10 LIGHT-REFLECTION AND REFRACTION

BASIC CONCEPTS – A FLOW CHART

LIGHT

Reflection

- Coming back of light rays to the same medium, when they fall on a body.
- Laws of reflection:
  Ist law: The incident ray, the reflected ray and the normal at the point of incidence all lie in the same plane.
  IInd law: The angle of incidence is always equal to the angle of reflection.

Reflecting surfaces → **Spherical Mirrors** → Important Items

- *Pole:* Midpoint or centre of the reflecting surface of a spherical mirror.
- *Centre of curvature:* Centre of the hollow sphere of which the mirror is a part.
- *Radius of curvature:* Radius of that sphere of which the mirror is a part.
- *Principal axis:* Line joining the pole and the centre of curvature.
- *Principal section:* Vertical section of a mirror by a plane passing through the principal axis of the mirror.

Types

Concave Mirror

- Reflecting surface is curved inwards.
- Polishing is done on outer surface.

Uses

- Used by dentists to focus light on the patient's teeth.
- Used as shaving mirrors.

Image formation

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F	Highly diminished, point-sized	Real and inverted
Beyond C	Between F and C	Diminished	Real and inverted
At C	At C	Same size	Real and inverted
Between C and F	Beyond C	Enlarged	Real and inverted
At F	At infinity	Highly enlarged	Real and inverted
Between P and F	Behind the mirror	Enlarged	Virtual and erect

Convex Mirror

- Reflecting surface is curved outwards.
- Polishing is done on inner surface.

Uses

- Used as rear view mirrors in vehicles
- Used as a reflector in street lamps.

Image formation

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F, behind the mirror	Highly diminished, point sized	Virtual and erect
Between infinity and the pole P of the mirror	Between P and F, behind the mirror	Diminished	Virtual and erect

Important Formulae

- Mirror formula, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$
- Magnification produced by mirror, $m=\frac{h'}{h}=-\frac{v}{u}$
- Snell's law $\frac{\sin i}{\sin r}=\frac{n_b}{n_a}={}_an_b=\frac{v_a}{v_b}=\frac{\lambda_a}{\lambda_b}$
- Absolute refractive index, $n=\frac{c}{v}$
- If C is critical angle, then refractive index $n=\frac{1}{\sin C}$
- Lens formula, $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$
- Magnification produced by lens, $m=\frac{h'}{h}=\frac{v}{u}$
- Power of a lens, $P=\frac{1}{f\,(\text{in m})}=\frac{100}{f\,(\text{in cm})}$
- Power of combination of lenses, $P=P_1+P_2+P_3+\ldots$
- For combination of lenses, $m=m_1\times m_2\times m_3\times\ldots$

Phenomena of Light → **Refraction**

- Bending of light when it passes from one medium to another.
- *Laws of refraction:*
  First law: The incident ray, the refracted ray, and the normal at the point of incidence all lie in the same plane.
  Second law (Snell's law): The ratio of sine of angle of incidence to the sine of angle of refraction is a constant for a given pair of media.
  $$i.e.,\ \frac{\sin i}{\sin r}=\text{constant}$$

Expression of extent of change in direction in a pair of media → **Refractive Index**

- Ratio of the speed of light in vacuum to the speed of light in the medium.

$$\text{Refractive index, } n=\frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}=\frac{c}{v}$$

- It is a ratio and has no unit.

Refracting surfaces → **Spherical Lenses**

Important terms

- Optical centre: Centre point of a lens.
- Principal axis: Line passing through the optical centre of the lens and perpendicular to both the faces of the lens.
- Principal focus of a convex lens: A point on its principal axis to which light rays parallel to principal axis converge after passing through the lens.
- Principal focus of a concave lens: A point on its principal axis from which light rays originally parallel to the axis, appear to diverge after passing through the concave lens.

Types

Convex Lens

- Thick at centre, thinner at edges.
- These converge light rays.

Image formation

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F_2	Highly diminished, point-sized	Real and inverted
Beyond $2F_1$	Between F_2 and $2F_2$	Diminished	Real and inverted
At $2F_1$	At $2F_2$	Same size	Real and inverted
Between F_1 and $2F_1$	Beyond $2F_2$	Enlarged	Real and inverted
At Focus F_1	At infinity	Infintely large or highly enlarged	Real and inverted
Between focus F_1 and optical centre O	On the same side of the lens as the object	Enlarged	Virtual and erect

Concave Lens

- Thin in the middle, thicker at edges.
- These diverge light rays.

Image formation

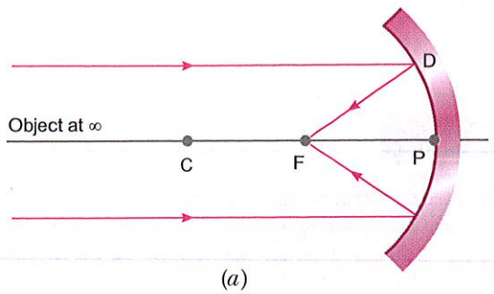
Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F_1	Highly diminished, point-sized	Virtual and erect
Between infinity and optical centre O of the lens	Between F_1 and O	Diminished	Virtual and erect

MORE POINTS TO REMEMBER

❒ Image formation by spherical mirrors:

- It is more convenient to consider only two rays, for the sake of clarity of the ray diagram.
- A ray parallel to the principal axis, after reflection, will pass through the principal focus in case of a concave mirror or appear to diverge from the principal focus in case of a convex mirror.
- A ray passing through the principal focus of a concave mirror or a ray which is directed towards the principal focus of a convex mirror, after reflection, will emerge parallel to the principal axis.
- A ray passing through the centre of curvature of a concave mirror or directed in the direction of the centre of curvature of a convex mirror, after reflection, is reflected back along the same path.
- A ray incident obliquely to the principal axis, towards a point P (pole of the mirror), on the concave mirror or a convex mirror, is reflected obliquely at the same angle.

❒ Image formation by concave mirror:



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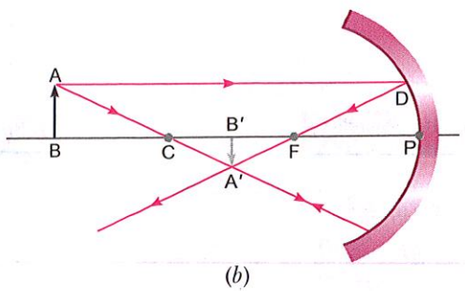

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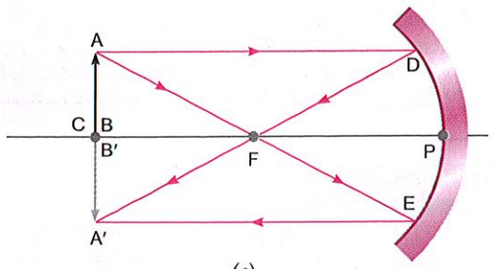

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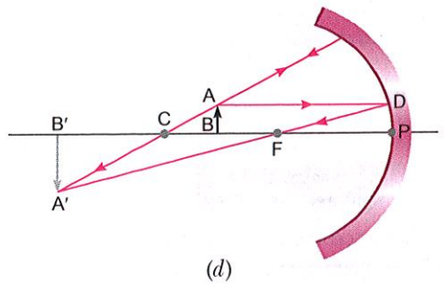

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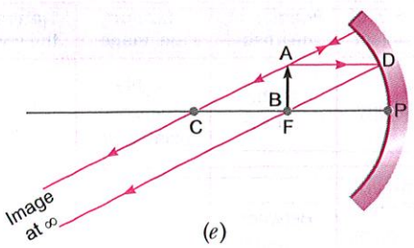

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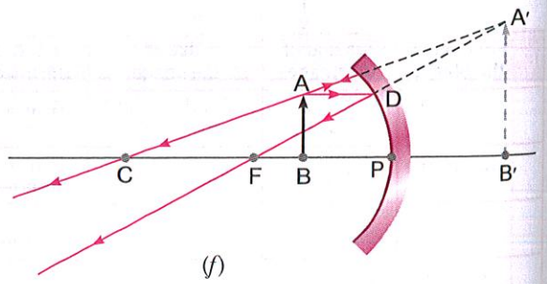

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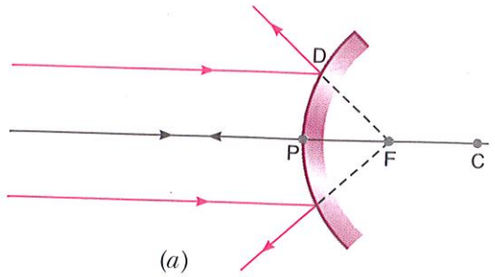
❒ Image formation by convex mirror:



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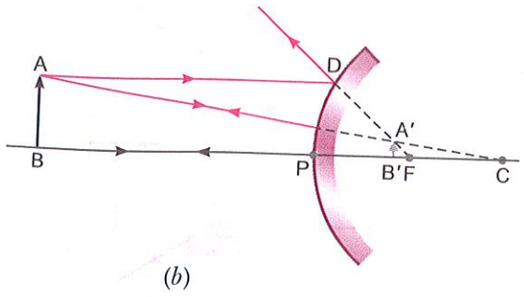
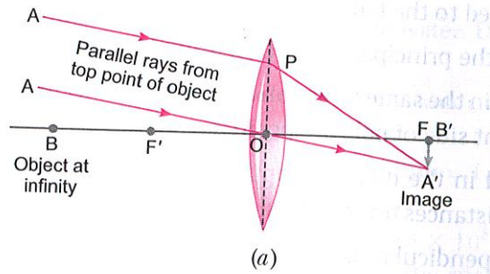


(b)

❒ Image formation by convex lens:



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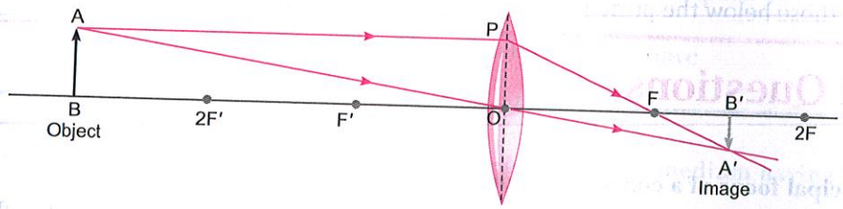

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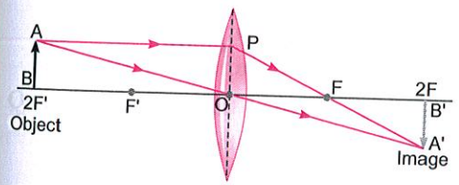

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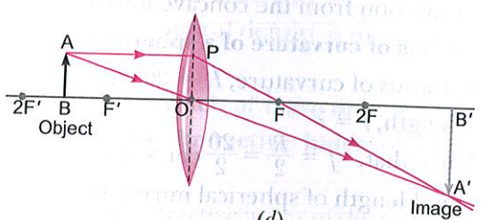

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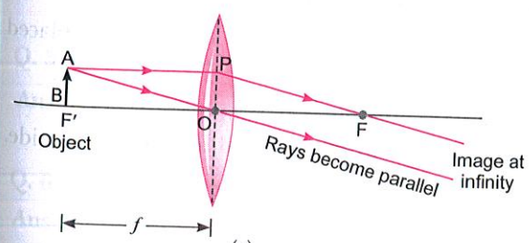

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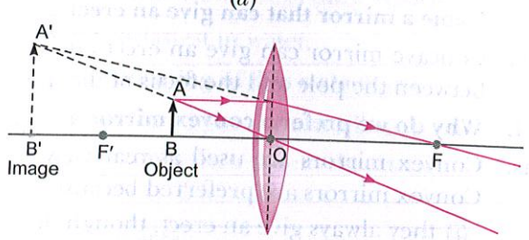

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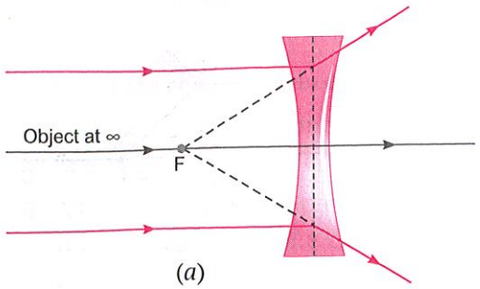
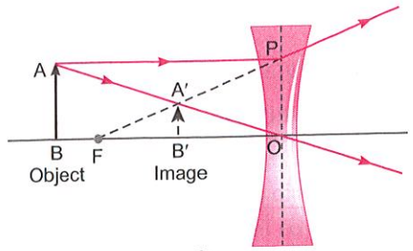
❒ Image formation by concave lens:



(*a*)



(*b*)

❒ Sign conventions for reflection and refraction:

- The object is always placed to the left of the mirror.
- All distances parallel to the principal axis are measured from the pole of the mirror.
- The distances measured in the same direction as that of the incident light are taken as positive, *i.e.*, distances on the right side of pole are positive.
- The distances measured in the direction opposite to the direction of the incident light are taken as negative, *i.e.*, distances on the left side of pole are taken as negative.
- Distances measured perpendicular to and above the principal axis (along + y axis) are taken as positive while those below the principal axis (along –y axis) are taken as negative.

NCERT Intext Questions

REFLECTION

Q. 1. Define the principal focus of a concave mirror.

Ans. The point on the principal axis at which all the rays parallel and close to the principal axis meet after reflection from the concave mirror is called principal focus.

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

Ans. Here, radius of curvature, $R = 20$ cm.

Focal length, $f = ?$

We know that, $f = \frac{R}{2} = \frac{20}{2}\text{cm} = 10\text{ cm}$

The focal length of spherical mirror is 10 cm.

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

Ans. Concave mirror can give an erect and enlarged image of an object, when the object is placed between the pole and the focus of the mirror.

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

Ans. Convex mirrors are used as rear-view mirrors in vehicles to see the traffic at the rear side. Convex mirrors are preferred because

(*i*) they always give an erect, though diminished image.

(*ii*) they have a wider field of view as they are curved outwards.

Thus, convex mirrors enable the driver to view much larger area than a plane mirror.

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

Ans. Here, $R = 32$ cm; $f = ?$ [convex mirror]

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

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

Ans. Here, in case of concave mirror

$u = -10$ cm [u is always negative]

$v = ?$; $m = -3$ [real image]

Now the magnification formula is

$$m = \frac{-v}{u} \qquad \text{or} \qquad -3 = -\left(\frac{v}{-10}\right)$$

or $v = -30$ cm.

Image will be formed at 30 cm from the mirror on the same side of the object.

REFRACTION

Q. 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. Light ray travelling in air and entering obliquely into water is bent towards the normal because the speed of the ray decreases in water.

Q. 2. Light enters from air into glass having refractive index 1.50. What is the speed of light in glass? The speed of light in vacuum is 3×10^8 ms^{-1}.

Ans. Given, $n = 1.5$ and the speed of light in vacuum, $c = 3 \times 10^8$ ms^{-1}. We know that the refractive index is given by the expression $n = \frac{c}{v}$ where c is the speed of light in vacuum and v is the speed of light in the given medium (glass). Hence we have

$$v = \frac{c}{n} = \frac{3\times10^8}{1.5} = 2.0\times10^8 \text{ ms}^{-1}$$

Q. 3. Find out, from table 10.3 (NCERT Page No. 175), the medium having highest optical density. Also find the medium with lowest optical density.

Ans. A substance having higher refractive index is optically denser than another substance having lower refractive index. So the medium having highest optical density is diamond. The medium with lowest optical density is air.

Q. 4. You are given kerosene, turpentine oil and water. In which of these does the light ray travel fastest? Given refractive index of kerosene = 1.44, Refractive index of turpentine 1.47, refractive index of water = 1.33.

Ans. Speed of light in a medium is inversely proportional to refractive index of the medium, *i.e.*, $v \propto \frac{1}{n}$.

As refractive index of water is minimum, so light travels fastest in water.

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

Ans. The refractive index of diamond is 2.42. It means that for a light ray travelling in vacuum and entering diamond, speed is slowed and becomes $\frac{1}{2.42}$ times than that in the vacuum.

Q. 6. Define 1 dioptre of power of a lens.

Ans. 1 dioptre is the power of a lens whose focal length is 1 metre.

Q. 7. A convex lens forms a real and inverted image of a needle at a distance of 50 cm from the lens. 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. When an object is placed, at $2F_1$, of a convex lens, its image is formed at $2F_2$ and is of the same size as object.

Here, 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 lens formula

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

$$\frac{1}{f} = \frac{1}{50} - \frac{1}{(-50)} = \frac{2}{50} = \frac{1}{25}$$

$f = 25$ cm $= 0.25$ m

$$\text{Power of lens} = \frac{1}{f(\text{in m})} = \frac{1}{0.25} = +4\text{D}$$

Q. 8. Find the power of a concave lens of focal length 2 m.

Ans. Given $f = -2$ m

Power, $P = \frac{1}{f} = \frac{1}{-2} = -0.5$ dioptre.

Thus, the power of concave lens is – 0.5 dioptre.

NCERT Exercises

REFLECTION

Q. 1. The image formed by a concave mirror is observed to be virtual, erect and larger than the object. What 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. The image formed by a concave mirror is virtual, erect and larger only when the object is placed between the pole of the mirror and its principal focus. So correct choice is (*d*).

Q. 2. No matter how far you stand from a mirror, your image appears erect. The mirror is likely to be

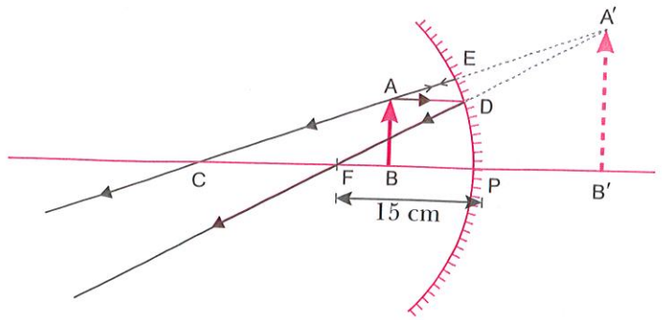
(*a*) plane **(*b*) concave**

(*c*) convex **(*d*) either plane or convex**

Ans. A plane mirror forms an erect image of equal size; while a convex mirror forms an erect image of smaller size irrespective of the distance of object from the mirror, so correct choice is (d).

Q. 3. 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 the 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.



When object is between pole and focus

An erect image is formed by a concave mirror, only if the object is placed between the pole and the principal focus of the mirror (*i.e.*, range of object distance is between 0 and 15 cm. *i.e.*, $0 < u < 15$ cm.)

Nature: The image is ***virtual***.

Size of Image: The image is larger than the object. The ray diagram is shown in figure.

Q. 4. Name the type of mirror used in 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*) Headlights of a car use a concave mirror.

Concave mirror renders the rays parallel when object is placed at its principal focus. The bulb of headlight is at focus of concave mirror, the rays reflected from the mirror are in the form of a strong parallel beam, which goes straight and makes the distant objects visible for safe driving.

(*b*) Side/rear view mirror of a vehicle is a convex mirror because of its larger field of view.

(*c*) Solar furnace uses a concave mirror. The object to be heated is placed at the focus of concave mirror. The parallel rays coming from the sun become incident on the mirror and get reflected at focus. That is sufficient energy is received from the sun and collected at one point (focus) to heat the object.

Q. 5. 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. Given, $u = -10$ cm, $f = +15$ cm, $v = ?$

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

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{15} - \frac{1}{(-10)} = \frac{1}{15} + \frac{1}{10} = \frac{2+3}{30}$$

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

That is the image is formed at a distance of 6 cm from the mirror behind it. The image is erect and virtual.

Q. 6. The magnification produced by a plane mirror is + 1. What does this mean?

Ans. The positive (+) sign of magnification (m) indicates that the image is virtual and erect. The magnification, $m = 1$ indicates that the image is of the same size as the object. Thus, the magnification of + 1 produced by a plane mirror means the image formed in a plane mirror is virtual, erect and of the same size as the object.

Q. 7. An object 5 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. Radius of curvature of convex mirror, $R = 30$ cm.

$\therefore$ Focal length of convex mirror, $f = \frac{R}{2} = \frac{30\text{ cm}}{2} = 15\text{ cm}$

Now $h = 5$ cm, $u = -20$ cm, $v = ?$, $h' = ?$

Using the mirror formula $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$, we have

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

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

Thus, image is formed at a distance of 8.6 cm behind the convex mirror. The image is virtual and erect.

$$m = \frac{h'}{h} = -\frac{v}{u}$$

$$\frac{h'}{5} = -\frac{8.6}{-20} \Rightarrow h' = \frac{8.6}{20} \times 5 = 2.15\text{ cm}$$

Thus, the size of the image is 2.15 cm which is positive. It indicates that the image formed is erect, virtual and diminished.

Q. 8. An object of size 7 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.

Ans. Here, $h = 7\text{cm}, u = -27\text{cm}, f = -18, v = ?, h' = ?$

Using the mirror formula $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$, we have

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

$$= \frac{1}{-18} - \frac{1}{-27} = \frac{1}{-18} + \frac{1}{27} = \frac{-3+2}{54} = -\frac{1}{54}$$

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

The image is formed at a distance of 54 cm in front of the mirror and '–' sign shows that image is formed on the same side as that of the object. It means image is real and inverted.

Further, we know that $m = \frac{h'}{h} = -\frac{v}{u}$

$$\frac{h'}{7} = \frac{-(-54)}{(-27)}$$

$$h' = -14\text{ cm}$$

Hence, the size of the image is 14 cm. The negative sign of the image shows that it is inverted. Thus, the nature of the image is real, inverted and enlarged.

REFRACTION

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

(a) water (b) glass (c) plastic (d) clay

Ans. Lens is made of a transparent material;

Clay is not transparent [choice (d) is correct].

Q. 2. 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. For real image of same size, the object must be placed at the distance $2f$ in front of convex lens, choice (*b*) is correct.

Q. 3. A spherical mirror and a thin spherical lens have each a focal length of –15 cm. The mirror and 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. Concave mirror and concave lens both have negative focal length, choice (*a*) is correct.

Q. 4. 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

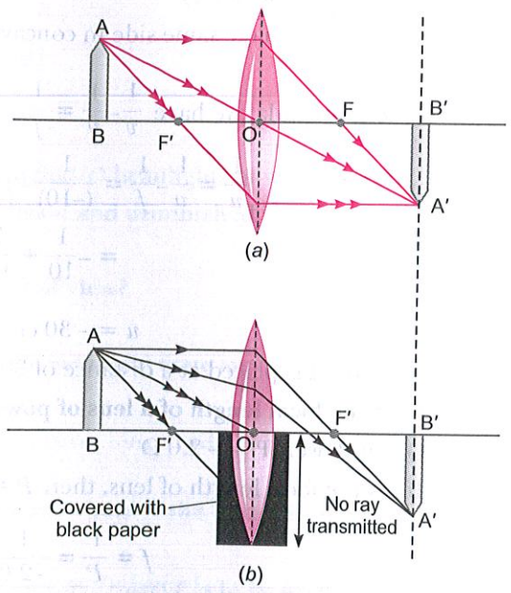
(c) A convex lens of focal length 5 cm (d) A concave lens of focal length 5 cm

Ans. Magnifier or a simple microscope consists of a convex lens of small focal length; choice (*c*) is correct.

Q. 5. 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. Take a live candle, put it in front of a convex lens mounted on an optical bench. Move the candle along the axis of the bench and take its full image on a screen fig. (*a*). Now cover the lower half of the lens with a black paper without changing the positions of candle, lens and screen fig. (*b*).

You will observe that the full image of the candle is still seen on the screen; but the intensity of image is reduced. The reason is that a large number of rays incident on the lens are refracted to form the image when lens is not covered. In the case of covered lower half of lens with black paper, the rays starting from candle and incident on lens are refracted from the upper part only and form the full image, having low intensity.



Q. 6. An object 5 cm in length is held 25 cm away 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. Here

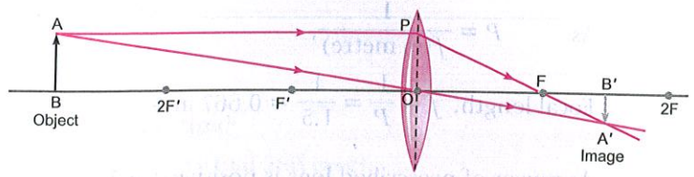
$u = -25$ (u is always negative)

$f = +10$ cm (convex lens)

$h = 5$ cm; $v = ?$ and $h' = ?$

From the lens formula

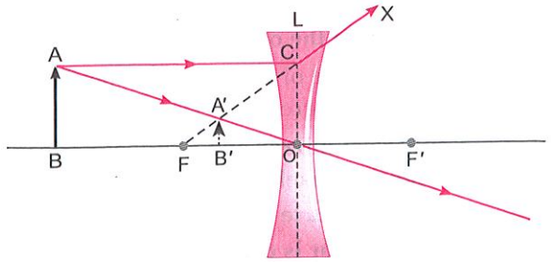
$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$



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

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

or $$v = \frac{50}{3} = 16.67 \text{ cm}$$



This image is formed at a distance 16.67 cm behind the lens.

Also, magnification

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

or $$h' = \frac{v}{u} \times h = \frac{16.67}{-25} \times 5 = -3.33 \text{ cm}$$

Thus, image is inverted, real and of size 3.33 cm.

Q. 7. A concave (diverging) lens of focal length 15 cm, forms an image at a distance of 10 cm from the lens. How far is the object placed from the lens? Draw the ray diagram.

Ans. Here, focal length of the concave (diverging) lens is

$f = -15$ cm (negative)

$v = -10$ cm (image same side in concave lens)

$u = ?$

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

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

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

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

The object is placed at a distance of 30 cm away from the lens.

Q. 8. Find the focal length of a lens of power – 2.0 D. What type of lens is this?

Ans. Given Power $P = -2.0$ D

If f is the focal length of lens, then $P = \frac{1}{f}$ gives

$$f = \frac{1}{P} = \frac{1}{-2.0} \text{ m} = -50 \text{ cm}$$

Negative sign shows that lens is concave. Thus focal length of lens is 50 cm and it is concave lens.

Q. 9. 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. Given $P = +1.5$ D

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

Focal length, $f = \frac{1}{P} = \frac{1}{1.5} = 0.667 \text{ m} = 66.7 \text{ cm}$

As power of prescribed lens is positive, the lens is converging (or convex) lens.

VERY SHORT ANSWER QUESTIONS [1 mark]

Q. 1. What is light?

Ans. Light is a form of energy which gives us the sensation of sight or vision.

Q. 2. What is a ray of light?

Ans. The path along which light travels is called a ray of light.

Q. 3. What is a beam of light?

Ray

Ans. A group of light rays originating from a source and travelling in some definite direction is known as a beam of light.

Q. 4. Define the term principal axis of a spherical mirror. *[CBSE Delhi (C) 2017]*

Ans. Principal axis of a spherical mirror is the line joining the pole and the centre of curvature of a spherical mirror.

Q. 5. Name a communication device which uses light for its working.

Ans. Optical fibres, which transmit many telephonic messages at the same time.

Q. 6. What is the angle of reflection when a ray of light falls normally on a plane mirror?

Ans. The angle of reflection is 0°.

Q. 7. What kind of image can be obtained on the screen?

Ans. Real image.

Q. 8. What type of image is formed:

(*i*) in a plane mirror, and (*ii*) on a cinema screen?

Ans. (*i*) Virtual image, and (*ii*) real image.

Q. 9. Write two different uses of concave mirrors. *[CBSE Delhi (C) 2017]*

Ans. Concave mirror are used in (*a*) Torches (*b*) Searchlights (*c*) headlights of vehicles, etc.

Q. 10. Name the type of mirror which always forms a virtual and diminished image.

Ans. Convex mirror.

Q. 11. Which mirror—convex or concave has larger field of view?

Ans. Convex mirror.

Q. 12. Why is convex mirror used as a rear view mirror in vehicles? State any one reason. *[CBSE Delhi (C) 2017]*

Ans. As convex mirror gives a wider field view of the approaching traffic it is used as a rear view mirror in vehicles.

Q. 13. If an object is placed at the focus of a concave mirror, where is the image formed?

Ans. At infinity.

Q. 14. What should be the position of the object when a concave mirror is to be used:

(*i*) as a shaving mirror?, and (*ii*) as a doctor's mirror?

Ans. (*i*) Between pole P, and focus F, and

(*ii*) At focus F.

Q. 15. What sign (+ve or –ve) is given to the focal length of:

(*a*) a concave mirror?, and (*b*) a convex mirror?

Ans. (*a*) Focal length of a concave mirror is – ve, and

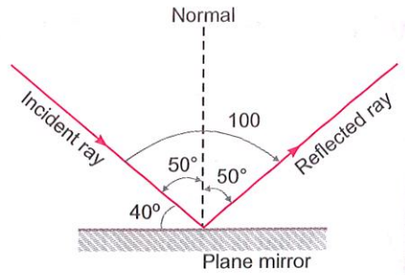
(*b*) Focal length of a convex mirror is + ve.

Q. 16. What is the significance of +ve sign of magnification?

Ans. + ve sign of magnification shows that the image is virtual and erect.

Q. 17. Can a plane mirror be called spherical mirror?

Ans. Yes, a plane mirror can be called a spherical mirror of infinite radius of curvature.



Q. 18. A man standing in front of a spherical mirror, finds his image having a very small head, a fat body and legs of normal size. What type of mirrors are used in these three parts?

Ans. A very small head: Convex mirror,

A fat body: Concave mirror, and

Legs of normal size: Plane mirror.

Q. 19. Differentiate between virtual image formed by a concave mirror and of a convex mirror.

Ans. The virtual image formed by a concave mirror is always magnified whereas the virtual image formed by a convex mirror is diminished.

Q. 20. What is the magnification produced by a plane mirror?

Ans. The magnification of a plane mirror is 1

Q. 21. The angle between an incident ray and the mirror is 40°.

(*i*) What is the angle of incidence?

(*ii*) What is the angle of reflection?

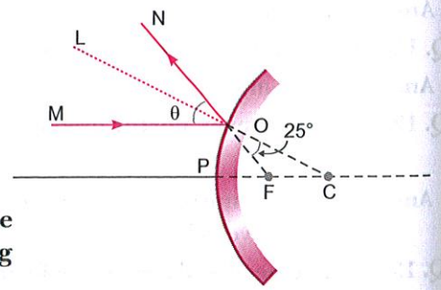
(*iii*) What is the total angle through which the ray of light turns?

Ans. (*i*) 50° (*ii*) 50° (*iii*) 100°

Q. 22. Why does a convex mirror is said to have a virtual principal focus?

Ans. In a convex mirror, a parallel beam after reflection do not actually pass through the focus (F) but it appears to come from the back side of the mirror from focus. So, a convex mirror has a virtual principal focus, which is situated behind the mirror.

Q. 23. What is the value of θ in the following ray diagram?



Ans. Here, $\angle MON = \angle MOL + \angle LON = \theta$

$\angle LON = \angle FOC = 25°$ (vertically opposite angles)

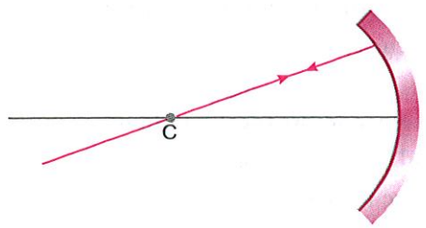
$\angle LON = \angle MOL = 25°$

[Angle of incidence = Angle of reflection]

$\angle MON = 25 + 25 = 50°$

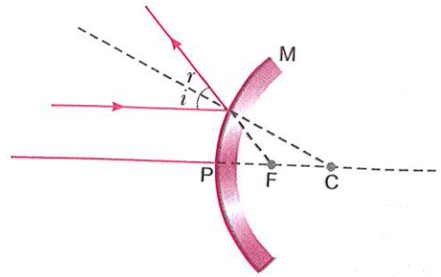
Q. 24. Explain why a ray of light passing through the centre of curvature of a concave mirror gets reflected along the same path after reflection.

Ans. This is because the angle of incidence is 0°. That is the ray passing through the centre of curvature is incident normally to the mirror. The angle of reflection should also be 0°.



Q. 25. Draw a ray diagram to show the path of the reflected ray corresponding to an incident ray of light parallel to the principal axis of a convex mirror and show the angle of incidence and angle of reflection on it. *[CBSE (AI) 2015]*

Ans.



Q. 26. What is the nature of the image formed by a concave mirror if the magnification produced by the mirror is +3?

Ans. Virtual and erect.

Q. 27. Between which two points of a concave mirror should an object be placed to obtain a magnification of – 3?

Ans. Between F and C.

Q. 28. The outer surface of a hollow sphere of aluminium of radius 50 cm is to be used as a mirror. What will be the focal length of this mirror? Which type of spherical mirror will it provide?

Ans. Focal length, $f = \frac{R}{2} = \frac{50}{2} = 25$ cm

It will provide a convex mirror.

Q. 29. Which property of concave mirror is utilised for using them as shaving mirrors? *[CBSE Sample Paper 2017]*

Ans. When an object is placed between the pole and focus of concave mirror a magnified, erect and virtual image is obtained.

Q. 30. What is an optically rarer medium?

Ans. A medium in which light travels comparatively faster than the other medium is called an optically rarer medium.

Q. 31. What is an optically denser medium?

Ans. A medium in which light travels comparatively slower than the other medium is called an optically denser medium.

Q. 32. Define the term refraction of light.

Ans. The bending of a ray of light falling obliquely on a surface when it passes from one transparent medium to another is called refraction.

Q. 33. Define the term angle of incidence.

Ans. The angle between the incident ray and the normal at the point of incidence is called angle of incidence.

Q. 34. Define the term angle of refraction.

Ans. The angle between the refracted ray and the normal at the point of incidence is called angle of refraction.

Q. 35. Define the term refractive index of a medium in terms of speed of light.

Ans. Refractive index of a medium is defined as the ratio of speed of light in vacuum to the speed of light in the medium. *i.e.*,

$$\text{Refractive index (of a medium)} = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}$$

Q. 36. What is absolute refractive index?

Ans. Refractive index of a medium with respect to vacuum is called absolute refractive index.

Q. 37. What is relative refractive index?

Ans. Refractive index of a medium with respect to another medium is called relative refractive index.

Q. 38. What is the unit of refractive index?

Ans. Refractive index has no units as it is a ratio of two similar physical quantities.

Q. 39. Refractive index of two material mediums X and Y are 1.3 and 1.5 respectively. In which of the two, the light would travel faster?

Ans. In medium 'X' because of lower value of refractive index.

Q. 40. What is the cause of refraction of light?

Ans. Refraction of light takes place when it travels from one medium to another because the speed of light is different in the two media.

Q. 41. What is the relationship between the refractive index of two media?

Ans. The refractive index for the light going from medium '1' to medium '2' is equal to the reciprocal of the refractive index for light going from medium '2' to medium '1'.

$$^1\mu_2 = \frac{1}{^2\mu_1}$$

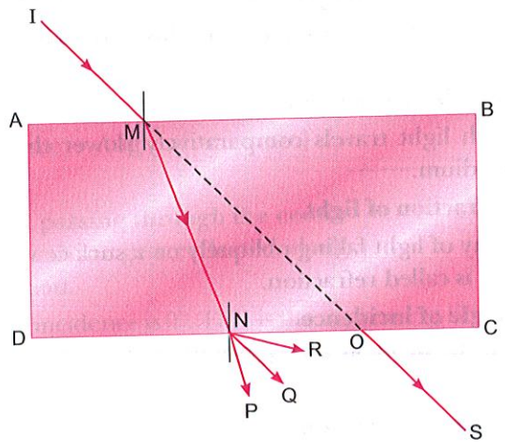
Q. 42. In which direction a ray of light bends when it goes from water to glass?

Ans. We know that glass is a denser medium than water. Therefore, a ray of light will bend towards the normal when it goes from water to glass.

Q. 43. If refractive indices of water and alcohol are 1.33 and 1.36 respectively, which of the two is optically denser medium?

Ans. The refractive index of alcohol is more than water, therefore, alcohol is optically denser medium.

Q. 44. If a light ray IM is incident on the surface AB as shown, identify the correct emergent ray.



Ans. Here, NQ is parallel to OS. Therefore, NQ is the correct emergent ray.

Q. 45. Why does a ray of light bend when it travels from one medium into another?

Ans. When a ray of light travels from one medium to another, its speed changes and this change in speed of light causes the bending of light (refraction of light).

Q. 46. What is a lens?

Ans. A lens is a piece of transparent medium bounded by two surfaces of which at least one surface is curved.

Q. 47. Name the point inside a lens such that a ray of light passing through it goes undeviated.

Ans. Optical centre.

Q. 48. Name the phenomena on which the working of a lens is based.

Ans. The working of a lens is based on the phenomenon of refraction of light.

Q. 49. State two examples of phenomenon of refraction of light in everyday life situations.

Ans. (*i*) A stick partly immersed in water appears to be bent at the water surface.

(*ii*) A pool of water appears less deep than it actually is.

Q. 50. What is meant by power of a lens? *[CBSE Delhi 2015]*

Ans. Power of a lens is the degree of convergence or divergence of light rays achieved by a lens, $P = \frac{1}{f}$ (where f = focal length).

Q. 51. Give the SI unit of power of lens. State whether the power of a converging lens is positive or negative.

Ans. The SI unit of power of a lens is dioptre.

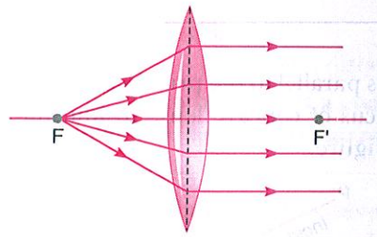
The power of a converging lens is positive as f is +ve.

Q. 52. A spherical mirror and a lens have same focal length of – 20 cm. What type of mirror and lens are these?

Ans. A concave mirror and concave lens have negative focal length. Hence, both mirror and lens are concave.

Q. 53. A small electric lamp is placed at the focus of a convex lens. What is the nature of beam of light produced by the lens?

Ans. The beam of light coming out of lens is a parallel beam of light as shown.



Q. 54. An object is placed 80 cm from a converging lens of focal length 25 cm. What is the nature of the image?

Ans. The image is real, inverted and diminished as the object is placed beyond 2F.

Q. 55. What is the power of a combination of lenses?

Ans. If a number of lenses are placed in close contact, then the power of the combination of lenses is equal to algebraic sum of the powers of the individual lenses.

$$P = P_1 + P_2 + P_3 + \ldots\ldots\ldots$$

Q. 56. State one advantage of using combination of lenses in optical instruments instead of a single lens.

Ans. The use of a combination of lenses increases the magnification and sharpness of the image.

Q. 57. What is monochromatic light?

Ans. The light of single wavelength is called monochromatic light, *e.g.*, Sodium lamp is a source of monochromatic light.

Q. 58 Name the component of white light that has the greatest wavelength. *[CBSE Sample Paper 2016]*

Ans. Red.

Q. 59. How does phenomenon of lateral inversion occurs?

Ans. The phenomenon of lateral inversion occurs due to the reflection of light by plane mirror.

Q. 60. Under what condition a lens becomes invisible when placed in a transparent liquid?

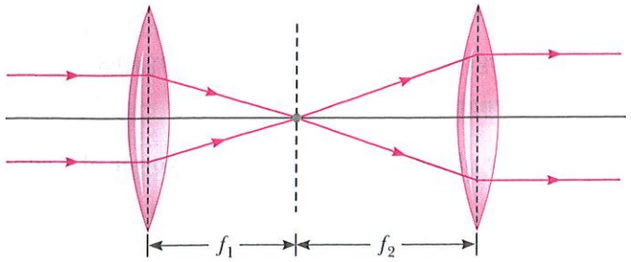
Ans. This happens when the refractive index of the lens becomes equal to that of the liquid.

Q. 61. Define the term magnification.

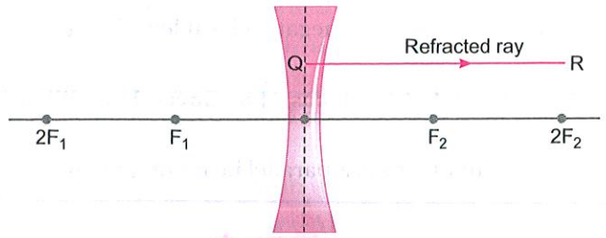
Ans. The ratio of the height of image to the height of object is called magnification.

Q. 62. Show diagrammatically, how should two converging lenses be arranged so that a parallel beam becomes parallel after passing through two lenses.

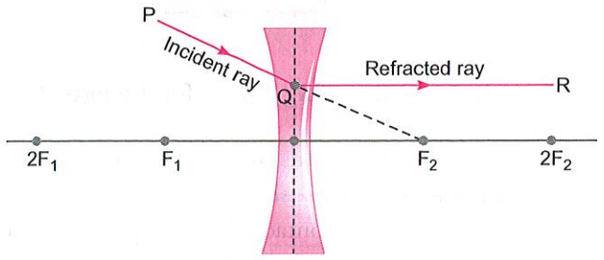
Ans. If the distance between two lenses becomes equal to sum of their focal lengths, then the parallel beam of light will emerge parallel after passing through the second lens.



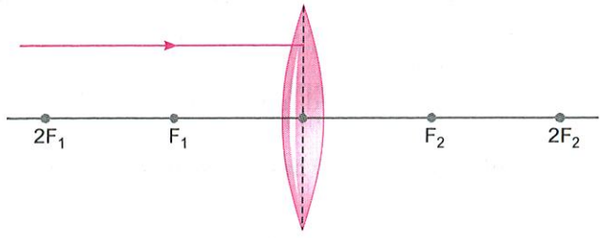
Q. 63. The diagram below shows the refracted ray QR through a concave lens. Complete the diagram by drawing the corresponding incident ray.



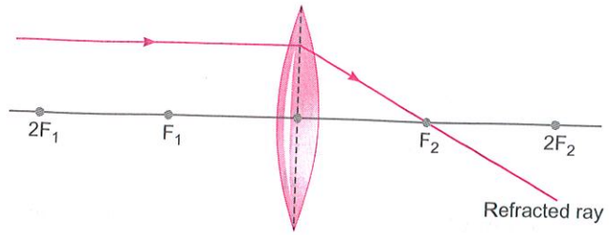
Ans. In figure the refracted ray is parallel to the principal axis. So, the incident ray must be appearing to meet at the principal focus of concave lens. To find the incident ray, F_2 is joined to Q and produced as shown in the figure.



Q. 64. Redraw the given diagram and show the path of the refracted ray.



Ans.



SHORT ANSWER QUESTIONS–I [2 marks]

Q. 1. What possible phenomenon can happen when light falls on a surface?

Ans. Any of the following phenomenon may happen:

(*i*) A portion of incident light is reflected back into the first medium.

(*ii*) Some portion travels through the second medium along a changed path, known as refraction.

(*iii*) The remaining part of the light may be absorbed by the second medium.

Q. 2. List four characteristics of the images formed by plane mirrors? *[CBSE Delhi 2015, 2017 (C)]*

Ans. (*i*) Image formed by a plane mirror is always virtual and erect.

(*ii*) The size of the image is equal to that of the object.

(*iii*) The image formed is as far behind the mirror as the object is in front of it.

(*iv*) The image is laterally inverted.

Q. 3. List four specific characteristics of the images of the objects formed by convex mirrors. *[CBSE Delhi 2015]*

Ans. (*i*) Virtual (*ii*) Erect

(*iii*) Diminished (*iv*) Object distance more than image distance

Q. 4. An object is placed at a distance of 30 cm in front of a convex mirror of focal length 15 cm. Write four characteristics of the image formed by the mirror. *[CBSE Delhi 2017]*

Ans. Virtual, erect, diminished, laterally inverted.

Q. 5. An object is placed at a distance of 40 cm in front of a convex mirror of radius of curvature 40 cm. List four characteristics of the image formed by the mirror. *[CBSE Delhi 2017]*

Ans. Virtual, erect, diminished, laterally inverted

Q. 6. An object is placed at a distance of 12 cm in front of a concave mirror of radius of curvature 30 cm. List four characteristics of the image formed by the mirror. *[CBSE Delhi 2017]*

Ans. Virtual, erect, diminished, laterally inverted.

Q. 7. Explain the term lateral inversion.

Ans. If an object is placed in front of a plane mirror, then the right side of the object appears to be the left side of the image, and the left side of the object appears to be the right side of its image. This change of sides of an object and its mirror image is called lateral inversion.

Q. 8. In what way is the word AMBULANCE printed in front of the hospital vans? Why is it printed this way?

Ans. The word AMBULANCE on the hospital vans is written in the form of its mirror image as ƎƆИAꞀUƎMA because any vehicle which is ahead of ambulance van can see the laterally inverted alphabets correctly from his rear-view mirror and make way for it to pass through and enable it to reach the hospital quickly.

Q. 9. How can you distinguish between a plane mirror, a concave mirror and a convex mirror without touching them?

Ans. By observing the virtual images formed by the three mirrors, we can distinguish between the mirrors as:

(*i*) Plane mirror will produce an image of the same size,

(*ii*) Concave mirror will produce a magnified image, and

(*iii*) Convex mirror will produce a diminished image.

Q. 10. State the laws of refraction of light. If the speed of light in vacuum is 3×10^8 m/s, find the absolute refractive index of a medium in which light travels with a speed of 1.4×10^8 m/s. *[CBSE (F) 2015]*

Ans. ■ **Laws of refraction of light:**

First law: The incident ray, the refracted ray, and the normal at the point of incidence all lie in the same plane.

Second law (Snell's law): The ratio of sine of angle of incidence to the sine of angle of refraction is a constant for a given pair of media.

i.e., $\dfrac{\sin i}{\sin r} = \text{Constant}$

■ Speed of light in vacuum, $c = 3 \times 10^8$ m/s

Speed of light in medium, $v = 1.4 \times 10^8$ m/s

$$\text{Absolute refractive index} = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}$$

$$= \frac{3 \times 10^8 \text{ m/s}}{1.4 \times 10^8 \text{ m/s}} = 2.14$$

Q. 11. State two positions in which a concave mirror produces a magnified image of a given object. List two differences between the two images. *[CBSE Delhi 2016]*

Ans. A concave mirror produces a magnified image when the object is placed in front of the mirror:

(*i*) between its pole and focus (*ii*) between the focus and centre of curvature

In case (*i*) the image is virtual and erect, whereas in case (*ii*) the image is real and inverted.

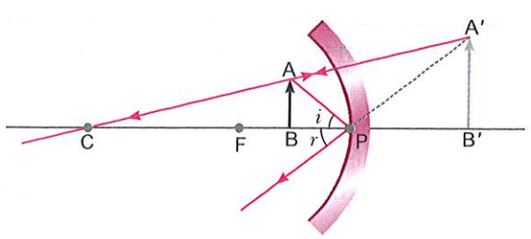
Q. 12. An object is placed at a distance of 30 cm from a concave lens of focal length 15 cm. List four characteristics (nature, position, etc.) of the image formed by the lens. *[CBSE (AI) 2017]*

Ans. ■ Virtual ■ Erect

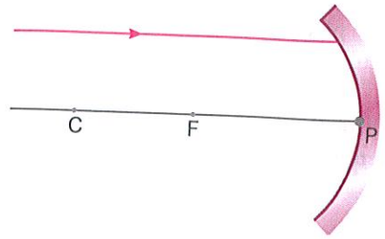
■ Diminished ■ On the same side as the object.

Q. 13. The linear magnification produced by a spherical mirror is +3. Analyse this value and state the (*i*) type of mirror and (*ii*) position of the object with respect to the pole of the mirror. Draw ray diagram to show the formation of image in this case. *[CBSE (F) 2016]*

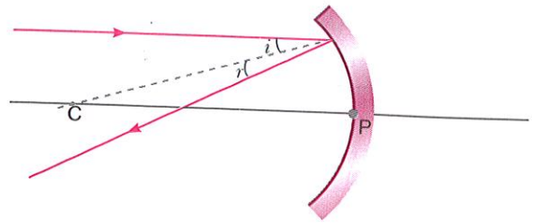
Ans. (*i*) Concave mirror (*ii*) Between the pole and focus



Q. 14. Redraw the following diagram on your answer-sheet and show the path of the reflected ray. Also mark the angle of incidence ($\angle i$) and the angle of reflection ($\angle r$) on the diagram. *[CBSE (F) 2017]*

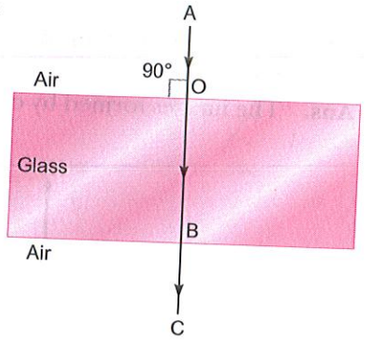


Ans.



Q. 15. What will happen to a ray of light when it falls normally on a surface? Show it diagrammatically.

Ans. When a ray of light falls normally on the surface of a medium, then, no bending of light ray occurs. It means the light ray goes straight from one medium to another.



Q. 16. Identify the device used (a spherical mirror or lens) in 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. *[NCERT Exemplar]*

Ans. (*a*) Concave mirror (*b*) Convex lens

(*c*) Concave lens (*d*) Convex mirror

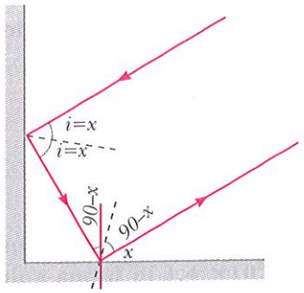
Q. 17. A convex lens of focal length 20 cm can produce a magnified virtual as well as real image. Is this a correct statement? If yes, where shall the object be placed in each case for obtaining these images? *[NCERT Exemplar]*

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.

Q. 18. 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? *[NCERT Exemplar]*

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

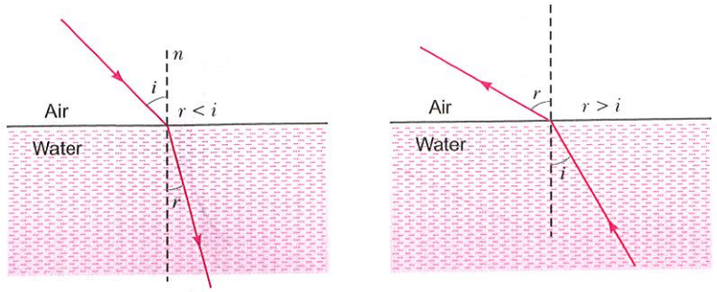
Q. 19. Under what condition in an arrangement of two plane mirrors, incident ray and reflected ray will always be parallel to each other, whatever may be angle of incidence. Show the same with the help of a ray diagram. *[NCERT Exemplar]*



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.

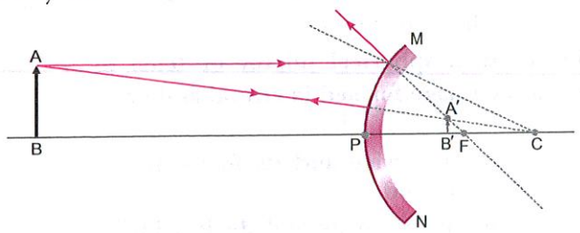
Q. 20. Draw a ray diagram showing the path of rays of light when it enters with oblique incidence (*i*) from air into water; (*ii*) from water into air. *[NCERT Exemplar]*

Ans.



Q. 21. List two properties of the images formed by convex mirrors. Draw ray diagram in support of your answer.

Ans. The images formed by convex mirrors are: Virtual, erect and smaller than the object



SHORT ANSWER QUESTIONS–II [3 marks]

Q. 1. Distinguish between real image and virtual image.

Ans.

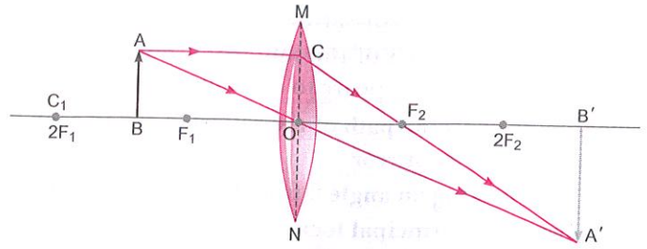
	Real Image		Virtual Image
1.	It is formed by the actual meeting of reflected (or refracted) rays.	1.	It is formed when reflected (or refracted) rays appear to meet when produced backwards.
2.	It can be obtained on the screen.	2.	It cannot be obtained on the screen.
3.	It is always inverted.	3.	It is always erect.
4.	It is formed by concave mirror or convex lens.	4.	It is formed by concave, convex and plane mirrors (or concave and convex lenses).

Q. 2. Study the ray diagram given below and answer the following questions:

(*i*) State the type of lens used in the figure.

(*ii*) List two properties of the image formed.

(*iii*) In which position of the object will the magnification be – 1?



Ans. (*i*) Convex lens. (*ii*) Real, inverted, enlarged.

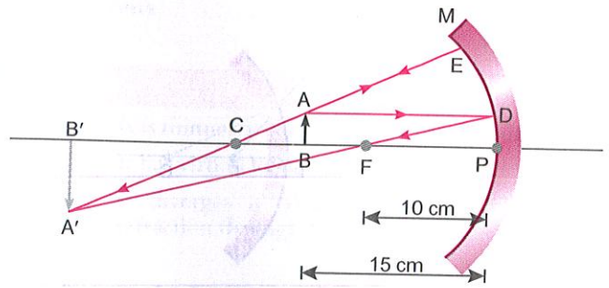
(*iii*) When object is at 2F.

Q. 3. To construct a ray diagram we use two rays of light which are so chosen that it is easy to determine their directions after reflection from the mirror. Choose these two rays and state the path of these rays after reflection from a concave mirror. Use these two rays to find the nature and position of the image of an object placed at a distance of 15 cm from a concave mirror of focal length 10 cm. *[CBSE Delhi 2015]*

Ans. The candidate may choose the following rays:

(*i*) A ray parallel to the principal axis, after reflection, will pass through the principal focus of a concave mirror.

(*ii*) A ray passing through the centre of curvature of a concave mirror after reflection is reflected back along the same path.



Object distance, $u = -15$ cm,

focal length, $f = -10$ cm, image distance, $v = ?$

Apply mirror formula,

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

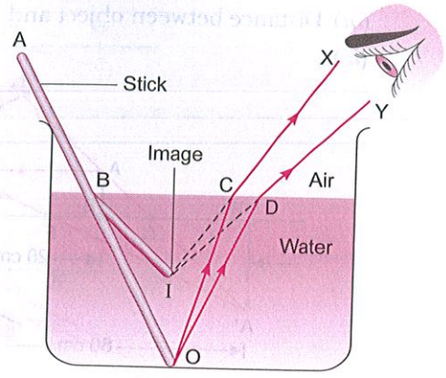
$$\therefore \quad \frac{1}{v} = \frac{1}{f} - \frac{1}{u} \qquad \frac{1}{v} = \frac{1}{-10} - \frac{1}{-15} \qquad \frac{1}{v} = -\frac{1}{10} + \frac{1}{15} = \frac{-3+2}{30} = \frac{-1}{30}$$

$$\therefore \quad v = -30 \text{ cm}$$

The image is formed at a distance of 30 cm in front of the mirror (negative sign means object and image are on the same side). It is real and inverted.

Q. 4. Explain with the help of a ray diagram, why a pencil partly immersed in water appears to be bent at the water surface.

Ans. A stick or a pencil half immersed in water at an angle appears bent due to refraction of light at the air-water interface. Figure shows a straight stick AO whose lower portion BO is immersed in water. It appears to be bent at point B in the direction BI. A ray of light OC coming from the lower end O passes from water into air at C and gets refracted away from the normal in the direction CX. Another ray OD gets refracted in the direction DY. The two refracted ray CX and



DY, when produced backward, appear to meet at point I, nearer to the water surface above the point O. Similarly each part of the immersed portion of the stick is raised. As a result immersed portion of the stick appears to be bent when viewed at an angle from outside.

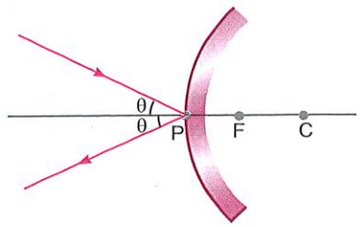
Q. 5. Draw a ray diagram to show the path of the reflected ray in each of the following cases. A ray of light incident on a convex mirror

(*a*) strikes at its pole making an angle θ from the principal axis.

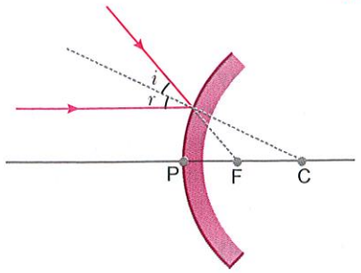
(*b*) is directed towards its principal focus.

(*c*) is parallel to its principal axis. *[CBSE (F) 2015]*

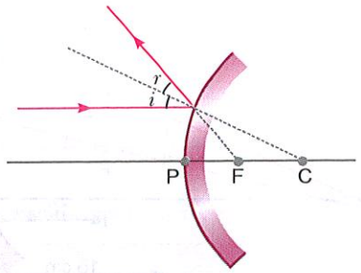
Ans. (*a*)



(*b*)



(*c*)



Q. 6. A student wants to project the image of a candle flame on a screen 80 cm in front of a mirror by keeping the candle flame at a distance of 20 cm from its pole.

(*i*) Which type of mirror should the student use?

(*ii*) Find the magnification of the image produced.

(*iii*) Find the distance between the object and its image.

(*iv*) Draw a ray diagram to show the image formation in this case and mark the distance between the object and its image. *[CBSE (F) 2015]*

Ans. (*i*) Concave mirror should be used.

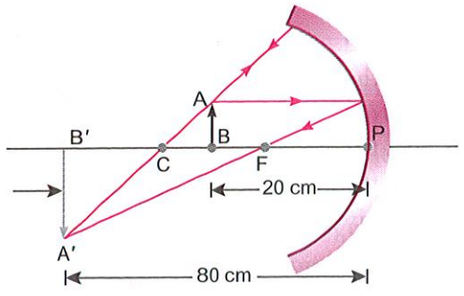
(*ii*) Object distance, $u = -20$ cm; image distance, $v = -80$ cm;

magnification, $m = ?$

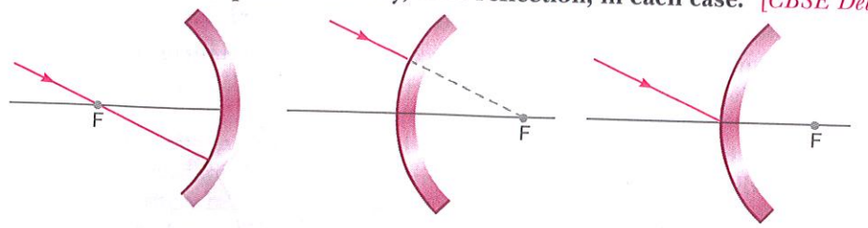
$$m = -\frac{v}{u} = \frac{(-80\text{ cm})}{(-20\text{ cm})} = -4$$

(*iii*) Distance between object and its image $= v - u = 60$ cm

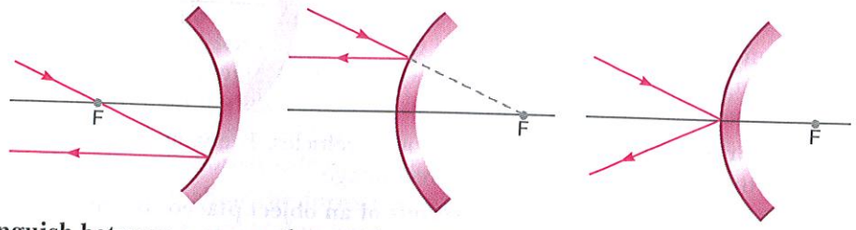
(*iv*)



Q. 7. Draw the following diagram, in which a ray of light is incident on a concave/convex mirror, on your answer sheet. Show the path of this ray, after reflection, in each case. *[CBSE Delhi 2016]*



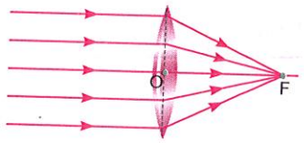
Ans.

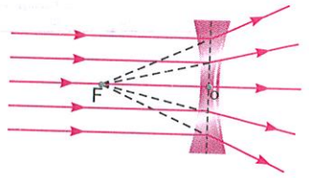


Q. 8. Distinguish between a convex lens and a concave lens.

Ans.

	Convex Lens		Concave Lens
1.	It is thicker at the centre than at the edges.	1.	It is thinner at the centre than at the edges.
2.	It has real focus.	2.	It has virtual focus.
3.	It converges a parallel beam of light after refraction through it.	3.	It diverges a parallel beam of light after refraction through it.

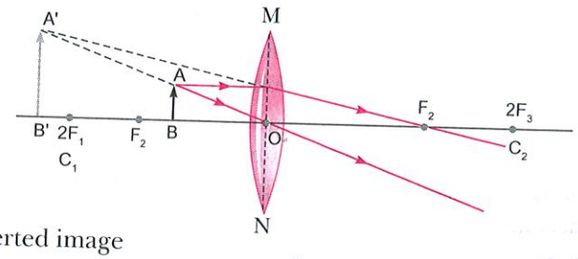




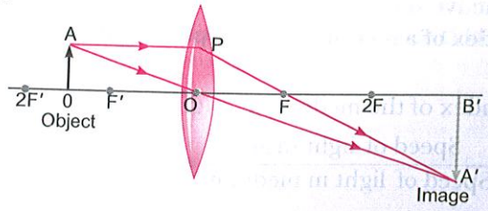
Q. 9. "A lens can form a magnified erect image as well as magnified inverted image of an object placed in front of it." State the nature of this lens and draw ray diagrams to justify the above statement. Mark the positions of O, F and 2F in the diagram. *[CBSE (AI) 2017]*

Ans. The lens is convex

(*a*) Magnified erect image

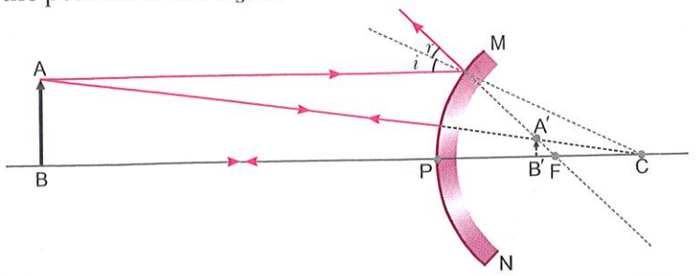


(*b*) Magnified inverted image



Q. 10. If the image formed by a mirror for all positions of the object placed in front of it is always erect and diminished, what type of mirror is it? Draw a ray diagram to justify your answer. Where and why do we generally use this type of mirror? *[CBSE (AI) 2015]*

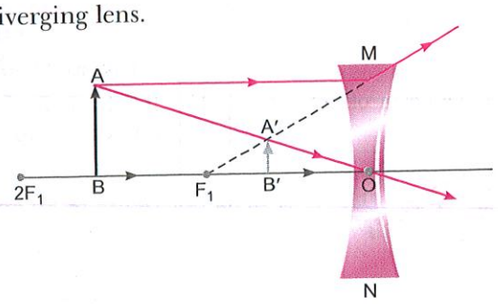
Ans. A convex mirror always produces an erect and diminished image of the object placed in front of it irrespective of the position of the object.



A convex mirror is used as a rear view mirror in vehicles. It enables the driver to view a much larger area of the traffic behind. It forms erect image.

Q. 11. If the image formed by a lens for all positions of an object placed in front of it is always erect and diminished, what is the nature of this lens? Draw a ray diagram to justify your answer. If the numerical value of the power of this lens is 10 D, what is its focal length in the Cartesian system? *[CBSE (AI) 2017]*

Ans. This is Concave or diverging lens.



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

Focal length, As $P = -10$ D,

$$\text{so, } f = \frac{1}{-10\text{ D}} = -0.1\text{ m or } -10\text{ cm}$$

Q. 12. 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. *[NCERT Exemplar]*

Ans. No. Bending will be different in different liquids since speed of light in the medium depends on the relative refractive index of the medium. A substance having higher refractive index is optically denser than another substance having lower refractive index. Thus higher the refractive index of a substance, more it will change the direction of a beam of light passing through it.

Q. 13. 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? *[NCERT Exemplar]*

Ans. The refractive index of the medium n_m is given by

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

Let v_1 be the speed of light in medium 1 and v_2 be the speed of light in medium 2. The refractive index of medium 2 with respect to medium 1 is given by the ratio of the speed of light in medium 1 and the speed of light in medium 2. This is usually represented by the symbol n_{21}.

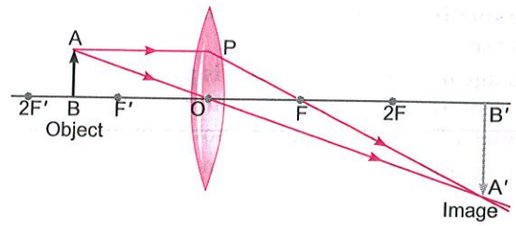
$$n_{21} = \frac{\text{Speed of light in medium 1}}{\text{Speed of light in medium 2}} = \frac{v_1}{v_2}$$

Q. 14. 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? *[NCERT Exemplar]*

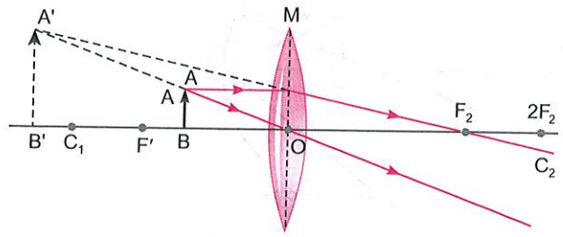
Ans. Sudha should move the screen towards the lens so as to obtain a clear image of the building. The approximate focal length of this lens will be 15 cm. The rays of light coming from distant object such as a tree (or a distant building or electricity pole) can be considered to be parallel to each other. When parallel rays of light are incident on a convex lens, the rays, after refraction, converge at focus on the other side of the lens.

Q. 15. Draw ray diagrams to show the formation of three times magnified (*a*) real, and (*b*) virtual image of an object by a converging lens. Mark the positions of O, F and 2F in each diagram. *[CBSE (AI) 2017]*

Ans. (*a*) Real image



(*b*) Virtual image



LONG ANSWER QUESTIONS [5 marks]

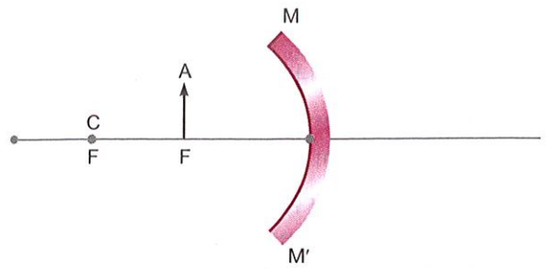
Q.1. (*a*) Define the following terms in the context of spherical mirrors :

(*i*) Pole **(*ii*) Centre of curvature**

(*iii*) Radius of curvature **(*iv*) Principal axis**

(*b*) Draw ray diagrams to show the principal focus of (*i*) a concave mirror, and (*ii*) a convex mirror.

(*c*) In the following diagram, MM′ is a concave mirror and AB is an object. Draw on your answer-sheet a ray diagram to show the formation of image of this object. *[CBSE (F) 2017]*



Ans. (*a*) (*i*) **Pole:** It is the centre of the reflecting surface of the spherical mirror.

(*ii*) **Centre of curvature:** It is the centre of the sphere of which mirror forms a part.

(*iii*) **Radius of curvature:** It is the radius of the sphere of which mirror forms a part.

(*iv*) **Principal axis:** It is an imaginary straight line passing through the pole and the centre of curvature of the mirror.

(*b*) (*i*) Refer to diagram (*a*), Page-234

(*ii*) Refer to diagram (*a*), Page-235

(*c*) Refer to diagram (*f*), Page-234

Q. 2. It is desired to obtain an erect image of an object, using concave mirror of focal length of 12 cm.

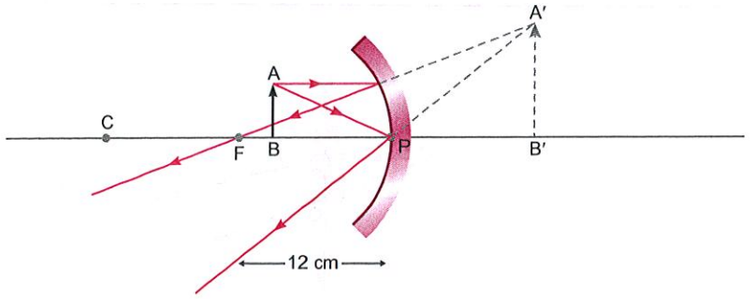
(*i*) What should be the range of distance of an object placed in front of the mirror?

(*ii*) Will the image be smaller or larger than the object. Draw ray diagram to show the formation of image in this case.

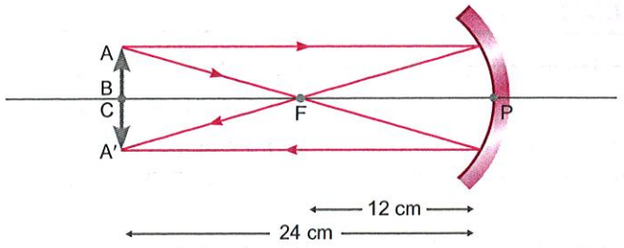
(*iii*) Where will the image of this object be, if it is placed 24 cm in front of the mirror? Draw ray diagram for this situation also to justify your answer. Show the positions of pole, principal focus and the centre of curvature in the above ray diagrams. *[CBSE (AI) 2016]*

Ans. (*i*) Range of distance should be 0 cm to <12 cm.

(*ii*) The image will larger than the object.



(*iii*) Image will be 24 cm in front of the mirror.



Q. 3. Suppose you have three concave mirrors A, B and C of focal lengths 10 cm, 15 cm and 20 cm. For each concave mirror you perform the experiment of image formation for three values of object distance of 10 cm, 20 cm and 30 cm. Giving reason answer the following:

(*a*) For the three object distances, identify the mirror/mirrors which will form an image of magnification – 1.

(*b*) Out of the three mirrors identify the mirror which would be preferred to be used for shaving purposes/makeup.

(*c*) For the mirror B draw ray diagram for image formation for object distances 10 cm and 20 cm. *[CBSE (F) 2016]*

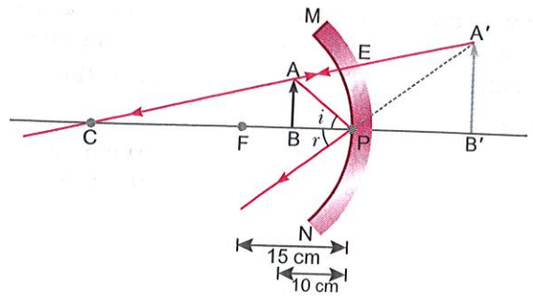
Ans. Given, $f_a = 10$ cm; $f_b = 15$ cm; $f_c = 20$ cm

$u_1 = 10$ cm; $u_2 = 20$ cm; $u_3 = 30$ cm

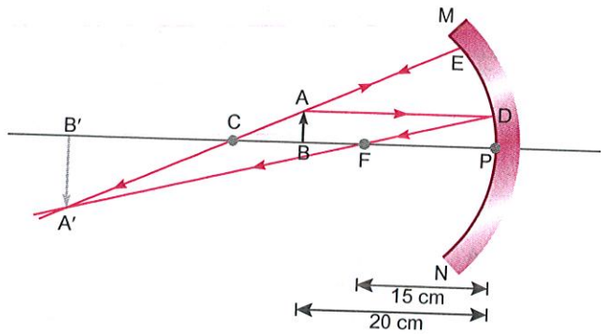
(*a*) $m = -1$ means $u = 2f$. For A it will be u_2 and for B it will be u_3.

(*b*) Mirror B or C can be used for shaving/makeup purposes because the distance should be less than focal length for erect and magnified image. The face is generally kept at a distance more than 10 cm from the mirror.

(*c*) When $u = 10$ cm



When $u = 20$ cm



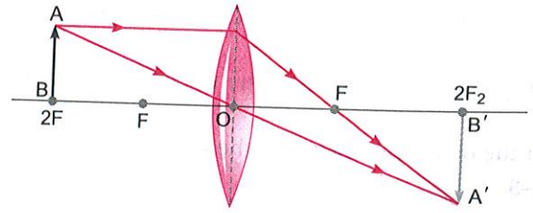
Q. 4. (*i*) Rohit claims to have obtained an image twice the size of object with a concave lens. Is he correct? Give reason for your answer.

(*ii*) Where should an object be placed in case of a convex lens to form an image of same size as of the object? Show with the help of ray diagram the position and the nature of the image formed.

(*iii*) With the help of ray diagram, illustrate the change in position, nature and size of the image formed if the convex lens in case of (*ii*) is replaced by concave lens of same focal length. *[CBSE Sample Paper 2016]*

Ans. (*i*) No, Rohit is incorrect because magnified image of an object cannot be formed by a concave lens ever.

(*ii*) The object should be placed at $2F$.



(*iii*)

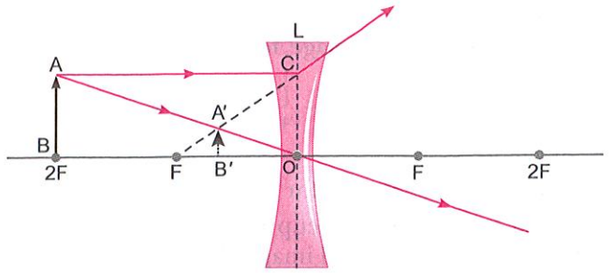


Image obtained is virtual, erect and diminished in case of concave lens.

Q. 5. (*a*) **Draw labelled ray diagrams for each of the following cases to show the position, nature and size of the image formed by a convex lens when the object is placed**

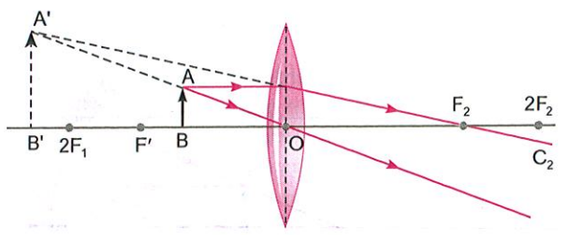
(*i*) **between its optical centre (O) and principal focus (F)**

(*ii*) **between F and 2F**

(*b*) **How will the nature and size of the image formed in the above two cases, (*i*) and (*ii*) change, if the convex lens is replaced by a concave lens of same focal length?**

[CBSE Delhi (C) 2017]

Ans. (*a*) (*i*)



(*ii*)

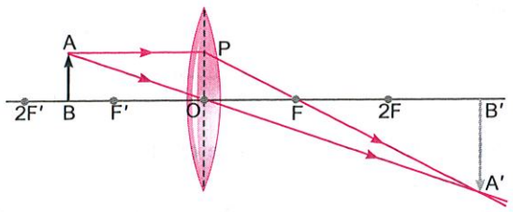


Image formed is virtual, erect and diminished in both cases.

Q. 6. (*a*) **To construct a ray diagram we use two rays which are so chosen that it is easy to know their directions after reflection from the mirror. List two such rays and state the path of these rays after reflection in case of concave mirrors. Use these two rays and draw ray diagram to locate the image of an object placed between pole and focus of a concave mirror.**

(*b*) **A concave mirror produces three times magnified image on a screen. If the object is placed 20 cm in front of the mirror, how far is the screen from the object?** *[CBSE Delhi 2017]*

Ans. (*a*) A ray of light incident parallel to the principal axis after reflection passes through the principal focus.

A ray of light which passes through the centre of curvature after reflection retraces its path back.

Ray diagram when the object is in between the pole and the focus of the mirror.

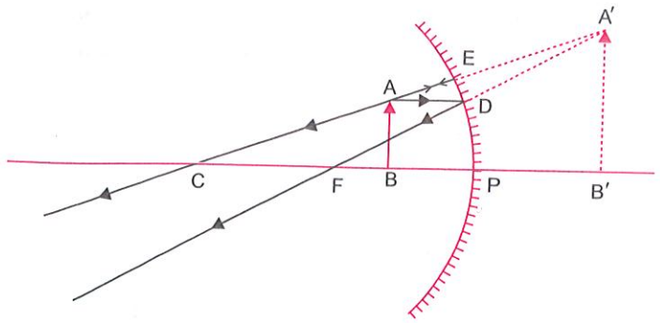
(*b*) $u = -20$ cm, $m = -3$

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

$$\therefore v = -m \times u$$

$$= -(-3)(-20\text{ cm}) = -60\text{ cm}$$

Distance between the object and the screen = – 60 cm – (– 20 cm) = – 40 cm, so, the distance between the object and the screen is 40 cm.



Q. 7. (*a*) **If the image formed by a mirror for all positions of the object placed in front of it is always diminished, erect and virtual, state the type of the mirror and also draw a ray diagram to justify your answer. Write one use such mirrors are put to and why.**

(*b*) **Define the radius of curvature of spherical mirrors. Find the nature and focal length of a spherical mirror whose radius of curvature is + 24 cm.** *[CBSE (AI) 2017]*

Ans. (*a*) It is Convex or diverging mirror.

Convex mirror is used as a rear view mirror

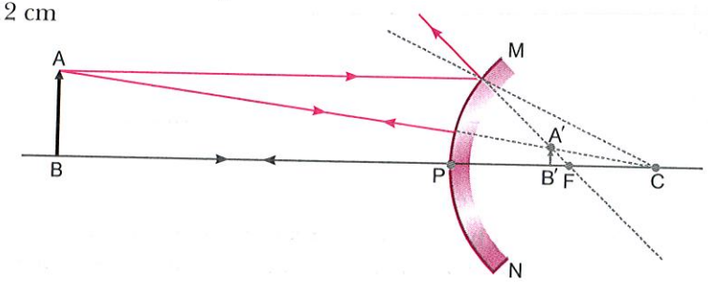
As it always give erect and diminished image and Large field of view.

(*b*) The radius of the sphere of which the mirror forms a part or the distance between pole and center of curvature of a mirror.

Nature of the mirror is convex or diverging mirror

Radius of curvature, $R = 2f = 24$ cm

$\therefore f = +12$ cm



Some Important Numericals

CONCAVE MIRROR

Q. 1. **The image of a candle flame placed at a distance of 30 cm from a mirror is formed on a screen placed in front of the mirror at a distance of 60 cm from its pole. What is the nature of the mirror? Find its focal length. If the height of the flame is 2.4 cm, find the height of its image. State whether the image formed is erect or inverted.**

Ans. The mirror is concave $h_1 = +2.4$ cm $u = -30$ cm $v = -60$ cm $f = ?$

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

$$\therefore f = -20\text{ cm}$$

$$m = \frac{h_2}{h_1} = -\frac{v}{u}$$

$$\therefore h_2 = -h_1 \times \frac{v}{u} = -2.4\text{ cm} \times \frac{-60\text{ cm}}{-30\text{ cm}} = -4.8\text{ cm}$$

–ve sign of h_2 (image size) indicates that the image is inverted

Q. 2. Find the size, nature and position of image formed when an object of size 1 cm is placed at a distance of 15 cm from a concave mirror of focal length 10 cm.

Ans. Object distance, $u = -15$ cm

Focal length, $f = -10$ cm

Object size, $h = 1$ cm

Image distance, $v = ?$

Image size, $h' = ?$

(i) Position of image

From mirror formula, $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$

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

Putting values, we get $\frac{1}{v}=\frac{1}{-10}-\frac{1}{-15}=\frac{-3-(-2)}{30}=-\frac{1}{30}$

$v = -30$ cm.

The image is formed at a distance 30 cm on the side of the object. Negative sign indicates that object and image are on the same side.

(ii) Nature of image: The image is in front of the mirror, its nature is **real and inverted.**

(iii) Size of image: From the expression for magnification, $m=\frac{h'}{h}=-\frac{v}{u}$

We have $h' = -h\times\frac{v}{u}$

Putting values, we get $h' = -1\times\frac{-30}{-15} = -2$

Image size, $h' = -2$ cm

The image formed has size 2 cm and negative sign means inverted and real.

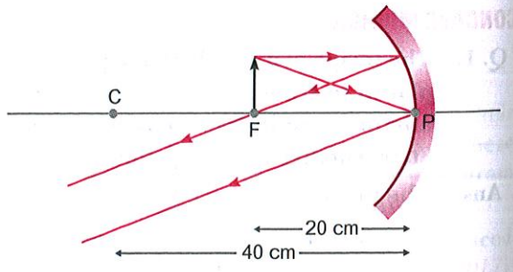
Q. 3. The image of an object formed by a mirror is real, inverted and is of magnification –1. If the image is at a distance of 40 cm from the mirror, where is the object placed? Where would the image be if the object is moved 20 cm towards the mirror? State reason and also draw ray diagram for the new position of the object to justify your answer. *[CBSE (AI) 2016]*

Ans. Object position: At C (Centre of curvature)

Object distance = 40 cm

Position of the image: at infinity because the focal length of the mirror is 20 cm.

If the object is moved 20 cm towards the mirror then its new position would be at the focus of the mirror.



Q. 4. An object 2 cm high is placed at a distance of 16 cm from a concave mirror which produces a real image 3 cm high.

(i) Find the position of the image.

(ii) What is the focal length of mirror?

Ans. Object height, $h = +2$ cm

Image height, $h' = -3$ cm (real image hence inverted)

Object distance, $u = -16$ cm

Image distance, $v = ?$

Focal length, $f = ?$

(i) Position of image

From the expression for magnification $m=\frac{h'}{h}=-\frac{v}{u}$

We have, $v = -u\frac{h'}{h}$

Putting values, we get $v = -(-16)\times\frac{-3}{2}$

$v = -24$ cm

The image is formed at distance of 24 cm in front of the mirror (negative sign means object and image are on the same side).

(ii) Focal length of mirror

Using mirror formula, $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$

Putting values, we get $\frac{1}{f}=\frac{1}{-16}+\frac{1}{-24}=-\frac{3+2}{48}=-\frac{5}{48}$

or $f=-\frac{48}{5}=-9.6$ cm

Q. 5. A concave mirror of focal length 10 cm is placed at a distance of 35 cm from a wall. How far from the wall an object be placed so that its image formed by the mirror falls on the wall?

Ans. Here, $f = -10$ cm; $v = -35$ cm (since the image is formed on the wall and distance between the wall and mirror is 35 cm). Image is beyond $2f$ so object has to be in between F and C.

Let the distance of the object from the wall be x.

$\therefore \quad u = -(35-x)$

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

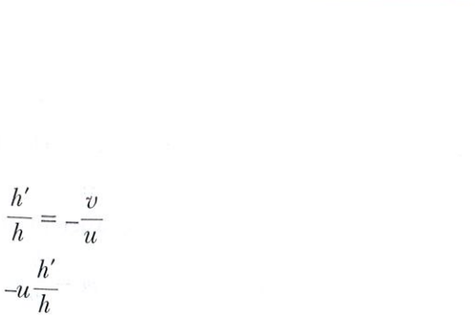
$\therefore \quad \frac{1}{-(35-x)}+\frac{1}{-35}=\frac{1}{-10}$

or $\frac{1}{35-x}+\frac{1}{35}=\frac{1}{10}$ or $\frac{1}{35-x}=\frac{1}{10}-\frac{1}{35}$

or $\frac{1}{35-x}=\frac{7-2}{70} \Rightarrow \frac{1}{35-x}=\frac{5}{70}$

$\Rightarrow \quad 35-x = 14$

$\therefore \quad \boldsymbol{x = 21}$ **cm**



Therefore, the distance of the object from the wall = **21 cm.**

Q. 6. A 2.0 cm tall object is placed perpendicular to the principal axis of a concave mirror of focal length 10 cm. The distance of the object from the mirror is 15 cm. Find the nature, position and size of the image formed. Represent the situation with the help of a ray diagram.

Ans. Given, $f = -10$ cm;

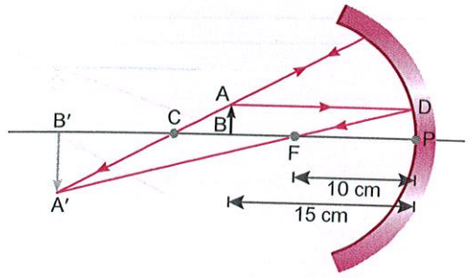
$u = -15$ cm;

$h = +2.0$ cm;

Using the mirror formula,

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

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



$$\frac{1}{v} = \frac{1}{15} - \frac{1}{10}$$

$\therefore$ $v = -30.0$ cm

The image is formed at a distance of 30 cm in front of the mirror.

Magnification, $m = \frac{h'}{h} = -\frac{v}{u}$

$$h' = h \times \frac{v}{u} = -2 \times \frac{-30}{-15}$$

$h' = -4$ cm

Hence, the size of image is 4 cm. –ve sign shows that image is inverted & real. Thus, image formed is real, inverted and enlarged.

Q. 7. A student has focused the image of a candle flame on a white screen using a concave mirror. The situation is as given below:

Length of the flame = 1.5 cm

Focal length of the mirror = 12 cm

Distance of flame from the mirror = 18 cm

If the flame is perpendicular to the principal axis of the mirror, then calculate the following:

(*a*) Distance of the image from the mirror

(*b*) Length of the image

If the distance between the mirror and the flame is reduced to 10 cm, then what would be observed on the screen? Draw ray diagram to justify your answer for this situation. *[CBSE (F) 2015]*

Ans. Given: height of object, $h = +1.5$ cm; focal length, $f = -12$ cm; object distance, $u = -18$ cm; image distance, $v = ?$; height of image, $h' = ?$

(*a*) Applying mirror formula,

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

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

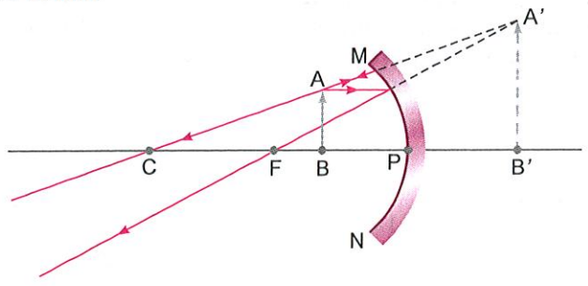
$$= \frac{1}{(-12)} - \frac{1}{(-18)} = \frac{-1}{12} + \frac{1}{18} = \frac{-3+2}{36} = \frac{-1}{36}$$

$v = -36$ cm

(*b*) $h' = -\frac{v}{u} \times h = -\frac{-36\text{ cm}}{-18\text{ cm}} \times 1.5\text{ cm}$

$= -3$ cm (Magnified, inverted image)

If $u = -10$ cm, no distinct image would be formed on the screen. In this case the image formed will be virtual.



Q. 8. A 2 cm high object is placed at a distance of 32 cm from a concave mirror. The image is real, inverted and 3 cm in size. Find the focal length of the mirror and the position where the image is formed? *[CBSE Sample Paper 2016]*

Ans. Given:

Object height, $h_o = 2$ cm

Image height, $h_e = -3$ cm

Object distance, $u = -32$ cm

$$m = \frac{-v}{u} = \frac{h_e}{h_0}$$

$$m = \frac{h_e}{h_0} = \frac{-3\text{ cm}}{2\text{ cm}} = -1.5$$

$$= \frac{-v}{u} = -1.5$$

$\therefore$ $v = -48$ cm

Also $\frac{1}{f} = \frac{1}{v} + \frac{1}{u} = \frac{1}{-48} + \frac{1}{-32} = -\frac{5}{96}$

$\therefore$ $f = -19.2$ cm

$\therefore$ Focal length of concave mirror is 19.2 cm and image is formed 48 cm in front of it.

Q. 9. An object 4 cm in height, is placed at 15 cm in front of a concave mirror of focal length 10 cm. At what distance from the mirror should a screen be placed to obtain a sharp image of the object. Calculate the height of the image. *[CBSE Delhi 2017]*

Ans. $h_1 = +4$ cm $\quad f = -10$ cm $\quad u = -15$ cm $\quad v = ?$ $\quad h_2 = ?$

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

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

$$\frac{1}{v} = \frac{1}{-10\text{ cm}} - \frac{1}{-15\text{ cm}}$$

$\therefore$ $v = -30$ cm

$$\frac{h_2}{h_1} = -\frac{v}{u}$$

$\therefore$ $h_2 = -\frac{v}{u} \times h_1 = -\frac{-30\text{ cm}}{-15\text{ cm}} \times \text{cm} = -8$ cm

CONVEX MIRROR

Q. 10. A convex mirror used for rear-view on an automobile has a radius of curvature of 3.00 m. If a bus is located at 5.00 m from this mirror, find the position, nature and size of the image.

Ans. Radius of curvature, $R = +3.00$ m;

Object distance, $u = -5.00$ m;

Image distance, $v = ?$

Height of the image, $h' = ?$

Focal length, $f = \frac{R}{2} = +\frac{3.00}{2} = 1.50$ m

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

or $$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = +\frac{1}{1.50} - \frac{1}{-5.00}$$

$$= \frac{1}{1.50} + \frac{1}{5.00} = \frac{2}{3} + \frac{1}{5}$$

$$\frac{1}{v} = \frac{13}{15}$$

$$v = \frac{15}{13} = +\ 1.15 \text{ m (approximately)}$$

The image is 1.15 m at the back of the mirror.

Magnification, $m = \frac{h'}{h} = -\frac{v}{u} = -\frac{1.15\text{ m}}{-5.00\text{ m}} = +\ 0.23$

The image is virtual, erect and smaller in size by a factor of 0.23.

Q. 11. Size of image of an object formed by a mirror having a focal length of 20 cm, is observed to be reduced to $\frac{1}{3}$ rd of its size. At what distance the object has been placed from the mirror? What is the nature of the image and the mirror? *[NCERT Exemplar]*

Ans. An image smaller in size can be formed both by a concave mirror as well as a convex mirror.

Case I: When mirror is concave, the image is real.

Hence, $m = -\frac{1}{3}, f = -20$ cm

As $m = -\frac{v}{u}$ $\therefore$ $-\frac{1}{3} = -\frac{v}{u}$

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

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

or $\frac{3}{u} + \frac{1}{u} = \frac{1}{-20}$

or $\frac{4}{u} = \frac{1}{-20}$

or $u = -\ 80$ cm

Now, $v = \frac{u}{3} = \frac{-80}{3}$ cm,

$\therefore$ Image is real and inverted.

Case II: When mirror is convex

$m = \frac{1}{3}, f = +\ 20$ cm

As $m = -\frac{v}{u} = \frac{1}{3}$

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

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

or $-\frac{3}{u} + \frac{1}{u} = \frac{1}{20}$

$u = -\ 40$ cm

and $v = -\frac{(-40)}{3} = \frac{40}{3}$ cm

$\therefore$ Image is virtual and erect.

Q. 12. A truck uses a convex mirror as view finder whose radius of curvature is 2.0 m. A maruti car is coming behind the truck at a distance of 10 m. What will be the position of the image of the car and size of the image of the car when observed by the driver of the truck through the convex mirror?

Ans. For convex mirror, we have given, $u = -\ 10$ m, $R = 2.0$ m

So, $f = \frac{R}{2} = \frac{2.0\text{ m}}{2} = 1.0\text{ m}$

Using the mirror formula, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

We get $\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{1.0} + \frac{1}{10} = \frac{11}{10}$ or, $v = \frac{10}{11} = 0.9\text{ m}$

Thus, the car would appear at 0.9 m from the convex mirror. We know that

$$m = -\frac{v}{u} = \frac{\frac{-10}{11}}{-10} = \frac{1}{11}$$

Thus, size of the image of the car will be a fraction of $\frac{1}{11}$ the actual size of the car through the convex mirror.

REFRACTIVE INDEX

Q. 13. If the angle of incidence (i) for a light ray in air be 45° and the angle of refraction (r) in glass be 30°, find refractive index of glass with respect to air.

Ans. Refractive index of glass, $\mu = \frac{\sin 45°}{\sin 30°} = \frac{1}{\sqrt{2}} \times 2 = \sqrt{2}$

Q. 14. Refractive index of water with respect to air is 1.33. What is the value of refractive index of air with respect to water?

Ans. Here, ${}^{a}\mu_{w} = 1.33$

We know ${}^{w}\mu_{a} = \frac{1}{{}^{a}\mu_{w}} = \frac{1}{1.33} = 0.75$

Q. 15. The absolute refractive indices of glass and water are 3/2 and 4/3 respectively. If the speed of light in glass is 2×10^8 m/s, calculate the speed of light in (i) vacuum, (ii) water. *[CBSE (AI) 2015, 2016]*

Ans. Refractive index of glass, $\mu_g = \frac{3}{2}$

$\therefore$ $\mu_g = \frac{\text{Speed of light in vaccum}}{\text{Speed of light in glass}}$

$\frac{3}{2} = \frac{\text{Speed of light in vaccum}}{2 \times 10^8}$

Speed of light in vacuum $= \frac{3 \times 2 \times 10^8}{2} = 3 \times 10^8$ m/s

Refractive index of water, $\mu_w = \frac{4}{3}$

$\mu_w = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in water}}$

$$\frac{4}{3} = \frac{3\times10^8}{\text{Speed of light in water}}$$

Speed of light in water = 2.25×10^8 m/s

Q. 16. Refractive index of water with respect to air is 4/3 and glass is 3/2. What is the refractive index of glass with respect to water?

Ans. When there are three media air, water and glass,
We have

$${}^a\mu_w \times {}^w\mu_g \times {}^g\mu_a = 1$$

$$\therefore \quad {}^w\mu_g = \frac{1}{{}^a\mu_w \times {}^g\mu_a} = \frac{{}^a\mu_g}{{}^a\mu_w} = \frac{3/2}{4/3} = \frac{9}{8}$$

$\therefore$ Refractive index of glass with respect to water is 9/8.

Q. 17. Refractive indices of water and benzene with respect to air are 1.33 and 1.50 respectively. Calculate the refractive index of benzene with respect to water.

Ans. For air, water and benzene,

$${}^a\mu_w \times {}^w\mu_B \times {}^B\mu_a = 1$$

$$\therefore \quad {}^w\mu_B = \frac{1}{{}^a\mu_w} \times {}^a\mu_B = \frac{1.50}{1.33} = 1.13.$$

Q. 18. 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.

Ans. For air, glass and diamond,

$${}^a\mu_g \times {}^g\mu_D \times {}^D\mu_a = 1$$

$$\therefore \quad {}^D\mu_a = \frac{1}{{}^a\mu_g \times {}^g\mu_D}$$

$$\Rightarrow \quad {}^a\mu_D = {}^a\mu_g \times {}^g\mu_D = 1.5 \times 1.6 = 2.4.$$

Q. 19. The absolute refractive indices of two media 'A' and 'B' are 2.0 and 1.5 respectively. If the speed of light in medium 'B' is 2×10^8 m/s, calculate the speed of light in:
(*i*) vacuum **(*ii*) medium 'A'.** *[CBSE Delhi 2015]*

Ans. $n_A = 2.0$; $n_B = 1.5$; speed of light in medium B, $v_B = 2 \times 10^8$ m/s

(*i*) $n_B = \frac{c}{v_B}$

$\therefore \quad c = n_B v_B$

$= 1.5 \times 2 \times 10^8$ m/s $= 3 \times 10^8$ m/s

(*ii*) $n_A = \frac{c}{v_A}$

$$v_A = \frac{c}{n_A} = \frac{3\times10^8 \text{ m/s}}{2} = 1.5 \times 10^8 \text{ m/s}$$

CONVEX LENS

Q. 20. An object is placed perpendicular to the principal axis of a convex lens of focal length 8 cm. The distance of the object from the lens is 12 cm. Find the position and nature of the image. *[CBSE Delhi (C) 2017]*

Ans. $u = -12$ cm, $f = +8$ cm, $v = ?$

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

$$\frac{1}{v} - \frac{1}{(-12)} = \frac{1}{8}$$

$v = +24$ cm

The image is real and inverted.

Q. 21. The image of a candle flame formed by a lens is obtained on a screen placed on the other side of the lens. If the image is three times the size of the flame and the distance between lens and image is 80 cm, at what distance should the candle be placed from the lens? What is the nature of the image at a distance of 80 cm from the lens? *[NCERT Exemplar]*

Ans. Here, $v = 80$ cm; $m = 3$

Using, $m = -\frac{v}{u} \quad \Rightarrow \quad 3 = \frac{-80}{u}$

$$\Rightarrow \quad u = -\frac{80}{3} \text{ cm}$$

Image is real and inverted as it is obtained on the other side of the lens. Thus, the lens is convex.

Q. 22. An object 3 cm high is placed 20 cm from convex lens of focal length 12 cm. Find the nature, position and height of the image.

Ans. Since lens is convex, therefore f is positive.
Given: $u = -20$ cm, $f = +12$ cm, $h = 3$ cm, $v = ?$, $h' = ?$

Using lens formula

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

We have $\frac{1}{v} - \frac{1}{-20} = \frac{1}{12}$

$$\Rightarrow \quad \frac{1}{v} + \frac{1}{20} = \frac{1}{12} \quad \Rightarrow \quad \frac{1}{v} = \frac{1}{12} - \frac{1}{20}$$

$$\Rightarrow \quad \frac{1}{v} = \frac{5-3}{60} = \frac{1}{30} \quad \Rightarrow \quad v = 30 \text{ cm}$$

Since 'v' is positive, the image is located on the other side of the lens.

$$m = \frac{v}{u} = \frac{+30}{-20} = -1.5$$

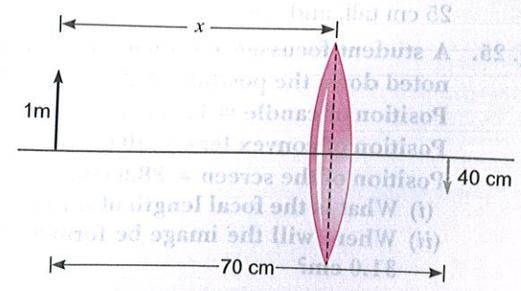
Since m is negative and greater than 1, the image is real, inverted and larger than the object.

$$m = \frac{h'}{h} \quad \Rightarrow \quad -1.5 = \frac{h'}{3}$$

or $h' = -4.5$ cm

Thus the image is 30 cm from the convex lens, located on the other side of the lens. It is real, inverted and 4.5 cm high.

Q. 23. An object 1 m tall is placed on the principal axis of a convex lens and its 40 cm tall image is formed on the screen placed at a distance of 70 cm from the object. What is the focal length of the lens?



Ans. Since, the image is formed on the screen, so the image is real and inverted,
Given: $h = 100$ cm; $h' = -40$ cm;

Let the object be kept at a distance x from the lens.

$\therefore \quad v = +(70 - x); f = ?$

Now $\quad m = \dfrac{h'}{h} = \dfrac{v}{u}$

$\therefore \quad \dfrac{-40}{+100} = \dfrac{(70-x)}{-x}$

or $\quad 40x = 7000 - 100x$

i.e., $\quad x = 50$ cm

$\therefore \quad u = -x = -50$ cm

and $\quad v = 70 - x = 70 - 50 = 20$ cm

Substituting the values of u and v in the lens formula,

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

We have, $\quad \dfrac{1}{20} - \dfrac{1}{-50} = \dfrac{1}{f}$

$\therefore \quad f = +\dfrac{100}{7} = +14.3$ cm

Therefore, focal length of the lens = 14.3 cm

Q. 24. A 5 cm tall object is placed on the principal axis of a convex lens of focal length 50 cm at a distance of 40 cm from it. Find the nature, position and size of the image.

Ans. Here, $u = -40$ cm; $f = +50$ cm; $h = 5$ cm; $v = ?$; $h' = ?$

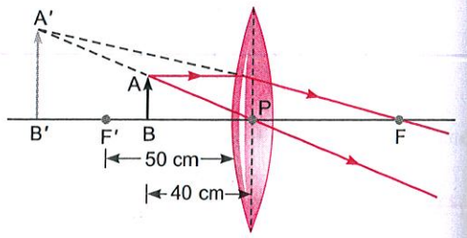
Using lens formula,

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

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

$\therefore \quad v = \dfrac{uf}{u+f}$

$$v = \frac{(-40)\times(+50)}{-40+50} = \frac{-2000}{10} = -200 \text{ cm}$$



Here the negative sign indicates that the image is formed on the same side of the lens as the object. Therefore, the image is virtual.

Now, $\quad m = \dfrac{h'}{h} = \dfrac{v}{u} = \dfrac{-200}{-40} = +5$ or $\dfrac{h'}{h} = +5$

$\therefore \quad h' = +5 \times h = +5 \times 5 = +25$ cm

The positive sign of h' shows that the image is erect. Thus in this case, the image is erect, virtual, 25 cm tall, and it is formed at a distance of 200 cm on the same side of the lens as the objects.

Q. 25. 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.

[*NCERT Exemplar*]

Ans. (*i*) Here, u = Distance of candle from the lens

$= (50 - 12)$ cm $= 38$ cm

According to sign convention, $u = -38$ cm

Now, v = Distance of screen from the lens

$= (88 - 50)$ cm $= 38$ cm

As per sign convention, $\quad v = +38$ cm

Using the lens formula, $\quad \dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f}$

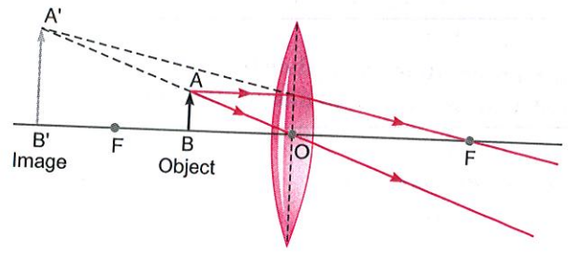
$$\frac{1}{38} + \frac{1}{38} = \frac{1}{f}$$

or $\quad f = \dfrac{38}{2} = 19$ cm

(*ii*) If the student shifts the candle towards the lens at a position of 31.0 cm, object distance $u = (50 - 31) = 19$ cm. Thus, candle lies at the focus. Hence, image will be formed at infinity.

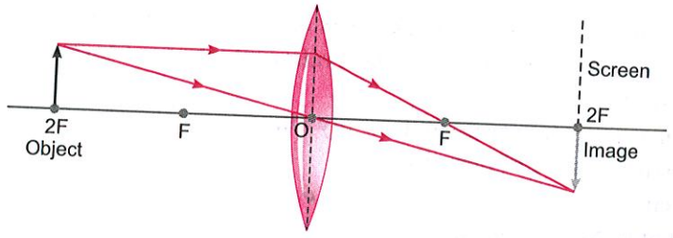
(*iii*) If the candle is further shifted towards the lens, the candle lies between the optical centre and focus of the lens. Thus a virtual, erect and magnified image is formed on the same side as the object.

(*iv*)



Q. 26. An object 2 cm high is placed at a distance of 64 cm from a white screen. On placing a convex lens at a distance of 32 cm from the object it is found that a distinct image of the object is formed on the screen. What is the focal length of the convex lens and size of the image formed on the screen?

Ans.



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

$$\frac{1}{32} - \frac{1}{-32} = \frac{1}{f} \quad \text{or} \quad \frac{1}{32} + \frac{1}{32} = \frac{1}{f}$$

or $\quad f = 16$ cm

Magnification, $\quad \dfrac{h'}{h} = \dfrac{v}{u}$

$$\Rightarrow \qquad h' = \frac{v}{u} \times h$$

$$\therefore \qquad h' = \frac{32}{-32} \times 2 = -2 \text{ cm}$$

Thus, image is inverted and of the same size as object.

Q. 27. A real image, $\frac{4}{5}$ size of the object is formed 18 cm from a lens. Calculate the focal length of the lens.

Ans. Since the image is real and diminished, the lens must be convex and the object must be placed beyond 2F.

Given: $v = +18$ cm

$$\frac{h'}{h} = \frac{-4}{5} \qquad [\because m = \frac{h'}{h} \text{ is negative for real image}]$$

We have, $m = \frac{h'}{h} = \frac{v}{u}$

$$\therefore \quad \frac{v}{u} = \frac{-4}{5} \qquad \Rightarrow \quad 4u = -5v$$

and $4u = -5 \times 18$ cm $\quad \therefore \quad u = -22.5$ cm

Also focal length is given by

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

$$= \frac{1}{18} - \frac{1}{-22.5} = \frac{1}{18} + \frac{1}{22.5} = \frac{9}{90}$$

$$f = 10 \text{ cm}$$

Q. 28. Analyse the following observation table showing variation of image distance (v) with object distance (u) in case of a convex lens and answer the questions that follow, without doing any calculations:

S. No.	Object distance u (cm)	Image distance v (cm)
1	– 90	+ 18
2	– 60	+ 20
3	– 30	+ 30
4	– 20	+ 60
5	– 18	+ 90
6	– 10	+ 100

(a) What is the focal length of the convex lens ? Give reason in support of your answer.

(b) Write the serial number of that observation which is not correct. How did you arrive at this conclusion?

(c) Take an appropriate scale to draw ray diagram for the observation at S. No. 4 and find the approximate value of magnification. *[CBSE Delhi 2017]*

Ans. (a) $f = 15$ cm

Object at S. No. (3) indicates $u = -30$ cm, $v = +30$ cm

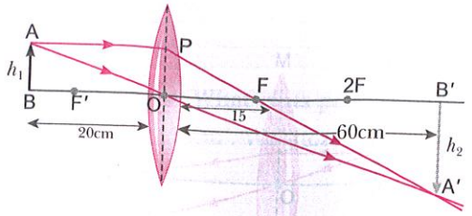
Thus, object is at 2F ($2f = 30$ cm)

$\therefore \qquad f = 15$ cm

(b) Observation at S. No. (6) is not correct

The value, u a=–10 cm, indicates that the object is in between the optical centre and the focus (*i.e.*, less than the focal length) of the lens and hence the image should be on the same side as the object. Thus, the image distance cannot be positive.

(c) $u = -20$ cm; v = +62 cm; $f = +15$ cm



Q. 29. The magnification of an image formed by a lens is –1. If the distance of the image from the optical centre of the lens is 25 cm, where is the object placed ? Find the nature and focal length of the lens. If the object is displaced 15 cm towards the optical centre of the lens, where would the image be formed ? Draw a ray diagram to justify your answer. *[CBSE (F) 2017]*

Ans. m = – 1, means that the image is real, inverted and of the same size as the object

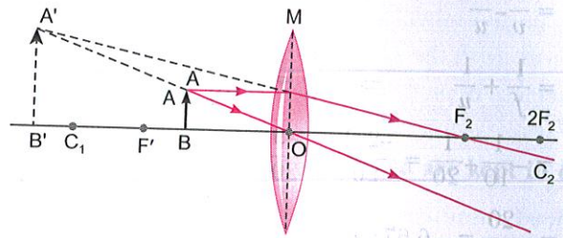
$\therefore$ Object distance =image distance= $2f = 25$ cm

$$\therefore \quad f = \frac{25}{2} = 12.5 \text{ cm}$$

Nature of the lens is convex or converging.

On displacing the object distance by 15 cm towards the lens, the object distance becomes 10 cm which is less than the focal length. Image formed now is virtual and on the same side of lens as the object.

Ray diagram



CONCAVE LENS

Q. 30. An object kept at a distance of 60 cm from a lens gives a virtual image at a distance of 20 cm over the same side of the lens. What is the focal length of the lens? Is the lens converging or diverging?

Ans. Here, $u = -60$ cm, $v = -20$ cm

From lens formula,

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

$$\frac{1}{-20} - \frac{1}{-60} = \frac{1}{f}$$

$$\Rightarrow \quad \frac{1}{f} = \frac{1}{60} - \frac{1}{20} = \frac{1-3}{60} = \frac{-2}{60};$$

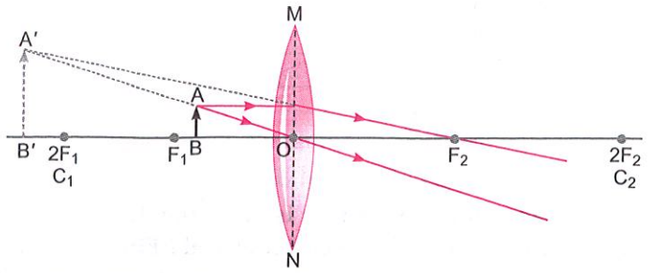
$$\Rightarrow \quad f = \frac{-60}{2} = -30 \text{ cm}$$

The focal length of the lens is 30 cm. The –ve sign shows that the lens is diverging.

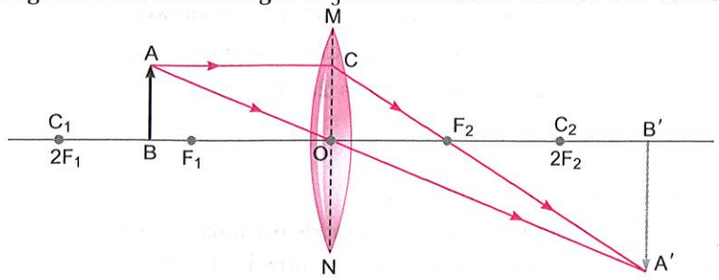
Q. 31. "A convex lens can form a magnified erect as well as magnified inverted image of an object placed in front of it." Draw ray diagram to justify this statement stating the position of the object with respect to the lens in each case.

An object of height 4 cm is placed at a distance of 20 cm from a concave lens of focal length 10 cm. Use lens formula to determine the position of the image formed. *[CBSE Delhi 2015]*

Ans. ■ **For magnified erect image:** Object is between the optical centre and principal focus of a convex lens.



For magnified inverted image: Object is between F and 2F of a convex lens.



■ Object distance, $u = -20$ cm, focal length, $f = -10$ cm, image distance, v = ?

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

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

$$\frac{1}{v} = -\frac{1}{10} - \frac{1}{20} = \frac{-2-1}{20} = \frac{-3}{20}$$

$$\therefore \quad v = -\frac{20}{3} = -6.67 \text{ cm}$$

The image is formed at a distance of 6.67 cm on the same side as that of the object.

Q. 32. At what distance from a concave lens of focal length 20 cm a 6 cm tall object be placed so as to obtain its image at 15 cm from the lens? Also calculate the size of the image formed.

Draw a ray diagram to justify your answer for the above situation and label it.

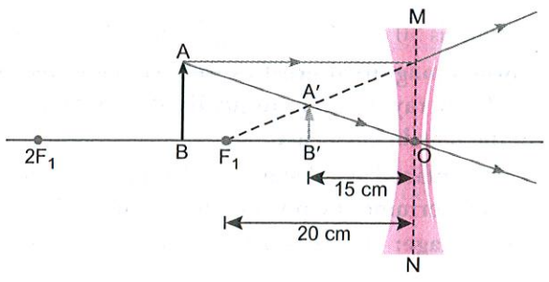
Ans. Given, $f = -20$ cm; $h_1 = 6$ cm; $v = -15$ cm; u = ?

Lens formula: $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$$\Rightarrow \quad u = \frac{vf}{f - v} = \frac{-15 \text{ cm} \times -20 \text{ cm}}{-20 \text{ cm} - (-15 \text{ cm})}$$

$= -60$ cm object at 60 cm from the lens

$$h_2 = \frac{v}{u} \times h_1 = \frac{-15 \text{ cm}}{-60 \text{ cm}} \times 6 \text{ cm} = +1.5 \text{ cm}$$ diminished erect



POWER OF A LENS

Q. 33. A convex lens has a focal length of 10 cm. What is its power?

Ans. Here, the focal length of the lens is given in 'cm'. We should first convert the focal length into 'm'.

Now, $10 \text{ cm} = \frac{10}{100} \text{m} = 0.1 \text{ m}$

So, focal length, $f = 0.1$ m (A convex lens has positive focal length)

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

We get $P = \frac{1}{0.1}$ or $P = \frac{1 \times 10}{1}$

Thus, power $P = +10$ dioptre (or $+10$ D).

Q. 34. A 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? *[NCERT Exemplar]*

Ans. **Case I:** When $f = 50 \text{ cm} = 0.5 \text{ m}$

$$P = \frac{1}{f \text{ (in m)}} = \frac{1}{0.5} = 2 \, D$$

$\therefore$ Lens is convex.

Case II: When $f = -50 \text{ cm} = -0.5 \text{ m}$

$$P = \frac{1}{f \text{ (in m)}} = \frac{1}{-0.5} = -2 \, D$$

$\therefore$ Lens is concave.

Q. 35. Two thin lenses of focal lengths + 10 cm and – 5 cm are kept in contact. What is the focal length and power of the combination?

Ans. Here, $f_1 = +10$ cm, $f_2 = -5$ cm,

$\therefore$ Focal length of the combination of lenses is given by

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} \quad \Rightarrow \quad \frac{1}{f} = \frac{1}{10} + \frac{1}{-5} = \frac{1}{10} - \frac{1}{5}$$

$$\Rightarrow \quad \frac{1}{f} = \frac{1-2}{10} \quad \Rightarrow \quad \frac{1}{f} = -\frac{1}{10}$$

$$\therefore \quad f = -10 \text{ cm}$$

Power of combination,

$$P = \frac{1}{f \text{(in cm)}} = \frac{100}{f \text{ (in cm)}}$$

$$P = -\frac{100}{10} \text{D} = -10 \text{ D}.$$

HOTS (Higher Order Thinking Skills)

Q. 1. Which one of the two—glass and water is optically denser and why?

Ans. Glass is denser than water because speed of light in glass is less than that of water.

Q. 2. Can a convergent lens in one medium become divergent in another medium?

Ans. Yes, a convergent lens in one medium becomes divergent in another medium when the refractive index of the medium is greater than the refractive index of the material of the lens.

Q. 3. A man is going away from the plane mirror with a velocity of 3 m/s. With what velocity is he going away from his own image in the mirror?

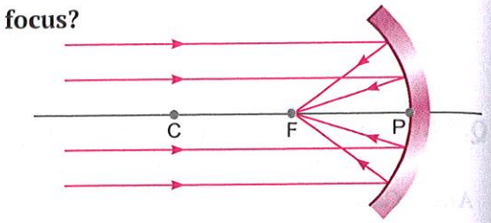
Ans. We know that the image formed by a plane mirror is as much behind the mirror as object is in front. So, the speed of image will be same as object but in opposite direction. Thus, net velocity between man and his image will be $3 - (-3) = 6$ m/s.

Q. 4. Under what condition a convex lens when placed in a medium behaves as an ordinary glass plate?

Ans. When the refractive index of a medium relative to lens is one, a convex lens will behave as an ordinary glass plate.

Q. 5. Why does a concave mirror has a real principal focus?

Ans. In a concave mirror, all the incident rays parallel to principal axis actually pass through the focus F after getting reflected from the concave mirror. Thus, concave mirror has a real principal focus.



Q. 6. A concave mirror and convex lens are immersed in water. What change, if any, do you expect in the focal length of the two?

Ans. Focal length of the concave mirror does not change because it is about half its radius of curvature and has nothing to do with the external medium. On the other hand, the focal length of the convex lens will increase because the refractive index of glass with respect to water is less than refractive index of glass with respect to air.

Q. 7. A man is holding a lighted candle in front of a thick glass mirror and on viewing it obliquely he noticed a number of images of the candle why?

Ans. The front surface of a thick glass mirror is both reflecting and refracting. The back surface is silvered and acts as a mirror. Images arise due to reflection of incident light by the front surface then by the back surface, followed by multiple reflection of light within the glass by the front and back surfaces.

Q. 8. A concave mirror of focal length f produces an image n times the size of the object. What would be the object distance for which the image is real?

Ans. We have given $\dfrac{\text{Size of the image}}{\text{Size of the object}} = n$

In case of concave mirror, if the image is real then it must be inverted.

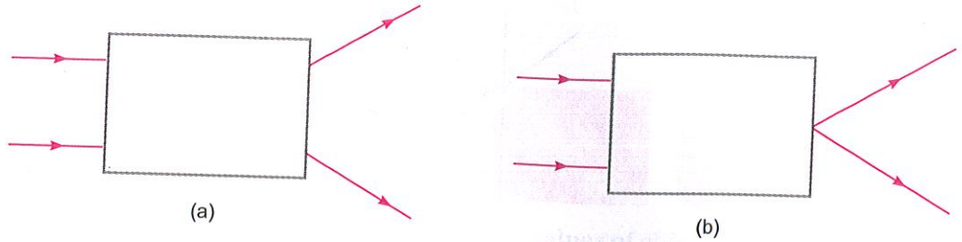
So, $m = -n = \dfrac{-v}{u}$ or $m = n = \dfrac{v}{u}$

From mirror formula, we get

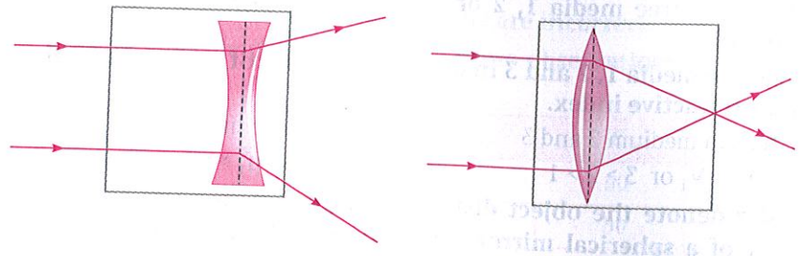
$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \quad \text{or} \quad 1 + \frac{u}{v} = \frac{u}{f}$$

or $1 + \dfrac{1}{n} = \dfrac{u}{f}$ or $u = \left(\dfrac{n+1}{n}\right) f$

Q. 9. In the following figures, one lens is placed inside each box. State the nature of the lens. Complete the ray diagrams.



Ans.



In figure (*a*), the incident rays are diverged after refraction, so the lens is concave.

In figure (*b*), the incident rays are converged after refraction, so the lens is convex.

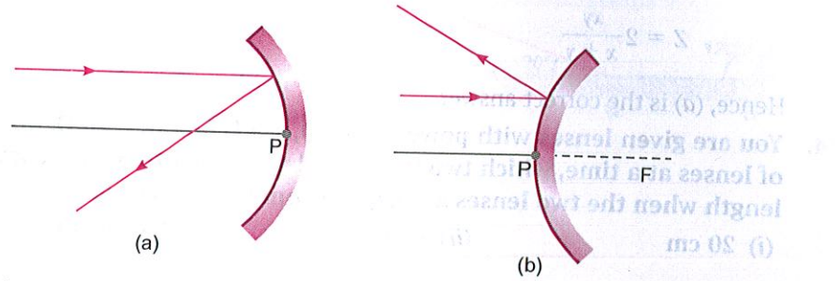
Q. 10. A convex lens forms a blurred image of an object on a screen. Suggest a suitable way to get a sharp image on a screen without disturbing the object, lens or the screen.

Ans. By placing another lens of suitable nature and focal length between the object and the screen.

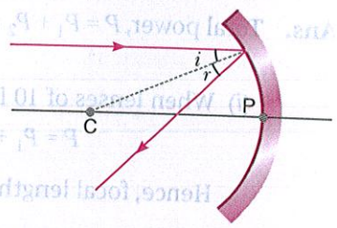
Q. 11. Why does a ray of light parallel to the principal axis

(*i*) bend towards the principal axis in the case of a concave mirror and

(*ii*) goes away from the principal axis in the case of a convex mirror as shown here?



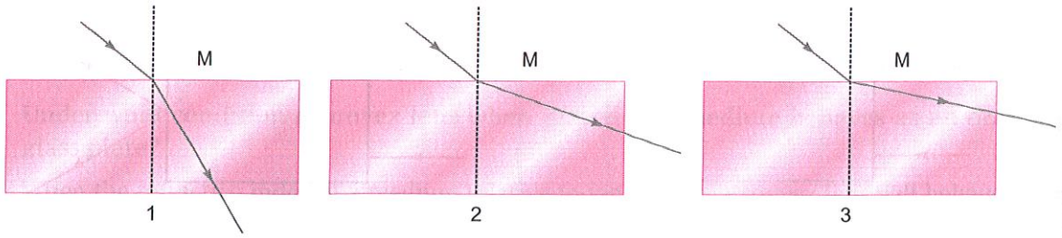
Ans. A ray of light incident on any spherical mirror follows the laws of the reflection.



(*i*) In case of a concave mirror, the line joining the point of incidence and the centre of curvature forms the normal as shown. The reflected ray goes on the other side of the normal following laws of reflection.

(*ii*) In the case of convex mirror, the normal at the point of incidence is as shown. The reflected ray goes on the other side of the normal. Following laws of reflection as shown. Hence, it goes away from the principal axis.

Q. 12. The ray diagrams given below show the paths of a ray of light travelling from a medium M into different media 1, 2 and 3.



(*a*) In which of three media 1, 2 or 3 does light travel: (*i*) faster, (*ii*) slower than in medium M?

(*b*) Arrange the media 1, 2 and 3 in descending order of (*i*) speed of light through them, (*ii*) their refractive index.

Ans. (*a*) (*i*) faster—in medium 2 and 3 (*ii*) slower—in medium 1

(*b*) (*i*) $v_3 > V_2 > V_1$ or $3 > 2 > 1$ (*ii*) $1 > 2 > 3$ or $\mu_1 > \mu_2 > \mu_3$

Q. 13. If *x*, *y* and *z* denote the object distance, image distance and the radius of curvature respectively of a spherical mirror, which one of the following is the correct relation between them?

(*a*) $Z = 2\dfrac{xy}{x+y}$ **(*b*)** $Z = 2\dfrac{x+y}{xy}$

(*c*) $Z = 2\dfrac{xy}{x-y}$ **(*d*)** $Z = 2\dfrac{x-y}{xy}$

Ans. For a spherical mirror,

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

$$\therefore \quad \frac{2}{Z} = \frac{1}{x} + \frac{1}{y} = \frac{y+x}{xy} \quad \Rightarrow \quad \frac{Z}{2} = \frac{xy}{x+y}$$

$$Z = 2\frac{xy}{x+y}$$

Hence, (*a*) is the correct answer.

Q. 14. You are given lenses with powers + 10 D, + 5 D, – 5 D, – 20 D, and – 10 D. Taking a pair of lenses at a time, which two lenses will you select to have a combination of total focal length when the two lenses are kept in contact in each case.

(*i*) 20 cm (*ii*) – 10 cm (*iii*) – 20 cm (*iv*) $\dfrac{20}{3}$ cm

Ans. Total power, $P = P_1 + P_2$ and total focal length f is $\dfrac{1}{f} = \dfrac{1}{f_1} + \dfrac{1}{f_2}$

(*i*) When lenses of 10 D and – 5 D are taken, total power

$$P = P_1 + P_2 = 10\text{ D} - 5\text{ D} = 5\text{ D}$$

Hence, focal length $= \dfrac{100}{5} = 20$ cm

(*ii*) When lenses of 10 D and – 20 D are taken

$$P = 10\text{ D} - 20\text{ D} = -10\text{ D}$$

Focal length $= \dfrac{100}{-10} = -10$ cm

(*iii*) When lenses of + 5 D and – 10 D

$$P = -5\text{ D}$$

$$f = \frac{100}{-5} = -20\text{ cm}$$

(*iv*) When lenses of 10 D and 5 D are taken

$$P = 15\text{ D}$$

$$f = \frac{100}{15} = \frac{20}{3}\text{ cm}$$

Q. 15. A student recorded the following data for the values of object distance and corresponding image distance while performing an experiment on real image formation by a convex lens of power + 4 D. Two of these observations are incorrect.

Without making any calculations, identify these observations and give reason for your choice.

Observation	A	B	C	D	E
Object Distance *u* (cm)	30	40	50	60	70
Image Distance *v* (cm)	20	60	50	70	30

Ans. Readings A and D are incorrect.

Reason: The focal length of the lens is 25 cm.

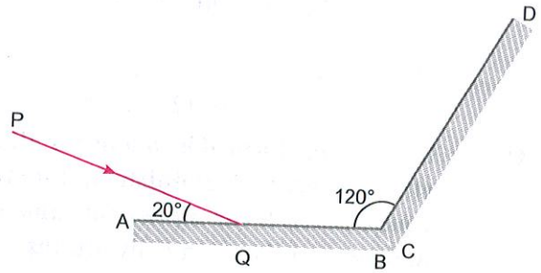
(*i*) In reading A, the object is kept at 30 cm from the lens, *i.e.*, between F and 2F. The image should be formed beyond 2F (50 cm). However, it is shown to be at 20 cm, which is incorrect.

(*ii*) In reading D, the object is kept beyond 2F, *i.e.*, 50 cm. The image should be formed between F and 2F. However, it is also shown to be formed at 60 cm, *i.e.*, beyond 2F. Hence it is incorrect.

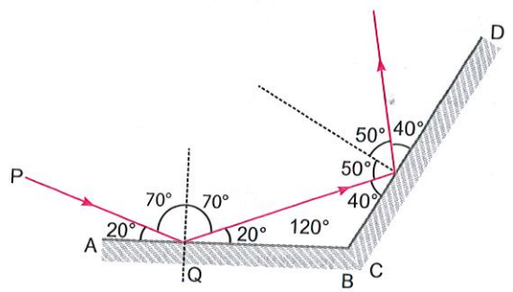
Q. 16. The given ray diagram shows a ray of light PQ striking a mirror AB. The mirror AB and CD are at an angle of 120° with each other. The ray PQ strikes the surface of the mirror AB at point Q.

(*i*) Draw the complete path of reflection of the ray at mirrors AB and CD.

(*ii*) Calculate the sum of angles which the reflected rays make with the surfaces of mirrors AB and CD.



Ans. (*i*)



(*ii*) The sum of the angles, made by reflected rays with mirrors AB and CD is

$$20° + 40° = 60°$$

Q. 17. Playing with an old lens one morning, Ravi discovers that if he holds the lens 10 cm away from a wall opposite to a window, he can see a sharp but upside-down picture of outside world on the wall. That evening, he covers a lighted lamp with a piece of opaque paper on which he has pierced, a small hole 1 mm in diameter. By placing the lens between the illuminated card and the wall, he manages to produce a sharp image of diameter 5 mm on the wall.

Answer the following questions based on the above information:

(*i*) What is the power of the lens?

(*ii*) In the evening experiment, how far away from the opaque paper did he place the lens?

(*iii*) How far apart were the card and the wall?

Ans. (*i*) Since the rays from far away object get focussed at the principal focus, distance between lens and wall is equal to focal length 10 cm.

$\therefore$ Power of the lens = + 10 D.

(*ii*) In the evening experiment,

$$m = \frac{h'}{h} = \frac{-5}{1} \Rightarrow m = -5$$

$$m = \frac{v}{u} \therefore v = -5u$$

Using, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, we get

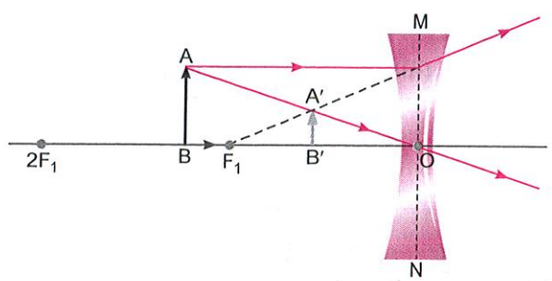
$$\frac{1}{-5u} - \frac{1}{u} = \frac{1}{20} \Rightarrow \mathbf{u = -12\ cm}$$

(*iii*) $v = 60$;

Thus $u + v = 60 + 12 = 72$ cm.

Q. 18. If the image formed by a lens for all positions of the object placed in front of it is always virtual, erect and diminished, state the type of the lens. Draw a ray diagram in support of your answer. If the numerical value of focal length of such a lens is 20 cm, find its power in new cartesian sign conventions. *[CBSE (F) 2016]*

Ans. It is diverging lens or concave lens.



Focal length = –20 cm (lens is concave, hence f is –ve)

Power, $\frac{1}{f} = \frac{100}{-20\ \text{cm}} = -5$ D

Some Important Numericals (For Practice)

1. A 3 cm tall object is placed 18 cm in front of a concave mirror of focal length 12 cm. At what distance from the mirror should a screen be placed to see a sharp image of the object on the screen. Also calculate the height of the image formed. *[CBSE Delhi 2017]*
[**Ans.** $\therefore$ v = –36 cm h_2 = –6 cm]
2. An object is placed at a distance of 10 cm from a convex mirror of focal length 5 cm.
(*i*) Draw a ray diagram showing the formation of image.
(*ii*) State two characteristics of the image formed.
(*iii*) Calculate the distance of the image from mirror.
[**Ans.** (*ii*) virtual and erect; diminished (*iii*) 3.3 cm]
3. An object placed 20 cm in front of a mirror is found to form an image of 15 cm (*i*) in front of it, (*ii*) behind the mirror. Find the focal length of the mirror and the kind of mirror in each case.
[**Ans.** (*i*) concave mirror of focal length 60/7 cm, (*ii*) convex mirror of focal length 60 cm]
4. An object is placed at a distance of 10 cm from a concave mirror of focal length 20 cm.
(*i*) Draw a ray diagram for the formation of image.
(*ii*) Calculate the image distance.
(*iii*) State two characteristics of the image formed.
[**Ans.** (*ii*) 20 cm; (*iii*) virtual and erect; magnified]
5. If an object 10 cm high is placed at a distance of 36 cm from a concave mirror of focal length 12 cm, find the position, nature and height of the image.[**Ans.** – 18 cm; real and inverted; – 5 cm]
6. If the magnification of an object of size 1 m is 2, what is the size of the image? [**Ans.** 2 cm]
7. An arrow 2.5 cm high is placed at a distance of 25 cm from a diverging mirror of focal length 20 cm. Find the nature, position and size of the image formed.
[**Ans.** v = 11.1 cm; virtual and erect; 1.1 cm tall]
8. A converging mirror forms a real image of height 4 cm of an object of height 1 cm placed 20 cm away from the mirror. Calculate
(*i*) image distance, (*ii*) focal length of the mirror. [**Ans.** (*i*) – 80 cm (*ii*) – 16 cm]
9. The speed of light in water is 2.25×10^8 m/s. If the speed of light in vacuum be 3×10^8 m/s, calculate the refractive index of water. [**Ans.** 1.33]
10. The refractive index of water with respect to air is 4/3. What is the refractive index of air with respect to water? [**Ans.** 3/4]
11. 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 in air making an angle of 42° with the normal. Draw a labelled ray diagram to show the path of this ray. What value would you assign to the angle of refraction and angle of emergence? [**Ans.** Angle of refraction = 42°, Angle of emergence = 60°]
12. Three beams of light 1, 2 and 3 of the same wavelength are sent through three different materials of refractive indices 1.60, 1.50 and 1.55. Arrange the speed of these beams in different materials in ascending order. [**Ans.** $v_1 < v_3 < v_2$]
13. The refractive index of glass with respect to air is 1.65 and that of water w.r.t air is 1.33. Calculate the refractive index of water with respect to glass. [**Ans.** 0.80]
14. A convex lens has a focal length of 10 cm. At what distance from the lens should the object be placed so that it forms a real and inverted image 20 cm away from the lens? What could be the size of the image formed if the object is 2 cm high? With the help of a ray diagram, show the formation of the image by the lens in this case. [**Ans.** u = – 20 cm; h' = – 2 cm]

15. The image of a candle flame placed at a distance of 30 cm from a spherical lens is formed on a screen placed on the other side of the lens at a distance of 60 cm from the optical centre of the lens. Identify the type of lens and calculate its focal length. If the height of the flame is 3 cm, find the height of its image.

[**Ans.** Convex lens, $f = +20$ cm, $h' = -6$ cm] *[CBSE Delhi 2015]*

16. An object of height 5 cm is placed perpendicular to the principal axis of a concave lens of focal length 10 cm. If the distance of the object from the optical centre of the lens is 20 cm, determine the position, nature and size of the image formed using the lens formula. *[CBSE (AI) 2015]*

[**Ans.** The image is virtual and erect, $v = -\frac{20}{3}$ cm, and $h' = 1.6$ cm]

17. The image of an object formed by a lens is of magnification −1. If the distance between the object and its image is 60 cm, what is the focal length of the lens? If the object is moved 20 cm towards the lens, where would the image be formed? State reason and also draw a ray diagram in support of your answer. *[CBSE (AI) 2016]*

18. A concave lens has focal length of 15 cm. At what distance should the object from the lens be placed so that it forms an image at 10 cm from the lens? Also, find the magnification of the lens. [**Ans.** $u = -30$ cm, +1/3]

19. At what distance should an object be placed from a convex lens of focal length 18 cm to obtain an image at 24 cm from it on the other side. What will be the magnification produced in this case? [**Ans.** $m = -1/3$]

20. A 2 cm high candle flame is placed at a distance of 80 cm from a white screen. On placing a convex lens exactly at the mid point of the candle and the screen, a distant image of the flame is seen on the screen. What is the focal length of the lens and the size of the candle flame image formed? Draw a ray diagram to show the formation of the image in this case.

[**Ans.** $f = -20$ cm, $h' = -2$ cm]

21. One half of a convex lens of focal length 10 cm is covered with a black paper. Can such a lens produce an image of a complete object placed at a distance of 30 cm from the lens? Draw a ray diagram to justify your answer.

A 4 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 15 cm. Find the nature, position and size of the image. *[CBSE (AI) 2015]*

[**Ans.** The image is virtual, erect and magnified, size of the image is 16 cm.]

22. The power of a lens is +4 D. What kind of lens is it and what is its focal length?

[**Ans.** Convex lens; 25 cm]

23. A lens has focal length of 10 cm. What is the power of the lens and what is its nature?

[**Ans.** 10 D; convex lens]

24. The power of a lens is − 2 D. What is its focal length? [**Ans.** − 50 cm]

25. Focal length of the lens in a photographic camera is 5 centimetres. What is the power of the lens? [**Ans.** + 20 D]

26. Two lenses of power 3D and −5D are placed in contact to form a composite lens. An object is placed at a distance 50 cm from this composite lens, find the position of the image.

[**Ans.** $v = -25$ cm]

Proficiency Exercise

Very Short Answer Questions [1 mark]

1. Name the type of mirror used as shaving mirror.
2. What does the negative sign in the value of magnification produced by a mirror indicates about an image?
3. If you want to see an enlarged image of your face, will you use a concave mirror or a convex mirror?
4. In which of the following media: glass, water and diamond
   (*a*) light travels slowest.
   (*b*) light travels fastest.
5. Given below are refractive indices of a few material media.

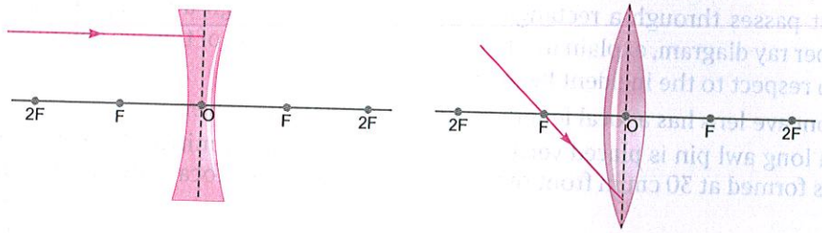
Rock salt	1.54	Ice	1.31
Dense flint glass	1.65	Crown glass	1.52

Arrange the media in the ascending order of optical density.

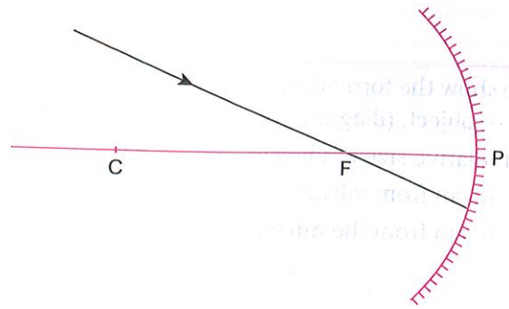
6. An object of 1 cm in length is placed at a distance of 2f from a convex lens. What is the size of the image formed?
7. If the image formed by a lens is always diminished and erect, what is the nature of the lens?
8. A concave lens has a focal length of 50 cm. Calculate its power. [**Ans.** P = − 2D]
9. State two laws of reflection of light. *[CBSE Delhi (C) 2017]*

Short Answer Questions–I [2 marks]

10. The magnification produced by a plane mirror is + 1. What does this mean?
11. Redraw the diagram given below in your answer book and complete the path of ray.



12. Draw a ray diagram to show why a stick half immersed in water appears to be bent at the surface.
13. Name the spherical mirror used as:
   (*a*) rear view mirror in vehicles (*b*) reflector in search-light.
14. What are laws of refraction of light?
15. An object is placed at a distance of 15 cm from a convex lens of focal length 20 cm. List four characteristics (nature, position, etc.) of the image formed by the lens. *[CBSE (AI) 2017]*
16. Redraw the following diagram on your answer-sheet and show the path of the reflected ray. Also mark the angle of incidence ($\angle i$) and the angle of reflection ($\angle r$) on the diagram. *[CBSE (F) 2017]*



Short Answer Questions–II [3 marks]

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

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

18. A child is standing in front of a magic mirror. She finds the image of her head bigger, the middle portion of her body of the same size and that of the leg smaller. Write the order of combinations for the magic mirror from the top.

19. The image of an object formed by a lens is real, inverted and of the same size as the object. If the image is at a distance of 40 cm from the lens, what is the nature and power of the lens? Draw ray diagram to justify your answer.

[**Ans.** P = 5 dioptre] *[CBSE (F) 2015]*

20. The image formed by a spherical mirror is real, inverted and is of magnification –2. If the image is at a distance of 30 cm from the mirror, where is the object placed? Find the focal length of the mirror. List two characteristics of the image formed if the object is moved 10 cm towards the mirror.

[**Ans.** $u = -15$ cm, $f = -10$ cm]

21. The refractive index of a medium 'X' with respect to medium 'Y' is $\frac{2}{3}$ and the refractive index of medium 'Y' with respect to medium 'Z' is $\frac{4}{3}$. Find the refractive index of medium 'Z' with respect to medium 'X'.

[**Ans.** $\frac{9}{8}$]

22. (*i*) Which property of concave mirror is utilised for using them as shaving mirrors?

(*ii*) Light passes through a rectangular glass slab and through a triangular glass prism. Using proper ray diagram, explain in what way does the direction of the two emergent beams differs with respect to the incident beam of light.

(*iii*) A concave lens has a focal length of 50 cm Calculate its power. [**Ans.** P = – 2D]

23. A 10 mm long awl pin is placed vertically in front of a concave mirror. A 5 mm long image of the awl pin is formed at 30 cm in front of the mirror. Calculate the focal length of this mirror.

[**Ans.** $f = -20$ cm]

24. The magnification of an image formed by a lens is – 1. If the distance of the image from the optical centre of the lens is 35 cm, where is the object placed ? What is the nature and focal length of the lens ? If the object is displaced 20 cm towards the optical centre of the lens, where would the image be formed and what will be its nature ? Draw a ray diagram to justify your answer. *[CBSE (F) 2017]*

[**Ans.** $u = 35$ cm $= v$; $f = 17.5$ cm]

25. An object is placed perpendicular to the principal axis of a convex lens of focal length 18 cm. The distance of the object from the lens is 27 cm. Find the position and nature of the image formed.

[CBSE Delhi (C) 2017]

[**Ans.** $v = 54$ cm, real and inverted]

Long Answer Questions [5 marks]

26. Draw the ray diagram to show the formation of image by a concave mirror of focal length 15 cm for the following positions of object. (diagrams may not be drawn to the scale).

Indicate the nature and relative size of image.

(*a*) object is placed at 30 cm from mirror.

(*b*) object is placed at 10 cm from the mirror.

27. Find the position of an object which when placed in front of a concave mirror of focal length 20 cm produces a virtual image twice the size of the object.

[**Ans.** $u = -10$ cm]

28. An object 2 cm in size is placed 20 cm in front of a concave mirror of focal length 10 cm. Find the distance from the mirror at which a screen should be placed in order to obtain sharp image. What will be the size and nature of the image formed?

[**Ans.** $v = -20$ cm, $h' = -2$ cm]

29. When an object is placed at a distance of 60 cm from a convex mirror the magnification produced is $\frac{1}{2}$. Where should the object be placed to get a magnification of $\frac{1}{3}$.

[**Ans.** $u = -120$ cm]

30. A concave lens has focal length of 20 cm. At what distance from the lens a 5 cm tall object be placed so that it forms an image at a distance of 15 cm from the lens? Also calculate the size of the image formed.

[**Ans.** $u = -60$ cm, $h' = 1.25$ cm]

31. At what distance should an object be placed from a convex lens of focal length 18 cm to obtain an image at 36 cm from it? What will be the magnification produced in this case?

[**Ans.** $u = -36$ cm, $m = -1$ cm]

32. You have two lenses A and B of focal lengths +10 cm and – 10 cm respectively. State the nature and power of each lens. Which of the two lenses will form a virtual and magnified image of an object placed 8 cm from the lens? Draw a ray diagram to justify your answer. *[CBSE (AI) 2015]*

33. Draw the ray diagram in each case to show the position and nature of the image formed when the object is placed: (*i*) in front of a convex lens at F, (*ii*) at 2F of a convex lens, (*iii*) between the lens and infinity of a concave lens.