Light-Reflection and Refraction

CHAPTER 10

EXAM DRILL

ANSWERS

1. Here, $m = 2$, $h_1 = 1$ m, $h_2 = ?$

As $m = \frac{h_2}{h_1}$ or $h_2 = m\,h_1 = 2 \times 1 = 2$ m.

2. Silver metal is the best reflector of light.

3(i) No change. The focal length of a concave mirror does not depend on the nature of medium.

3(ii) Two concave mirror with smaller aperture forms the sharper image.

3(iii) As R is negative for a concave mirror,

so $f = \frac{R}{2} = \frac{-15}{2} = -7.5$ cm

3(iv) The ratio of height of the image to that of object is called magnification.

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

4(i) Convex mirror as magnification is always positive for convex mirror.

4(ii) For a concave mirror,

focal length $f = \frac{R}{2}$

Here, $f = -20.0$ cm, then radius of curvature.

$R = -20.0 \times 2 = -40.0$ cm

4(iii) **(b)**

4(iv) **(d)**

5. **(c)**

6. **(a)**

7. **(c) :** When object is placed between the focus and centre of curvature of a concave mirror, a real and inverted image larger than the actual object is formed.

OR

(a) : As the emergent rays are parallel to the incident rays and shifted sidewards, therefore, a rectangular glass slab can be inside the box.

8. **(b) :** In torches, searchlights and headlights of vehicles, the bulb is placed very near to the focus of the reflector to get powerful parallel beams of light.

9. **(c) :** When light is refracted/reflected from a surface, then frequency of light does not change because it depends on the source of light.

OR

(c) : A convex lens produces an erect, enlarged image if the object lies between focus and pole *i.e.*, $u < f$. Hence, $u = -15$ cm.

10. **(d) :** A convex mirror always forms a virtual erect and diminished image.

11. **(a)**

12. **(d) :** For concave lens $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$$\Rightarrow \frac{u}{v} - 1 = \frac{u}{f} \Rightarrow \left(\frac{1}{n} - 1\right) = \frac{u}{f} \;\therefore\; u = \left(\frac{1-n}{n}\right) f$$

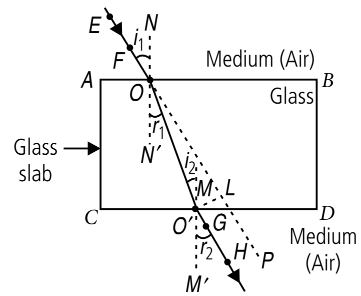
13. **(d) :** $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \Rightarrow -\frac{1}{15} + \frac{1}{v} = \frac{1}{5}$

$$\left[\because f = \frac{R}{2} \; i.e. \; f = 5 \text{ cm}\right]$$

$\therefore \quad v = \frac{15}{4}$ cm $= 3.75$ cm (behind the mirror).

14. **(a) :** Optical density and mass density are not related to each other. Mass density is mass per unit volume. It is not possible that mass density of an optically denser medium may be less than that of an optically rarer medium (optical density is the ratio of the speed of light in two media). *e.g.*, turpentine and water. Mass density of turpentine is less than that of water but its optical density is higher.

15.



A light ray incident on a rectangular glass slab immersed in any medium emerges parallel to itself because the extent of bending of the ray of light at the opposite parallel faces AB (medium-glass interface) and CD (glass-medium interface) of the rectangular glass slab is equal and opposite.

OR

Distance of the object from the pole (u) = – 10 cm

[u is always negative]

Distance of the image from the pole (v) = ? [To be calculated]

Focal length of convex mirror (f) = + 15 cm [f for the convex mirror is positive]

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

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

$\therefore \quad v = +6$ cm

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

Nature : Image is virtual, erect and diminished.

16. Given that : $\mu_g = 1.52,\ \mu_r = 1.71, v_g = 2\times10^8$ m/s

Absolute refractive index of a medium, $\mu_m = \frac{c}{v}$

where, c is the speed of light in vacuum and v is the speed of light in medium.

(a) $\therefore\ \mu_g = \frac{c}{v_g}$

or $c = \mu_g \times v_g = 1.52\times2\times10^8 = 3.04\times10^8$ m/s

(b) As, $\mu_{gr} = \frac{\mu_g}{\mu_r} = \frac{v_r}{v_g}$

$\therefore \quad \frac{1.52}{1.71} = \frac{v_r}{2\times10^8}$ or $v_r = 0.89\times2\times10^8$

$\Rightarrow \quad v_r = 1.78\times10^8$ m/s

17. Laws of refraction of light :

(i) The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie in the same plane.

(ii) The ratio of sine of angle of incidence to the sine of the angle of refraction is constant, for the light of a given colour and for the given pair of media.

This law is also known as Snell's law of refraction.

$\frac{\sin i}{\sin r}$ = constant,

where i is the angle of incidence and r is the angle of refraction.

This constant value is called refractive index of the second medium with respect to the first when the light travels from first medium to second medium.

$\Rightarrow$ constant $= \mu_{21} = \frac{v_1}{v_2} \quad \therefore \quad \frac{\sin i}{\sin r} = \frac{v_1}{v_2}$

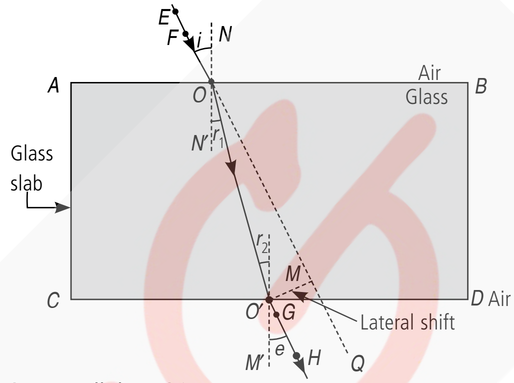
If μ is the absolute refractive index of the medium, c is the velocity of light in vacuum and v is the speed of light in a given medium, then $\mu = c/v$.

18. Principle of reversibility of light states that the light will follow exactly the same path if the direction is reversed.

Using Snell's law of refraction,

$\frac{\sin i}{\sin r_1} = \frac{\sin e}{\sin r_2}$

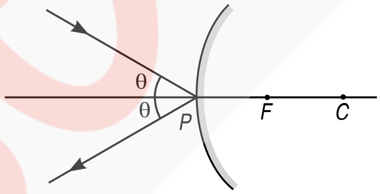
Since $r_1 = r_2$, so $i = e$



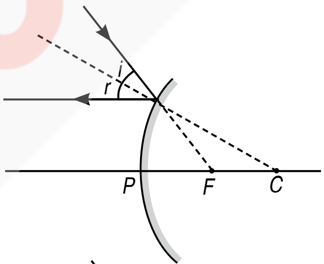
So, PQ is parallel to $O'H$.

So, we can conclude that incident ray is parallel to the emergent ray.

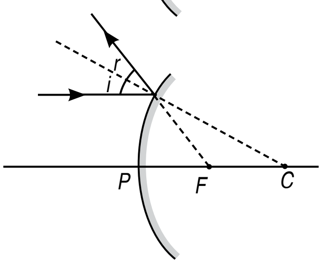
19. (a)



(b)



(c)



OR

(a) $\mu_{ag} = \frac{c_{air}}{v_{glass}}$

$\therefore \quad v_{glass} = \frac{c_{air}}{\mu_{ag}} = \frac{3\times10^8 \text{m/s}}{1.5} = 2\times10^8$ m/s.

(b) Frequency of light does not change with change in optical medium, hence, remains the same.

(c) $\frac{\text{Speed of light in air}}{\text{Speed of light in glass}} = \frac{\text{Wavelength of light in air}}{\text{Wavelength of light in glass}}$

$$\frac{3\times10^8 \text{m/s}}{2\times10^8 \text{m/s}} = \frac{500 \text{ nm}}{\text{Wavelength of light in glass}}$$

$\therefore$ Wavelength of light in glass $= \frac{500\times2}{3} = 333.3$ nm.

20. $P = P_1 + P_2 = 12.5 - 2.5 = 10$ D

$$f = \frac{1}{P} = \frac{1}{10} = 0.1 \text{m} = 10 \text{ cm}$$

$u = -15$ cm

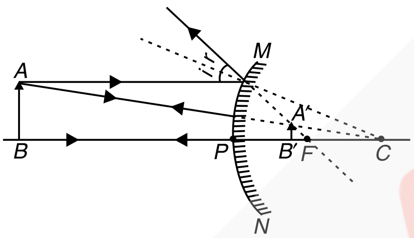
$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{10} - \frac{1}{15}$$

or $v = +30$ cm

$$m = \frac{v}{u} = \frac{30}{15} = -2$$

Image formed is real, inverted and magnified.

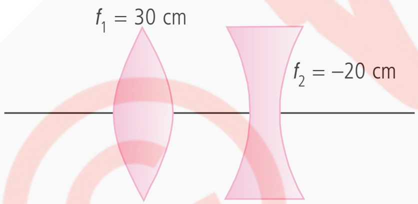
21. **(a)** If the image formed by a spherical mirror is always erect and diminished then it is convex mirror.



(b) Thick convex lens will have shorter focal length than that of thin convex lens.

OR

Equivalent focal length of the combination



$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2} \Rightarrow \frac{1}{f_{eq}} = \frac{1}{30} + \frac{1}{-20} = \frac{2-3}{60}$$

$f_{eq} = -60$ cm

System will behave as a diverging lens of focal length 60 cm.

22. Given, $f = -30$ cm, $v = -40$ cm, $u = ?$

Using $\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{u} = \frac{1}{f} - \frac{1}{v} = \frac{1}{-30} - \frac{1}{-40} = \frac{-4+3}{120}$

$\Rightarrow$ $u = -120$ cm

$\therefore$ Object is placed at 120 cm from the mirror.

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

$$\Rightarrow h' = \frac{-(-40)}{-120} \times 6 = -2 \text{ cm}$$

$\therefore$ The size of the image is 2 cm.

23. Given, $h' = \frac{1}{3}h$, $u = -9$ cm

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

$$\Rightarrow v = \frac{h'}{h} \times u = \frac{-\frac{1}{3}h}{h} \times (-9) = 3 \text{ cm}$$

Using lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$$\Rightarrow \frac{1}{f} = \frac{1}{3} - \frac{1}{-9} = \frac{3+1}{9} \Rightarrow f = 2.25 \text{ cm}$$

$\therefore$ Focal length of the convex lens = 2.25 cm

24. Power is the degree of convergence or divergence of light rays achieved by a lens.

It is defined as the reciprocal of its focal length.

i.e., $P = \frac{1}{f}$

Positive sign (+) of power indicates that lens is convex and negative sign (–) of power indicates that lens is concave.

The SI unit of power is dioptre. Thus, 1 dioptre is the power of lens whose focal length is 1 metre. 1 D = 1 m^{-1}

Given that :

Focal length of lens *A*, $f_A = +40$ cm

Focal length of lens *B*, $f_B = -20$ cm

Lens *A* is converging and lens *B* is diverging.

Power of lens $A = \frac{100}{f_A(\text{in cm})} = \frac{100}{40} = +2.5$ D

Power of lens $B = \frac{100}{f_B(\text{in cm})} = \frac{100}{-20} = -5$ D

25. Given : Focal length (f) = – 40 cm

Magnification (m) = 3

Distance of the object (u) = ?

Since the nature of the image so formed is not specified, so two cases arise here.

Formula to be used : $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

Since only f and m are given, therefore, we cannot use this formula directly and instead first use the formula,

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

Case I : When image formed is real, $v = +3u$ cm

Substituting the given values, we get

$$\frac{1}{3u} + \frac{1}{u} = \frac{1}{-40} \Rightarrow \frac{1+3}{3u} = \frac{1}{-40} \Rightarrow \frac{3u}{4} = -40$$

$\therefore \quad u = -53.33$ cm

Case II : When image formed is virtual, $v = -3\,u$ cm

Substituting the given values, we get

$$-\frac{1}{3u} + \frac{1}{u} = -\frac{1}{40} \Rightarrow \frac{-1+3}{3u} = -\frac{1}{40}$$

$$\Rightarrow \frac{2}{3u} = -\frac{1}{40} \Rightarrow u = \frac{-80}{3} \quad \therefore u = -26.67 \text{ cm}$$

Hence, if the object is held at a distance of 53.33 cm, a real image thrice in size is obtained. Also, a virtual image of thrice the size is obtained if the distance of the object is 26.67 cm.

OR

To calculate position of the image

$$\frac{h_i}{h_0} = \frac{-v}{u} \quad \begin{cases} h_i = -1\cdot5, \text{because real image is inverted} \\ u = -15, \text{because } u \text{ is always negative} \end{cases}$$

$$\Rightarrow \frac{-1.5}{1} = -\frac{v}{-15} \qquad \therefore \quad v = \frac{1.5}{1} \times -15 = -22\cdot5 \text{ cm}$$

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

To calculate the focal length of the mirror

$$\Rightarrow \frac{1}{f} = \frac{1}{u} + \frac{1}{v} \begin{cases} u = -15 \text{ cm as } u \text{ is always negative} \\ v = -22\cdot5 \text{ cm as calculated above} \end{cases}$$

$$\Rightarrow \frac{1}{f} = \frac{1}{-15} + \frac{1}{-22\cdot5} = \frac{-5}{45} \Rightarrow \frac{1}{f} = -\frac{1}{9}$$

$\therefore \quad f = -9$ cm

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

26. **(a)** Given, $f = -30$ cm, $u = -60$ cm, $v = ?$

Using lens formula,

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

$$\frac{1}{v} = \frac{1}{-30} - \frac{1}{60} = -\frac{3}{60} \Rightarrow v = -20 \text{ cm}$$

(b) (i) The image is virtual in nature.

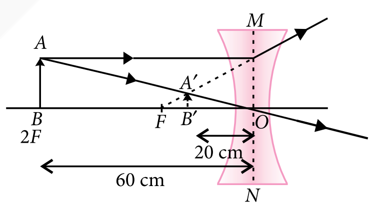
(ii) The image is formed at a distance of 20 cm on the left from the concave lens.

(iii) Magnification, $m = \frac{v}{u}$

Here, $v = -20$ cm; $u = -60$ cm, So, $m = \frac{20}{60} = \frac{1}{3} = +0.3$

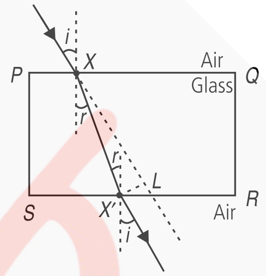
Since value of magnification is less than 1, therefore, the image is diminished.

(iv) The plus sign for the magnification shows that the image is erect.



27. Consider a rectangular glass slab *PQRS* placed in air. When a ray of light is incident on surface *PQ* (air-glass interface) making angle *i* with normal, it bends towards the normal. The refracted ray makes angle *r* with normal. Now, this refracted ray falls on surface *RS* (glass-air interface) and emergent ray bends away from the normal.

At air-glass interface, the refracted ray bends towards normal as it enters from rarer to denser medium and it bends away from normal at glass-air interface because light ray passes from denser to rarer medium.



As can be seen that at point *X* and *X*′, the incident ray, the refracted ray and the normal all lie in the same plane.

Also, refractive index of glass with respect to air,

$$\mu_{ga} = \frac{\sin i}{\sin r}$$

and refractive index of air with respect to glass,

$$\mu_{ag} = \frac{\sin r}{\sin i} \quad \text{or} \quad \mu_{ga} = \frac{1}{\mu_{ag}}$$

OR

Here, $u = -16$ cm and $f = 12$ cm.

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

$$= \frac{1}{-16 \text{ cm}} + \frac{1}{12 \text{ cm}} = \frac{1}{48 \text{ cm}} \text{ or } v = +48 \text{ cm.}$$

The image if formed 48 cm from the lens on the left side of the lens. The image is, therefore, real.

The magnification is $m = \frac{v}{u} = \frac{48 \text{ cm}}{-16 \text{ cm}} = -3$.

or $\frac{h_i}{h_0} = -3$ or $h_i = -3h_0 = -3 \times 2 \text{ cm} = -6$ cm.

The image is inverted and is 6 cm in size. So an inverted and real image of size 6 cm is formed at a distance 48 cm from the lens.

28. **(a)** Given, $h = 5$ cm, $f = 20$ cm, $u = -30$ cm

Using lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

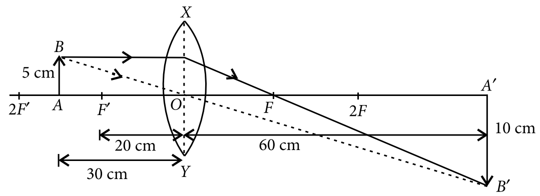
$$\frac{1}{v} = \frac{1}{u} + \frac{1}{f} = \frac{1}{-30} + \frac{1}{20} = \frac{-2+3}{60} = \frac{1}{60} \Rightarrow v = 60 \text{ cm}$$

Now, magnification, $m = \frac{h'}{h} = \frac{v}{u}$

$$\Rightarrow h' = \frac{v}{u} \times h = \frac{60}{-30} \times 5 = -10 \text{ cm}$$

Hence, image of size 10 cm, which is real, inverted and magnified, is formed at 60 cm from the lens.

(b)



29. For lenses, we follow sign convention, similar to one used for spherical mirrors. We apply the rules for signs of distances, except that all measurements are taken from the optical centre of the lens.

Sign Convention for Reflection by Spherical Mirrors : While dealing with the reflection of light by spherical mirrors, we shall follow a set of sign conventions called the New Cartesian Sign Convention. The conventions are as follows:

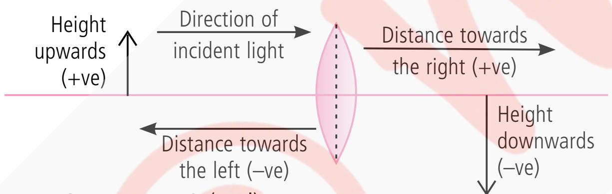
(i) The object is always placed to the left of the mirror. This implies that the light from the object falls on the mirror from the left-hand side.

(ii) All distances parallel to the principal axis are measured from the pole of the mirror.

(iii) All the distances measured to the right of the origin (along + x-axis) are taken as positive while those measured to the left of the origin (along – x-axis) are taken as negative.

(iv) Distances measured perpendicular to and above the principal axis (along + y-axis) are taken as positive.

(v) Distances measured perpendicular to and below the principal axis (along-y-axis) are taken as negative.



$u = -16$ cm, $m = -3$ (real)

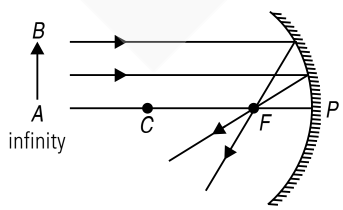
As, $m = \frac{v}{u}$ $\therefore$ $-3 = \frac{v}{-16}$ or $v = 48$ cm

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

$\therefore$ $\frac{1}{48} - \frac{1}{-16} = \frac{1}{f}$ or $\frac{1+3}{48} = \frac{1}{f} \Rightarrow \frac{1}{f} = \frac{1}{12}$ or $f = 12$ cm

Spherical lens is convex lens or converging lens of focal length 12 cm.

30.



Differences between concave and convex mirrors

	Concave mirror	Convex mirror
(i)	Its focus is situated in front of the mirror.	Its focus is situated behind the mirror.
(ii)	Its radius of curvature and the focal length are negative.	Its radius of curvature and focal length are positive.
(iii)	The incident rays are reflected from its concave surface.	The incident rays are reflected from its convex surface.
(iv)	Its convex side is polished.	Its concave side is polished.
(v)	The image distance for this may be positive or negative because the real image is formed in front of the mirror and virtual image is formed behind the mirror.	The image distance is always positive.
(vi)	The image formed by it may be erect, inverted magnified or smaller.	The image formed by it is erect and smaller.
(vii)	Its field of view is narrow.	Its field of view is broad.
(viii)	Concave mirrors are used as make-up mirrors, as reflectors, for medical purposes in light houses in seas, in ophthalmoscope, in torch for hunting purpose.	Convex mirrors are used in night lamps on roads and as side mirrors in cars to view the vehicles behind.

OR

(a) Distance between the principal focus and the optical centre is known as the focal length of the lens.

(b) Given, $f = -30$ cm, $v = -15$ cm, $h = 6$ cm

Now, from lens formula,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{-1}{30} = \frac{-1}{15} - \frac{1}{u} \Rightarrow \frac{1}{u} = \frac{-1}{15} + \frac{1}{30} \Rightarrow u = -30 \text{ cm}$$

$$m = \frac{h'}{h} = \frac{v}{u} \Rightarrow h' = \left(\frac{v}{u}\right)h \Rightarrow h' = \frac{-15}{-30} \times 6 \text{ cm} = 3 \text{ cm}$$

(c)