10

Light – Reflection and Refraction

In the Chapter

- Light appears to travel in straight lines.
- Mirrors and lenses form images of objects. Images can be either virtual or real, depending on the position of the object.
- The reflecting surfaces, of all types, follow the laws of reflection. The refracting surfaces follow the laws of refraction.
- New Cartesian Sign Conventions are followed for spherical lenses and mirrors.
- Mirror formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ represents the relationship between the object-distance (u), image-distance (v), and focal length (f) of a spherical mirror.
- The magnification produced by a spherical mirror is the ratio of the height of the image to the height of the object.
- The focal length of a spherical mirror is equal to half its radius of curvature.
- A light ray travelling obliquely from a denser medium to a rarer medium moves away from the normal. A light ray moves towards the normal when it travels obliquely from a rarer to a denser medium.
- Light moves in vacuum with an enormous speed of 3×10^8 m s-1. The speed of light is different in different media.
- The refractive index of a transparent medium is the ratio of the speed of light in vacuum to that in the medium.
- In case of a rectangular glass slab, the refraction takes place at both air-glass interface and glass-air interface. The emergent ray is parallel to the direction of incident ray.
- Lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ shows the relationship between the object-distance (u), image-distance (v), and the focal length (f) of a spherical lens.
- Power of a lens is the reciprocal of its focal length. The SI unit of power of a lens is dioptre.

Intext Exercises

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1. Define the principal focus of a concave mirror.

Ans. The point on principal axis where beam of rays parallel to principal axis meet after reflection is known as principal focus.

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

Ans. We know that

$R = 2f$

Here $R = 20$ cm

$f = 20/2 = 10$ cm.

$\therefore$ Focal length of concave mirror = 10 cm.

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

Ans. Concave mirror.

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

Ans. Convex mirror is used as a rear view mirror in vehicle because its aperture is large and it always forms a virtual, erect and full size diminished image of even further object.

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

Ans. Given $R = 32$ cm

$R = 2f$

$$f = \frac{R}{2} = \frac{32}{2} = 16\,cm.$$

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

Ans.

$$m = \frac{-v}{u} \text{ (real)}$$

or $$\frac{-v}{u} = -3$$

or $$v = 3u$$

$$u = -10 \text{ cm}$$

$$v = -3 \times 10 = -30 \text{ cm}.$$

Image is formed at a distance of 30 cm from pole in front of convex mirror.

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

Ans. It will bend towards the normal because its velocity will decrease as it will enter in water.

2. Light enters from air to glass having refractive index 1.50. What is the speed of light in the glass? The speed of light in vacuum is 3 × 108 m s–1.

Ans.

$$n_g = \frac{C}{v_g}$$

$$n_g = \frac{3 \times 10^8}{v_g}$$

$$n_g = \frac{3 \times 10^8}{1.5}$$

$V_g = 2 \times 10^8$ m/s

C = velocity of light in air

V_g = velocity of light in glass.

3. Find out, from Table 10.3, the medium having highest optical density. Also find the medium with lowest optical density.

Ans. Medium having highest optical density = Diamond.

Medium having largest optical density = air = 1.003.

4. You are given kerosene, turpentine and water. In which of these does the light travel fastest? Use the information given in Table 10.3.

Ans. Light travels faster in water as its refractive index is higher than kerosene oil and turpentine oil.

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

Ans. This means that diamond is very dense substance.

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1. Define 1 dioptre of power of a lens.

Ans. When the focal length of a lense is one meter, then the power of the lens is known as dioptre.

2. 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. Here image distance = + 50 cm

v = 50 cm

m = 1

P = 1/f = ?

For real image by lens

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

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

v = u

u = – 50 cm

Object distance = 50 cm.

Now,

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

$$\frac{1}{50} - \frac{1}{-50} = \frac{1}{f} \Rightarrow \frac{1+1}{50} = \frac{1}{f}$$

f = 25 cm

$$P = \frac{1}{\frac{25}{100}\text{m}} = \frac{1}{\frac{1}{4}}$$

P = 4 dioptre.

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

Ans. For concave lens

f = – 2 m

P = –1/f

P = –1/2

P = – 0.5 dioptre.

Exercise

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

(a) Water **(b) Glass**

(c) Plastic **(d) Clay**

Ans. (d) Clay

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

(a) Between the principal focus and the centre of curvature

(b) At the centre of curvature

(c) Beyond the centre of curvature

(d) Between the pole of the mirror and its principal focus.

Ans. (d) Between the pole of the mirror and its principal focus.

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

(a) At the principal focus of the lens

(b) At twice the focal length

(c) At infinity

(d) Between the optical centre of the lens and its principal focus.

Ans. (c) At infinity

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

(a) both concave.

(b) both convex.

(c) the mirror is concave and the lens is convex.

(d) the mirror is convex, but the lens is concave.

Ans. **(a)** both concave.

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

(a) plane. **(b) concave.**

(c) convex.

(d) either plane or convex.

Ans. (d) either plane or convex.

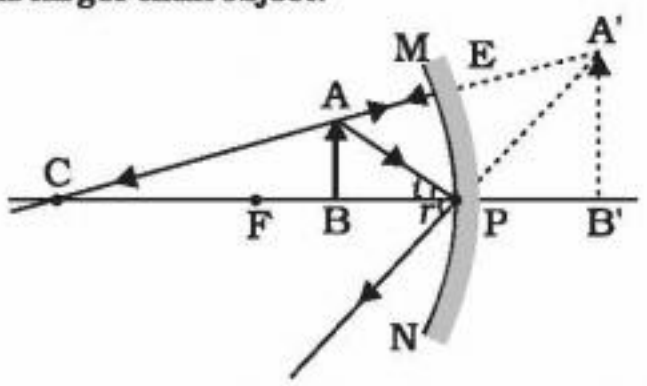
6. Which of the following lenses would you prefer to use while reading small letters found in a dictionary?

(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) A convex lens of focal length 5 cm.

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

Ans. Range of distance of the object is 0 to 15 cm. (i.e. less than 15 cm) in front of mirror from pole of mirror.
(i) Nature of image : Virtual and erect.
(ii) Image is larger than object.



8. 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 reason.

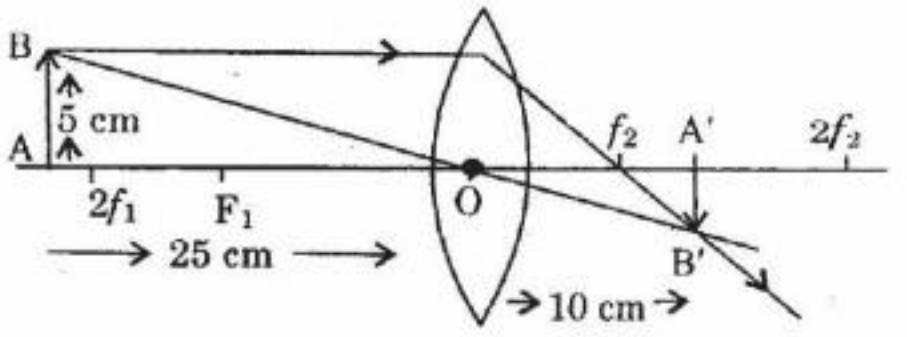
Ans. (a) Concave Mirror
(b) Convex mirror.
(c) Concave Mirror.

9. One-half of a convex lens is covered with a black paper. Will this lens produce a complete image of the object? Verify your answer experimentally. Explain your observations.

Ans. Yes, the lens will produce the full size image of the object.
Verification : Take a convex lens one half covered with a black paper. Put an object before it and obtain an image on the screen by adjustment. Observe that the lens produces complete of the object.

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

Ans.



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

$$\Rightarrow \frac{1}{v}-\frac{1}{-25}=\frac{1}{10}$$

$$\frac{1}{v}=\frac{1}{10}-\frac{1}{25}$$

$$=\frac{5-2}{50}=\frac{3}{50}$$

$$v=\frac{50}{3}=16.66\,cm$$

Images is for16.66 cm (ray 16.7 cm) from the lens on other side, i.e., behind the lens. Image is real and inverted.

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

$$\frac{h_2}{h_1}=\frac{\frac{50}{3}}{-25}$$

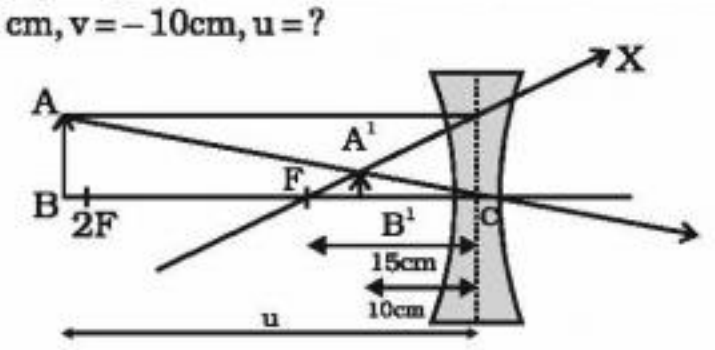
$$\frac{h_2}{5}=\frac{50}{-3\times 25}$$

$$h_2=\frac{-10}{3}=-3.33\,cm$$

Image is inverted at a height of 3.33 cm.

11. 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 the ray diagram.

Ans. $f=-15\,cm, v=-10cm, u=?$



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

$f = -15$ cm $v = -10$ cm

$$\frac{1}{(-15)}=\frac{1}{(-10)}-\frac{1}{u}$$

$$\frac{1}{u}=\frac{1}{(-10)}+\frac{1}{(15)}$$

$$\frac{1}{u} = \frac{-3+2}{30} = \frac{-1}{30}$$

$$u = -30 \text{ cm.}$$

Object is placed at a distance of 30 cm from concave lens.

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

Ans. F = 15 cm, u = – 10, v = ?

We know for spherical mirror.

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

$$\frac{1}{15} = \frac{1}{v} + \frac{1}{(-10)}$$

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

$$v = \frac{30}{5} = 6\text{cm}$$

Image is formed 6 cm behind the mirror. Image is virtual and erect.

13. The magnification produced by a plane mirror is +1. What does this mean?

Ans. The positive sign means image formed a plane mirror is virtual and erect the size of image is equal to the size of object.

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

Ans. $h_1 = 5$ cm,

$$f = \frac{r}{2} = \frac{30}{2} = 15 \text{ cm.}$$

u = –20 cm v = ? h_2 = ?

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

$$\frac{1}{15} = \frac{1}{(-20)} + \frac{1}{v}$$

$$\frac{1}{v} = \frac{1}{15} + \frac{1}{20} = \frac{4+3}{60} = \frac{7}{60},$$

$$\frac{1}{v} = \frac{7}{60}, v = \frac{60}{7} = 8.6 \text{ cm}$$

The image is formed behind the mirror at a distance of 8.6 cm.

$$\frac{-v}{u} = \frac{h_2}{h_1} \Rightarrow -\frac{8.6}{-20} = \frac{h_2}{5}$$

$$h_2 = \frac{-8.6 \times 5}{-20} = 2.15 \text{ cm}$$

Size of image = 2.175 (say 2.2 cm)
Image is virtual, erect and of height 2.2 cm reduced.

15. An object of size 7.0 cm is placed at 27 cm in front of a 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 the nature of the image.

Ans. $h_1 = 5.0$ cm, $u = -27$ cm, $f = -18$ cm
$v = ?$ $h_2 = ?$

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

$$\frac{1}{(-27)} + \frac{1}{v} = \frac{1}{-18}$$

or $$\frac{1}{v} = \frac{1}{-18} + \frac{1}{27}$$

or $$= \frac{-3+2}{54} = \frac{-1}{54}$$

or $$v = -54 \text{ cm.}$$

or $$= \frac{-v}{u} = \frac{h_2}{h_1} = \frac{54}{-27} = \frac{h_2}{7}$$

$$h_2 = -14 \text{ cm.}$$

Height of image is 14 cm, the image is real and inverted.

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

Ans.

$$P = \frac{1}{f} \Rightarrow -2.0 = \frac{1}{f}$$

$$f = \frac{-1}{2} m$$

$$f = \frac{-1}{2} x 100cm$$

$f = -50$ cm $= -0.50$ m
The lens is concave lens.

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

Ans.

$$P = \frac{1}{f} \Rightarrow 1.5 = \frac{1}{f}$$

$$f = \frac{1}{1.5} m = \frac{10}{15} m = \frac{2}{3} m = +0.67m$$

Focal length of the lens is + 0.67m. The prescribed lens is converging in nature.

Additional Questions

1. A coin appears to be raised when viewed obliquely as it is dipped in water. Give reason.

Ans. This is due to phenomenon of refraction of light. When ray of light moves from air to water, it bends towards the normal and then suffers reflection at the coin. To an observer, this appears to come from a raised position.

2. We do not see seven colours due to refraction by glass slab. Give reason.

Ans. In a glass slab,

(a) Opposite sides are parallel to each other, as a result angle of incidence = angle of emergence.

(b) A slab may also be considered to be made up of two prisms kept inverted to each other, as a result effect due to one gets nullified by other.

3. What are the characteristics of the image A'B' formed by a convex mirror for any position of the object AB in front of the mirror?

Ans. (i) The image is always formed behind the mirror between the pole P and the focus F for any position of the object AB in front of the mirror.

(ii) The image of the object is always virtual, erect and diminished in size.

4. (a) The image of a distant object is formed at 30 cm from a concave mirror. What is the focal length of the mirror?

(b) Define the term 'Principal Focus' of a spherical mirror.

Ans. (a) 30 cm.

(b) **Principal focus of a spherical mirror:** A point on the principal axis of a spherical mirror where the rays of light parallel to the principal axis meet or appear to meet after reflection from the spherical mirror is called principal focus.

5 (a) Which type of mirror is preferred as a rear-view mirror in vehicles and why?

(b) Which type of mirror is known as 'shaving mirror' and why?

Ans. (a) Convex mirror: Convex mirror is preferred as rear-view mirror because:

(i) A convex mirror always produces an erect image of the objects.

(ii) The image formed in a convex mirror is highly diminished than the object, due to which a convex mirror gives a wide field of view. A convex mirror enables a driver to view much larger area of the traffic behind him that would be possible with a plane mirror. A plane mirror gives a narrow field of view.

(b) Concave mirrors are used as shaving mirrors. This is because when the face is held within the focus of a concave mirror, then an enlarged image of the face is seen in the concave mirror. This helps in making a smooth shave.

6. Which mirror is used by the dentist and in solar concentrators ? Give reason to support your answer.

Ans. Concave mirrors are used by the dentists. This is because when a tooth is within the focus of a concave mirror, then an enlarged image of the tooth is seen in the concave mirror. Due to this, it becomes easier to locate the defect in the tooth.

Large concave mirrors are used in solar concentrators. The solar furnace is placed at the focus of a large concave reflector. The concave reflector focusses the sun's heat rays on the furnace due to which the solar furnace gets very hot.

7. Which type of mirror is used for: (i) headlights of cars, (ii) rear view mirror in cars, and why ?

Ans. (i) Concave mirror is used for headlights of cars. When a lighted bulb is placed at the focus of a concave reflector, then the concave reflector collects all the diverging rays of light of the

bulb and converts them into a powerful beam of parallel light rays. This parallel beam of light rays can reach a large distance in the darkness of night and make us see things up to a considerable distance.

(ii) Convex mirror is used as rear view in cars. Convex mirror forms erect and diminished image of vehicles coming from side behind.

Thus, it provides a wider field of view to the driver.

8. Define centre of curvature of a spherical mirror. Why does a ray of light passing through the centre of curvature of a spherical mirror retrace its path on reflection from the mirror ?

Ans. The centre of curvature of a spherical mirror is the centre of the hollow sphere of glass of which the mirror is a part.

A ray of light passing through the centre of curvature of a spherical mirror retrace its path on reflection from the mirror because the angle of incidence in this case is 0° and the angle of reflection is also 0°. This is because a ray of light going towards the centre of curvature falls normally on the surface of spherical mirror.

9. Object is placed between device and its focus, image formed is enlarged and behind it.

Ans. Concave mirror is the required device.

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

Ans. Convex lens is the required device.

11. 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.

Ans. Concave lens is the required device.

12. Object is placed between infinity and device, image formed is diminished and between pole and focus, behind it.

Ans. Convex mirror is the required device.

13. Is optical centre always at the centre of the lens ?

Ans. Not necessarily. However it must be on principal axis of the lens.

14. Can virtual image be obtained on screen ?

Ans. No, it cannot be had on the screen.

15. What is an image?

Ans. Point of convergence or the point from where light appears to diverge after reflection or refraction is called an image.

16. What is an erect image?

Ans. Image is said to be erect if it is in the direction of the object.

17. What is an inverted image?

Ans. If the image is upside down view of the object, the image is said to be inverted.

18. What is first law of refraction ?

Ans. Incident ray, refracted ray and normal lie in the same plane.

19. What is the second law of refraction?

Ans. Line of angle of incidence is proportional to line of angle of refraction.

$\sin i \propto \sin r$.

20. Are laws of reflection applicable to plane mirror ?

Ans. Laws of reflection are aplicable to all types of mirror, plane or spherical.

21. What is magnification ?

Ans. It is the ratio of size of image to the size of object.

22. Magnifying power of a mirror is + 1, what do you conclude from this?

Ans. Mirror is plane. Erect image of same size as the object is formed as far behind as the mirror as object is in front of it.

23. What is aperture of a mirror ?

Ans. Width of the reflecting surface is called its aperture.

24. What is radius of curvature of a mirror ?

Ans. It is radius of the sphere whose mirror forms a part.

25. What is principal axis of a mirror ?

Ans. A straight line joining the centre of curvature to the pole of the mirror and produced both ways.

26. What is radius of curvature of a plane mirror ?

Ans. It is infinity.

27. What is focus ?

Ans. The point on principal axis where all parallel rays meet or apper to diverge from after reflection or refraction is called focus.

28. What is SI unit of refractive index?

Ans. It has no units since it is the ratio of two velocities.

29. What is the cetere of spherical mirror called?

Ans. Pole.

30. What is angle of incidence ?

Ans. It is the angle between incident ray and normal.

Multiple Choice Questions

1. Focal length or concave mirror is :

(a) Always positive
(b) Always negative
(c) Positive when it forms a real image and negative when it forms virtual image
(d) Positive for erect image and negative for virtual image.

Ans. (b) Always negative

2. Focal length or plane mirror is :

(a) Zero
(b) Infinity
(c) Dependent on its size
(d) None of these.

Ans. (b) Infinity

3. Magnification of mirror is +2/3, the type or mirror is:

(a) Concave (b) Plane
(c) Convex (d) Combination of all.

Ans. (c)Convex

4. Radius or curvature of a mirror is 20 an. It is a :

(a) Convex mirror
(b) Concave mirror
(c) Plane mirror
(d) Nothing can be said with certainty.

Ans. (a) Convex mirror

5. Magnification produced by convex mirror is:
(a) always positive and greater than one
(b) always negative
(c) always positive and less than one
(d) zero.
Ans. (c)always positive and less than one

6. A concave mirror is a part or sphere of radius 20 cm, the focal length or concave mirror is:
(a) 10 cm (b) 20 cm
(c) – 20 cm (d) – 10 cm
Ans. (d) – 10 cm.

7. Plane mirror is a part or sphere of radius:
(a) zero (b) infinity
(c) nil since it is not a part of sphere
(d) any value depending upon its size.
Ans. (b) infinity

8. Image formed by plane mirror is:
(a) erect and perverted (b) erect and inverted
(c) inverted and real (d) inverted and virtual.
Ans. (a) erect and perverted

9. An object 20 cm high is placed at a distance of 90 cm from a plane mirror, the size of image will be:
(a) 20 cm (b) 90 cm
(c) 180 cm (d) 40 cm
Ans. (a) 20 cm

10. A concave mirror gives a virtual, erect and magnified image of an object if the object is placed:
(a) at infinity
(b) between P and F
(c) beyond C
(d) between C and F.
Ans. (b) between P and F

11. A convergent lens is:
(a) same thickness throughout
(b) thicker in middle, thinner at edges
(c) thinner in middle, thicker at edges
(d) thickness throughout
Ans. (b) thicker in middle, thinner at edges

12. Focal length of a plane glass is:
(a) zero (b) infinity
(c) finite.
Ans. (b) infinity

13. Image or real object formed by concave lens is:
(a) always real
(b) sometimes real, sometimes virtual
(c) always virtual.
Ans. (c) always virtual.