10 LIGHT–REFLECTION AND REFRACTION

CONCEPTS

- To revise the laws of reflection at plane surface and the characteristics of image formed as well as the uses of reflection at plane surfaces.
- To introduce the concepts of reflection at curved surfaces and the general terms related to the reflection at curved surfaces.
- To introduce the concept of geometric diagrams for the reflection at convex and concave surfaces at various distances from the pole, and hence, deduce the nature, position and size of the image.
- To learn uses of convex and concave mirrors.
- To introduce sign conventions for reflection by spherical mirrors, and hence, solve simple numerical problems.
- To introduce concept of refraction of light while travelling from different media by doing activities.
- To verify the Snell's law of refraction, using a rectangular glass slab.
- To introduce concept of refractive index as a ratio between sin *i* and sin *r*.
- To introduce concept of refractive index as the ratio of velocity of light in air or vacuum to the velocity of light in a given medium.
- To show simple effects of refraction of light by geometric diagrams.
- To introduce the concept of lateral displacement.
- To introduce the concept of lenses as spherical optical pieces, and their kinds.
- To learn simple terms associated with lenses.
- To learn experimentally the images formed by the convex and concave lenses and their geometric diagrams as well as characteristics of the images formed.
- To learn uses of convex and concave lenses.
- To learn about the power of lens and its merits.
- To learn sign conventions in solving simple problems on convex and concave lenses.

I. SUMMATIVE ASSESSMENT

NCERT QUESTIONS WITH THIER ANSWERS

SECTION A : IN-TEXT QUESTIONS

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1. Define the principal focus of a concave mirror.

Ans. A point in front of a concave mirror, on its principal axis, such that parallel rays travelling parallel to the principal axis, after reflection actually converge at this point.

2. The radius of curvature of a spherical mirror is 20 cm. What is its focal length ?

Ans. Focal length = $\frac{\text{Radius of curvature}}{2} = \frac{20\,\text{cm}}{2} =$ **10 cm**

3. Name a mirror that can give an erect and enlarged image of an object.

Ans. The mirror is called concave mirror.

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

Ans. It is because, it covers a wide rear field and forms small, erect and virtual image, close to the eye of the driver of the vehicle.

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1. Find the focal length of a convex mirror whose radius of curvature is 32 cm.

Ans. Focal length = $\frac{\text{Radius of curvature}}{2} = \frac{32\,\text{cm}}{2}$ = **16 cm.**

2. A concave mirror produces three times magnified real image of an object, placed at 10 cm in front of it. Where is the image located?

Ans. $u = -10$ cm, $v = ?$ $m = -3$

Now, $m = -\frac{v}{u} \Rightarrow -3 = \frac{-v}{-10\,\text{cm}}$

$\therefore -v = 30$ cm $\Rightarrow$ $\boldsymbol{v = -30}$ **cm.**

Thus the real and inverted image is formed at a distance of ***30 cm from the pole and in front of it.***

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1. A ray of light travelling in air enters obliquely into water. Does the light ray bend towards normal or away from normal? Why?

Ans. The ray bends towards normal. It is because the velocity of light decreases in water as compared to the air.

2. Light enters from air to glass having refractive index 1.5. What is the speed of light in the glass? Speed of light in vacuum is 3×10^8 ms^{-1}.

Ans. Speed of light in glass = $\frac{\text{Speed of light in vacuum}}{\text{Refractive index}} = \frac{3\times\ 10^8 \text{ms}^{-1}}{1.5} = \mathbf{2\times10^8\ ms^{-1}}$.

3. Name a medium which has : (i) highest optical density (ii) lowest optical density.

Ans. (i) Highest optical density of material medium is 2.42 for diamond.

(ii) Lowest optical density of material medium is 1.0003 for air.

4. You are given kerosene oil, turpentine oil and water having optical densities 1.44, 1.47 and 1.33 respectively. In which of these medium the light travels fastest and why?

Ans. Light travels fastest in water, as lesser the optical density, more is the speed of light.

5. The refractive index of diamond is 2.42. What is the meaning of this statement?

Ans. From the statement it implies that the ratio of speed of light in vacuum to the speed of light in diamond is 2.42.

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1. Define 1 dioptre power of lens.

Ans. A lens having a focal length of 1 m is said to have a power of 1 dioptre.

2. Find the power of a concave lens of focal length 2 m.

Ans. Power of lens $= \frac{1}{\text{Focal length in metres}} = \frac{1}{-2\,\text{m}} =$ **– 0.5 D.**

3. A convex lens forms a real and inverted image of a needle at a distance of 50 cm from it. Where is the needle placed in front of the convex lens, if the image is equal to the size of the object? Also find the power of the lens.

Ans. As the convex lens forms a real and inverted image of the needle equal to the size of the object, therefore, we can say that the needle is located at $2F_1$ which is 50 cm from the convex lens.

$\therefore$ Focal length of convex lens $= \frac{50\,\text{cm}}{2} =$ **25 cm**

$\therefore$ Power of the lens $= \frac{100\,\text{cm}}{\text{Focal length (in cm)}} = \frac{100\text{ cm}}{25\text{ cm}} =$ **+ 4D**

SECTION B : QUESTIONS FROM THE END OF THE CHAPTER

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

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

Ans. (d) is the correct choice as clay is an opaque substance.

2. Where should an object be placed in front of a convex lens to get a real image of the same 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.

Ans. (b) is the correct answer.

3. A spherical mirror and a thin spherical lens have each focal length – 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 and the lens is concave.

Ans. (a) is the correct answer.

4. Which of the following lenses would you prefer to use while reading small letters found in dictionary?

(a) A convex lens of focal length 50 cm. (b) A concave lens of focal length 50 cm.

(c) A convex lens of focal length 5 cm. (d) A concave lens of focal length 5 cm.

Ans. (c) is the correct answer as lesser the focal length of a convex lens, more is the magnification.

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

(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.

Ans. The correct answer is (d).

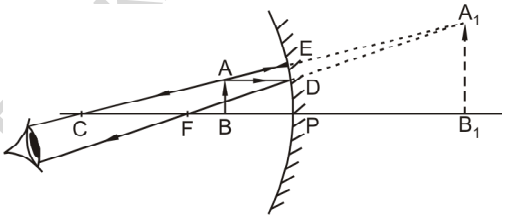
6. No matter how far you stand from a mirror, your image appears erect. The mirror may be :

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

Ans. The correct answer is (d)

7. You wish to obtain an erect image of an object, using concave mirror of focal length 15 cm. What should be the range of the distance of the object from the mirror? What is the nature of image? Is the image larger or smaller than the object ? Draw a ray diagram to show the formation of image in this case.

Ans. (a) The object should lie between P and F. Thus the range of object from the pole of mirror is from 0 to 15 cm.



(b) The image is virtual.

(c) Image is larger than the size of the object.

(d) Image is behind the mirror.

8. For a plane mirror, magnification $m = +1$, what does this signify for :

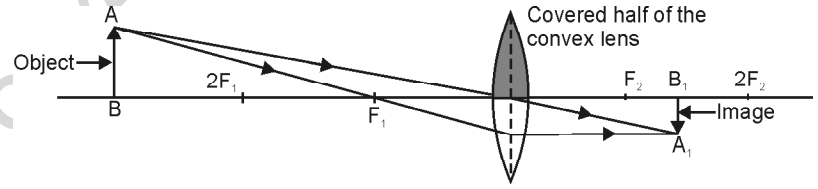
(a) $m = 1$ (b) positive sign of m?

Ans. (a) $m = 1$ signifies that size of the image is equal to the size of the object.

(b) The positive sign signifies that image formed by the plane mirror is erect and virtual.

9. One half a convex lens is covered with a black paper. Will this lens produce a complete image of the object? Verify your answer and explain your observation.

Ans. The lens will produce complete image of the object as illustrated by the diagram below.



The image formed is not as bright as the object because half of the lens is blackened. However, it forms a complete image, because each part of the lens by itself is converging in nature.

10. An object is placed at a distance of 10 cm from a convex mirror of focal length 15 cm. Find the position and the nature of the image.

Ans. Distance of the object from the convex mirror (u) = –10 cm

Focal length of the convex mirror (f) = 15 cm

Distance of the image from the convex mirror (v) = ?

Applying, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f} \Rightarrow \frac{1}{v}-\frac{1}{10}=\frac{1}{15}$

$$\frac{1}{v}=\frac{1}{15}+\frac{1}{10}=\frac{2+3}{30}=\frac{5}{30}=\frac{1}{6}$$

$\therefore$ v = **6 cm**

Thus, the image is formed at a distance of **6 cm** behind the mirror. The image is virtual, erect and **smaller in size** than object.

11. An object 5.0 cm in length is placed at a distance of 20 cm in front of a convex mirror of radius 30 cm. Find the position of image, its nature and size.

Ans. **To calculate the position.**

Distance of the object from the pole,

(u) = – 20 cm [u is always negative]

Distance of the image from the pole,

(v) = ? [To be calculated]

Focal length of convex mirror,

$(f)=\frac{30\,\text{cm}}{2}$ = 15 cm [f for convex mirror is positive]

Applying, $\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \Rightarrow \frac{1}{-20}+\frac{1}{v}=\frac{1}{15} \Rightarrow \frac{1}{v}=\frac{1}{15}+\frac{1}{20}=\frac{4+3}{60}=\frac{7}{60}$

$\therefore$ $v=\frac{60}{7}=$ **8.57 cm**

To calculate size :

$$\frac{h_i}{h_o}=-\frac{v}{u} \Rightarrow h_i=h_0\times\frac{-v}{u}=\frac{5.0\times(-8.57)}{-20}=\textbf{2.14 cm}$$

Thus, position of image is 8.57 cm behind the mirror which is diminished to 2.14 cm. It is a virtual and erect image.

12. An object of size 7.0 cm is placed 27 cm in front of concave mirror of focal length 18 cm. At what distance from the mirror, should a screen be placed, so that a sharp focussed image can be obtained ? Find the size and nature of the image.

Ans. (i) **To calculate the position :**

Distance of object from the pole,

(u) = – 27 cm [u is always negative]

Distance of image from the pole,

(v) = ? [To be calculated]

Focal length of concave mirror

(f) = – 18 cm [f for concave mirror is negative]

Applying, $\frac{1}{f}=\frac{1}{u}+\frac{1}{v} \Rightarrow \frac{1}{-18}=\frac{1}{-27}+\frac{1}{v} \Rightarrow -\frac{1}{v}=-\frac{1}{27}+\frac{1}{18}=\frac{-2+3}{54}$

$\Rightarrow$ $-\frac{1}{v}=\frac{1}{54}$ $\therefore$ $v=$ **–54 cm**.

Thus, the image is formed at a distance of 54 cm in front of the concave mirror.

(ii) **To calculate size :**

$$\Rightarrow \frac{h_i}{h_o} = -\frac{v}{u} \Rightarrow \frac{h_i}{+7.0} = -\frac{-54}{-27} \Rightarrow h_i = -2 \times 7.0 = \mathbf{-14\ cm}.$$

Thus, size of image is 14 cm and it is an inverted, magnified and real image.

13. A doctor has prescribed a corrective lens of power +1.5D. Find the focal length of the lens. Is the prescribed lens converging or diverging?

Ans. (i) Focal length of lens $= \dfrac{1\text{m}}{\text{Power of lens}} = \dfrac{1\text{m}}{1.5}$

$= 0.6666$ m = **66.66 cm**

(ii) The lens is converging in nature as its power is positive.

14. Find the focal length of lens of power – 2.0 D. What type of lens is this ?

Ans. (i) Focal length of lens $= \dfrac{1\text{m}}{\text{Power of lens}} = \dfrac{1\text{m}}{-2} = -0.5\text{m} = \mathbf{-50.00\ cm}$

(ii) The lens is concave as its power is negative.

15. An object 5 cm high is held 25 cm from a converging lens of focal length 10 cm. Draw a ray diagram and find the position, size and the nature of the image formed.

Ans. Height of object, h_o = 5 cm.

Distance of the object from converging lens, u = – 25 cm

Focal length of converging lens, f = 10 cm

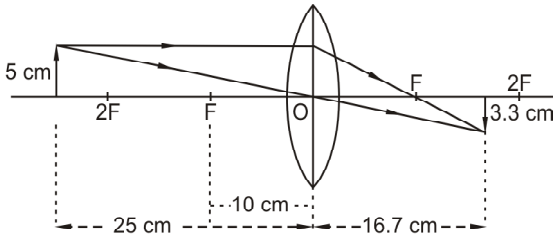
Distance of the image from converging lens, v = ?

Using lens formula, $\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f} \Rightarrow \dfrac{1}{v} - \dfrac{1}{-25} = \dfrac{1}{10}$

$$\Rightarrow \frac{1}{v} = \frac{1}{10} - \frac{1}{25} = \frac{5-2}{50} = \frac{3}{50} \quad \therefore\ v = \frac{50}{3} = 16.67\text{cm} = \mathbf{16.7\,cm}.$$

Also, for a converging lens $\dfrac{h_i}{h_o} = \dfrac{v}{u} \Rightarrow h_i = \dfrac{v}{u} \times h_o = \dfrac{50 \times 5}{3 \times -25} = \dfrac{10}{-3} \quad \therefore\ h_i = \mathbf{-3.3\,cm}.$

Thus, the image is inverted and formed at a distance of 16.7 cm behind the lens and measures 3.3 cm. The ray diagram is shown below.



16. A concave lens of focal length 15 cm, forms an image 10 cm from the lens. How far is the object placed from the lens? Draw a ray diagram.

Ans. Focal length of the concave lens (f) = –15 cm

Distance of the image from concave lens(v)= –10 cm.

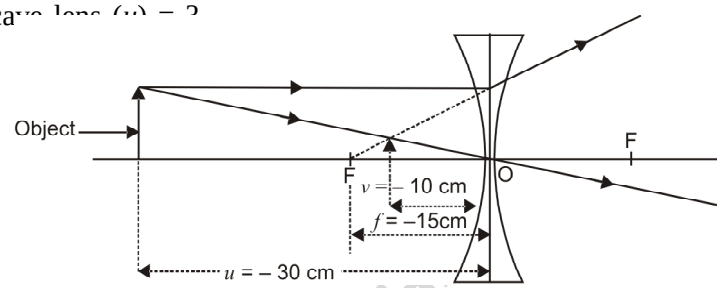
Distance of the object from concave lens (u) = ?

Applying the lens formula,

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}\Rightarrow\frac{1}{-10}-\frac{1}{u}=\frac{1}{-15}$$

or $$\frac{1}{u}=\frac{1}{15}-\frac{1}{10}=\frac{2-3}{30}=-\frac{1}{30}$$

$$\therefore\quad u=-\mathbf{30\,cm}$$



Thus, the object is placed at a distance of 30 cm in front of the concave lens. The ray diagram is shown above.

17. Name the type of mirror used in the following situations :

(a) Headlights of a car (b) Side/ rear-view mirror of a vehicle (c) Solar furnace.

Support your answer with reasons

Ans. (a) A concave mirror, as it diverges the rays of light when bulb is between P and F.

(b) A convex mirror, as it cover a wide field and forms a small erect image close to the eye of the driver.

(c) A concave mirror, as it concentrates the parallel rays of sun at principal focus.

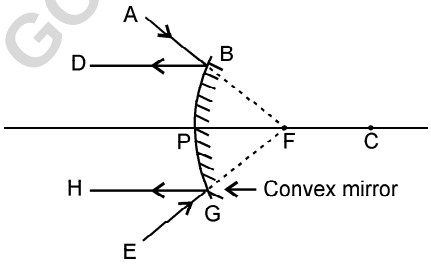
ADDITIONAL QUESTIONS
(As Per CCE Patterns)

A. Very Short Answer Questions [1 Mark]

Previous Years' Questions

1. Draw a ray diagram to show reflection of an incident ray parallel to principal axis by a convex mirror. **[2011 (T-II)]**

Ans.



2. What is the minimum distance between an object and its real image in case of a concave mirror ? **[2011 (T-II)]**

Ans. Zero, when object is at centre of curvature, its real image is also formed at the same point.

3. What are the two factors on which the lateral displacement of an emergent ray from a glass slab depends ? **[2011 (T-II)]**

Ans. (i) Angle of incidence (ii) Thickness of glass slab

4. Between which two points related to a concave mirror should an object be placed to obtain on a screen an image twice the size of the object? **[2010]**

Ans. Between centre of curvature and the principal focus.

Other Important Questions

1. Define lens.

Ans. A piece of optical material bounded by one or two spherical surfaces is called lens.

2. Why is a convex lens called converging lens?

Ans. It is because a parallel beam of light on passing through it converges at a point.

3. Define optical centre of a lens.

Ans. A point within the lens, where a line drawn through its aperture intersects the principal axis.

4. Define principal focus for a convex lens.

Ans. A point on the principal axis of a lens, where the rays coming parallel to the principal axis after refraction meet is called principal focus of the convex lens.

5. Define principal focus of a concave lens?

Ans. A point on the principal axis of a lens, where the rays coming parallel to the principal axis after refraction, appear to meet is called principal focus of the concave lens.

6. A virtual, erect and enlarged image is formed by a lens. Is the lens convex or concave?

Ans. The lens is convex lens.

7. Where will you place an electric lamp from a convex lens, so that a parallel beam of light comes out of it ?

Ans. The lamp should be placed at the principal focus of the lens.

8. A small object is placed in front of convex lens, when a real, inverted and enlarged image is formed on the other side of lens. Where is the object placed?

Ans. The object is between F and 2F of the convex lens.

9. Printed letters appear diminished when viewed through a lens. What is the nature of lens?

Ans. The lens is a concave lens.

10. A thin spherical lens has a focal length – 20 cm. What is the nature of lens?

Ans. The lens is a concave lens.

11. A thin spherical lens has radius of curvature 50 cm. What is its focal length?

Ans. $\text{Focal length} = \frac{\text{Radius of curvature}}{2} = \frac{50\,\text{cm}}{2} = \mathbf{25\,cm}$

12. What do you understand by the term power of lens?

Ans. The reciprocal of focal length of a lens in metres, is called power of lens.

13. Name the unit in which power of lens is measured.

Ans. The power of lens is measured in dioptres.

14. The power of a lens is +1.5 D. Is the lens convex or concave?

Ans. It is a convex lens.

15. The power of a lens is –2 D. Is the lens converging or divering?

Ans. It is a diverging lens.

16. P_1 and P_2 are the power of two thin lenses. What is the power P when both lenses are placed in contact with one another?

Ans. $P = P_1 + P_2$.

17. What do you understand by the term refractive index?

Ans. The ratio between the sine of angle of incidence (in air) to the sine of angle of refraction (in a denser medium) is called refractive index.

18. Refractive index of glass is 1.5. What do you understand from the statement?

Ans. It means that ratio of sine of angle of incidence (in air) to sine of angle of refraction (in glass) is 1.5.

19. At what angle a ray of light should strike the surface of glass, so that it does not suffer any refraction?

Ans. It should strike normally *i.e.*, angle of incidence should be zero.

20. How is refractive index related to velocity of light in a medium and velocity of light in vacuum?

Ans. $\text{Refractive index} = \dfrac{\text{Velocity of light in vacuum}}{\text{Velocity of light in medium}}$

21. What do you understand from the term lateral displacement?

Ans. Lateral displacement is perpendicular shift in the path of the incident ray, while emerging out from an optical slab.

22. Will the lateral displacement increase/decrease, if glass block is made thicker?

Ans. The lateral displacement will increase.

23. How is the focal length of a spherical mirror related to its radius of curvature?

Ans. Focal length is half of the radius of curvature.

24. Why is a convex mirror is called diverging mirror?

Ans. It is because, a parallel beam of light after reflection from it, diverges outward.

25. Why is a concave mirror is called converging mirror?

Ans. It is because, a parallel beam of light after reflection from it, converges at one point.

26. Is the image formed in a convex mirror always virtual?

Ans. Yes, image formed by convex mirror is always virtual.

27. Where is the image formed in a concave mirror, when the object is between infinity and centre of curvature?

Ans. The image is formed between the principal focus and centre of curvature, in front of the concave mirror.

28. Where is the image formed in a convex mirror, when the object is anywhere in front of it?

Ans. The image is formed between the pole and principal focus, behind the convex mirror.

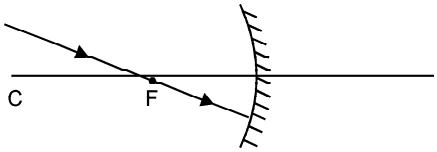
29. No matter how far you stand from a spherical mirror, your image appears always erect. What is the kind of spherical mirror?

Ans. The spherical mirror is a convex mirror.

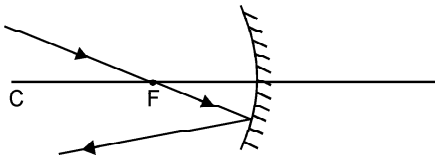
30. A spherical mirror has focal length of – 40 cm. What is the kind of mirror?

Ans. The spherical mirror is a concave mirror.

31. Copy this figure in your answer book and show the directions of light ray after reflection.



Ans.



32. How does the frequency of a beam of ultraviolet light change when it does from air into glass?

Ans. Frequency of ultraviolet light does not change.

33. What is the focal length of a plane mirror?

Ans. The focal length of a plane mirror is infinite.

34. When light undergoes refraction at the surface of separation of two media, what happens to its wavelength?

Ans. Wavelength changes.

35. When light undergoes refraction, what happens to its frequency?

Ans. Frequency does not change.

36. How does a focal length of convex lens change if monochromatic red light is used instead of monochromatic blue light?

Ans. Because red light and blue light both has different refractive indices.

37. If the power of a lens is + 5 dioptre, what is its focal length?

Ans. Focal length of lens = $\frac{100\text{ cm}}{\text{power}} = \frac{100\,\text{cm}}{+5} = \mathbf{20\,cm}$ **?**

B. Short Answer Questions - I [2 Marks]

Previous Years' Questions

1. How can you identify the three types of mirrors without touching? **[2011 (T-II)]**

Ans. Placing an object in front of a mirror and observing the image of the object for different positions.

(i) The image in plane mirror is formed of same size.

(ii) The errect and smaller image is formed in convex mirror.

(iii) The inverted image of different size beyond focal point and within this point enlarge and errect image is formed in concave mirror.

2. The refractive indices of alcohol and turpentine oil with respect to air are 1.36 and 1.47 respectively. Find the refractive index of turpentine oil with respect to alcohol. Which one of these will permit the light to travel faster? **[2011 (T-II)]**

Ans. Given, ${}^{a}\mu_{al}$ = 1.36, ${}^{al}\mu_{t}$ = 1.47, ${}^{al}\mu_{t}$ = ?

Now, ${}^{al}\mu_t = \dfrac{{}^{a}\mu_t}{{}^{a}\mu_{al}} = \dfrac{1.47}{1.36} = \mathbf{1.08}$.

The alcohol having less value of refractive index so it will permit the light to travel faster.

3. (a) What happens to a ray of light when it travels from one medium to another having equal refractive indices? **[2011 (T-II)]**

(b) State the cause of refraction of light.

Ans. (a) It does not deviate from its path.

(b) When light travels from one medium to another medium its speed changes due to which it deviates from its path.

4. (a) What should be the position of the object, when a concave mirror is to be used :
(i) as a shaving mirror, and (ii) in torches producing parallel beam of light?

(b) A man standing in front of a mirror, finds his image having a very small head and legs of normal size. What type of mirrors are used in designing such a mirror ? **[2011 (T-II)]**

Ans. (a) (i) Between pole and principal focus. (ii) At principal focus

(b) The upper portion is convex mirror and lower portion is a plane mirror.

5. Light enters from air to kerosene having refractive index 1.47. What is the speed of light in kerosene? The speed of light in air is 3×10^8 m/s. **[2011 (T-II)]**

Ans. Speed of light in kerosene = $\dfrac{\text{Speed of light in air}}{\text{Refractive index of kerosene}}$

$= \dfrac{3\times10^8 \text{ m/s}}{1.47} = \mathbf{2.04 \times 10^8 \text{ m/s}}$

6. Where should an object be placed in front of a concave mirror of focal length 20 cm so as to obtain real image two times magnified? **[2011 (T-II)]**

Ans. $m = -2$, $f = -20$ cm; $u = ?$

$m = -\dfrac{v}{u} \Rightarrow -2 = -\dfrac{v}{u} \qquad \therefore v = 2u$

$\dfrac{1}{v} + \dfrac{1}{u} = \dfrac{1}{f} \Rightarrow \dfrac{1}{2u} + \dfrac{1}{u} = -\dfrac{1}{20} \Rightarrow \dfrac{3}{2u} = -\dfrac{1}{20}$

$\therefore u = -\dfrac{20\times3}{2} = \mathbf{-30 \text{ cm.}}$

Thus, object should be placed at a distance of 30 cm in front of the concave mirror.

7. Identify the nature of the mirror and mention two characteristics of the image formed when magnification (m) = + 6. **[2011 (T-II)]**

Ans. For magnification (m) = + 6, the mirror is concave. The image formed is enlarge, virtual and erect. The object is placed between pole and focal point of the mirror.

8. The power of a lens is –1.5 D. Find the focal length of the lens and state its nature. **[2011 (T-II)]**

Ans. P = –1.5 D, $f = ?$

$f = \frac{1}{\text{P}}\text{m} = \frac{1}{-1.5}\text{m} = \frac{100}{-1.5}\text{cm} =$ **– 66.67 cm**

The nature of the lens is concave.

9. A convex lens of focal length 10 cm is placed at a distance of 12 cm from a wall. Calculate the distance from the lens where an object be placed so as to form its distinct real image on the wall. **[2011 (T-II)]**

Ans. f = 10 cm, v = 12 cm, u = ?

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \quad \Rightarrow \frac{1}{10} = \frac{1}{12} - \frac{1}{u}, \quad \Rightarrow \frac{1}{u} = \frac{1}{12} - \frac{1}{10} = \frac{5-6}{60} = -\frac{1}{60}$$

$\therefore$ u = – **60 cm.** (The distance of the object from the lens).

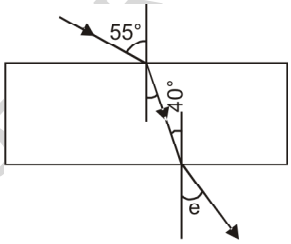
10. Two lenses of power –2.5 D and + 1.5 D are placed in contact. Find the total power of the combination of lens. Calculate the focal length of this combination. **[2011 (T-II)]**

Ans. Power of the combination = $P_1 + P_2$ = –2.5 + 1.5 = **–1.0 D**

The focal length of this combination, $f = -\frac{1}{1.0}\text{m} =$ **–100 cm.**

11. In an experiment with a rectangular glass slab, a student observed that a ray of light incident at an angle of 55° with the normal on one face of the slab, after refraction strikes the opposite face of the slab before emerging out into air making an angle of 40° with the normal. Draw a labelled diagram to show the path of this ray. What value would you assign to the angle of refraction and angle of emergence? **[2010]**

Ans.

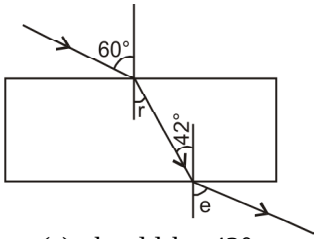


Angle of refraction (r) = 40°.

Angle of emergence (e) = 55°.

12. In an experiment with a rectangular glass slab, a student observed that a ray of light incident at an angle of 60° with the normal on one face of the slab, after refraction strikes the opposite face of the slab before emerging out into air making an angle of 42° with the normal. Draw a labelled diagram to show the path of this ray. What value would you assign to the angle of refraction and angle of emergence? **[2010]**

Ans.

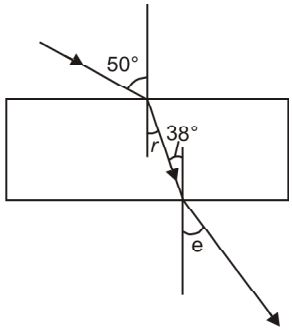


The value of angle of refraction (r) should be 42°.

The value of angle of emergence (e) should be 60°.

13. In an experiment with a rectangular glass slab, a student observed that a ray of light incident at an angle of 50° with the normal on one face of the slab. After refraction strikes the opposite face of the slab before emerging out into air making an angle of 38° with the normal. Draw a labelled diagram to show the path of this ray. What value would you assign to the angle of refraction and angle of emergence? **[2010]**

Ans.

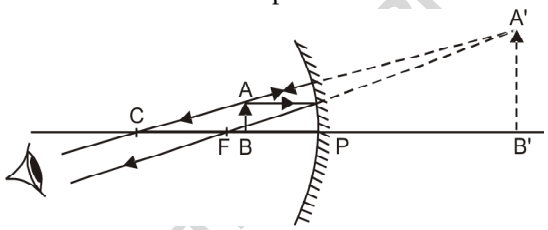


The angle of refraction (*r*) should be 38°.

The angle of emergence (*e*) should be 50°.

14. Draw a ray diagram to show the (i) position and (ii) nature of the image formed when an object is placed between focus F and pole P of a concave mirror. **[2006]**

Ans.



Other Important Questions

1. Give one use of each : (i) regular reflection (ii) irregular reflection.

Ans. (i) Regular reflection helps in the formation of virtual images as in case of plane mirror.

(ii) Irregular reflection cuts off glare and helps in illuminating the areas where light is not falling directly.

2. State four characteristics of an image formed in a plane mirror.

Ans. (i) Image is erect. (ii) Image is virtual.

(iii) Image is of the same size as the object.

(iv) Image is formed as far behind the mirror as the object is in front of it.

3. State the laws of reflection.

Ans. (i) Incident ray, the reflected ray and the normal lie in the same plane at the point of incidence.

(ii) Angle of incidence at the point of incidence is always equal to angle of reflection.

4. Give any two uses of plane mirror other than looking glass.

Ans. (i) It is used as reflector in box type solar cooker for increasing the concentration of solar radiation inside the cooker.

(ii) It is used for making reflecting periscope and keleidoscope.

5. Convex mirror and a plane mirror form virtual images. How will you distinguish between the two by looking at the images of an object?

Ans. In case of convex mirror the size of image is smaller than the size of the object.

In case of plane mirror the size of image is equal to the size of the object.

6. An object 1 cm high produces a real image 1.5 cm high, when placed at a distance of 15 cm from concave mirror. Calculate the position of image.

Ans. $\frac{v}{u} = \frac{-I}{O}$ $\quad \therefore \quad \frac{v}{-15} = \frac{-(-1.5)}{1} \Rightarrow v = 1.5 \times -15 = -\mathbf{22.5\ cm}$

7. State two uses of concave mirrors.

Ans. (i) Concave mirror are used as reflectors in automobile headlights.

(ii) Concave mirrors are used by E.N.T. surgeons to reflect light in the inaccessible parts of ear, nose or throat.

8. State two uses of convex mirrors.

Ans. (i) Convex mirrors are used as rear view mirrors in automobiles

(ii) Convex mirrors are used as reflectors of street light lamp.

9. The velocity of light in air is 3×10^8 ms^{-1} and in diamond is 1.2×10^8 ms^{-1}. Find the refractive index of diamond.

Ans. $\mu = \frac{\text{Velocity of light in air}}{\text{Velocity of light in diamond}} \Rightarrow \mu = \frac{3\times 10^8 \text{ ms}^{-1}}{1.2\times 10^8 \text{ ms}^{-1}} = \mathbf{2.5}$

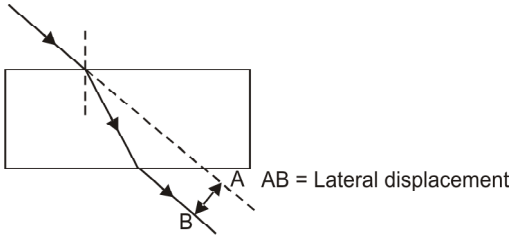
10. State two factors which determine lateral displacement of ray of light passing through a rectangular glass slab.

Ans. (i) Lateral displacement is directly proportional to the thickness of optical glass slab.

(ii) Lateral displacement is directly proportional to the angle of incidence.

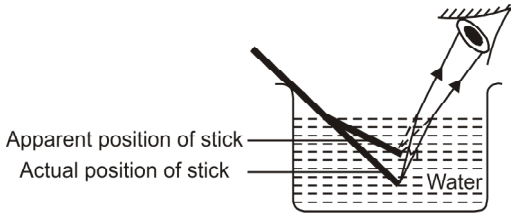
11. Show the path of a ray of light through a rectangular glass block, showing clearly the lateral displacement of the ray of light.

Ans.



12. With the help of diagram show how a stick held obliquely in water appears bent and short.

Ans.



13. The refractive index of flint glass is 1.60 and that of water is 1.33 with respect to air. What is the refractive index of flint glass with respect to water?

Ans. ${}^{water}\mu_{flint} = {}^{air}\mu_{flint} \div {}^{air}\mu_{water} = 1.60 \div 1.33 = 1.20.$

14. Give two uses of convex lens.

Ans. (i) Convex lens is used as an objective lens for telescopes.

(ii) Convex lens is used in cine projectors.

15. Give two uses of concave lens.

Ans. (i) Concave lens is used in correcting short sightedness.

(ii) Concave lens is used as an eye lens for Galilean telescope.

16. State whether the following are positive or negative when a convex lens forms real image (i) distance of object from lens (ii) distance of image from lens.

Ans. (i) Distance of object from lens is negative.

(ii) Distance of image from lens is positive.

17. State whether the following are positive or negative when a concave lens forms a virtual image.

(i) distance of image from lens (ii) focal length of lens.

Ans. (i) Distance of image from lens is negative (ii) Focal length of lens is negative

18. Light enters from air to water having refractive index 4/3. What is the speed of light in water? Speed of light in vacuum is 3×10^8 ms^{-1}.

Ans. $\mu = \dfrac{\text{Speed of light in vacuum}}{\text{Speed of light in water}}$

$\therefore$ Speed of light in water $= \dfrac{\text{Speed of light in vacuum}}{\mu} = \dfrac{3\times10^8 ms^{-1}}{\frac{4}{3}} = \mathbf{2.25\times10^8\ ms^{-1}}.$

19. The focal length of the glasses of a short-sighted person is 37.5 cm. Calculate the power of glasses and their nature.

Ans. Applying , $P = \dfrac{100}{f\,(\text{in cm})} = \dfrac{100}{-37.5} = \mathbf{-2.67\ D.}$

The minus sign indicates that lens is concave in nature.

20. The image of an object is formed on itself when placed at a distance of 30 cm from concave mirror. What is the focal length of concave mirror?

Ans. When the image forms on the object, then the object as well as the image are situated at centre of curvature of concave mirror.

$\therefore$ Radius of curvature of concave mirror = 30 cm.

$\therefore$ Focal length of concave mirror = $\dfrac{30\,cm}{2}$ = **15 cm.**

21. Fill in the blank spaces :

(a) When a ray of light, travelling obliquely in denser medium, enters a —— medium, it always bends away from the ——.

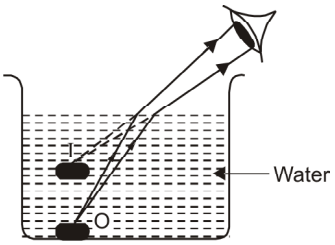
(b) When a ray of light strikes the surface of separation of two optical media at right angles, it —— suffer any ——.

Ans. (a) (i) Rarer (ii) Normal

(b) (i) does not (ii) Refraction

22. By drawing a neat diagram show, why a coin placed in water tank appears raised.

Ans.



23. What is name given to linear distance between the pole and principal focus of a spherical mirror? If this distance is 25 cm, how far is the centre of curvature from the pole of the spherical mirror?

Ans. The linear distance between the pole and principal focus is called focal length.

Now, as the focal length of the spherical mirror is 25 cm. Therefore, its radius of curvature is 2 × 25 cm = **50 cm.**

Thus, centre of curvature of this spherical mirror should be at a distance of 50 cm from the pole.

C. Short Answer Questiions-II [3 Marks]

Previous Years' Questions

1. A 5.0 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 the lens is 30 cm. By calculation determine (*i*) the position and (ii) the size of the image formed. **[2006, 2011 (T-II)]**

Ans. Given h_o = 5 cm, f = 20 cm, u = – 30 cm

v = ? (To be calculated)

h_i = ? (To be calculated)

(i) Applying, $\frac{1}{f}=\frac{1}{v}-\frac{1}{u} \Rightarrow \frac{1}{v}=\frac{1}{f}+\frac{1}{u} \Rightarrow \frac{1}{v}=\frac{1}{20}+\frac{1}{-30}$

$\Rightarrow \frac{1}{v}=\frac{3-2}{60}=\frac{1}{60}$ or v = **60 cm**

(ii) Applying, $\frac{h_i}{h_o}=\frac{v}{u} \Rightarrow \frac{h_i}{5}=\frac{60}{-30} \Rightarrow h_i=\frac{-60\times 5}{30}=$ **–10 cm**

2. A real image, $\frac{1}{5}^{\text{th}}$ the size of object is formed at a distance of 18 cm from a mirror. What is the nature of mirror? Calculate its focal length. **[2011 (T-II)]**

Ans. $m = -\frac{v}{u} \Rightarrow -\frac{1}{5}=-\frac{-18}{u} \Rightarrow u = -5 \times 18 = -90$ cm

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} = -\frac{1}{90} + \frac{1}{-18} = \frac{-1-5}{90} = -\frac{6}{90} = -\frac{1}{15}$$

$\therefore f = -15$ cm

Thus, real, inverted and smaller image is formed in the concave mirror.

3. A convex lens forms a real image 4 times magnified at a distance of 60 cm from the lens. Calculate the focal length and the power of the lens. **[2011 (T-II)]**

Ans. $v = 60$ cm, $m = -4$ (For real image)

$$\frac{v}{u} = -4 \Rightarrow u = \frac{v}{-4} = -\frac{60}{4} = -15\,\text{cm}$$

Now, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{60} - \frac{1}{-15} = \frac{1+4}{60} = \frac{5}{60} = \frac{1}{12}$

$\therefore$ Focal length, $f = 12$ cm $= \frac{12}{100}$ m

The power of the lens $= \frac{1}{f\,(\text{in m})} = \frac{1}{\frac{12}{100}\text{m}} = \frac{100}{12}\text{D} = 8.33\,\text{D}$

4. (i) Define power of a lens and write its S.I unit.

(ii) A convex lens of power 4 D is placed at a distance of 40 cm from a wall. At what distance from the lens should a candle be placed so that its image is formed on the wall ?

[2011 (T-II)]

Ans. (i) Power of a lens is reciprocal of its focal length in metre. The SI unit of it is dioptre.

(ii) Focal length of the lens, $f = \frac{1}{4} = 0.25$ m $= 25$ cm

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{25} = \frac{1}{40} - \frac{1}{u} \Rightarrow \frac{1}{u} = \frac{1}{40} - \frac{1}{25} = \frac{5-8}{200} = -\frac{3}{200}$$

$\therefore u = -\frac{200}{3} =$ **– 66.67 cm**

5. An object is 2m away from a lens, which forms an erect image one-fourth the size of the object. Determine the focal length of the lens. What type of lens is this ? **[2011 (T-II)]**

Ans. $u = -2$ m

$m = \frac{v}{u} \Rightarrow \frac{1}{4} = \frac{v}{u}$, $\therefore v = \frac{u}{4} = -\frac{2}{4}\text{m} = -0.5\,\text{m}$

As image is erect and also $\frac{1}{4}$th the size of the object, so, lens is concave lens.

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{f} = \frac{1}{-0.5} - \frac{1}{-2}$$

$\Rightarrow \frac{1}{f} = \frac{-4+1}{2} = -\frac{3}{2}$

Thus, focal length, $f = -\frac{2}{3}$ m = – 0.67 m = – 67 cm

6. A concave mirror produces three times enlarged real image of an object placed at 12 cm in front of it. Calculate the radius of curvature of the mirror. **[2011 (T-II)]**

Ans. u = –12 cm, m = – 3 (For real image)

$\Rightarrow m = -\frac{v}{u} \Rightarrow -3 = -\frac{v}{-12} \quad \therefore v = -3 \times 12 = -36$ cm

Now, $\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \Rightarrow \frac{1}{f} = -\frac{1}{12} - \frac{1}{36} = \frac{-3-1}{36} = \frac{-4}{36} = -\frac{1}{9}$

Thus, focal length, f = – 9 cm

The radius of curvature, R = $2f$ = 2 × – 9 cm = –18 cm

7. (a) What is meant by 'Power' of a lens?
(b) State its unit and define it.
(c) Which of the two lenses has a greater power :
(i) a convex lens of focal length 5 cm?
(ii) a convex lens of focal length 50 cm?
Justify your answer. **[2011 (T-II)]**

Ans. (a) Power of a lens is reciprocal of its focal length in metre.

$$P = \frac{1}{f \text{ (in m)}}$$

(b) Unit of power of a lens is dioptre. When focal length of a lens is 1 m then its power will be 1 dioptre.

(c) (i) $P = \frac{100}{5}$ = 20 D (ii) $P = \frac{100}{5}$ = 2 D

Thus, first lens has greater power having smaller focal length.

8. A student focussed the image of a candle flame on a white screen by placing the flame at various distances from a convex lens. He noted his observation in the following table : **[2011 (T-II)]**

Distance of the flame from lens (cm)	Distance of the screen from lens (cm)
60	20
40	24
30	30
24	40
12	70

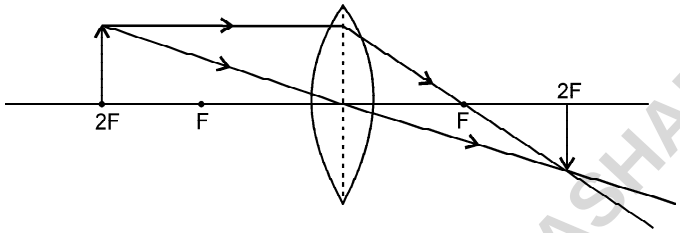
Analyse the above table and answer the following questions :
(i) What is the focal length of convex lens?
(ii) Which set of observation is incorrect and why?
(iii) Draw the ray diagram to show the image formation for any correct set of observation.

Ans. (i) From observation third, distance of object from lens = distance of image from lens
So, radius of curvature, R = 30 cm

Thus, focal length, $f = \frac{R}{2} = \frac{30\,cm}{2}$ **= 15 cm**

(ii) Last observation is incorrect, because when object is placed less than 15 cm (focal length) from the convex lens will have virtual image, which cannot be taken on the screen.

(iii) Ray diagram for image formation for third observation.



9. An object is placed at a distance of 20 cm from the optical centre of a convex lens of focal length 30 cm. Find the distance of the image from the lens. What will be the height of the image if the object is 2 cm tall? **[2010]**

Ans. Given, u = – 20 cm, f = 30 cm, v = ? (To be calculated), h_i = ? (To be calculated)
h_o = 2 cm

Applying, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{30} = \frac{1}{v} - \frac{1}{-20} \Rightarrow \frac{1}{v} = \frac{1}{30} - \frac{1}{20} = \frac{2-3}{60} = \frac{-1}{60}$

or $v = -$**60 cm**

Applying, $\frac{h_i}{h_o} = \frac{v}{u} \Rightarrow \frac{h_i}{2} = \frac{-60}{-20} \Rightarrow h_i$ **= 6 cm**

10. An object is placed at a distance of 24 cm from the optical centre of a convex lens of focal length 18 cm. Find the distance of the image from the lens. What will be the height of the image if the object is 3.0 cm tall? **[2010]**

Ans. Given u = – 24 cm, f = 18 cm, v = ? (To be calculated)
h_i = ? (To be calculated) h_o = 3 cm

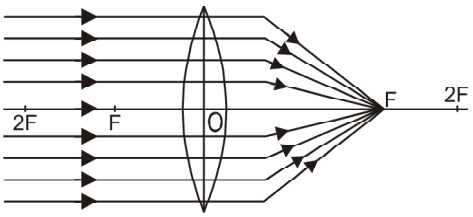
Applying, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ or $\frac{1}{v} = \frac{1}{f} + \frac{1}{u} \Rightarrow \frac{1}{v} = \frac{1}{18} - \frac{1}{24} \Rightarrow \frac{1}{v} = \frac{4-3}{72} = \frac{1}{72}$ or v = **72 cm**

Applying, $\frac{h_i}{h_o} = \frac{v}{u} \Rightarrow \frac{h_i}{3} = \frac{72}{-24} \Rightarrow h_i = -3 \times 3 =$ **–9 cm**

Other Important Questions

1. A convex lens is used as burning glass. Show it by drawing a neat diagram, stating clearly where the image is formed. Is there any relation between the distance from lens at which image is formed and focal length of lens?

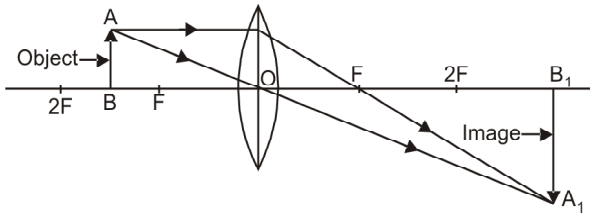
Ans.



The distance at which image is formed is equal to the focal length of the convex lens.

2. By drawing a neat diagram show how the image of a small slide can be projected on large screen. State two characteristics of image.

Ans.



Characteristics of image :

(i) Image is real and inverted.

(ii) Image is enlarged.

3. State the sign convention of *u*, *v* and *f* for a concave mirror when image is real.

Ans. (i) The distance of the object from the pole of the mirror (*u*) is always negative.

(ii) The distance of the image from the pole of the mirror (*v*) is always negative.

(iii) The focal length (*f*) is always negative.

4. State the sign convention of *u*, *v* and *f* for a concave mirror when it forms a virtual image.

Ans. (i) The distance of the object from the pole of the mirror (*u*) is always negative.

(ii) The distance of the image from the pole of the mirror (*v*) is always positive.

(iii) The focal length (*f*) is always negative.

5. State the sign convention of *u*, *v* and *f* for a convex mirror.

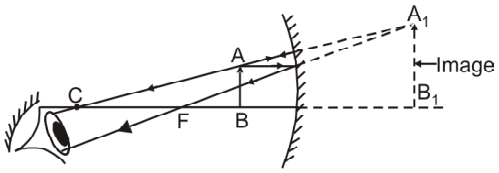
Ans. (i) The distance of the object from the pole of the mirror (*u*) is always negative.

(ii) The distance of the image from the pole of the mirror (*v*) is always positive.

(iii) The focal length (*f*) is always positive.

6. You are required to obtain an erect image of an object placed in front of a concave mirror. Draw a ray diagram to show the formation of image and state its characteristics.

Ans.



Characteristics of image :

(i) Image is virtual, (ii) erect, (iii) enlarged, and (iv) formed behind the concave mirror.

7. A convex lens produces a real and inverted image 2.5 times magnified at a distance of 25 cm from the lens. Calculate focal length of the lens.

Ans. Magnification (m) = – 2.5 (real image)
Distance of the image from the lens (v) = 25 cm.
Distance of the object from the lens (u) =? (to be calculated)
Focal length of the lens (f) =? (to be calculated)

Applying, $m = \frac{v}{u} \Rightarrow -2.5 = \frac{25}{u}$

$\therefore \quad u = \frac{25}{-2.5} = -10\,\text{cm}$

Applying, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \Rightarrow \quad \frac{1}{25} - \frac{1}{-10} = \frac{1}{f} \Rightarrow \quad \frac{1}{f} = \frac{2+5}{50} = \frac{7}{50}$

$\therefore \quad f = \frac{50}{7} = 7.14$ cm

Thus, the focal length of the lens is **7.14 cm.**

8. Two thin lenses of power + 2.5 D and –1.5 D are placed in contact with each other. Calculate : (i) power of the combination, (ii) focal length of the combination.

Ans. (i) Power of the combination
$P = P_1 + P_2 \Rightarrow P = +2.5 - 1.5$ D = **+ 1.0 D**

(ii) Focal length of the combination, $f = \frac{1(\text{m})}{\text{P}} = \frac{1}{1} = \mathbf{1\ m}$.

9. A convex lens of focal length 40 cm and a concave lens of focal length 50 cm are placed in contact with each other. Calculate : (i) the power of the combination, (ii) focal length of the combination.

Ans. Power of the convex lens (P_1) = $+\frac{1(\text{m})}{f\,(\text{m})} = +\frac{1(\text{m})}{0.4(\text{m})} = +2.5$ D

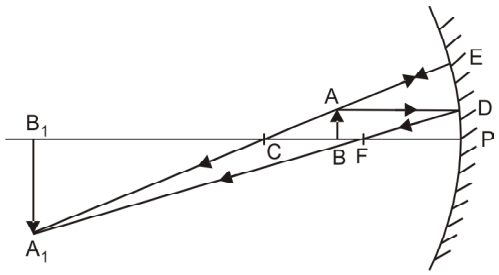
Power of the concave lens (P_2) = $+\frac{-1(\text{m})}{f\,(\text{m})} = \frac{-1(\text{m})}{0.5(\text{m})} = -2$ D

(i) Power of the combination $P = P_1 + P_2 = +2.5$ D – 2 D = **+ 0.5 D**

(ii) $F = \frac{1(\text{m})}{\text{Power of combination}} = \frac{1(\text{m})}{0.5} = \mathbf{2m}$.

10. You are required to obtain an inverted image of an object placed in front of a concave mirror. If the image is larger than the size of object, draw a ray diagram to show the formation of image and state its characteristics.

Ans.



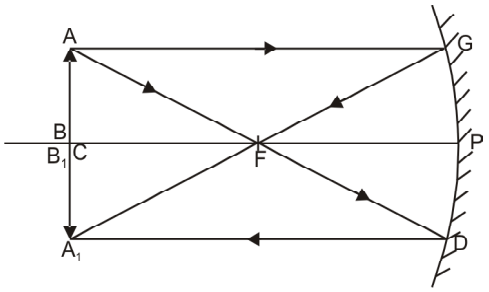
Characteristics of image

(i) Image is real, (ii) inverted (iii) enlarged and

(iv) formed between C and infinity, in front of the concave mirror.

11. A student places an object at a certain distance C from a concave mirror, when he notices that image is formed directly above the object. Draw a ray diagram to show the formation of image and state its characteristics.

Ans.



Characteristics of image

(i) Image is real, (ii) inverted (iii) same size as object and

(iv) formed at C, in front of the concave mirror.

12. An object is placed in front of a convex mirror, such that its virtual image is formed behind the mirror. Draw a ray diagram for the formation of image and state its characteristics.

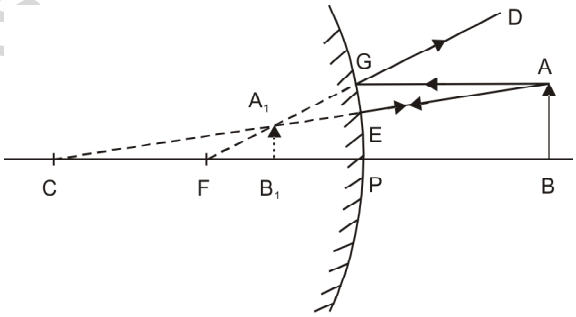
Ans. Characteristics of image :

(i) Image is virtual,

(ii) erect,

(iii) diminished and

(iv) formed between pole and principal focus, behind the convex mirror.



13. Identify the device used as spherical mirror or lens in the following cases, when the image formed is virtual and erect in each case.

(a) Object is placed between device and its focus, image formed is enlarged and behind it.

(b) Object is placed between the focus and device, image formed is enlarged and on the same side as that of the object.

(c) Object is placed between infinity and device, image formed is diminished and between focus and optical centre on the same side as that of the object.

(d) Object is placed between infinity and device, image formed is diminished and between pole and focus, behind it. **[HOTS]**

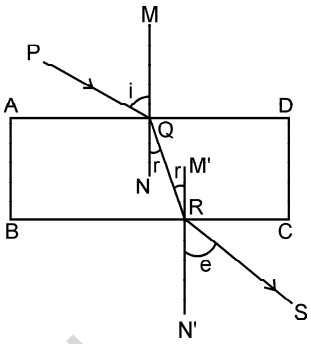
Ans. (a) concave mirror (b) convex lens (c) concave lens (d) convex mirror

14. Why does a light ray incident on a rectangular glass slab immersed in any medium emerges parallel to itself? Explain using a diagram.

Ans. We know that any ray of light travelling obliquely in an optically rarer medium, on passing through optically denser medium, bends towards the normal, drawn at the point of incidence.

We also know that, any ray of light travelling obliquely in an optically denser medium, on passing through optically rarer medium bends away from the normal, drawn at the point of incidence.

When light ray PQ enters into glass (denser medium) it bends towards normal as QR. When this ray QR emerges into air (rarer medium), it bends away from normal as RS. Because ray of light after refraction comes into same medium so, light ray emerges parallel to itself.



15. A pencil when dipped in water in a glass tumbler appears to be bent at the interface of air and water. Will the pencil appear to be bent to the same extent, if instead of water we use liquids like, kerosene or turpentine. Support your answer with reason. **[HOTS]**

Ans. No.

Bending will be different in different liquids since velocity of light at the interface separating two media depends on the relative refractive index of the medium.

16. How is the refractive index of a medium related to the speed of light? Obtain an expression for refractive index of a medium with respect to another in terms of speed of light in these two media. **[HOTS]**

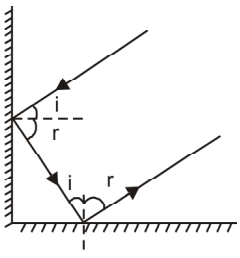
Ans. $\mu = \dfrac{\text{Speed of light in air or vacuum}}{\text{Speed of light in a given optical medium}}$

i.e $\mu = \dfrac{c}{v}$

When the ray of light travels in two different optical media, say from medium 1 to medium 2, then

$\mu_{12} = \dfrac{\text{Speed of light in medium 1}}{\text{Speed of light in medium 2}}$

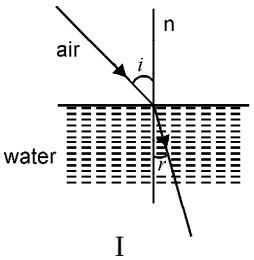
17. Under what condition in an arrangement of two plane mirrors incident ray and reflected ray will always be parallel to each other, whatever may be angle of incidence. Show the same with the help of diagram.



Ans. When two plane mirrors are placed at right angle to each other then the incident and reflected rays will always be parallel to each other.

18. Draw a ray diagram showing the path of rays of light when it enters with oblique incidence (i) from air into water (ii) from water into air. **[HOTS]**

Ans.



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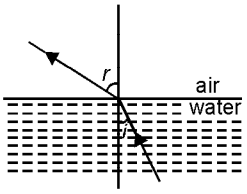


II

19. Refractive index of diamond with respect to glass is 1.6 and absolute refractive index of glass is 1.5. Find out the absolute refractive index of diamond. **[HOTS]**

Ans. $\mu_{gd} = \frac{v_g}{v_d} = 1.6 \Rightarrow \mu_g = 1.5$

We know that, $\mu_g = \frac{c}{v_g}$ and $\mu_d = \frac{c}{v_d}$

Therefore, $\mu_d = \frac{c}{v_d} = \frac{v_g}{v_d} \times \frac{c}{v_g}$ = 1.6 × 1.5 = **2.4**

20. A convex lens of focal length 20 cm can produce a magnified virtual as well as real image. Is this a correct statement? If yes, where shall the object be placed in each case for obtaining these images? **[HOTS]**

Ans. Statement is correct if the object is placed within 20 cm from the lens in the first case and between 20 cm and 40 cm in the second case.

21. Sudha finds out that the sharp image of the window pane of her science laboratory is formed at a distance of 15 cm from the lens. She now tries to focus the building visible to her outside the window instead of the window pane without disturbing the lens. In which direction will she move the screen to obtain a sharp image of the building? What is the approximate focal length of this lens? **[HOTS]**

Ans. Sudha should move the screen towards the lens so as to obtain a clear image of the building. The approximate focal length of this lens will be 15 cm.

22. How are power and focal length of a lens related? You are provided with two lenses of focal length 20 cm and 40 cm respectively. Which lens will you use to obtain more convergent light? **[HOTS]**

Ans. $P \propto \frac{1}{f_0}$, power of a lens is inversely proportional to its focal length, therefore, lens having focal length of 20 cm will provide more convergence.

D. Long Answer Questions [5 Marks]

Previous Years' Questions

1. Draw a ray diagram in each of the following cases to show the formation of image, when the object is placed : **[2011 (T-11)]**

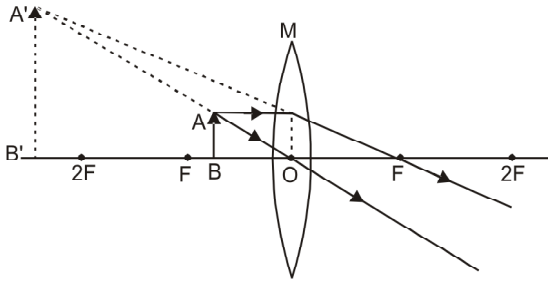
(i) between optical centre and principal focus of a convex lens

(ii) between F and 2F of a concave lens

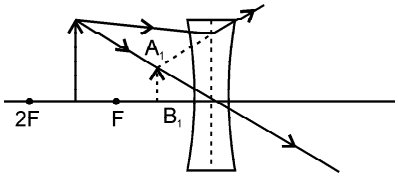
(iii) At 2F of a convex lens

What can say about sign and value of linear magnification ratio in, (i) and (ii) above.

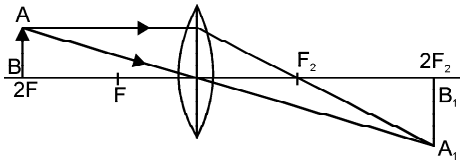
Ans. (i)



(ii)



(iii)



Sign and value of linear magnification ratio in

(i) Positive and > 1

(ii) Positive and < 1

2. (i) Define real image of an object.

(ii) Name the mirror that **[2011 (T-11)]**

(a) can give real as well as virtual image of an object.

(b) will always give virtual image of same size of an object.

(c) will always give virtual and diminished image of an object.

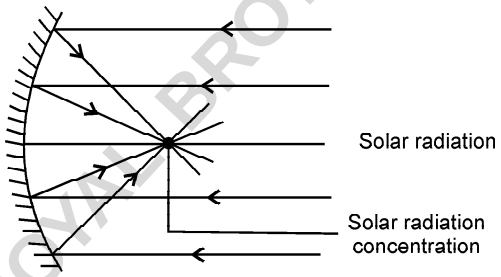
(d) is used by a doctor in examining teeth.

(iii) With the help of a ray diagram explain the use of concave mirror as solar concentrators.

Ans. (i) Real image of an object is the image formed due to actual intersection of light rays comming from object through an optical device. It can always be taken on screen.

(ii) (a) concave mirror (b) plane mirror (c) convex mirror (d) concave mirror

(iii)



3. A thin converging lens forms a : **[2011 (T-11)]**

(i) Real magnified image

(ii) Virtual magnified image of an object placed in front of it

(a) Write the positions of the objects in each case.

(b) Draw labelled ray diagrams to show the image formation in each case.

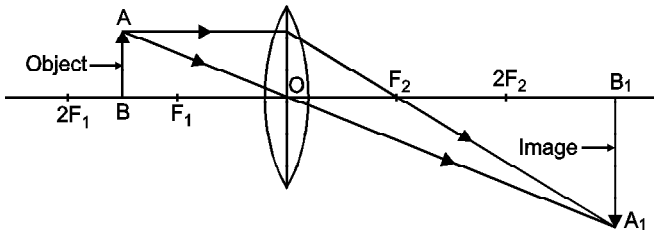
(c) How will the following be affected on cutting this lens into two halves along the principal axis?

(i) Focal length, (ii) Intensity of the image formed by half lens

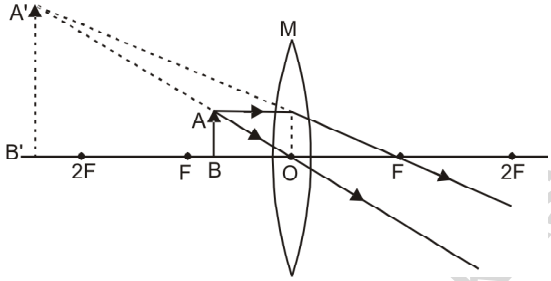
Ans. (a) (i) Objects is placed between F and 2F.

(ii) Object is placed between optical centre and F.

(b) In case (i)



In case (ii)



(c) (i) There will be no change in focal length.

(ii) Intensity will become one-fourth.

4. (a) For the given data showing object distance and focal length of three concave mirrors, answer the following questions : **[2011 (T-11)]**

S. No.	object distance (cm)	focal length (cm)
1	30	20
2	10	15
3	20	10

(i) Out of the three in which case the mirror will form the image having same size as the object ?

(ii) Which mirror is being used as a make-up mirror ?

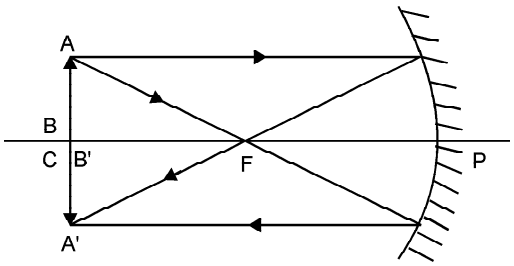
(iii) Draw the ray diagrams for part (i) and part (ii)

(b) No matter how far you stand from a mirror, your image always appears erect and diminished. Identify the type of mirror.

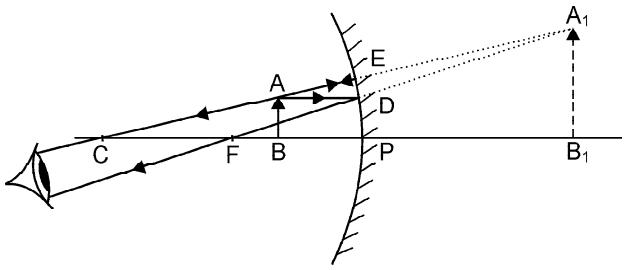
Ans. (a) (i) In case 3

(ii) In case 2

(iii) For part (i)



For part (ii)



(b) Convex mirror

5. (a) Define 1 dioptre of power. Find the focal length of a lens of power –2.0 D. **[2011 (T-11)]**

(b) Why does a lemon kept in water in a glass tumbler appear to be bigger than its actual size?

(c) Study the table given below and state the medium in which light ray will travel fastest. Why?

Medium	A	B	C
Refractive Index	1.33	1.5	2.4

Ans. (a) One dioptre is the power of a lens of focal length 1 m.

Focal length, $f = \frac{1}{P} = \frac{1}{-2.0} = -0.5$ m $= -50$ cm.

(b) It is because of refraction from denser medium to rarer medium.

(c) Light ray will travel fastest in medium A due to its least refractive index.

6. (a) State the laws of refraction. **[2011 (T-11)]**

(b) What is meant by the term absolute refractive index? The speed of light in a transparent medium is 0.6 times that the speed in vacuum. Find refractive index of the medium.

(c) How should a ray of light be incident on a rectangular glass slab so that it comes out from the opposite side of the slab without being displaced? Draw a ray diagram to illustrate your answer.

Ans. (a) Laws of refraction :

(i) The incident ray, refracted ray and normal drawn at the point of incidence all lie in the same plane.

(ii) The ratio of sine of angle of incidence to the sine of angle of refraction is a constant quantity called refractive index.

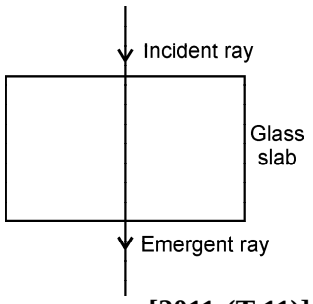
$$\mu = \frac{\sin i}{\sin r}$$

(b) The refractive index of an objective or medium with respect to free space (vacuum or air) is called absolute refractive index.

Refractive index, $\mu = \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}}$

$$= \frac{3\times10^8 \text{ m/s}}{0.6\times3\times10^8 \text{ m/s}} = 1.67$$

(c) It should incident normally to glass slab as shown in alongside.



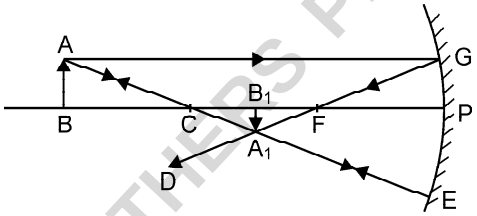
7. (a) Define Principal focus of a spherical mirror. **[2011 (T-11)]**

(b) For what position of the object does a concave mirror form a real, inverted and diminished image of the object? Draw the ray diagram.

(c) An object 4 cm high is placed at a distance of 6 cm in front of a concave mirror of focal length 12.0 cm. Find the position of the image formed.

Ans. (a) The point where light rays coming parallel to the principal axis after reflection from the mirror meet is called principal focus of a spherical mirror.

(b) When an object is placed beyond centre of curvature of a concave mirror then a real, inverted and dimenished image of the object is formed.



(c) $f = -12$ cm, $u = -6$ cm, v = ?

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

$\Rightarrow \frac{1}{v}=\frac{1}{-12}-\frac{1}{-6}=\frac{-1+2}{12}=\frac{1}{12}$

$\therefore v = 12$ cm

Thus, image will form at a distance of 12 cm behind the mirror.

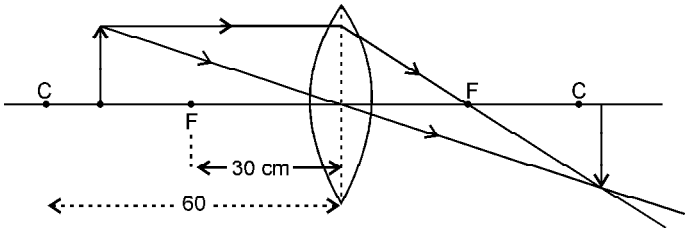
8. (a) Define optical centre of a spherical lens. **[2011 (T-11)]**

(b) You are given a convex lens of focal length 30 cm. Where you place an object to get a real, inverted and highly enlarged image of the object? Draw a ray diagram showing the image formation.

(c) A concave lens has a focal length of 20 cm. At what distance should an object be placed so that it forms an image at 15 cm away from the lens?

Ans. (a) Central point of the spherical lens is called optical centre of a spherical lens, which is a point within spherical lens, where a line drawn through the aperture meets the principal axis.

(b) In convex lens object should be placed between F and 2F (R) to get real, inverted and highly enlarged image. So in given convex lens object should be placed between 30 cm and 60 cm for required image.



(c) $f = -20$ cm, $v = -15$ cm (In case of concave lens)

Now, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{u} = \frac{1}{v} - \frac{1}{f}$

$\Rightarrow \frac{1}{u} = \frac{1}{-15} - \frac{1}{-20} = \frac{-4+3}{60} = -\frac{1}{60}$

$\therefore\ u = -60$ cm

Thus, object should be placed at a distance of 60 cm in front of concave lens.

Other Important Questions

1. An object 1 cm high produces a real image 1.5 cm high, when placed at a distance of 15 cm from a concave mirror, Calculate : (i) the position of the image, (ii) focal length of the concave mirror.

Ans. To calculate position.

$\frac{h_i}{h_o} = -\frac{v}{u}$ $\left\{\begin{array}{l} h_i = -1.5, \text{ because real image is inverted} \\ u = -15, \text{ because } u \text{ is always negative} \end{array}\right\}$

$\Rightarrow \frac{-1.5}{1} = -\frac{v}{-15}$

$\therefore\ v = \frac{1.5}{1} \times -15 = \mathbf{-22.5\ cm}$

Thus, the image is formed 22.5 cm in front of the concave mirror.

To calculate the focal length. $\Rightarrow \frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ $\left\{\begin{array}{l} u = -15 \text{ cm as } u \text{ is always negative} \\ v = -22.5 \text{ cm as calculated above} \end{array}\right\}$

$\Rightarrow \frac{1}{f} = \frac{1}{-15} + \frac{1}{-22.5} \Rightarrow \frac{1}{f} = \frac{-3-2}{45} \Rightarrow \frac{1}{f} = \frac{-5}{45} = -\frac{1}{9}$ $\therefore$ $\mathbf{f = -9\ cm}$

Thus the focal length of the concave mirror is –9 cm.

2. An object 2 cm high when placed in front of a coverging mirror produces a virtual image 3 cm high. If the object is placed at a distance of 8 cm from the pole of the mirror, calculate : (i) the position of the image, (ii) the focal length of the coverging mirror.

Ans. (i) To calculate the position

$\frac{h_i}{h_o} = -\frac{v}{u}$ {As image is virtual, h_i = 3 cm is +ve, u is always negative}

$\Rightarrow \frac{3}{2} = -\frac{v}{-8} \Rightarrow v$ = **12 cm**

Thus, image is formed 12 cm behind the mirror.

(ii) To calculate the focal length

$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ $\left\{\begin{array}{l} u = -8 \text{ as } u \text{ is always negative} \\ v = +12 \text{ as } v \text{ is +ve for virtual image} \end{array}\right\}$

$\Rightarrow \frac{1}{f} = \frac{1}{u} + \frac{1}{v} \Rightarrow \frac{1}{f} = \frac{-3+2}{24} \Rightarrow \frac{1}{f} = \frac{-1}{24} \quad \therefore$ f = **–24cm.**

Thus the focal length of the converging mirror is –24 cm.

3. An object placed in front of a diverging mirror at a distance of 30 cm, forms a virtual and erect image which is 1/5 of the size of the object. Calculate : (i) the position of the image, (ii) the focal length of the diverging mirror.

Ans. (i) To calculate the position

$m = \frac{h_i}{h_o} = \frac{h_o/5}{h_o} = \frac{1}{5}$

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

$\Rightarrow \frac{1}{5} = -\frac{v}{-30}$ [u is always negative] $\Rightarrow v$ = **6cm**

Thus, image is formed at a distance of 6 cm behind the mirror.

(ii) To calculate the focal length.

$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ $\left\{\begin{array}{l} u \text{ is always negative} \\ v \text{ is positive as the image is virtual} \end{array}\right\}$

$\Rightarrow \frac{1}{f} = \frac{1}{-30} + \frac{1}{6}$

$\Rightarrow \frac{1}{f} = \frac{-1+5}{30} \Rightarrow \frac{1}{f} = \frac{4}{30} \Rightarrow f = \frac{30}{4}$ **= 7.5 cm**

Thus, the focal length of the diverging mirror is 7.5 cm.

4. An object 5 cm high is held 25 cm from a converging lens of focal length 10 cm. Draw a ray diagram and find the position, size and the nature of the image formed.

Ans. Height of object, h_o = 5 cm.

Distance of the object from convex lens, u = – 25 cm.

Focal length of convex lens, f = 10 cm

Distance of the image from convex lens, v = *?*

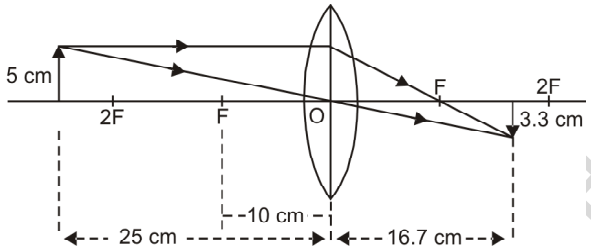
Using lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v} - \frac{1}{-25} = \frac{1}{10} \Rightarrow \frac{1}{v} = \frac{1}{10} - \frac{1}{25} = \frac{5-2}{50} = \frac{3}{50}$

$\therefore\ v = \frac{50}{3}$ = 16.67 = **16.7 cm.**

Also, for a convex lens

$\frac{h_i}{h_o} = \frac{v}{u} \Rightarrow h_i = \frac{v}{u} \times h_o = \frac{50 \times 5}{3 \times -25} = -\frac{10}{3}$ $\therefore$ hi = **–33 cm.**

Thus, the image is inverted and formed at a distance of 16.7 cm from the lens and measures 3.3 cm. The ray diagram is shown below.



5. A concave lens of focal length 15 cm, forms an image 10 cm from the lens. How far is the object placed from the lens? Draw a ray diagram.

Ans. Focal length of the concave lens (*f*) = – 15 cm

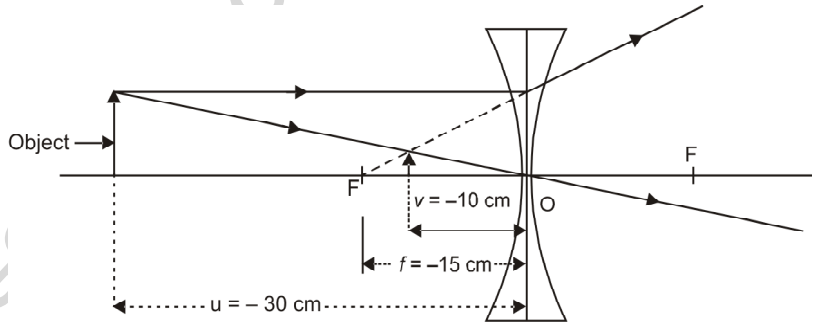
Distance of the image from concave lens (*v*) = –10 cm.

Distance of the object from concave lens (*u*) = ?

Applying the lens formula,

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{-10} - \frac{1}{u} = \frac{1}{-15}$ or $\frac{1}{u} = \frac{1}{15} - \frac{1}{10} = \frac{2-3}{30} = -\frac{1}{30}$ $\therefore$ u = **–30 cm.**

Thus, the object is placed at a distance of **–30 cm from the concave lens.** The ray diagram is shown below.



6. Define power of a lens. What is its unit? One student uses a lens of focal length 50 cm and another of –50 cm. What is the nature of the lens and its power used by each of them?

[HOTS]

Ans. The reciprocal of focal length in metres is called power of a lens. Its unit is dioptre. Lens is convex in the first case and concave in the second case. Power is equal to 2 dioptre in the first case and –2 dioptre in the second case.

7. A student focussed the image of a candle flame on a white screen using a convex lens. He noted down the position of the candle screen and the lens as under.

Position of candle = 12.0 cm

Position of convex lens = 50.0 cm

Position of the screen = 88.0 cm

(i) What is the focal length of the convex lens?

(ii) Where will the image be formed if he shifts the candle towards the lens at a position of 31.0 cm?

(iii) What will be the nature of the image formed if he further shifts the candle towards the lens?

(iv) Draw a ray diagram to show the formation of the image in case (iii) as said above.

Ans. $u = 12 - 50 = -38\,\text{cm}$, $v = 88 - 50 = 38\,\text{cm}$

(i) Applying $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{38} + \frac{1}{38} \Rightarrow \frac{1}{f} = \frac{1+1}{38}$ or $f = \frac{38}{2} = \mathbf{19\ cm}$

(ii) $u = 31 - 50 = -19\,\text{cm}$

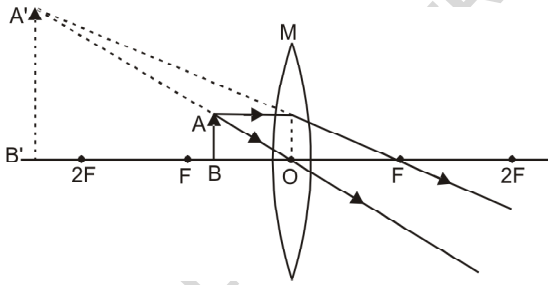
$f = 19\,\text{cm}$, $v = ?$

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

or $\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{19} - \frac{1}{19} = \frac{0}{19}$ or $v = \infty$

(iii) Virtual and erect

(iv)



8. Draw the ray diagram in each case to show the position and nature of the image formed when the object is placed :

(i) at the centre of curvature of a concave mirror.

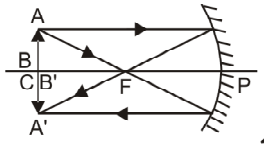
(ii) between the pole P and focus F of a concave mirror

(iii) in front of a convex mirror

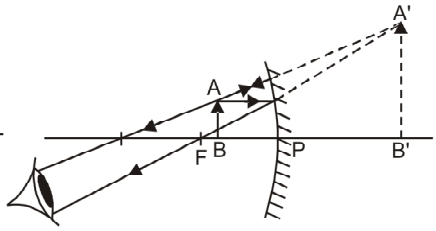
(iv) at 2F of a convex lens

(v) In front of a concave lens.

Ans.



(i)



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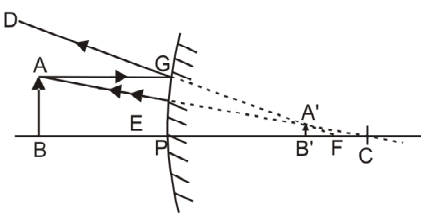

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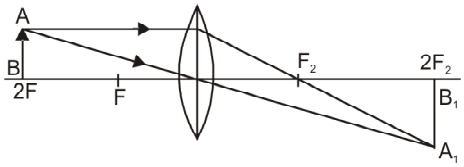
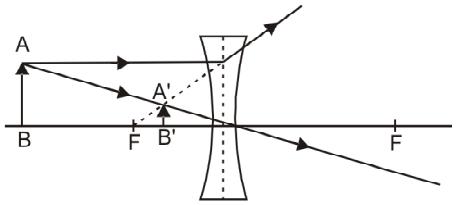


(iv)



(v)

9. (a) State the relation between object distance, image distance and focal length of a spherical mirror.

(b) A concave mirror of focal length 15 cm form an image of an object kept at a distance of 10 cm from the mirror. Find the position, nature and size of the image formed by it.

(c) Draw a ray diagram to show the image formed by a concave mirror when an object is placed between pole and focus of the mirror.

Ans. (a) $\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$

Where f is the focal length of the mirror, u is the distance of the object from pole and v is the distance of the image from pole.

(b) Given, f = – 15 cm ; u = – 10 cm ; v = ? h_i = ?

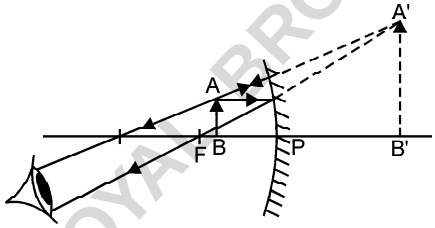
Applying, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ or $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{-15}+\frac{1}{10}$ or $\frac{1}{v}=\frac{-2+3}{30}$

or v = 30 cm.

Magnification, $m=-\frac{v}{u}=\frac{-30}{-10}=3$

Thus the image is virtual, erect and three times larger than the object.

(c)



II. FORMATIVE ASSESSMENT

A. Classroom Discussion

Discuss in class :

(i) Why do the faces of people sitting around camp fire twinkle?

(ii) Why one must check the depth of a clear water stream with a wooden rod, before crossing it?

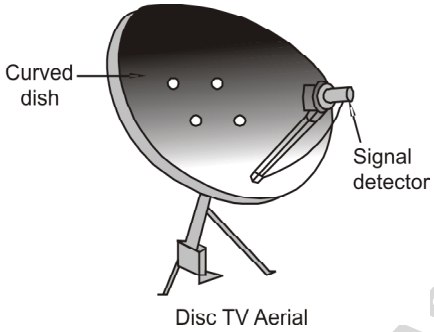
(iii) Why does the water tank filled with water appears shallow?

(iv) Why is a stick immersed in water at angle appears bent and short?

B. Quiz

1. A person with a weak sight looked in a spherical mirror. He found his image very much enlarged. He got that mirror fixed in his car as rear view mirror. To his horror, he found that images seen in the mirror are not only smaller, but inverted. Explain the mistake of person in detail.

2.



The diagram above shows a dish TV aerial used to receive television signals from a geostationary satellite. The signal detector is fixed in front of the curved dish. Answer the following questions :

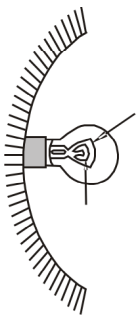
(i) What is the purpose of curved dish?

(ii) Is this dish convex, concave or flat in shape?

(iii) Where should the signal detector placed to receive strongest signal?

(iv) What change would you expect in the signal if a smaller dish was used?

3. The diagram below shows a car headlight bulb, which has two filaments. The filament B is at the principal focus of the concave reflector. Enlarge and copy the diagram and draw rays of light from each filament. Show the rays in different colours.



Why is this arrangement used in car headlights?

Ask an automobile mechanic, if you do not know.

4. Which mirror (convex, concave or plane) is used for the following:

(i) Shaving mirror (ii) Car headlight mirror (iii) Street light reflector

(iv) Driving mirror (v) Rear view mirror (vi) Dentist's inspection mirror

(vii) Make up mirror (viii) Reflecting telescope mirror (ix) Reflecting periscope mirror

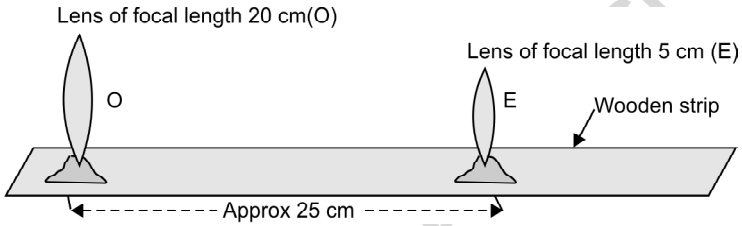
(x) Dish T.V. mirror

C. Chart and Models

1. Prepare a chart showing formation of images for concave mirror when an object travels from infinity to the pole of mirror. Write characteristics of the images.
2. Prepare a chart showing formation of images for convex lens, when an object travels from infinity to the optical centre of lens. Write characteristics of images and one or more possible uses in each case.
3. Prepare a chart showing how (i) convex mirror is used as rear view mirror and convex lens as a simple microscope.
4. Prepare the model of simple astronomical telescope.

Materials required

A flat wooden strip or a half-metre scale, two convex lens, one of focal length 20 cm and other of focal length 5 cm and plasticine.



Procedure

1. Place the wooden strip flat on the table. Near its one end fix a convex lens of focal length 20 cm in an upright position with the help of plasticine. Clear the lens, if it gets dirty during fixing.

2. Now turn the whole apparatus towards a distant tree or a building. Hold the convex lens of focal length 5 cm, at a distance of 25 cm from the lens (O). Looking through this lens, move it slightly forward or backward, till you see a clear, magnified image of the distant building or tree. At this moment fix thin lens (E) with help of plasticine. Clear the lens E if required. Your simple astronomical telescope is ready for use.

D. Visit

Visit an optician and find out how he makes the lens of different powers by using a set of lenses. Make a detailed note of your visit.

or

Request the local optician to visit your school and explain how he uses a set of lenses to find the correct power of a lens required by a patient.