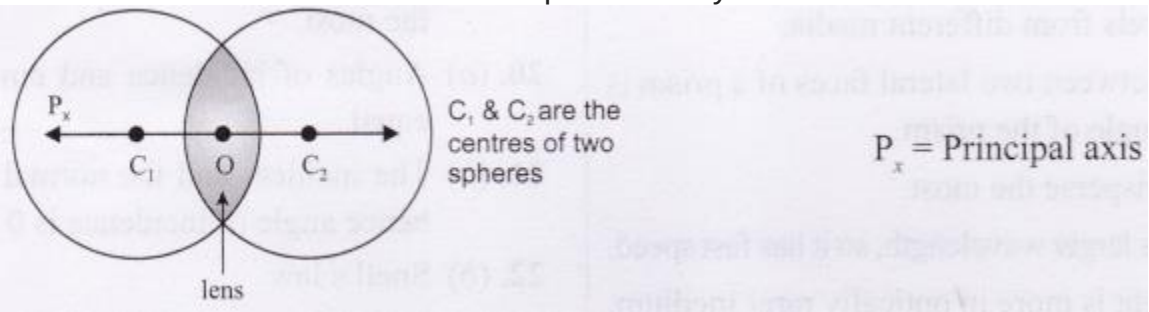
Image Formation by a Convex Lens

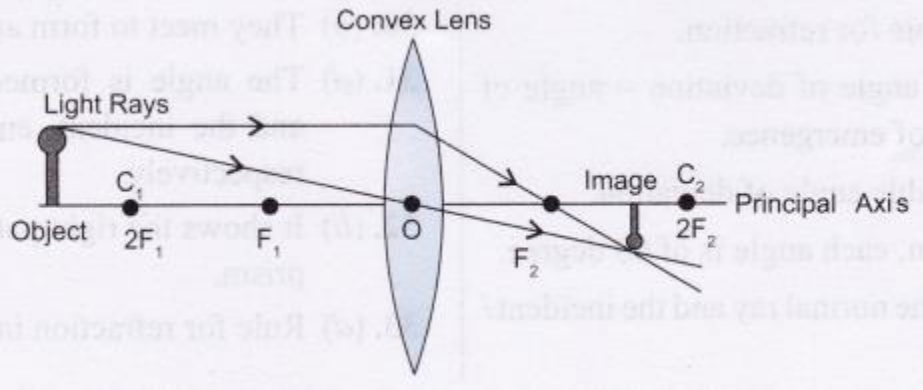
Introduction

- **Lens:** A transparent material bound by two surfaces, of which one or both surfaces are spherical, forms a lens.
  Convex lens: Convex lens is a transparent curved device that is used to refract light. A lens is usually made from glass. There are two different shapes for lenses. They are called convex and concave lens. A convex lens is thicker in the middle and thinner at the edges, it is also called a converging lens. A convex lens will focus light and make a real and inverted image. The size of the image will depend on the position of the object and lens.
- **Concave lens:** A concave lens is thinner in the middle and thicker at the edges. A concave lens is also called a diverging lens. A concave lens will disperse light and make an image that is always virtual, upright and smaller than the object.
- **Principal axis:** The principal axis is a line that is perpendicular to and passes through the centre of the lens.
- **Principal focus:** The principal focus, F is the point through which all incident rays travelling parallel to the principal axis after refraction appear to meet.
- The focal length "*f*' is the distance from the center of the lens, O to the principal focus, F.
- **Centre of curvature of lens:** A convex lens is made up of two spherical surfaces. These surfaces are the parts of a sphere. The centre of these spheres are called centres of curvature of the lens. It is represented by



- **Optical centre:** The central point of a lens is its optical centre (O).
- **Aperture of lens:** The diameter of the circular outline of a spherical lens is called its aperture. Lenses with thin apertures are called thin lenses.
- **Real image:** When the light rays after refraction actually meet at a point to form the image is said to be real image, it is always inverted and can be obtained on the screen.
- **Virtual image:** When the light rays after i-efraction through a lens do not actually meet but appears to meet, then the image formed is virtual. It cannot be obtained on the screen and is always erect.

- **Magnification of image:** When an image is formed after refraction, then its size may be same, enlarged or diminished. The ratio of size of image to size of object is called magnification.
- **Power of a lens:** The power of a lens is the reciprocal of the focal length (f in metres). The S.I. unit of power is dioptre (D).
- Ray diagram through the convex lens:



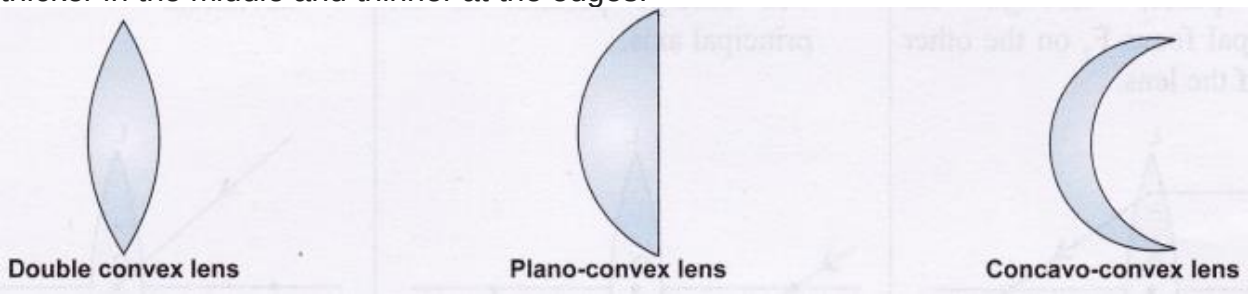
Science Lab Manual Experiment 7

Aim

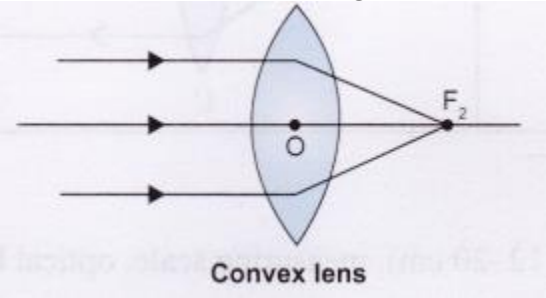
To find the image distance for varying object distances in case of a convex lens and draw corresponding ray diagrams to show the nature of image formed.

Theory

- **Lens:** It is a piece of a transparent medium. It may be curved at both the surfaces or may be plane at one surface and curved at the other surface. Two main types of lenses are: (a) convex lens or converging lens and (b) concave lens or diverging lens.
- **Convex lens and its types:** It is also called converging lens because it converges a beam of light incident on it. Double convex lens is bulging in the centre, i.e., it is thicker in the middle and thinner at the edges.

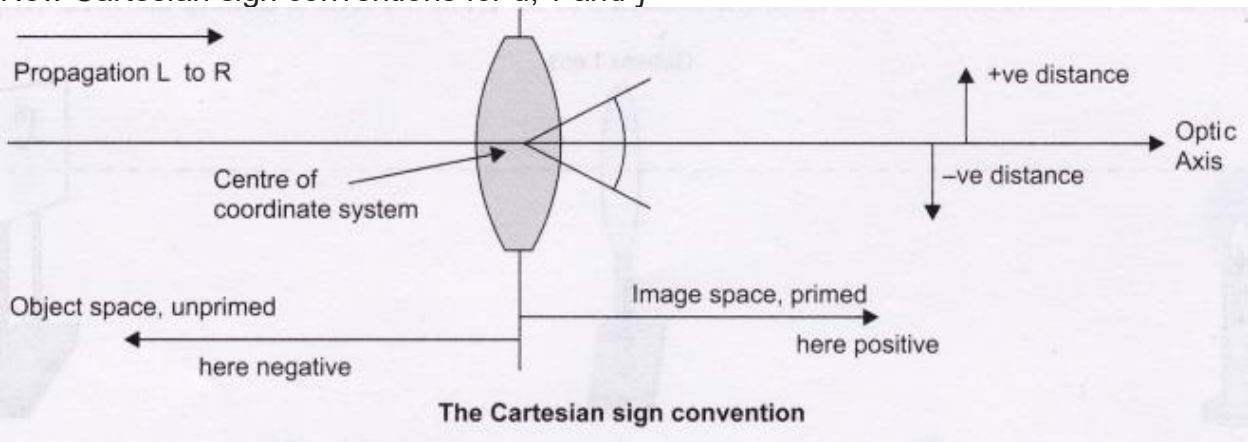


- **Convex lens:** It is a converging lens with real focus. These lenses are thick in the middle and thin at the edges.



Convex lens

- The distance of object from the centre of lens is represented by letter ‘u’. The distance of image from the centre of lens is represented by letter V.
- **Lens formula:** This formula gives the relationship between object distance (u), image-distance (v) and the focal length (f). The lens formula is expressed as $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$
- New Cartesian sign conventions for u, v and f

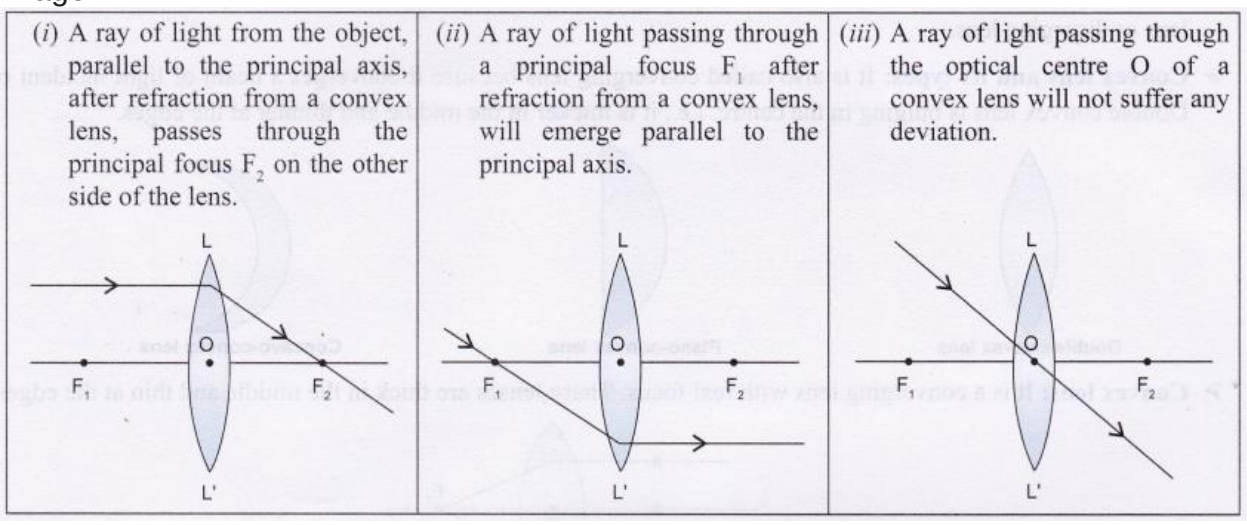


The Cartesian sign convention

1. The object is always placed to the left of the lens.
2. Incident rays are drawn from left towards the right of the lens.
3. All distances are measured from the optical centre as origin.
4. Distances measured in the direction of the incident rays are taken as positive.
5. Distances measured opposite to the direction of the incident rays are taken as negative.
6. Distances measured perpendicular to and above the principal axis are taken as positive.
7. Distances measured perpendicular to and below the principal axis are taken a negative.
8. Focal length of a convex lens is taken as positive while that of concave lens is taken as negative.

- For the sake of clarity of ray diagrams, only two rays are considered.
- The intersection of atleast two refracted rays gives the position of image of the point object. Any two of the following rays can be considered for locating the

image:

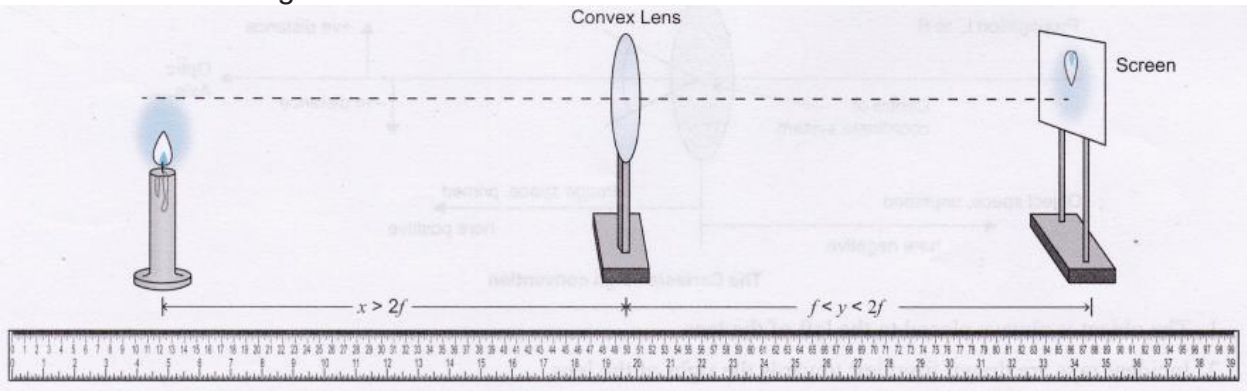


Materials Required

A convex lens of a short focal length (12-20 cm), measuring scale, optical bench and a needle or a candle.

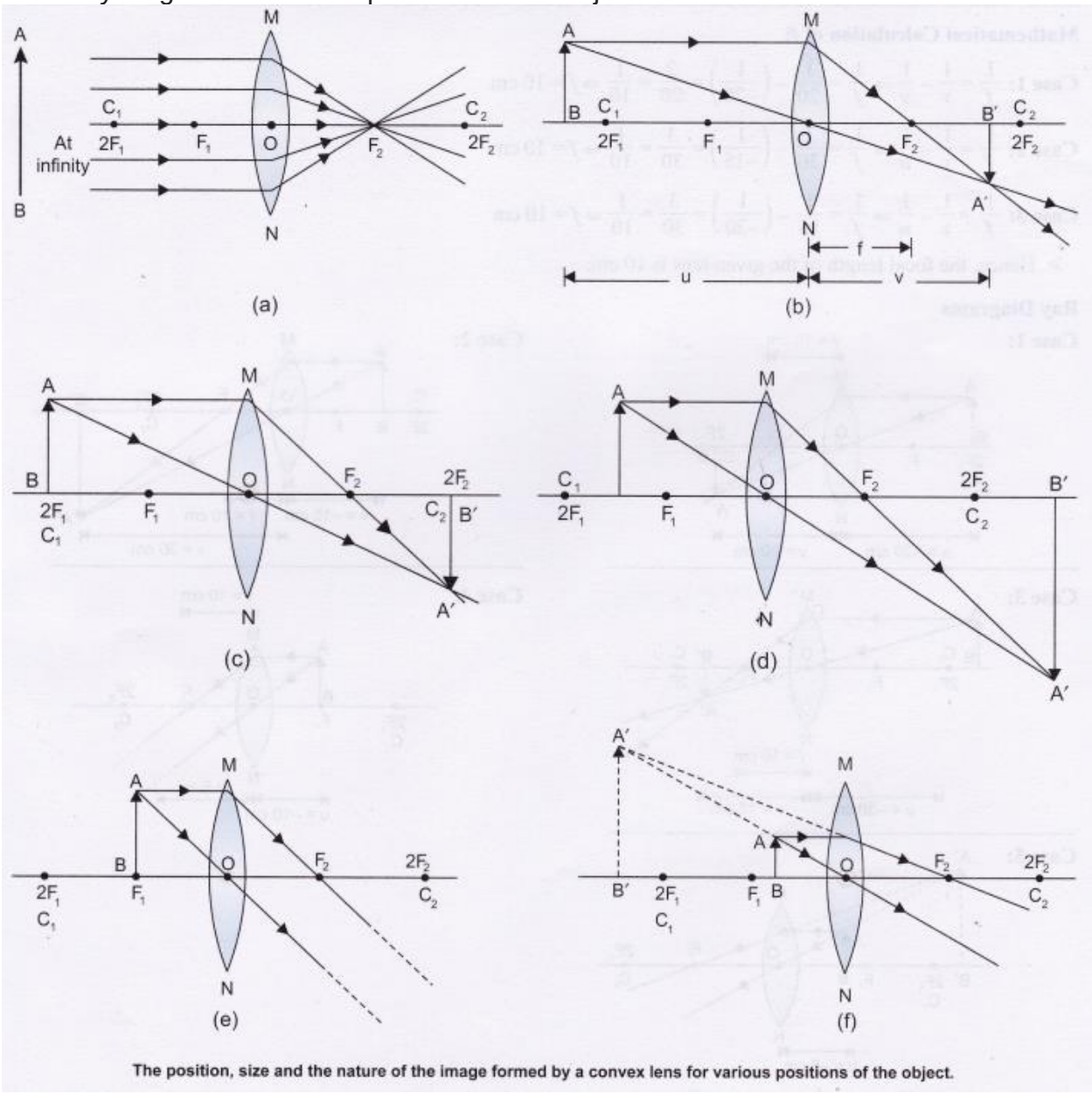
Procedure

1. Fix a thin convex lens on a lens holder and place the screen on the other side of the lens.
2. Focus a sharp, clear and inverted image of the distant object on the screen. This is the rough focal length, measure it with the help of a metre scale.
3. Mark the position of lens on optical bench or on a table. Fix the lens at this point, label it as ‘O’.
4. Mark a point ‘F’ at both the sides of the lens as focus of the lens by knowing the focal length as calculated in first step.
5. Mark a point 2F at both the sides of the lens, the distance of 2F from the lens is double the focal length of the lens.



Locating the image of a lighted candle flame placed beyond twice the focal length of a thin lens

6. Place a candle on the table or needle on optical bench at distance beyond 2F and adjust the height of the centre of lens nearly equal to the height of the flame of the candle.
7. To locate a sharp image of the candle flame in the convex lens from the other side of the lens, adjust the position of the screen and record your observations.
8. Now, place the object, e., the lighted candle or the needle at 2F and record your observations.
9. Now, shift the object between F and 2F and record the observations.
10. Now, place the object at F and record the observations.
11. Place the object between O and F of the lens and record your observations.
12. Draw ray diagrams for all the positions of the object.



The position, size and the nature of the image formed by a convex lens for various positions of the object.

Observation Table

S. No.	Position of the optical centre O of the lens 'l' (cm)	Position of candle 'a' (cm)	Position of screen 's' (cm)	Distance between lens and candle (object distance) $u = a - l$ (cm)	Distance between lens and screen (image distance) $v = s - l$ (cm)	Focal length (f)
1.	50	30	70	–20	20	10 cm
2.	50	35	80	–15	30	10 cm
3.	50	20	65	–30	15	10 cm
4.	50	40	No image obtained on screen	–10	Infinity	
5.	50	45	No image obtained on screen	–5	Virtual image obtained and cannot be taken on screen	

Mathematical Calculation of f:

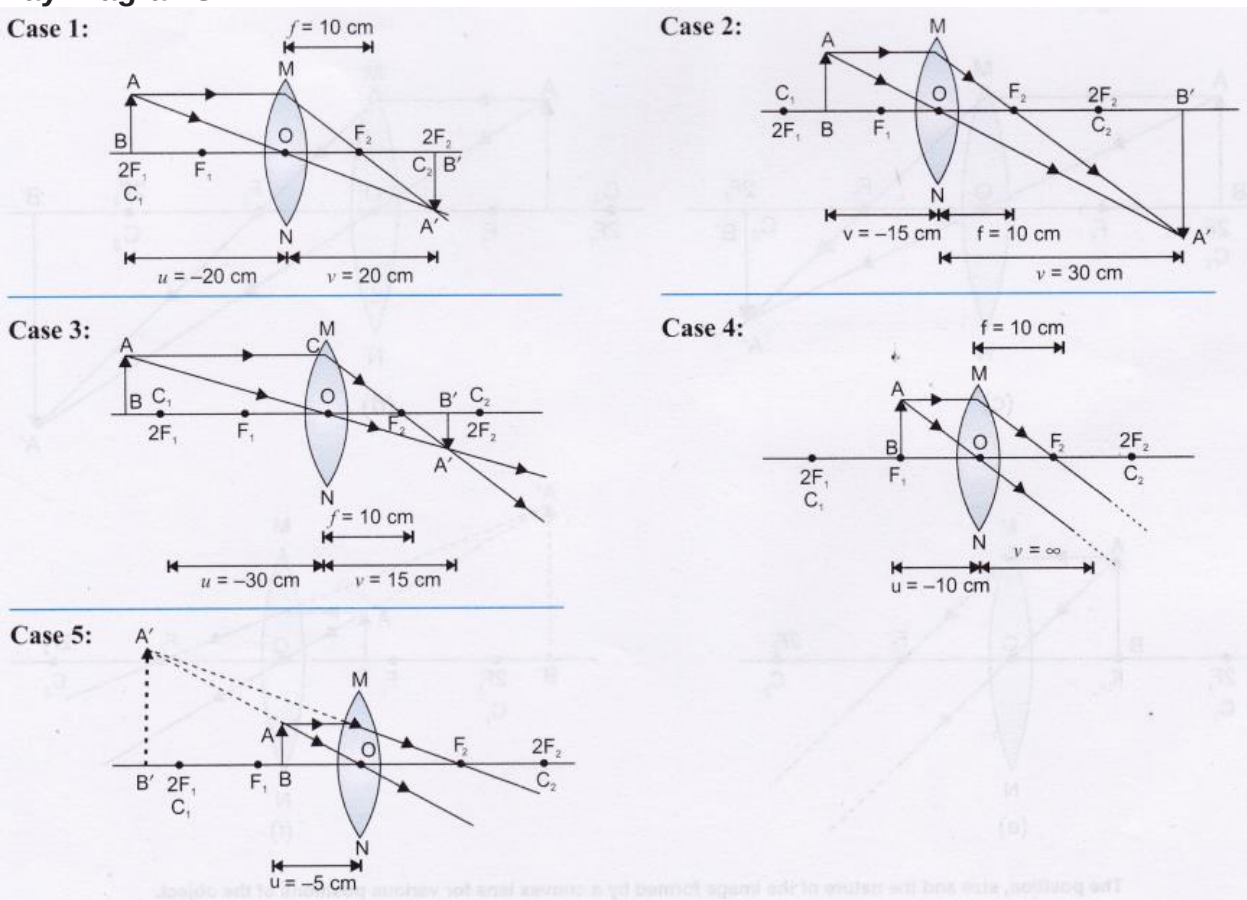
Case 1: $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{f} = \frac{1}{20} - \left(\frac{1}{-20}\right) = \frac{2}{20} = \frac{1}{10} \Rightarrow f = 10 \text{ cm}$

Case 2: $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{f} = \frac{1}{30} - \left(\frac{1}{-15}\right) = \frac{3}{30} = \frac{1}{10} \Rightarrow f = 10 \text{ cm}$

Case 3: $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{f} = \frac{1}{15} - \left(\frac{1}{-30}\right) = \frac{3}{30} = \frac{1}{10} \Rightarrow f = 10 \text{ cm}$

> Hence, the focal length of the given lens is 10 cm.

Ray Diagrams



Result

S.No.	Position of the object	Position of the image	Relative size of the image	Nature of the image
1.	At $2F_1$	At $2F_2$	Same size	Real and inverted
2.	Between F_1 and $2F_1$	Beyond $2F_2$	Enlarged	Real and inverted
3.	Beyond $2F_1$	Between F_2 and $2F_2$	Diminished	Real and inverted
4.	At focus F_1	At infinity	Infinitely large or highly enlarged	Real and inverted
5.	Between focus F_1 and optical centre O	On the same side of the lens as the object	Enlarged	Virtual and erect
6.	At infinity	At focus F_2	Highly diminished, point-sized	Real and inverted

The focal length of the given lens is 10 cm.

Precautions

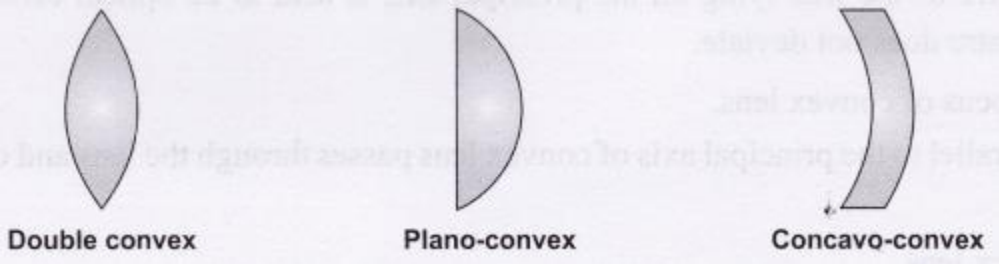
1. The focal length of the convex lens must be between 15 to 20 cm.
2. Use thin convex lens of small aperture.
3. Perform this experiment in calm air to avoid the flickering of the candle flame.

4. To obtain distinct and sharp image of the candle flame, perform this experiment in a dark room.
5. The optical bench or the bench holding the lens, object and image screen should not be shaky.

Science Lab Manual Viva Voce

Question 1:
What is a lens?
Answer:
It is a transparent medium bounded by two surfaces, one or both may be curved.

Question 2:
How many types of convex lens do you know?
Answer:
The three types of lens are double convex lens, plano-convex and concavo-convex lens.



Question 3:
What is meant by principal axis of a lens?
Answer:
A straight ray of light passing through the centre of a lens and centre of curvatures is called principal axis

Question 4:
If half of the convex lens is covered by a paper, will you get an image?
Answer:
Yes, the image will be obtained but little blurred.

Question 5:
Define focal length of a lens.
Answer:
It is the distance between the optical centre and its principal focus. Its unit is metre.

Question 6:
Define power of a lens.
Answer:

Power of lens is defined as the reciprocal of its focal length in metre.
$p = \frac{1}{f}$(in metres)
Unit of power of a lens is dioptre.

Question 7:
Define one dioptre.
Answer:
One dioptre is the power of a lens when focal length is 1 metre.

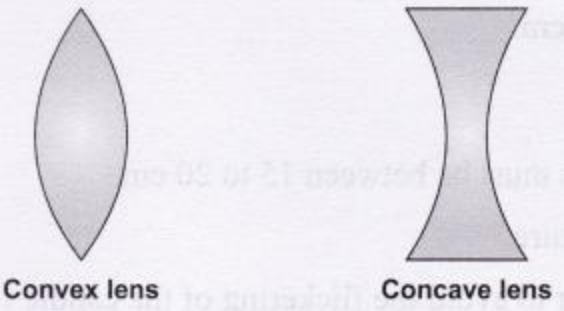
Question 8:
Give one use of concave lens.
Answer:
Concave lens is used in spectacles.

Question 9:
Which lens is used to correct myopia, i.e., short sightedness?
Answer:
A concave lens.

Question 10:
Which lens is used to correct hypermetropia, i.e., long sightedness?
Answer:
A convex lens.

Science Lab Manual Practical Based Questions

Question 1:
How is convex lens different from concave lens?
Answer:
Convex lens is thicker in the middle and thinner at the edges. Concave lens is thinner in the middle than at the edges



Question 2:
Without touching the lenses how can you distinguish between the convex and concave lens.

Answer:
If the image formed by the given lens is inverted then it is convex lens otherwise it is a concave lens.

Question 3:
Which lens is called converging lens and why?
Answer:
Convex lens is called converging lens because it converges the parallel beam of light passing through it at a point.

Question 4:
Which lens is called diverging lens and why?
Answer:
Concave lens is called diverging lens because it diverges all the rays incident on it.

Question 5:
What do you mean by optical centre of a lens?
Answer:
A point in the centre of the lens lying on the principal axis is said to be optical centre. A ray of light passing through optical centre does not deviate.

Question 6:
Define principal focus of convex lens.
Answer:
A beam of light parallel to the principal axis of convex lens passes through the lens and converges at a point called principal focus.

Question 7:
Give uses of convex lens.
Answer:
Convex lens is used in spectacles, telescopes and microscopes (simple and compound).

Question 8:
What is the nature of image formed by convex lens when object is placed at 2F.
Answer:
The image formed is inverted, real and of same size as that of object, obtained on the screen at 2F.

Question 9:
What is the nature of image formed by convex lens if the object is placed beyond 2F?
Answer:
The image formed is real, inverted and diminished, between F and 2F.

Question 10:
What is magnification of image?
Answer:
The ratio of height of image to height of object is said to be the magnification. It is given by m = $\frac{-v}{u} = \frac{h'}{h}$.

Question 11:
What type of image is formed by convex lens?
Answer:
Convex lens forms real image. It can be magnified or diminished.

Question 12:
How can you use convex lens as a magnifying glass?
Answer:
When the object is placed between focus of the lens and the aperture of the lens then the image formed will be magnified and lens can be used as magnifying lens.

Question 13:
What type of image is formed by concave lens?
Answer:
A concave lens always form virtual, erect and diminished image.

Question 14:
If an object is placed at infinity where is the image formed in case of concave lens?
Answer:
If the object is placed at infinity the image is formed at the focus, virtual, erect and diminished.

Question 15:
The power of the lens is -ID. What is the nature of the lens?
Answer:
If the power of the lens is negative then it is concave lens.

Question 16:
The power of the lens is +1.5D. What is the nature of the lens?
Answer:
When the power of the lens is positive, then it is a convex lens.

Question 17:
Where will you keep an object to obtain real and enlarged image?
Answer:
To obtain real and enlarged image we will use convex lens and place the object between F and 2F.

Science Lab Manual Questions

Question 1:
What is the nature of an image formed by a thin convex lens for a distant object? What change do you expect if the lens were rather thick?
Answer:
The image formed by thin convex lens for distant object is real, inverted, highly diminished and at the focus.
If the convex lens is thick the image formed will be real, inverted, highly diminished and the focal length will be smaller as compared to the thin lens.

Question 2:
You are provided with two convex lenses of same aperture and different thickness. Which one of them will be of shorter focal length?
Answer:
Thick convex lens will have shorter focal length.

Question 3:
If we cover one half of the convex lens while focusing a distant object, in what way will it affect the image formed?
Answer:
The image formed will be blurred and less clear but complete image will be formed of the object.

Question 4:
Which type of lens is used by the watch-makers while repairing fine parts of a wrist watch?
Answer:
Convex lens.

Question 5:
Sometimes, the image formed by a convex lens, of an object placed at $2F_1$ is not of the same size and at location $2F_2$ on the other side of the convex lens. What could be the possible reason(s) for such a situation?
Answer:
The convex lens generally produces the image of the object placed at $2F_1$ of same size at $2F_2$ as that of the object. But this is true only for thin convex lenses with small apertures. For thick convex lens with larger aperture does not show the image of same size.

Question 6:
A ray of light is passing through the principal focus of a convex lens. How will it emerge after refraction through the lens?
Answer:

A ray of light passing through the principal focus of a convex lens will be parallel to the principal axis after refraction through the lens.

Question 7:
An object is placed on the left side of a lens (having 10 cm focal length) at a distance of 20 cm. What will be the sign of object distance?
Answer:
The distance of the object is measured against the direction of incident ray of light and hence will be negative.

Question 8:
How will you distinguish between a convex lens and a concave lens by holding in hand and looking the printed page through them?
Answer:
If the print on the page is magnified than the lens is convex and if the print appears to be diminished then the lens is concave.

Question 9:
In what way will image of the lighted candle be affected when the experiment is performed in a bright light area and on a windy day?
Answer:
In a bright light area the clarity of the image will be less and on the windy day the image will be shaky.

Question 10:
A distinct image of the lighted candle has been obtained on screen with fixed position, using a thin convex lens. Why does the image of the candle get blurred if the position of any one of them is slightly disturbed?
Answer:
The sharp and clear image of the object is formed only when all the rays after refraction meet sharply at one place and if the position of the object or screen is changed then all the refracted rays don't meet on the screen and hence the image formed is not clear, sharp and is blurred.

Question 11:
What effect do you expect if the lens is thick?
Answer:
The focal length of the lens will change thereby affecting the position of the image formed.

Question 12:
Why do we require a calm atmosphere to perform this experiment?
Answer:

The calm atmosphere allows the accuracy in measuring the distances, focal length and position of the image formed.

Question 13:
Why is it preferred to perform this experiment in dark or in shade?
Answer:
To obtain the clear and sharp image of the candle flame.

Science Lab Manual Multiple Choice Questions (MCQ's)

Questions based on Procedural and Manipulative Skills

1. The part of the lens through which the ray of light passes without suffering any deviation is
(a) focus
(b) centre of curvature
(c) optical centre
(d) pole

2. Double convex lens is used in
(a) spectacles
(b) microscope
(c) telescope
(d) all of these

3. The unit of power of a lens is
(a) metre
(b) dioptre
(c) centimetre
(d) none of these

4. The lens formula is:

(a) $\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$ (b) $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}$
(c) $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$ (d) $\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$

5. A lens that always produces virtual image is
(a) convex lens
(b) concave lens
(c) double convex lens
(d) concavo-convex lens

6. The lens used by watch maker is:
(a) concave lens
(b) convex lens
(c) both (a) and (b)
(d) none of these

7. The imaginary straight line passing through the centre of the lens is called:
(a) optical centre
(b) pole
(c) principal axis
(d) principal focus

8. The power of the lens is -2.5 D. The nature of the lens is:
(a) concave
(b) convex
(c) concavo-convex
(d) convexo-concave

9. The diameter of the convex lens is called:
(a) curvature
(b) aperture
(c) focal point
(d) focal length

Questions based on Observational Skills

10. Convex lens always gives real image only if the object is placed
(a) beyond optical centre 'O'
(b) beyond centre of curvature
(c) beyond focus F
(d) beyond radius of curvature

11. Incident rays parallel to the principal axis on passing through convex lens meet at
(a) focus
(b) optical centre
(c) at centre of curvature
(d) radius of curvatures

12. Convex lens produces an image of same size as that of object. The position of object is
(a) at F
(b) at 2F
(c) between F and O
(d) between F and 2F

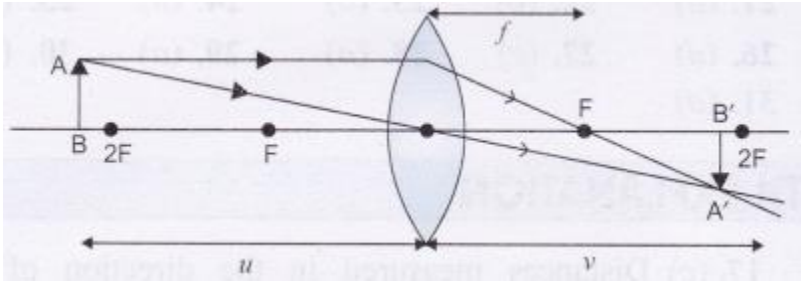
13. Convex lens is used as a magnifying glass. To see the size of object magnified, the object must be placed at a distance
(a) less than double focal length
(b) more than double focal length
(c) less than focal length
(d) more than focal length

14. An object is placed beyond 2F of a convex lens. The image formed will be
(a) diminished
(b) real and inverted
(c) between F and 2F
(d) all of these

15. The image formed by convex lens is virtual, erect and enlarged only when the object is placed
(a) at F
(b) between F and lens
(c) at 2F
(d) at infinity

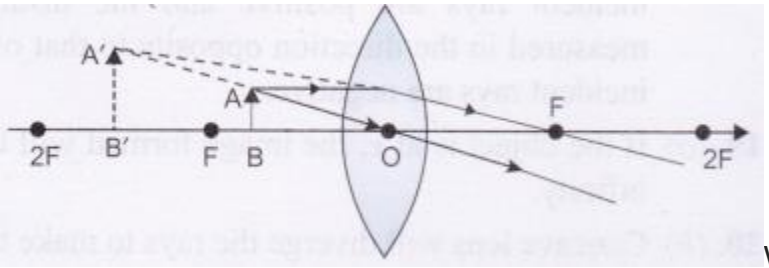
16. A child covered more than half of the convex lens to get an image of a distant object. The correct observation would be
(a) no image is
(b) virtual image is formed
(c) real image is formed
(d) real image is formed but blurred in nature

17.



In the above figure, AB is object and A' B' is image formed. The correct sign convention for u, v and/is
(a) -u, -v, -f
(b) – u, -f, + v
(c) –u, +f, + *v*
(d) +u,+f, +v

18.



When the object is placed between F and O of the convex lens the correct sign convention for u, v and/is

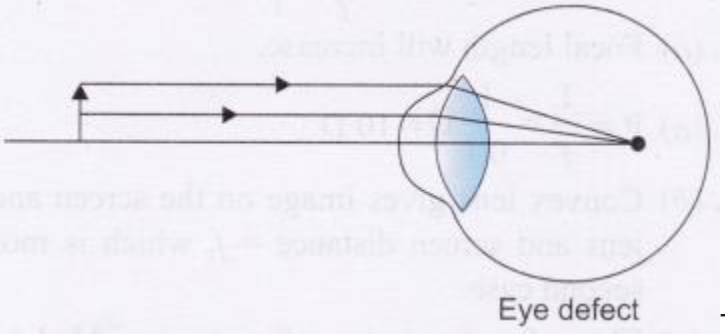
(a) +u, + v, +f
(b) – u, – v, +f
(c) – u, – v, -f
(d) – u, + v, +f

19. To obtain the image at infinity in a convex lens the object should be placed

(a) at F
(b) at 2F
(c) between F and 2F
(d) beyond 2F

Questions based on Reporting and Interpretation Skills

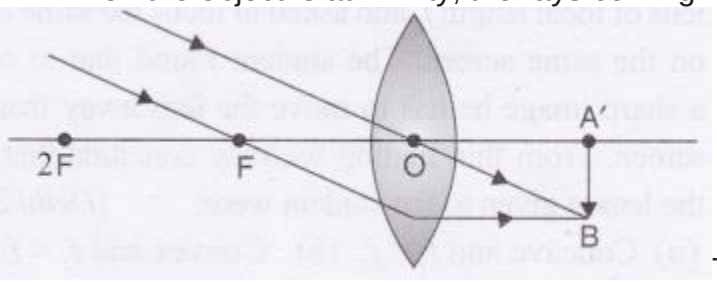
20. A person is suffering from an eye defect in which his eye lens is not able to focus the image on retina. But the image is formed in front of retina.



To correct this eye defect a patient should be advised to use

(a) convex lens which is converging in nature
(b) concave lens which is diverging in nature
(c) combination of both the lenses
(d) none of the above

21. When the object is at infinity, the rays coming from it are parallel to each other



The image is formed
(a) at F
(b) at 2F
(c) between F and 2F
(d) beyond 2F.

22. In the given figure of Q.21, the nature of image formed is
(a) real, erect, magnified
(b) real, inverted, highly diminished
(c) real, erect, diminished
(d) virtual, erect, diminished

23. To obtain a magnified image on screen of an object for convex lens the object should be placed at
(a) F
(b) between F and 2F
(c) beyond 2F
(d) between F and O

24. To get a real, inverted and enlarged image and beyond 2F, the object should be placed:
(a) at 2F
(b) between F and 2F
(c) beyond 2F
(d) between F and O

25. A convex lens has focal length of 20 cm. To get an image of same size, real and inverted the object should be placed from the lens:
(a) at 30 cm
(b) 20 cm
(c) at 10 cm
(d) 40 cm

26. A candle with flame is kept at the focus (F) of the convex lens. The image is formed:
(a) between F and 2F
(b) at 2F

(c) at F
(d) at infinity

27. The power of the lens is one dioptre when its focal length is:
(a) 1 cm
(b) 1000 cm .
(c) 100 cm
(d) 10 cm

28. A convex lens of power +5 dioptre is dipped in a beaker containing water. The power will:
(a) decrease
(b) increase
(c) no change
(d) none of these

29. A convex lens has focal length of 10 cm. What is its power?
(a) 10 D
(b) ID
(c) 0.1 D
(d) 100 D

30. A student obtained an image of a distant object on a screen to determine the focal length f_1 of the given lens. His teacher after checking the image, gave him another lens of focal length f_2 and asked to focus the same object on the same screen. The student found that to obtain a sharp image he has to move the lens away from the screen. From this finding we may conclude that both the lenses given to the student were: [Delhi 2014]
(a) Concave and $f_1 < f_2$
(b) Convex and $f_1 < f_2$
(c) Convex and $f_1 > f_2$
(d) Concave and $f_1 > f_2$

31. A concave lens is dipped in a beaker containing water it will behave like:
(a) convex lens
(b) plane glass
(c) concave lens

(d) none of these

ANSWERS				
1. (c)	2. (d)	3. (b)	4. (c)	5. (b)
6. (b)	7. (c)	8. (a)	9. (b)	10. (c)
11. (a)	12. (b)	13. (a)	14. (d)	15. (b)
16. (d)	17. (c)	18. (b)	19. (a)	20. (b)
21. (a)	22. (b)	23. (b)	24. (b)	25. (d)
26. (d)	27. (c)	28. (a)	29. (a)	30. (b)
31. (a)				

Science Lab Practicals MCQ Scoring Key With Explanation

1. (c) Optical center is the point through which any ray passes straight.

2. (d) The double convex lens,helps in magnifying the object.

3. (b) When / is in metre, the unit of power is in dioptre.

4. (c) Lens formula, $\frac{1}{v} = \frac{1}{u} = \frac{1}{f}$, gives the relationship between the object-distance (u), image-distance (v), and the focal length (f) of a spherical lens.

5. (b) Concave lens produces virtual focus.

6. (b) It gives magnified image.

7. (c) Principal axis is an imaginary straight line passing through the centre of the lens.

8. (a) Concave lens has -ve power.

9. (b) Aperture of lens = diameter of lens.

10. (c) Rays coming from beyond F meet after refraction.

11. (a) All rays parallel to principal axis meet at F after refraction through lens.

12. (b) The object placed at 2F will give same size image at 2F on the other side of the lens.

13. (a) For convex lens, if object is placed between F and 2F, the image is magnified.

14. (d) For convex lens when the object is placed beyond 2F, the image formed is diminished, real and between F and 2F.

15. (b) For convex lens when object is placed between focus F and optical centre O, the image is virtual and erect.

16. (d) On covering half or more lens the image is formed in the same position but it is blurred.

17. (c) Distances measured in the direction of the incident rays are positive and the distances measured in the direction opposite to that of the incident rays are negative.

18. (b) Distances measured in the direction of the incident rays are positive and the distances measured in the direction opposite to that of the incident rays are negative.

19. (a) If the object is at F, the image formed will be at infinity.

20. (b) Concave lens will diverge the rays to make them meet at retina.

21. (a) The parallel rays converge at F of convex lens.

22. (b) For object at infinity the image formed at F is highly diminished, real and inverted.

23. (b) If object is placed between F and 2F, the image is magnified.

24. (b) If object is placed between F and 2F, the image is magnified.

25. (d) f = 20 cm, then 2f= 40 cm, the object at 2F gives the image at 2F.

26. (d) Object at F gives image at infinity.

27. (c) 100 cm = 1 m; P = $\frac{1}{f} = \frac{1}{1}$ = 1 D

28. (a) Focal length will increase.

29. p=$\frac{1}{f} = \frac{1}{0.1}$D=10 D

30. (b) Convex lens gives image on the screen and the lens and screen distance = f which is more in second case.

31. (a) The refractive index of water is added to the refraction of light.