Light-Reflection And Refraction

Assess Yourself

Q. 1. What is the magnification produced by a plane mirror?

Answer: The magnification produced by a plane mirror is +1. Because,

$$\text{Magnification} = \frac{\text{Height Of Image}}{\text{Height Of Object}}$$

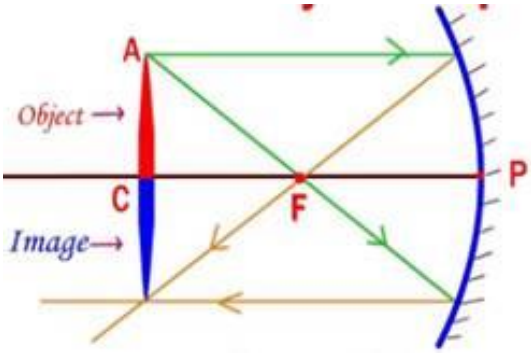
And the height of image formed by plane mirror is equal to height of object.

Therefore, Height of Image = Height of Object.

Hence Magnification is +1.

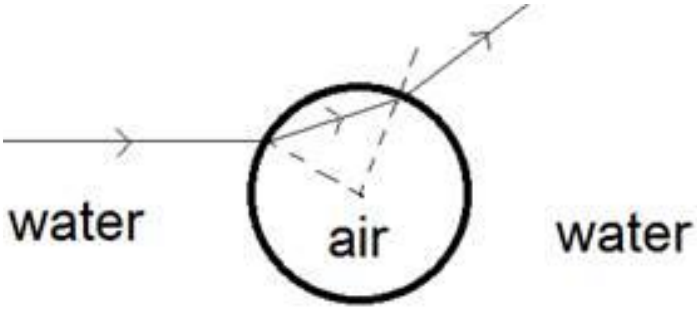
Q. 2. When do an object and its image coincide in a convergent mirror?

Answer: When the object is kept at the centre of curvature of the concave mirror the image of object coincide with the object, because image is formed at the centre of curvature and is same as the size of the object as shown in the figure below.



Q. 3. What type of lens is an air bubble inside water?

Answer: Due to higher refractive index of water (1.33) than air (1.0003) the air bubble acts as the diverging lens (Concave lens).The figure below illustrates it.



Q. 4. Which kind of mirrors are used in the headlights of a motorcar and why?

Answer: A concave mirror is used in the headlight of a car because concave mirror is a converging mirror. In headlights the bulb is kept at the focus of the mirror, due to which the rays emerging from the bulb after reflection from the mirror becomes parallel to the principal axis hence we get the powerful beam of light which can go to farther distances.

Q. 5. What is the value of $1^n2 \times 2^n1$?

Answer:

$$_1n_2 = \frac{n_2}{n_1} \text{ and}$$

$$_2n_1 = \frac{n_1}{n_2}$$

$$\Rightarrow {}_1n_2 \times {}_2n_1 = \frac{n_2}{n_1} \times \frac{n_1}{n_2} = 1.$$

Hence the answer is 1.

Q. 6. The velocity of light in water is $\frac{3}{4}$ times the velocity of light in vacuum. Find the refractive index of water.

Answer: Let velocity of light in vacuum = v

$\Rightarrow$ Velocity of light in water $= \frac{3}{4}v$

Now,

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

$\Rightarrow$ Refractive index = $\frac{4}{3} = 1.33\ldots$

Hence Refractive index of water = 1.33.

Q. 7. What is the distance between the image and the plane mirror, if the object is at 15 m?

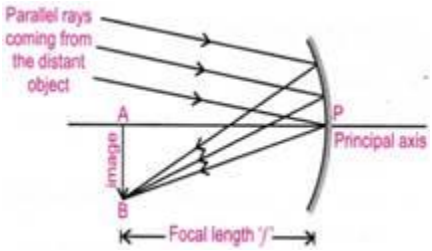
Answer: In plane mirror the distance between object and mirror is same as the distance between the image and mirror.

$\Rightarrow$ Image Distance = Object Distance.

$\therefore$ Distance between image and plane mirror is 15 cm.

Q. 8. How can we find the (rough) focal length of a concave mirror?

Answer: Method We can put the object far away from the concave mirror and place the screen where the image is formed. The place where the image formed is sharpest is the focus of the mirror, measure the distance between the focus and mirror to get the focal length.



Explanation when an object is kept at the infinity than the image is formed at the focus of the concave mirror.

Q. 9. A concave mirror of focal length 1.5m forms an image of an object placed at a distance of 40cm. Find the position and nature of the image.

Answer: According to the question;

Focal length (f) = -1.5m;

Object distance (u) = -40cm = 0.40m; (1m = 100 cm)

By mirror formula;

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

$$\Rightarrow \frac{1}{v}+\frac{1}{-0.40}=\frac{1}{-1.5}$$

$$\Rightarrow \frac{1}{v}=\frac{1}{0.40}-\frac{1}{1.5}$$

$$\Rightarrow \frac{1}{v}=\frac{10}{4}-\frac{10}{15}$$

$$\Rightarrow \frac{1}{v}=\frac{5}{2}-\frac{2}{3}$$

$$\Rightarrow \frac{1}{v}=\frac{15-4}{6}$$

$$\Rightarrow \frac{1}{v}=\frac{11}{6}$$

⇒ v = 0.5454m = 54.54cm (1m = 100 cm).

Since v = 54.54cm which is positive hence image is behind the mirror.

The image is formed at the distance of 54.54 cm behind the mirror and is virtual and erect.

Q. 10.A. A person wants to see the full length image of tall building in a small mirror. Which type of mirror is used by him?

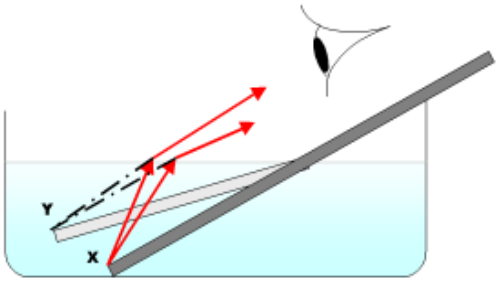
Answer: Person will use the convex mirror because it always forms virtual and erect image and has the wider field of view which will help in capturing the whole building.

The figure below shows the image of tall building in convex mirror.

Q. 10.B. Why do we not see the actual depth of a lake?

Answer: This is due to the refraction of light; light rays bend as they move from water to the air. When the light ray from water reaches our eye, the eye traces them back as straight lines (shown as dashed lines) which intersect at a higher position than where the actual rays originated. This cause the depth to appear higher and we cannot see the actual depth of the lake.

The figure below illustrates the same.



Q. 11. The refractive indices of water and glass are $\frac{4}{3}$ and $\frac{3}{2}$ respectively. Write the relation and find the value of refractive index of water with respect to glass and glass with respect to water.

Answer: Refractive index of air, μair = 1;

Given;

Refractive index of water w.r.t air, ${}^{a}\mu_{w} = \frac{4}{3}$

Refractive index of glass w.r.t air, ${}^{a}\mu_{g} = \frac{3}{2}$

Refractive index of water w.r.t glass $= {}^{g}\mu_{w} = \frac{{}^{a}\mu_{w}}{{}^{a}\mu_{g^c}} = \frac{\frac{4}{3}}{\frac{3}{2}}$

$\Rightarrow {}^{g}\mu_{w} = \frac{4 \times 2}{3 \times 3} = \frac{8}{9}$

∴ Refractive index of water w.r.t glass is 8/9.

Also;

Refractive index of water w.r.t glass. = $\frac{1}{\text{Refractive index of glass w.r.t water.}}$

⇒ Refractive index of glass w.r.t water = $\frac{1}{\text{Refractive index of water w.r.t glass}}$

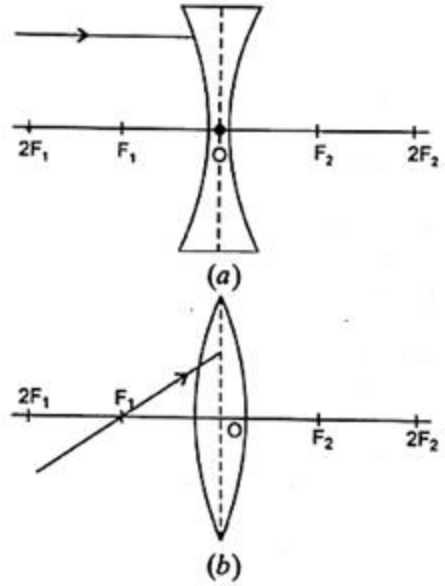
∴ Refractive index of glass w.r.t water = $\frac{1}{\frac{8}{9}} = \frac{9}{8}$

Refractive index of glass w.r.t water = 9/8.

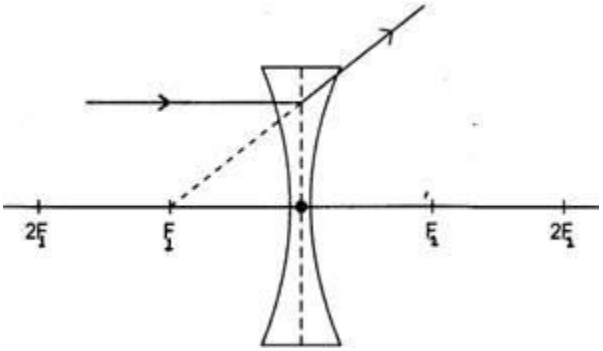
Q. 12. A concave mirror and a convex lens are held separately in water. What changes, if any, do you expect in the focal length of either?

Answer: The focal length of a mirror does not depend upon the nature of the medium in which it is placed whereas the focal length of a lens depends upon the medium in which it is placed. Thus, there will be no change in the focal length of the concave mirror whereas the focal length of the convex lens will change. If the refractive index of the material of the convex lens is greater than water it will increase, if it is equal to water it will become infinity and if it is less than water it will be negative.

Q. 13. Redraw the following diagrams given below in your answer book and show the direction of the light ray after refraction from the lens.

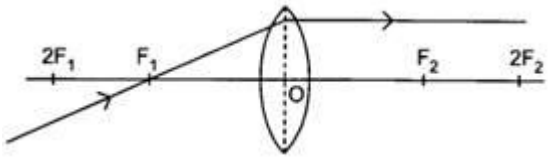


Answer:



The lens is concave lens, hence it diverges the ray of the light coming from infinity after refraction;

(b)



The above lens is the convex lens; hence the ray of light passing through focus after refraction will become parallel to the principal axis after refraction.

Q. 14. A convergent lens has a focal length of 15 cm. At what distance should an object from the optical centre of the lens be placed so that its real image is formed at 30 cm on the other side of the lens?

Answer: According to the question;

Focal length (f) = 15cm;

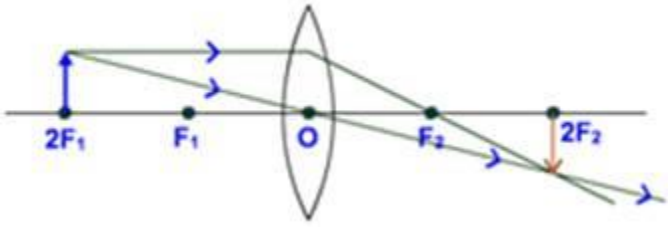
Radius of curvature(R=2f) = 30cm;

Image distance (u) = 30cm;

Since the image distance is 30 cm and the Radius of curvature of the lens is also 30 cm.

∴ The object must be placed at the radius of curvature (30cm) in front of lens, because when the object is kept at radius of curvature its image is also formed at radius of curvature on other side of the lens.

Figure below shows the image formation.



Object should be placed at 30cm in front of lens.

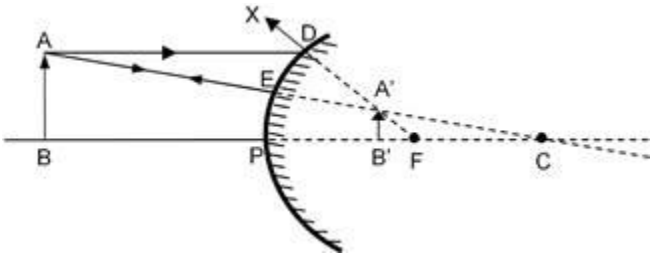
Q. 15. An object is placed between infinity and the pole of a convex mirror. Draw a ray diagram and also state the position, the relative size and the nature of the image formed.

Answer: Position of Image: Between Pole and Focus

Size of Image: Diminished

Nature of Image: Virtual and erect.

Ray diagram:



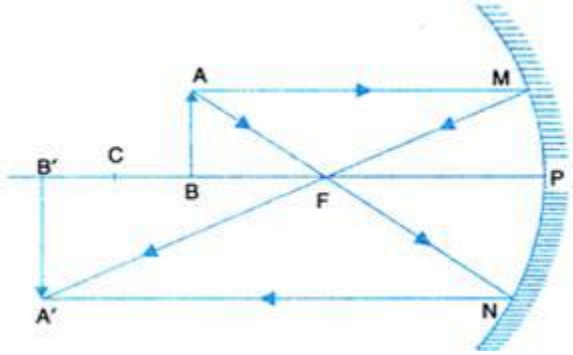
Q. 16. Draw the ray diagram and also state the position, relative size and nature of the image formed by a concave mirror when the object is placed between its centre of curvature, C and the focus, F.

Answer: Position of Image: Beyond the centre of curvature.

Size of Image: Magnified

Nature of Image: Real and inverted

Ray diagram:



Q. 17. Define 'refractive index of a transparent medium.' What is its unit? Which has a higher refractive index, glass or water?

Answer: Refractive index of transparent medium is defined as the ratio of speed of light in vacuum to the speed of light through medium.

Refractive index (n) = $\frac{c}{v}$

Where;

C = speed of light;

V = speed of light in medium;

It has no unit because it is the ratio of two quantities of same type (speed);

Glass has higher refractive index of 1.52. (Because Refractive index of water = 1.33).

Q. 18. The image of a candle flame placed at a distance of 45 cm from a spherical lens is formed on a screen placed at a distance of 90 cm from the lens. Identify the type of lens and calculate its focal length. If the height of the flame is 2 cm, find the height of its image.

Answer: According to the question;

Object distance (u) = -45cm;

Image distance (v) = 90cm;

By lens formula;

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

$$\Rightarrow \frac{1}{90}-\frac{1}{-45}=\frac{1}{f}$$

$$\Rightarrow \frac{1}{f} = \frac{1}{90} + \frac{1}{45}$$

$$\Rightarrow \frac{1}{f} = \frac{1+2}{90} = \frac{3}{90}$$

$$\Rightarrow \frac{1}{f} = \frac{1}{30}$$

⇒ f = 30cm.

Since f = 30cm which is positive hence it is a convex lens of focal length 30cm.

Now;

Height of Flame h_1= 2cm;

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

Putting values of v and u

Magnification = $\frac{h_2}{2} = -\frac{90}{45}$

$$\Rightarrow \frac{h_2}{2} = -2\,;$$

$$\Rightarrow h_2 = -2 \times 2 = -4$$

Height of image is 4 cm.

Negative sign means image is inverted.

Q. 19. An object 2 cm in size is placed 30cm in front of a concave mirror of focal length 15cm. At what distance from the mirror should a screen be placed in order to obtain a sharp image? What will be the nature and the size of the image formed? Draw a ray diagram to show the formation of the image in this case.

Answer: According to the question;

Object distance (u) = -30cm;

Focal length (f) = -15cm;

Image distance = v;

By mirror formula;

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

$$\Rightarrow \frac{1}{v} + \frac{1}{-30} = \frac{1}{-15}$$

$$\Rightarrow \frac{1}{v} = \frac{1}{30} - \frac{1}{15}$$

$$\Rightarrow \frac{1}{v} = \frac{1-2}{30}$$

$$\frac{1}{v} = -\frac{1}{30}$$

⇒ v = 30cm.

Thus, screen should be placed 30cm in front of the mirror (Centre of curvature) to obtain the real image.

Height of object h_1= 2cm;

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

Putting values of v and u

Magnification = $\frac{h_2}{2} = -\frac{-30}{-30}$

$$\Rightarrow \frac{h_2}{2} = -1;$$

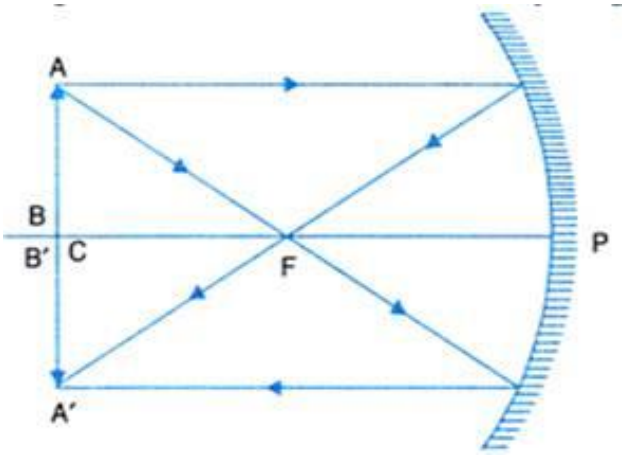
$$\Rightarrow h_2 = 2 \times -1 = -2.$$

Height of image is 2 cm.

Negative sign means image is inverted.

Thus real, inverted image of size same as that of object is formed.

Diagram below shows the image formation.



Q. 20. 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 would 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.

Answer: According to the question;

Object distance = u;

Image distance (v) = 20cm;

Focal length = 10cm

By lens formula;

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

$$\Rightarrow \frac{1}{20}-\frac{1}{u}=\frac{1}{10}$$

$$\Rightarrow \frac{1}{u}=\frac{1}{20}-\frac{1}{10}$$

$$\Rightarrow \frac{1}{u}=\frac{1-2}{20}=\frac{-1}{20}$$

$$\Rightarrow \frac{1}{u}=\frac{-1}{20}$$

⇒ u = -20cm.

Therefore, object is placed at 20 cm in front of lens.

Now;

Height of object h_1= 2cm;

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

Putting values of v and u

Magnification = $\frac{h_2}{2} = \frac{20}{-20}$

$\Rightarrow \frac{h_2}{2} = -1$;

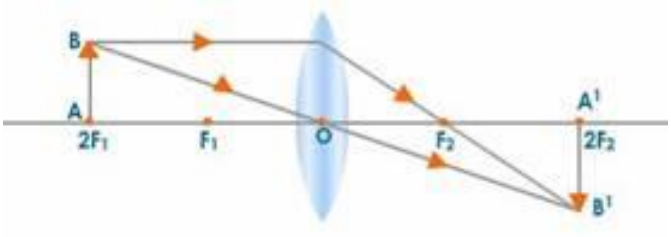
$\Rightarrow h_2 = 2 \times -1 = -2$

Height of image is 2 cm.

Negative sign means image is inverted.

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

Diagram below shows the image formation.



Q. 21. 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 15 cm from the lens? Also calculate the size of the image formed.

Answer: According to the question;

Object distance = u;

Image distance (v) = -15cm;

Focal length = -20cm

By lens formula;

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

$$\Rightarrow \frac{1}{-15} - \frac{1}{u} = \frac{1}{-20}$$

$$\Rightarrow \frac{1}{u} = \frac{1}{20} - \frac{1}{15}$$

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

⇒ u = -60cm.

Therefore, object is placed at 60 cm in front of lens.

Now;

Height of object h_1= 5cm;

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

Putting values of v and u

Magnification = $\frac{h_2}{5} = \frac{-15}{-60}$

$$\Rightarrow \frac{h_2}{5} = \frac{1}{4};$$

$$\Rightarrow h_2 = \frac{5}{4} = 1.25$$

Height of image is 1.25 cm.

Positive sign means image is virtual.

Q. 22. What is meant by power of a lens? Name and define its S.I. unit.

One student uses a lens of focal length +50 cm and another of –50cm. State the nature and find the power of each lens. Which of the two lenses will always give a virtual, erect and diminished image irrespective of the position of the object?

Answer: Power of lens is defined as the efficiency with which a lens can converge or diverge the light ray.

The reciprocal of focal length of the lens is called the power of the lens (P).

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

The S.I unit of power of lens is dioptre denoted by D.

f_1 = 50cm = 0.5m (1m = 100cm)

⇒ $P_1 = 1/f1$

$P_1 = 1/0.5$

P_1 = 2D

Since Power is positive therefore the lens with focal length 50cm is convex lens.f_2 = -50cm = -0.5m (1m = 100cm)

⇒ P_2 = 1/f1

P_2 = 1/-0.5

P_2 = -2D

Since Power is negative therefore the lens with focal length -50cm is concave lens. The image formed by the concave lens is virtual, erect and diminished irrespective of the position of the object.

Q. 23. A 5 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 18 cm at a distance of 12 cm from it. Use lens formula to determine the position, size and nature to the image formed.

Answer: According to the question;

Object distance = -12cm;

Image distance = v;

Focal length = 18cm;

By lens formula;

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

$$\Rightarrow \frac{1}{v}-\frac{1}{-12}=\frac{1}{18}$$

$$\Rightarrow \frac{1}{v}=\frac{1}{18}-\frac{1}{12}$$

$$\Rightarrow \frac{1}{v}=\frac{2-3}{36}=\frac{-1}{36}$$

$$\Rightarrow \frac{1}{v}=\frac{-1}{36}$$

⇒ v = -36cm.

Therefore, image is formed at 36 cm in front of lens.

Now;

Height of object h_1= 5cm;

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

Putting values of v and u

Magnification = $\frac{h_2}{5} = \frac{-36}{-12}$

$\Rightarrow \frac{h_2}{5} = 3;$

$\Rightarrow h_2 = 3 \times 5 = 15$

Height of image is 15 cm.

Thus, the image is virtual, enlarged, and erect and three times the size of object.

Q. 24.A. What is meant by 'power of a lens'?

Answer: Power of lens is defined as the efficiency with which a lens can converge or diverge the light ray.

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

Q. 24.B. State and define the S.I. unit of power of a lens.

Answer: The S.I unit of power of lens is dioptre denoted by D.

1 D = $\frac{1}{1m} = 1m^{-1}$

Thus 1 Dioptre is the power of the lens having focal length of 1m.

Q. 24.C. A convex lens of focal length 25 cm and a concave lens of focal length 10 cm are placed in close focal contact with each other. Calculate the lens power of this combination.

Answer: Given;

Focal Length of convex lens f_1 = 25cm = 0.25m (1m = 100cm);

Focal Length of concave lens f_2 = -10cm = -0.1m (1m = 100cm);

Power of convex lens $P_1 = \frac{1}{f_1} = \frac{1}{0.25} = \frac{1}{1/4}$

∴ P1 = 4D.

Power of concave lens $P_2 = \frac{1}{f_2} = \frac{1}{-0.1} = \frac{-1}{1/10}$

∴ P_2 = -10D.

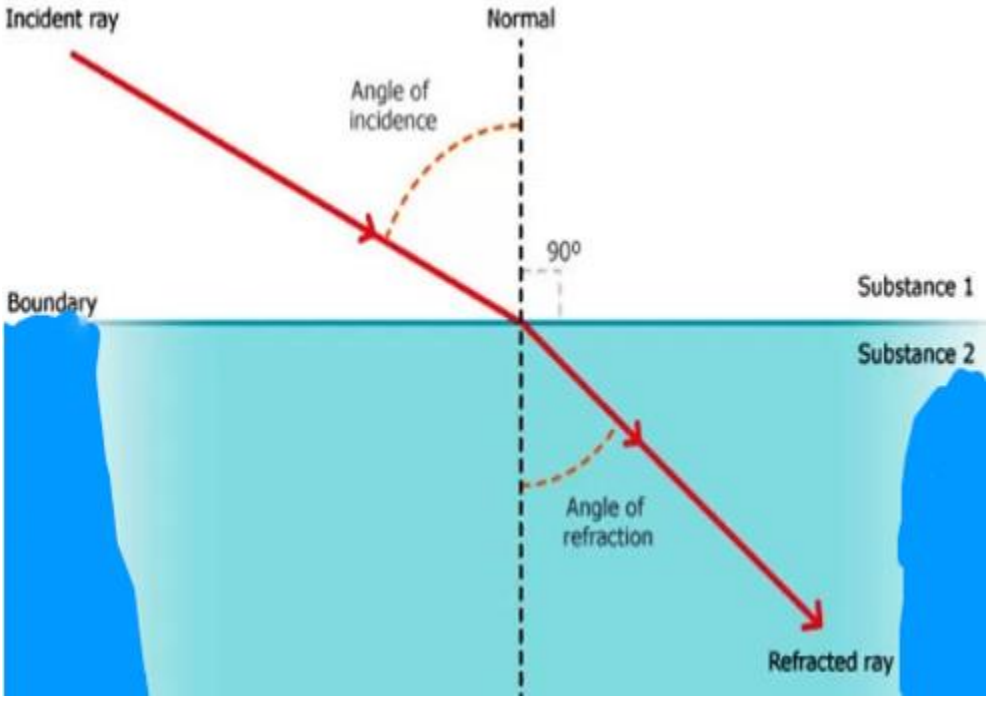
Power of combination = $P_1 + P_2$ = 4-10 = 6D.

Thus, power of combination is -6 Dioptre.

Q. 25.A. With the help of a ray diagram, state the meaning of refraction of light. State Snell's law of refraction of light and also express it mathematically.

Answer: Refraction of light is the phenomenon of bending of light as it travels from one medium to the other. When a ray of light travels from one transparent medium to the other it bends at the surface, this is due to the different optical density of different medium.

The figure below illustrates the refraction of light.



Snell's Law states that ratio of sine of angle of incidence and angle of refraction of two medium is always constant.

Mathematically it is given as

$$\frac{\sin i}{\sin r} = \text{constant} = {}^{a}\mu_{b}$$

${}^{a}\mu_{b}$ = is the refractive index of medium a with respect to medium b

Q. 25.B. The refractive index of water with respect to vacuum is $\frac{4}{3}$ and refractive index of vacuum with respect to glass is $\frac{2}{3}$. If the speed the speed of light in glass is 2×10^8 ms^{-1}, find the speed of light in (i) vacuum, (ii) water.

Answer: Given;

Refractive index of (R.I) water w.r.t vacuum $= \frac{4}{3}$

Refractive index (R.I) of vacuum w.r.t glass $= \frac{2}{3}$

Refractive index (R.I) of glass to vacuum will be = $\frac{3}{2}$

Refractive index of glass to water = $\frac{\text{R.I of glass}}{\text{R.I of water}} = \frac{\frac{3}{2}}{\frac{4}{3}}$

$\Rightarrow$ Refractive index of glass w.r.t water = $\frac{3 \times 3}{4 \times 2} = \frac{9}{8}$

$\Rightarrow \frac{\text{speed of light in water}}{\text{speed of light in glass}} = \frac{9}{8}$

$\Rightarrow \frac{\text{speed of light in water}}{2 \times 10^8} = \frac{9}{8}$

$\Rightarrow$ Speed of light in water $= \frac{9 \times 2 \times 10\text{^}8}{8}$

$\Rightarrow$ Speed of light in water $= \frac{9 \times 10^8}{4} = 2.25 \times 10^8$

Thus, speed of light in water = 2.25×10^8.

Refractive index of water w.r.t vacuum = $_v\mu_w = \frac{4}{3}$.

$\Rightarrow \frac{\text{Speed of light in vacuum}}{\text{speed of light in water}} = \frac{4}{3}$

$\Rightarrow \frac{\text{speed of light in vacuum}}{2.25 \times 10^8} = \frac{4}{3}$

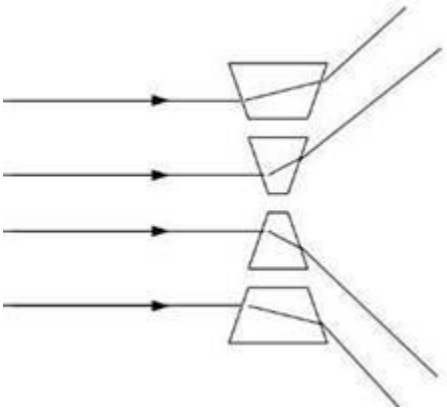
$$\text{Speed of light in vacuum} = \frac{4 \times 2.25 \times 10^8}{3}$$

$$\Rightarrow \text{speed of light in vacuum} = \frac{9\times10^8}{3}$$

Thus, speed of light in vacuum is 3×10^8 m/s.

Q. 26.A. With the help of a ray diagram explain why a concave lens diverges the rays of a parallel beam of light.

Answer: Concave lens works on the principle of refraction. We can divide the lens into tiny pieces which resembles a triangular prism (shown in figure), thus when the light ray fall it refracts the light either inwards or outwards due to its shape. Concave lens is thicker outside and thinner at edges. So the light rays are refracted outside the figure below illustrates it more clearly.



Q. 26.B. A 2.0 cm tall object is place perpendicular to the principal axis of a concave lens of focal length 15 cm. At what distance from the lens, should the object be placed so that it forms an image 10 cm from the lens? Also find the nature and the size of image formed.

Answer: According to the question;

Object distance = u;

Image distance (v) = -10cm;

Focal length = -15cm;

By lens formula;

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

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

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

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

$$\Rightarrow \frac{1}{u} = \frac{-1}{30}$$

⇒ u = -30cm.

Thus, object should be placed 30cm in front of lens.

Now;

Height of object h_1= 2cm;

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

Putting values of v and u

Magnification = $\frac{h_2}{2} = \frac{-10}{-30}$

$$\Rightarrow \frac{h_2}{5} = \frac{1}{3};$$

$$\Rightarrow h_2 = \frac{5}{3} = 1.67$$

Height of image is 1.67 cm.

Thus, the image is virtual, diminished, and erect and one-third of the size of object.

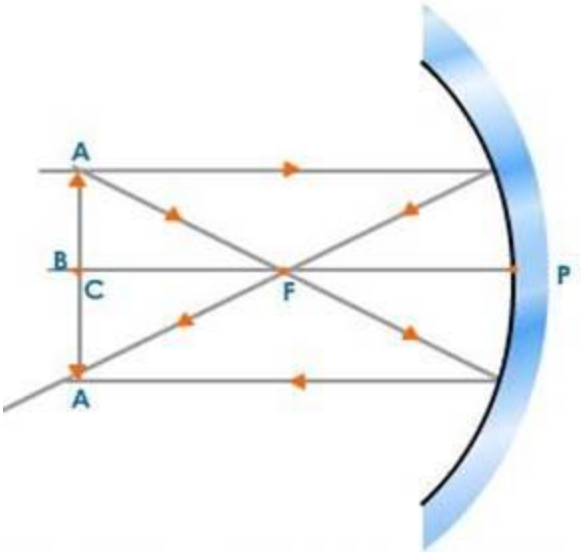
Q. 27.A. Draw the ray diagram in each case to show the position and nature of the image formed when the object is placed:

At the centre of curvature of a concave mirror

Answer: Position of Image: At the centre of curvature.

Nature of Image: Real and inverted and same as object size

Ray diagram:



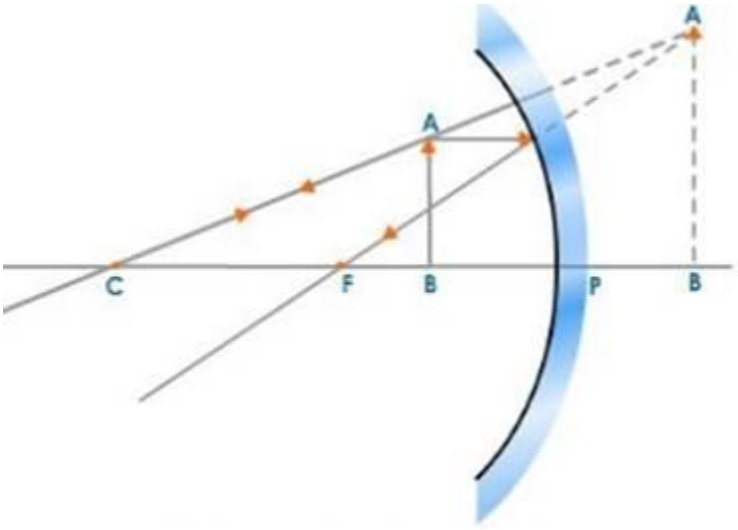
Q. 27.B. Draw the ray diagram in each case to show the position and nature of the image formed when the object is placed:

Between the pole P and focus F of a concave mirror

Answer: Position of Image: Behind the mirror

Nature of Image: Virtual, erect and magnified.

Ray diagram:



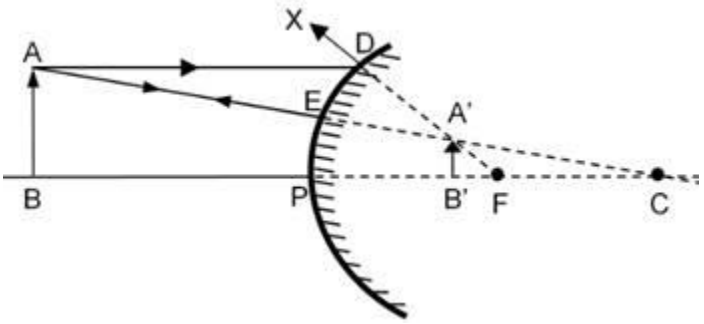
Q. 27.C. Draw the ray diagram in each case to show the position and nature of the image formed when the object is placed:

In front of a convex mirror

Answer: Position of Image: Behind the mirror

Nature of Image: Virtual, erect and diminished.

Ray diagram:



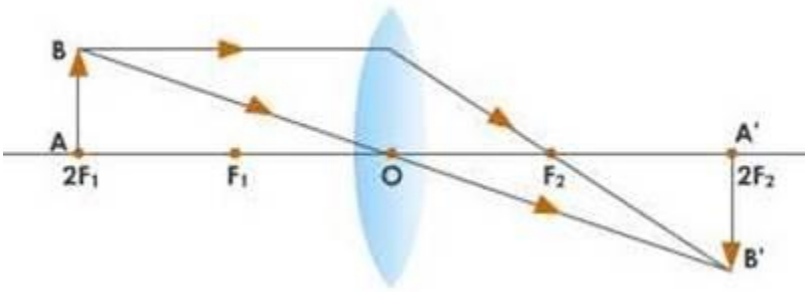
Q. 27.D. Draw the ray diagram in each case to show the position and nature of the image formed when the object is placed:

At 2f of a convex lens

Answer: Position of Image: At 2f Behind the lens.

Nature of Image: Real, inverted and same as object size.

Ray diagram:



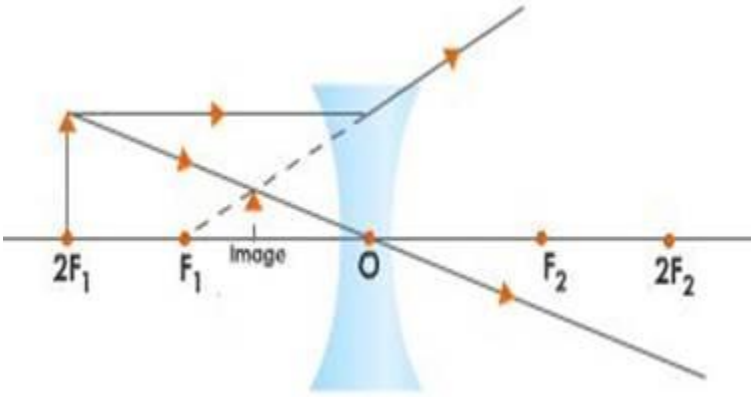
Q. 27.E. Draw the ray diagram in each case to show the position and nature of the image formed when the object is placed:

In front of a concave lens

Answer: Position of Image: Behind the lens

Nature of Image: Virtual, erect and diminished.

Ray diagram:


2F1
F1
Image
O
F2
2F2