40 cm in front of the convex lens. Negative sign shows, the image formed is real and inverted. **[1]**

36. An object is placed at a distance of 12 cm from a convex lens of focal length 8 cm. Find

(i) the position of the image

(ii) nature of the image. **[2018]**

Sol. Given, distance of object $(u) = -12$ cm

Focal length of lens $(f) = 8$ cm

(i) We know that, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{8} = \frac{1}{v} - \frac{1}{(-12)}$

$\frac{1}{v} = \frac{1}{8} - \frac{1}{12} \Rightarrow \frac{1}{v} = \frac{3-2}{24}$

$\frac{1}{v} = \frac{1}{24} \Rightarrow v = 24$ cm **[2]**

(ii) Real, inverted and magnified. **[2]**

37. An object is placed perpendicular to the principal axis of a convex lens of focal length 20 cm. If the distances of the object is 30 cm from the lens, find the position nature and magnification of the image.

Sol. Given, $f = 20$ cm, $u = 30$ cm

$v = ?, m = ?$

Now by using lens formula, $-\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

We have, $-\frac{1}{(-30)} + \frac{1}{v} = \frac{1}{20}$

or $\quad \frac{1}{v} = \frac{1}{20} - \frac{1}{30}$

or $\quad \frac{1}{v} = \frac{1}{60}$ or $v = 60$ cm

Thus, the image is formed at 60 cm on other side (i.e., right side) of the lens. **[2]**

Magnification, $m = \frac{v}{u} = \frac{60}{20} = 3$

Thus, magnification is 3. **[1]**

38. An object is placed 25 cm away from a converging lens of focal length 10 cm. Draw the ray diagram and find position and nature of image formed.

Sol. Object distance, $u = -25$ cm

Image distance, $v = ?$

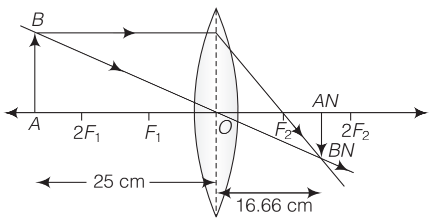
Focal length, $f = 10$ cm

From lens formula, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ or $\frac{1}{v} = \frac{1}{f} + \frac{1}{u}$

$$= \frac{1}{10} + \frac{1}{(-25)} = \frac{3}{50}$$

or $v = \frac{50}{3} = 16.66$ cm from the lens **[1]**

Ray diagram



[1]

The image is real, diminished and inverted. **[1]**

39. A 6 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 25 cm. The distance of the object from the lens is 40 cm.

By calculation determine

(i) the position and

(ii) the size of the image formed.

Sol. Given, height of object, $h_o = 6$ cm

Focal length of lens, $f = 25$ cm

Distance of object, $u = -40$ cm

(i) Using lens formula, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{25} + \frac{1}{(-40)}$$

$$= \frac{8-5}{200} = \frac{3}{200}$$

$$v = \frac{200}{3} = 66.67 \text{ cm}$$

[1½]

(ii) $\therefore$ Magnification, $m = \frac{h_i}{h_o} = \frac{v}{u}$

$$\Rightarrow \quad h_i = \frac{v}{u} \times h_o = \frac{200}{3 \times (-40)} \times 6 = -10 \text{ cm}$$

[1½]

40. A concave lens of focal length 20 cm forms an image at a distance of 10 cm from the lens. What is the distance of the object from the lens? Also draw ray diagram.

Sol. Given, $f = -20$ cm (sign convention), $v = -10$ cm

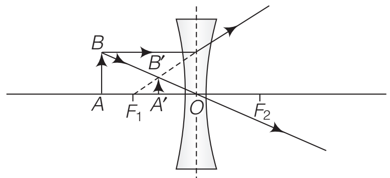
($\because$ image formed by concave lens is virtual)

By using lens formula, $\frac{1}{u} - \frac{1}{v} = \frac{1}{f}$

We have, $-\frac{1}{u} - \frac{1}{10} = -\frac{1}{20}$

or $\frac{1}{u} = -\frac{1}{20} + \frac{1}{10} = \frac{1}{20}$ or $u = -20$ cm **[1]**

Ray diagram



[1]

Thus, the object is placed at 30 cm from the concave lens.

41. An object of height 5 cm is placed perpendicular to the principal axis of a concave lens of focal length 10 cm. If the distance of the object from the optical centre of the lens is 20 cm, determine the position, nature and size of the image formed using the lens formula.

Sol. Given, height of object, $h_o = 5$ cm,

focal length, $f = -10$ cm,

distance of object, $u = -20$ cm, $v = ?$

Using lens formula, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{(-10)} + \frac{1}{(-20)} = \frac{-1}{10} - \frac{1}{20}$$

$$= \frac{-2-1}{20} = \frac{-3}{20}$$

$$\Rightarrow \quad v = -6.67 \text{ cm}$$

Image is at 6.67 cm from concave lens. **[1½]**

As, magnification, $m = \frac{h_i}{h_o} = \frac{v}{u}$

$$\Rightarrow \quad h_i = h_o \times \frac{v}{u} = 5 \times \frac{-20}{3} \times \frac{1}{-20}$$

$$= \frac{5}{3} = 1.67 \text{ cm}$$

The image is virtual, erect and diminished. **[1½]**

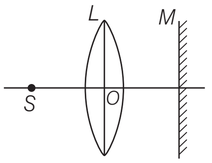
CHAPTER EXERCISE

2 Marks Questions

1. Copy and complete the following table. ***[2009]***

Type of Lens	Position of Object	Nature of Image	Size of Image
Convex	At F		
Concave	At infinity		

2. The diagram shows a point source of light S, a convex lens L and a plane mirror M. These are placed such that rays of light from S return to it after reflection from M.



(i) What is the distance OS called?

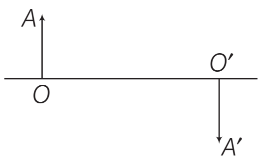
(ii) To which point (left of S or right of S) will the rays return, if M is moved to the left and brought in contact with L?

3. Distinguish between a real and a virtual image.

4. An object is placed in front of a concave lens. Is it possible that the image formed has the same size as that of the object? If yes, then draw the ray diagram.

3 Marks Questions

5. The diagram shows an object (OA) and its image ($O'A'$) formed by a lens. Complete the ray diagram and locate the focus of the lens. State whether the lens is concave or convex?



6. (i) Where should an object be placed so that, a real and inverted image of the same size as the object is obtained using a convex lens?

(ii) Draw a ray diagram to show the formation of the image as specified in the part a (i). ***[2015]***

7. Explain the action of a simple microscope as a magnifier. Draw the ray diagram for the image formation.

8. State three characteristics of the image of an extended source, formed by a concave lens.

4 Marks Questions

9. (i) Where should an object be placed so that, a real and inverted image of double the size of the object is obtained using a convex lens?

(ii) Draw a ray diagram to show the formation of the image as specified in the part (i).

(iii) Ramesh claims to have obtained an image thrice the size of the object with a concave lens. Is he correct? Give reason for your answer.

10. An object is placed in front of a lens between its optical centre and the focus and forms a virtual, erect and diminished image.

(i) Name the lens which forms this image.

(ii) Draw a ray diagram to show the formation of the image with the above stated characteristics. ***[2011]***

Numerical Based Questions

11. Find the focal length of a lens of power + 4.0 D. What type of lens is this? ***Ans.*** 0.25 m

12. A lens produce an erect and magnified image of an object when the object is placed at 20 cm from its optical centre.

(i) Identify the nature of lens.

(ii) What is the position of the object if the focal length of the lens is 25 cm? ***Ans.*** 100 cm

13. An object is placed at a distance of 10 cm from a lens of power 4D. Find the position and nature of image so formed. ***Ans.*** –7.14 cm, diminished virtual and erect

14. An object is placed perpendicular to the principal axis of a convex lens of focal length 10 cm. The distance of the object from the lens is 15 cm. Find the position of the image. What is the nature of the image formed? ***Ans.*** 30 cm, real and inverted

15. A convex lens has focal length equal to 25 cm. An object is placed at a distance 12.5 cm from the lens. Draw the diagram to find the position of image. ***Ans.*** 25 cm on the object side