Light - Reflection and Refraction

Question 1: Define the principal focus of a concave mirror.

Answer: Light rays that are parallel to the principal axis of a concave mirror converge at a specific point on its principal axis after reflecting from the mirror. This point is known as the principal focus of the concave mirror.

Question 2: The radius of curvature of a spherical mirror is 20 cm. What is it s focal length?

Answer: Radius of curvature, R = 20 cm
Radius of curvature of a spherical mirror = 2 × Focal length (f)
R = 2f

$$f = \frac{R}{2} = \frac{20}{2} = 10 \text{ cm}$$

Hence, the focal length of the given spherical mirror is 10 cm.

Question 3: Name the mirror that can give an erect and enlarged image of an object.

Answer: When an object is placed between the pole and the principal focus of a concave mirror, the image formed is virtual, erect, and enlarged.

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

Answer: Convex mirrors give a virtual, erect, and diminished image of the objects placed in front of them. They are preferred as a rear-view mirror in vehicles because they give a wider field of view, which allows the driver to see most of the traffic behind him.

Question 5: Find the focal length of a convex mirror whose radius of curvature is 32 cm.

Answer: Radius of curvature, R = 32 cm
Radius of curvature = 2 × Focal length (f)
R = 2f

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

Hence, the focal length of the given convex mirror is 16 cm.

Question 6: A concave mirror produces three times magnified (enlarged) real image of object placed at 10 cm in front of it. Where is the image located?

Answer: Magnification produced by a spherical mirror is given by the relation,

$$m = \frac{\text{Height of the image}}{\text{Height of the object}} = -\frac{\text{Image distance}}{\text{Object distance}}$$

$$m = \frac{h_1}{h_o} = -\frac{v}{u}$$

Let the height of the object, ho = h

Then, height of the image, hI = −3h (Image formed is real)

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

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

Object distance, u = −10 cm

v = 3 × (−10) = −30 cm

Here, the negative sign indicates that an inverted image is formed at a distance of
30 cm in front of the given concave mirror.

Question 7: 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?

Answer: The light ray bends t owards the normal.

When a ray of light travels from an optically rarer medium to an optically denser medium, it gets bent towards the normal. Since water is optically denser than air, a ray of light travelling from air into the water will bend towards the normal.

Question 8: 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.
Refractive index of a medium nm is given by,

$$n_m = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in the medium}} = \frac{c}{v}$$

Speed of li ght i n vacuu m, c = 3 × 108 m s −1
Refractive index of glass, ng = 1.50

Speed of light in the glass, $v = \frac{c}{n_g} = \frac{3\times10^8}{1.50} = 2\times10^8\,\text{m s}^{-1}$

Question 11: The refractive index of diamond is 2.42. What is the meaning of this statement?
Answer: Refractive index of a medium nm is related to the speed of light in that medium v by the
relation:

$$n_m = \frac{\text{Speed of light in air}}{\text{Speed of light in the medium}} = \frac{c}{v}$$

Where, c is the speed of light in vacuum/air

The refractive index of diamond is 2. 42. This suggests that t he speed of light in diamond will reduce by a factor 2.42 compared to its speed in air.

Question 12: Define 1 dioptre of power of a lens.

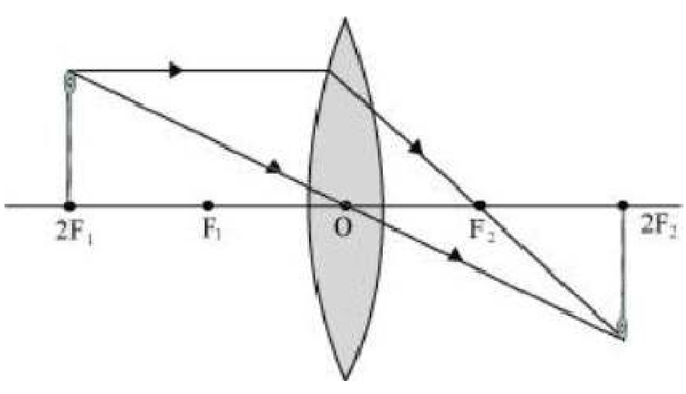
Answer: Power of lens is defined as the reciprocal of its focal length. If P is the power of a lens of focal length Fin metres, then

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

The S.I. unit of power of a lens is Dioptre. It is denot ed by D.
1 dioptre is defined as the power of a lens of focal length 1 metre.
1 D = 1 m−1

Question 13: 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.

Answer: When an object is placed at the centre of curvature, 2F1, of a convex lens, its image is formed at the centre of curvature, 2F2, on the other side of the lens. The image formed is inverted and of the same size as the object, as shown in the given figure.



It is given that the image of the needle is formed at a distance of 50 cm from the convex lens. Hence, the needle is placed in front of the lens at a distance of 50 cm.

Object distance, u = −50 cm

Image distance, v = 50 cm

Focal length = f

According to the lens formula,

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$
$$\frac{1}{f}=\frac{1}{50}-\frac{1}{(-50)}=\frac{1}{50}+\frac{1}{50}=\frac{1}{25}$$
$$f=25\,\text{cm}\ =0.25\ \text{m}$$

$$\text{Power of the lens, } P=\frac{1}{f(\text{in meters})}=\frac{1}{0.25}=+4\ \text{D}$$

Hence, the power of the given lens is +4 D.

Question 14: Find the power of a concave lens of focal length 2 m.

Answer: Focal length of concave lens, f = 2 m

$$\text{Power of a lens, } P=\frac{1}{f(\text{in meters})}=\frac{1}{(-50)}=-0.5\,\text{D}$$

Question 15: Which one of the following materials cannot be used to make a lens?

(a) Water

(b) Glass

(c) Plastic

(d) Clay

Answer: (d) A lens allows light to pass through it. Since clay does not show such property, it cannot be used to make a lens.

Question 16: The image formed by a concave mirror is observed t o be virt ual, 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

Question 17: 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.

Answer: (b) When an object is placed at the centre of curvature in front of a convex lens, its i mage is f or med at t he centre of cur vat ur e on t he ot her si de of t he l ens. The i mage f or med is r eal, i nvert ed, and of t he same si ze as t he obj ect.

Question 18: 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

Answer: (a) By convention, the focal length of a concave mirror and a concave lens are taken as negative. Hence, both the spherical mirror and the thin spherical lens are concave in nature.

Question 19: No matter how far you stand from a mirror, your image appears erect. The mirror i likely to be

(a) plane

(b) concave

(c) convex

(d) either plane or convex

Answer: (d) A convex mirror always gives a virtual and erect image of smaller size of the object placed in front of it. Similarly, a plane mirror will always give a virtual and erect image of same size as that of the object placed in front of it. Therefore, the given mirror could be either plane or convex.

Question 20: 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

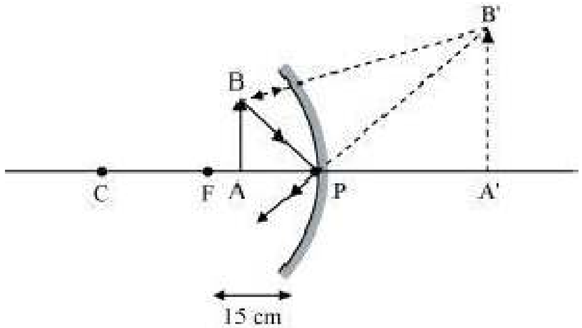
(d) A concave lens of focal length 5 cm

Answer: (c) A convex lens gives a magnified image of an object when it is placed between the radius of curvature and focal length. Also, magnification is more for convex lenses having shorter focal length. Therefore, for reading small letters, a convex lens of focal length 5 cm should be used.

Question 21: We wish to obtain an erect image of an object, using a concave mirror of focal lengt h 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.

Answer: Range of object distance = 0 cm to15 cm
A concave mirror gives an erect image when an object is placed between its pole (P) and the principal focus (F).

Hence, to obtain an erect image of an object from a concave mirror of focal length 15 cm, the object must be placed anywhere between the pole and the focus. The image formed will be virtual, erect, and magnified in nature, as shown in the given figure.



Question 19: 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 ans wer with reason.

Answer: (a) Concave (b) Convex (c) Concave
Explanation

(a) Concave mirror is used in the headlights of a car. This is because concave mirrors can produce powerful parallel beam of light when the light source is placed at their principal focus.

(b) Convex mirror is used in side/rear view mirror of a vehicle. Convex mirrors give a virtual, erect, and diminished image of the objects placed in front of it. Because of this, they have a wide field of view. It enables the driver to see most of the traffic behind him/her.

(c) Concave mirrors are convergent mirrors. That is why they are used to construct solar furnaces. Concave mirrors converge the light incident on them at a single point known as principal focus.

Hence, they can be used to produce a large amount of heat at that point.

Question 20: 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.

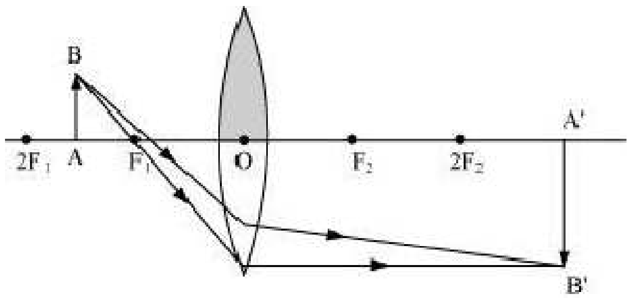
Answer: The convex lens will form complete image of an object, even if it s one half is covered with black paper. It can be understood by the following two cases.

Case I

When the upper half of the lens is covered

In this case, a ray of light coming from the object will be refracted by the lower half of the lens.

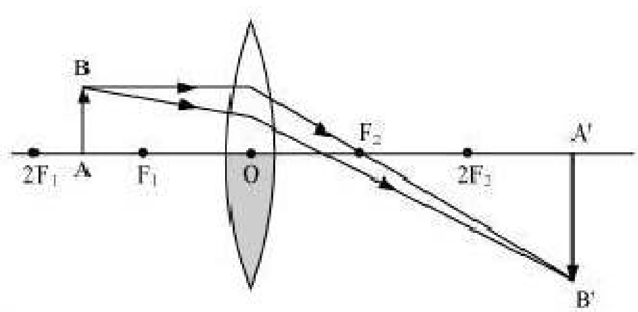
These rays meet at t he ot her side of t he lens to form t he image of t he given object, as shown in the following figure.



Case II

When the lower half of the lens is covered

In this case, a ray of light coming from the object is refracted by the upper half of the lens. These rays meet at the other side of the lens to form the image of the given object, as shown in the following figure.



Question 21: 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.

Answer: Object distance, u = −25 cm

Object height, ho = 5 cm

Focal length, f = +10 cm
According to the lens formula, .

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

$$\frac{1}{v}=\frac{1}{f}+\frac{1}{u}=\frac{1}{10}-\frac{1}{25}=\frac{15}{250}$$

$$v=\frac{250}{15}=16.66\text{ cm}$$

The positive value of v shows t hat the image is formed at t he ot her side of the lens.

$$\text{Magnification}, m=-\frac{\text{Image distance}}{\text{Object distance}}=-\frac{v}{u}=\frac{-16.66}{25}=-0.66$$

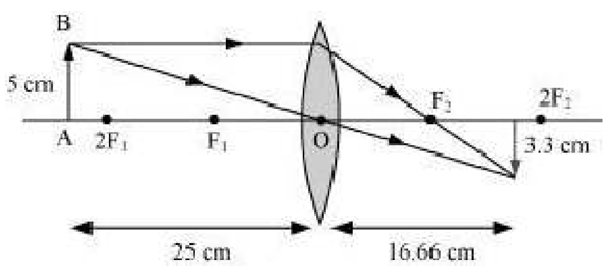
The negative sign shows that t he image is real and formed behind the lens.

$$\text{Magnification}, m=\frac{\text{Image height}}{\text{Object height}}=\frac{H_1}{H_o}=\frac{H_1}{5}$$

$$H_1=m\times H_o=-0.66\times 5=-3.3\text{ cm}$$

The negative value of image height indicates t hat the image formed is inverted.

The position, size, and nature of image are shown in t he following ray diagram.



Question 22: 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.

Answer: Focal length of concave lens (OF1), f = −15 cm

Image distance, v = −10 cm

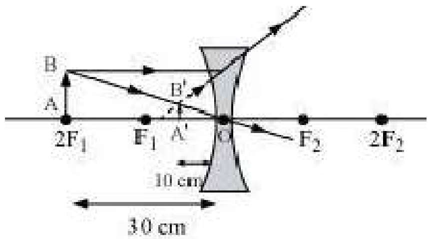
According to the lens formula,

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

$$\frac{1}{u}=\frac{1}{v}-\frac{1}{f}=\frac{-1}{10}-\frac{1}{(-15)}=\frac{-1}{10}+\frac{1}{15}=\frac{-5}{150}$$

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

The negative value of u indicates that the object is placed 30 cm in front of the lens. This is show in the following ray diagram.



Question 23: 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.

Answer: Focal length of convex mirror, f = +15 cm

Object distance, u = −10 cm

According to the mirror formula,

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

$$\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{15}+\frac{1}{10}=\frac{25}{150}$$

$$v=6\text{ cm}$$

The positive value of v indicates that the image is formed behind the mirror.

$$\text{Magnification}, m=-\frac{\text{Image distance}}{\text{Object distance}}=-\frac{v}{u}=\frac{-6}{-10}=+0.6$$

The positive value of magnification indicates t hat the image formed is virt ual and erect.

The magnification produced by a plane mirror is +1. What does t his mean?

Magnification produced by a mirror is given by the relation

$$\text{Magnification}, m=\frac{\text{Image height }(H_1)}{\text{Object height }(H_o)}$$

The magnification produced by a plane mirror is +1. It shows t hat the image formed by the plane mirror is of the same size as that of the object. The positive sign shows that the image for med is virtual and erect.

Question 24: 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, it s nature and size.

Answer: Object distance, u = −20 cm

Object height, h = 5 cm

Radius of curvature, R = 30 cm

Radius of curvature = 2 × Focal length

R = 2f

f = 15 cm

According to the mirror formula,

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$
$$\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{15}+\frac{1}{20}=\frac{4+3}{60}=\frac{7}{60}$$
$$v=8.57\text{ cm}$$

The positive value of v indicates t hat t he image is formed behind t he mirror.

$$\text{Magnification, } m=-\frac{\text{Image distance}}{\text{Object distance}}=\frac{-8.57}{-20}=0.428$$

The positive value of magnification indicates that the image formed is virtual.

$$\text{Magnification,} m=\frac{\text{Height of the image}}{\text{Height of the object}}=\frac{h'}{h}$$
$$h'=m\times h=0.428\times 5=2.14\text{ cm}$$

The positive value of image height indicates that t he image formed is erect.

Therefore, the image formed is virt ual, erect, and smaller in size.

Question 25: 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 focused image can be obtained? Find the size and the nature of the image.

Answer: Object distance, u = −27 cm

Object height, h = 7 cm

Focal length, f = −18 cm

According to the mirror formula,

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$$
$$\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{-1}{18}+\frac{1}{27}=\frac{-1}{54}$$
$$v=-54 \text{ cm}$$

The screen should be placed at a distance of 54 cm in front of the given mirror.

$$\text{Magnification, } m=-\frac{\text{Image distance}}{\text{Object distance}}=\frac{-54}{27}=-2$$

The negative value of magnification indicat es that t he image formed is real.

$$\text{Magnification, } m=\frac{\text{Height of the image}}{\text{Height of the object}}=\frac{h'}{h}$$
$$h'=7\times(-2)=-14 \text{ cm}$$

The negative value of image height indicat es t hat the image formed is invert ed.

Question 26: Find the focal length of a lens of power −2.0 D. What type of lens is this?

$$\text{Power of a lens, } P=\frac{1}{f(\text{in metres})}$$
$$P=-2 \text{ D}$$
$$f=\frac{-1}{2}=-0.5 \text{ m}$$

Answer: A concave lens has a negative focal length. Hence, it is a concave lens.

Question 27: 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?

$$\text{Power of a lens, } P=\frac{1}{f(\text{in metres})}$$
$$\text{Power, } P=1.5 \text{ D}$$
$$f=\frac{1}{1.5}=\frac{10}{15}=0.66 \text{ m}$$

Answer: A convex lens has a positive focal length. Hence, it is a convex lens or a converging lens.