4 LIGHT REFLECTION AND REFRACTION

4.1 INTRODUCTION

A thought always comes to our mind that how the various things (objects) become visible to us? Which phenomenon is the cause for it? Actually it is the light that helps us in visualizing the objects.

Light is an electromagnetic waves within a small range of wavelength of about 400×10^{-9} m to 750×10^{-9} m.

When the light relfected from an object excites the retina of our eye then the object becomes visible to us.

In this chapter, first of all, we will study about the nature of light and will try to understand in what form the light is emitted from a source and it propagates from one place to another place?

After this, we will consider the phenomenon of reflection and refraction, using the ray picture of light. Using the basic laws of reflection and refraction, we shall study the image formation by plane and spherical reflecting and refracting surfaces.

4.2 PROPERTIES OF LIGHT

Light is an electromagnetic wave within a small range of wavelength of about 4000×10^{-10} m to 7500×10^{-10} m. In some phenomena light behaves as particle and in some other phenomena it behaves as wave.

Since wavelength of light is very small compared to the size of ordinary objects that we encounter commonly. So, it can be considered to travel from one point to another along a straight line joining them. The path is called a ray of light, and the bundle of such rays constitutes a beam of light.

The light has the following properties:

(i) Light travel in a straight line

(ii) Medium is not required for the propagation of this wave.

(iii) Velocity of light is maximum in vacuum and is equal to 3×10^{8} m/s.

(iv) These waves are transverse in nature and the properties of the medium through which these waves propagate remain unaffected.

(v) When these waves are incident upon some surface they produce pressure on the surface. This is known as radiation pressure.

4.3 REFLECTION OF LIGHT

4.4 IMAGE

The reproduction of an object formed by mirrors or lenses is called image of the object. Images are of two types:

(i) An image which is formed by actual convergence of the rays of light is called ***real image***. It can be obtained on a screen.

(ii) An image which only appears to the eye to be formed by the rays of light is called ***virtual image***. It cannot be obtained on a screen.

*4.5 REFLECTION FROM PLANE SURFACE

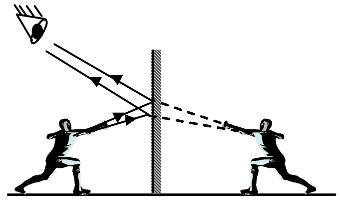


Figure 4.4

The bundle of rays from the top of the object appears to originate from the image behind the mirror

- **Characteristics of image formed by a plane mirror**

(i) It is virtual, erect and of the same size as object.

(ii) It is as far behind the mirror as the object is in front of it.

(iii) It is laterally inverted.

- **Some facts:**

(i) The focal length and radius of curvature of a plane mirror are infinite. This means that the power of plane mirror is zero.

(ii) The magnification of a plane mirror is 1.

(iii) If the object moves with speed 'u' towards a fixed mirror, the image also moves towards the mirror with speed 'u'. The speed of the image relative to the object in this case in '2u'

(iv) If the mirror moves with speed 'u' towards or away from a fixed object, then image appears to move towards or away from the observer with speed '2u'

(v) If the mirror moves away or towards an object by a distance 'd', then the image moves away or towards the object by a distance '2d'.

(vi) If a mirror is rotated in the plane of incidence by an angle θ, then the reflected ray is turned through an angle '2θ'.

(vii) On reflection from a plane mirror, a ray is deviated through an angle $\delta = (180 - 2i)$, where 'i' is the angle of incidence. If α is the glancing angle (i.e. angle between the plane mirror and the incident ray), then the deviation on reflection $\delta = 2\alpha$, $(\alpha = 90 - i)$

(viii) The minimum size of the mirror required to see full size image of one self is equal to half the height of the observer.

Illustration 2

A car is moving towards a plane mirror at a speed of 30 m/s. Then the relative speed of its image with respect to the car will be

(A) 30 m/s ***(B) 60 m/s*** ***(C) 15 m/s*** ***(D) 45 m/s***

Solution

Speed of car towards the mirror = 30 m/s

And speed of image of car with respect to car = 2 × 30 = 60 m/s

$\therefore$ **(B)**

4.6 REFLECTION FROM SPHERICAL SURFACE

4.6.1 Spherical Mirror

A part of a spherical reflecting surface. Spherical mirrors are of two kinds.

(i) **Concave mirror :** The reflecting surface is towards the centre of the sphere (or bent in reflecting surface).

(ii) **Convex mirror :** The reflecting surface is away from the centre (or bulged-out reflecting surface).

4.6.2 Important Terms

(i) **Pole :** The centre of the spherical mirror.

(ii) **Centre of Curvature :** Centre of the sphere of which the mirror forms a part.

(iii) **Radius of curvature :** The radius of the spherical surface of which the mirror is a part.

(iv) **Linear aperture :** Distance between two extreme points on the periphery of the spherical mirror

(v) **Angular aperture :** The angle which the periphery of spherical mirror subtends at the centre of curvature.

(vi) **Principal axis :** The line joining the pole and the centre of curvature.

(vii) **Principal focus :** The point on the principal axis at which all the light rays parallel to the principal axis after reflection from the spherical mirror converge (concave mirror) or appear to diverge from (convex mirror).

(viii) **Focal length :** The distance between the pole and principal focus denoted by f.

(ix) **Paraxial rays :** The rays parallel and close to the principal axis.

(x) **Marginal or Peripherial rays :** The rays parallel and away from the principal axis and strike the mirror near its boundary.

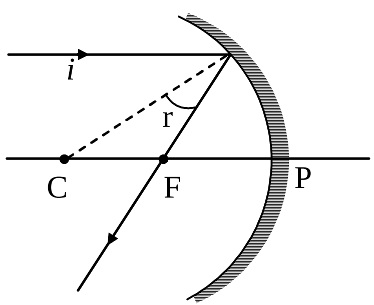
(xi) **Focal Plane :** Plane passing through the principal focus and at right angles to the principal axis.

4.6.3 Rules for constructing the images formed by spherical mirrors

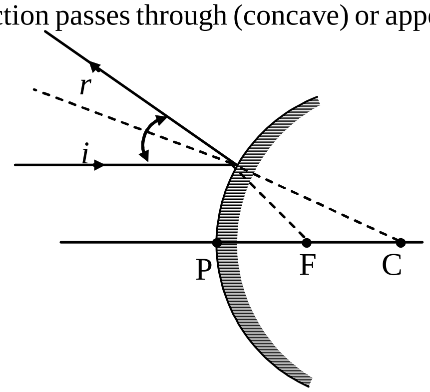
To construct the ray diagram, in order to locate the image of an object, it is convenient to consider only two rays.

The intersection of at least two reflected rays give the position of image of the point object. Any two of the following rays can be considered for locating the image.

(i) A ray parallel to the principal axis after reflection passes through (concave) or appear to come from the principal focus (convex).



Concave mirror
(a)



Convex mirror
(b)

4.6.4 Image formation in case of spherical mirrors

(i) As the object gradually moves from infinity towards the focus of a concave mirror, the image moves from focus to infinity. The image formed is real, inverted and its size increases gradually.

(ii) As the object comes at the focus of the concave mirror, its real inverted and highly magnified image is formed at infinity.

(iii) As the object come between the focus and pole of the concave mirror, its virtual, erect and magnified image is formed behind the mirror.

(iv) As the object gradually moves from infinity towards the pole of a convex mirror, then irrespective of the placement of the object in front of the mirror, the image formed is always virtual, erect and diminished and is formed behind the mirror. The size of the image goes on increasing as the object is moved closer to the mirror.

(a) Image formation by concave mirror

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

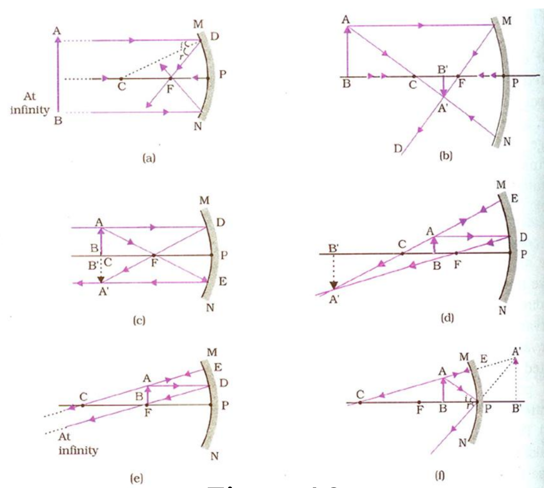


Figure 4.9

(a) Image formation by convex mirror

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

In this convention, the pole (P) of the mirror is taken as the origin. The pricipal axis of the mirror is taken as the x-axis (X´X) of the coordinate system. 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.

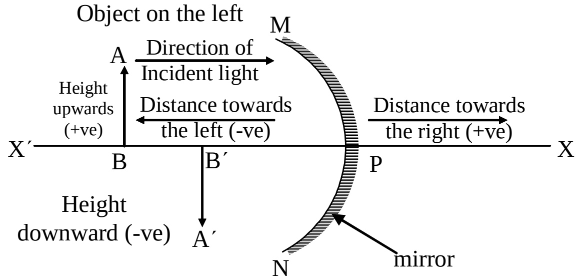


Figure 4.12

4.6.7 Mirror Formula and Magnification

(a) Mirror Formula: $\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$

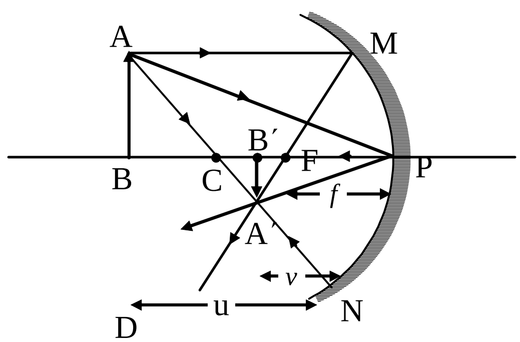


Figure 4.13

(b) Linear Magnification (m)

Linear magnification is define as the ratio of the height of the image (h´) to the height of the object (h)

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

In triangles A´B´P and ABP, we have

$$\frac{B'A'}{BA}=\frac{B'P}{BP}$$

with the sign convention, this becomes

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

So that,

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

or $\frac{1}{v} = -\frac{1}{7.5} + \frac{1}{5}$ or $\frac{1}{v} = \frac{-5+7.5}{7.5 \times 5}$

or $v = \frac{7.5 \times 5}{2.5}$ or $v = 15$ cm

This image is formed at 15 cm behind the mirror. It is a virtual image.

Magnification, $m = -\frac{v}{u} = -\frac{15}{(-5)} = 3$

The image is magnified, virtual and erect.

Try Yourself

4. The radius of curvature of a convex mirror used on a moving automobile is 2 m. A truck is coming behind it at a distance of 3.5 m. Calculate (i) the position and (ii) the size of the image relative to the size of the truck. What will be the nature of the image?

*4.6.9 Spherical Abberation

The rays of light after reflection from a concave mirror meet at a single point only if a narrow beam of light falls on the mirror. In case of a wide beam, it is found that the marginal rays get focussed relatively close to the pole in comparison to the paraxial rays.

The reflected lines form a pattern and this has an envelope known as the **caustic curve**. Because of this the image is distorted. This defect is called **spherical aberration**.

The spherical aberration is not present in **parabolic mirrors**.

4.6.10 Identification of Mirrors

(a) By Touching : (i) plane, it is a plane mirror. (ii) depressed inwards at the middle, it is a concave mirror. (iii) projected outwards at the middle, it is a convex mirror.

(b) By Seeing the Image :

(i) If the image formed is always erect and of the same size, it is a plane mirror.

(ii) If the image formed is always erect and smaller in size, it is a convex mirror.

(iii) If the image formed is erect and magnified when mirror is close to the face and the size and nature (virtual to real) of the image change on moving the mirror, it is concave mirror.

4.6.11 Uses of Mirror

(a) Concave Mirror :

(i) As reflectors in the headlights of cars, searchlights, etc.

(ii) Dentists (as the dentist's mirror) to focus light on the tooth to be examined.

(iii) Shaving mirrors and as make-up mirrors to see the enlarged erect image of the face. For this to happen, face must be placed closer to the mirror.

(iv) Concave mirror (or parabolic mirrors) are used as radiation collector in solar heating devices.

(b) Convex Mirror :

(i) rear-view mirrors or side-mirror (also called driver's mirror) on automobiles, such as cars, trucks and buses to see the traffic coming from behind.

(ii) staircase-mirrors on the double-decker buses.

(iii) vigilance-mirrors in big shops and stores.

4.7 REFRACTION

(ii) wavelength or colour of light, and

(iii) temperature of the medium.

Refractive index decreases with increase in temperature.

$$n_{21} = 1/n_{21}$$

$$n = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + ...$$

$$n_{red} < n_{yellow} < n_{violet}$$

Illustration 5

The speed of light in air is 3 × 10⁸ m/s. What will be its speed in diamond whose refractive index is 2.4?

(A) 3×10^8 m/s (B) 1.25×10^8 m/s (C) 7.2×10^8 m/s (D) 332 m/s

Solution

Speed of light in air = 3×10^8 m/s

Refractive index of diamond = 2.4

Let the speed of light in diamond = v m/s

Then, n = c/v

or $$v = \frac{c}{n} = \frac{3\times10^8}{2.4} = 1.25 \times 10^8 \text{ m/s}$$

∴ **(B)**

Illustration 6

A beam of monochromatic blue light of wavelength 420 nm in air travels in water (n = 4/3). Its wavelength in water will be

Solution

Wavelength of blue light in air = 420×10^{-9} m

Refractive index of water = 4/3

Let the wavelength of blue light in water be 'λ'

Then, $$n = \frac{c}{v} = \frac{\lambda_{air}}{\lambda_{medium}}$$

or $$\frac{4}{3} = \frac{420\times10^{-9}}{\lambda}$$

or $$\lambda = \frac{420\times10^{-9}}{40}\times3 = 315 \times 10^{-9} \text{ m} = 315 \text{ nm}$$

Try Yourself

5. The velocity of light in glass is 2×10^8 ms^{-1}, while in vacuum it is 3×10^8 ms^{-1}. What is the absolute refractive index of glass?

4.7.5 $n_{21} = \frac{n_2}{n_1}$

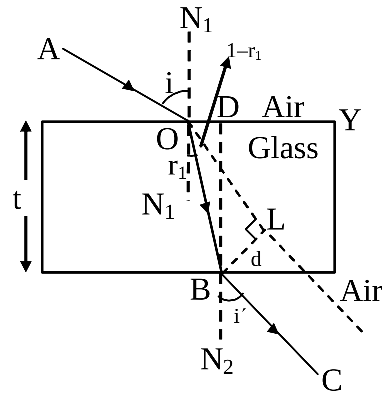


Figure 4.15

where n_{21} is refractive index of glass slab with respect to air.

At point A,

$$n_{21} = \frac{\sin i}{\sin r_1} \qquad ...(i)$$

At point B, the refractive index of air w.r.t. glass slab.

$$n_{12} = \frac{\sin r_1}{\sin i'} \qquad ..(ii)$$

We know that,

$$n_{21} = \frac{1}{n_{12}} \qquad ..(iii)$$

From equations (i), (ii) and (iii), we get

$$\frac{\sin i}{\sin r_1} = \frac{\sin i'}{\sin r_1}$$

or $\quad i = i'$

This shows that a ray of light incident obliquely on the parallel sided glass slab emerges out parallel to the incident ray. However, the incident ray is laterally displaced.

*4.8.(b) Lateral shift (d):

The perpendicular distance between the direction of incident ray and the emergent ray is known as lateral shift.

From right angled ΔBOL,

$$\sin(i - r_1) = \frac{BL}{OB} = \frac{d}{OB}$$

or $\quad d = OB \sin(i - r_1) \qquad ...(iv)$

From right angled ΔBOD,

Let an object O lie at the bottom of the bucket

i = Angle of incidence

r = Angle of refraction

OA = Real depth

O′A = Apparent depth

n_{21} = Refractive index of denser medium w.r.t. rarer medium.

According to Snell's law

$$\frac{\sin i}{\sin r} = n_{12} = \frac{1}{n_{21}} \quad ...(i)$$

From ΔAOC,

$$\sin i = \frac{AC}{OC} \quad ...(ii)$$

and from ΔAO′C,

$$\sin r = \frac{AC}{O'C} \quad ...(iii)$$

From equations (i), (ii) and (iii), we get

$$\frac{1}{n_{21}} = \frac{AC}{OC} \times \frac{O'C}{AC} \quad \text{or} \quad n_{21} = \frac{OC}{O'C}$$

Since point *C* lies very close to A, so O′C ~ O′A and OC ~ OA

or $$n_{21} = \frac{OA}{O'A}; \quad n_{21} = \frac{\text{Real depth}}{\text{Apparent depth}}$$

Normal shift in the position of the object is given by

x = AO – AO′

or $$x = AO - \frac{AO}{n_{21}} \quad \text{or} \quad x = \text{AO}\left(1 - \frac{1}{n_{21}}\right)$$

Note: If a vessel is filled with two immisible liquids of refractive indices n_1 and n_2 respectively. Such that one liquid is filled upto depth d_1 and another liquid is filled upto depth d_2 respectively, then apparent depth is given by

$$\text{Apparent depth} = \frac{d_1}{n_1} + \frac{d_2}{n_2}$$

4.9.(b) If object in rarer medium is observed from denser medium, then

$$n_{21} = \frac{\text{Apparent depth}}{\text{Real depth}}$$

where n_{21} = Refractive index of denser medium w.r.t. rarer medium.

Illustration 8

A fish in the pond of a water appears at a depth of 6 cm. What is the actual depth of the fish if refractive index of water is 4/3 ?

Try yourself

7. The refractive index of air w.r.t. glass is 2/3. The refractive index of the diamond w.r.t. air is 12/5. What is the refractive index of glass w.r.t. the diamond?

4.11 REFRACTION BY SPHERICAL LENSES

4.11.1 Lens

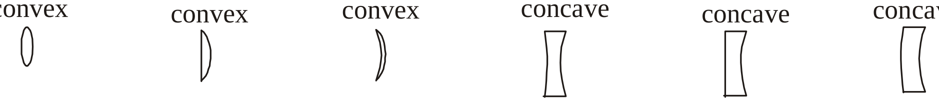
A piece of a transparent medium bounded by at least one spherical surface.

4.11.2 Types of Lens

LENS

(A piece of a transparent medium bounded by at least one spherical surface)

- Convex or coverging (thick in the middle and thin at the edges)
  - Double convex
  - Plano convex
  - Concavo convex
- Concave or diverging (Thin in the middle and thick at the edges)
  - Double concave
  - Plano concave
  - Convexo concave



4.11.3 Terms associated with spherical Lenses

(i) **Principal axis** : Line passing through the optical centre and joining the centres of curvature of the two curved surface.

(ii) **Optical centre**: It is a point lying within a lens through which the ray of light pass undeviated.

(iii) **Principal focus** : It is a point on the principal axis of the lens where all the rays of light coming parallel to the principal axis either converge actually (convex lens) or appear to diverge (concave).

(iv) **Focal length (f)** : The distance between the optical centre and the principal focus.

For a convex lens : f = +ve. For a concave lens : f = –ve

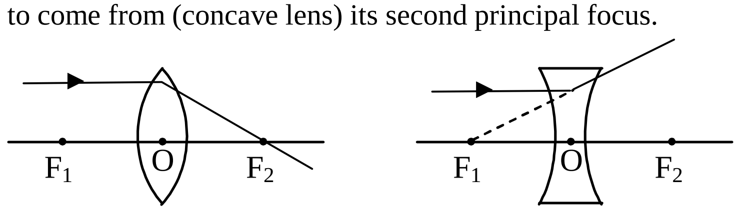
(v) **Focal plane** : A plane passing through the principal focus and perpendicular to the principal axis.

(vi) **Aperture** : The effective diameter of the light transmitting portion of the lens.

Brightness of image is directly proportional to square of aperture of the lens.

4.11.4 Rules for image formation by a Lens

(i) A ray of light travelling parallel to the principal axis, after refraction passes through (convex lens) or appears to come from (concave lens) its second principal focus.



(a) Convex lens (b) Concave lens

Figure 4.18

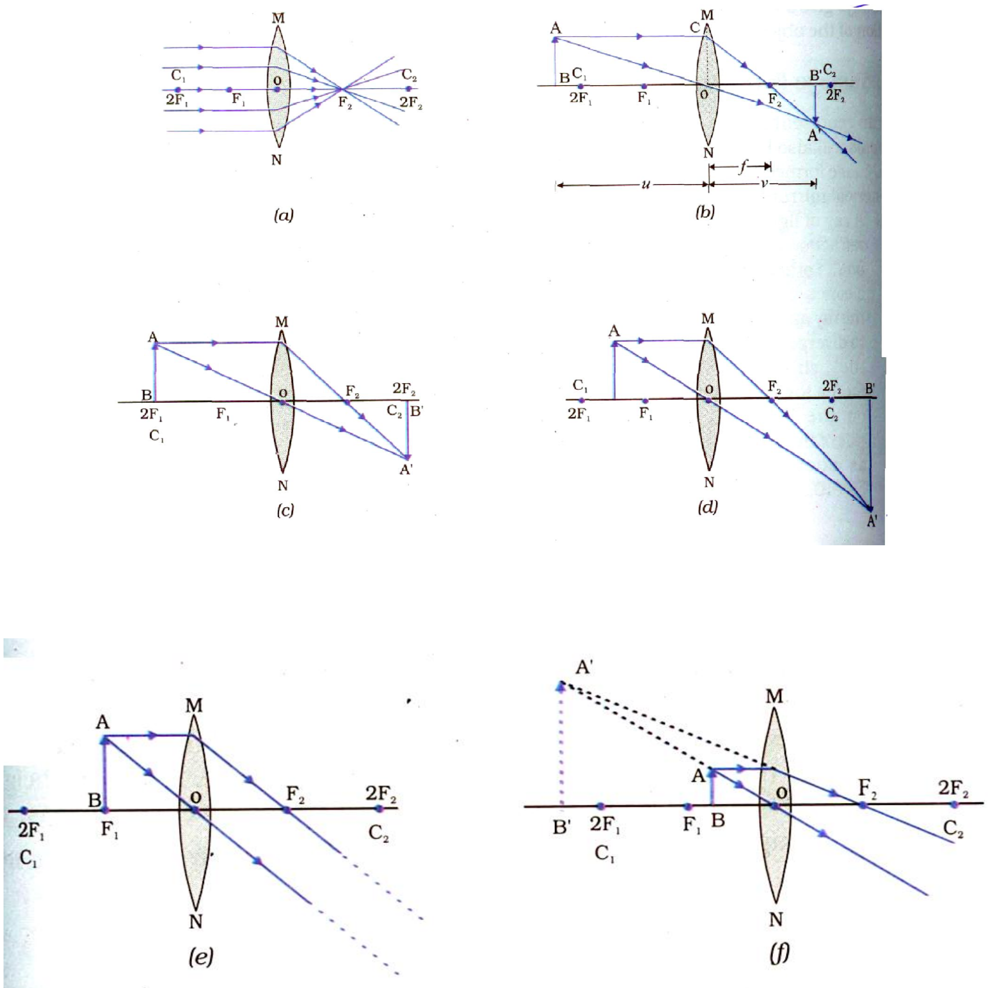


Figure. 4.21 The position, size and the nature of the image formed by a convex lens for various positions of the object

(B) Image formed by a concave lens

Position of the object	Position of the image	Relative 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 focus F_1 and optical centre O	Diminished	Virtual and erect

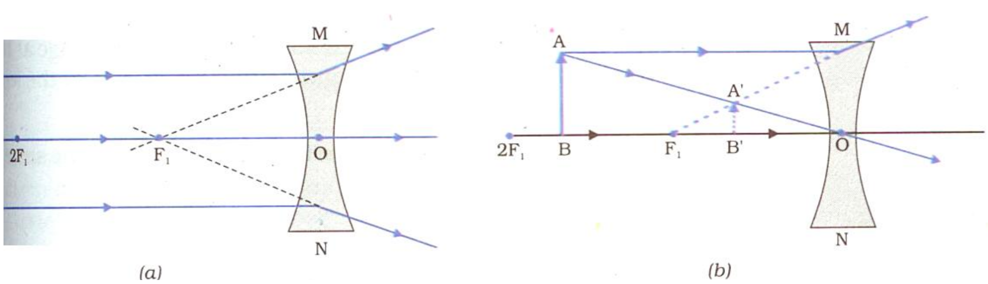


Figure. 4.22 The position, size and the nature of the image formed by a concave lens for various positions of the object

4.17.9 Power of Lens (P)

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

SI unit of power is dioptre (D).

(i) Power of a convex lens is +ve. (ii) Power of a concave lens is -ve.

• Power of a lens is the measure of its degree of convergences or divergence of light rays falling on it.

Illustration 10

The image of a needle placed 45 cm from a lens is formed on a screen placed 90 cm on the other side of the lens. Find the displacement of the image, if the object is moved by 5 cm away from the lens. Also find the power of the lens.

Solution

Case I: u = –45 cm, v = 90 cm, f = ?

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

or $\frac{1}{f} = \frac{1}{90} + \frac{1}{45} = \frac{3}{90} = \frac{1}{30}$ or f = 30 cm

Case II: u′ = –45 – 5 = –50 cm

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

or $\frac{1}{v'} = \frac{1}{f} + \frac{1}{u'} = \frac{1}{30} - \frac{1}{50}$ or $\frac{1}{v'} = \frac{2}{150}$

or $v' = \frac{150}{2} = 75$ cm or Displacement of image = 90 – 75 = 15 cm

Power of lens, $P = \frac{1}{f} = \frac{1}{30} = +0.033\ D$

Try yourself

8. An object 10 cm high is placed at the principal focus of a concave lens of focal length 20 cm. Find the size, position and nature of the image. Also find the power of lens.

*4.12 LENSES IN CONTACT

Consider two thin lens of focal lengths, f_1 and f_2 respectively placed in contact with each other.

Let O be the point object placed on the principal axis of the lenses. If second lens is not present, then the first lens forms an image I_1 of the object O at a distance v_1 from it.

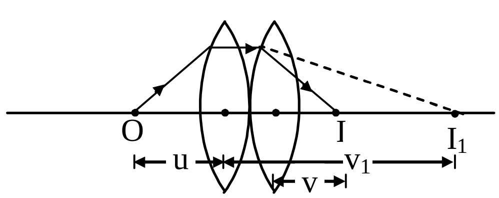


Figure 4.25

*4.13 DEFECTS OF LENSES

(i) **Chromatic aberration** : Due to dispersion the image has coloured edges.

(ii) **Spherical aberration** : Due to different focal length for marginal rays and paraxial rays.

(iii) **Coma** : Comet like tail added to all images.

(iv) **Astigmatism** : Defect in image shape when the rays from horizontal plane and rays from vertical plane focus at different points.

(v) **Distortion** : Due to different magnification of a lens for the upper or lower portion and central portion.

4.14 USES OF LENSES

(i) Concave, convex and other types of lenses are used in spectacles for correcting the defects of vision.

(ii) Almost all the optical instruments such as projector, telescope, microscope, camera, periscope etc. make use of lenses.

(iii) Now-a-days powerful lenses of large aperture are used to focus solar energy.

*4.15 LENS MAKER'S FORMULA

The relation between the focal length (f) of the lens, radii of curvature of its surfaces and refractive index (n) of the material of the lens is called lens maker's formula

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

When lens made of glass is immersed in liquid then focal length of the lens in the liquid is

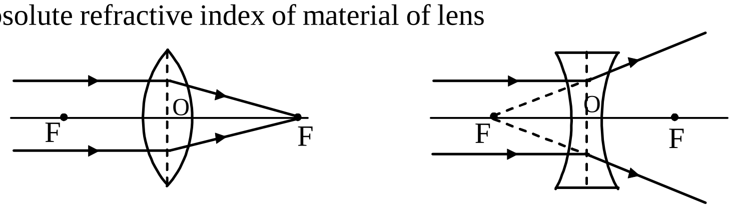
$$f_l = (n_{lg} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{or} \quad \frac{f_l}{f_a} = \frac{(n_{ga} - 1)n_{la}}{(n_{ga} - n_{la})}$$

*4.16 BEHAVIOUR OF LENSES IN DIFFERENT OPTICAL MEDIUM

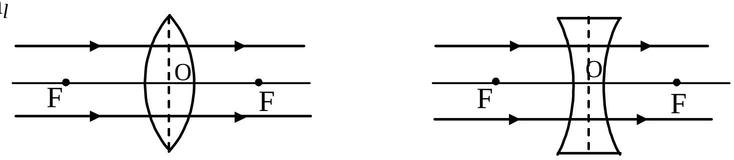
Case I: $n_m < n_l$

where n_m = Absolute refractive index of medium.

n_l = Absolute refractive index of material of lens



Case II: $n_m = n_l$



Case III: $n_m < n_l$

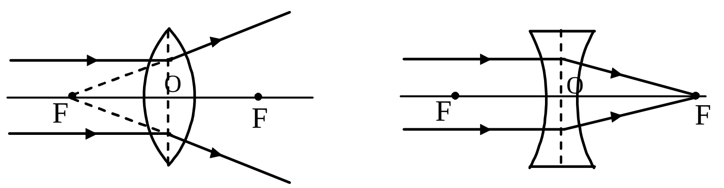
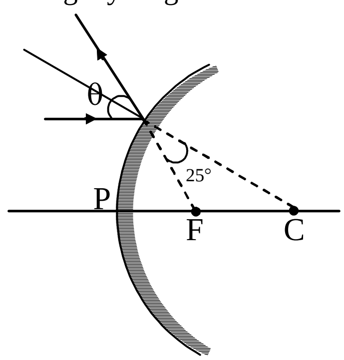


Figure 4.26

EXERCISE-I

1. What type of waves are light waves?
2. What is the radius of a plane mirror?
3. What is the angle of reflection if a ray falls normally on a plane mirror?
4. Relate the focal length f and radius of curvature R.
5. What is a real image?
6. What is a virtual image?
7. What type of image is formed:
   (i) in a plane mirro and (ii) on a cinema screen?
8. Write the mirror formula
9. Name the type of mirror which always forms a virtual and diminished image.
10. Which mirror convex or concave has more field of view?
11. For what position of an object, a concave mirror forms a real image equal in size to the object?
12. 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?
13. Differentiate between virtual image of a convave mirror and of a convex mirror.
14. The angle between an incident ray and the mirror is θ. The total angle turned by the ray of light is 80°. What is the value of θ?
15. What is the value of θ in the following ray diagram?



16. What is a rarer medium?
17. What is the unit of refractive index?
18. Name a point inside a lens through which the light passes undeviated.
19. Define the power of a lens. Give its SI unit. State whether the power of a converging lens is positive or negative.
20. A spherical mirror and a lens both have focal length of –20 cm. What type of mirror and lens are these?
21. What is dioptre?

EXERCISE-II

1. What is the nature of light?
2. What is a ray?
3. State two effects caused by the refraction of light
4. Distinguish between real and virtual image.
5. If you are driving a car, what type of mirror would you prefer to use for observing traffic at your back and why?

The distance of the object from the lens is 15 cm. Find the nature, position and size of the image. Also find its magnification.

EXERCISE-III

SECTION-A

- **Fill in the blanks**

1. A light wave of frequency 5×10^{14} Hz enters a medium of refractive index 1.5. In the medium the velocity of light wave is __________ and its wavelength is __________.

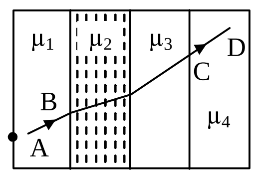
SECTION-B

- **Multiple choice question with one correct answers**

1. When a ray of light enters a glass slab from air.
(A) its wavelength decreases
(B) its wavelength increases
(C) its frequency decreases
(D) neither its wavelength nor its frequency changes

2. An eye specialist prescribes spectracles having combination of convex lens of focal length 40 cm in contact with a concave lens of focal length 25 cm. The power of this lens combination in diopters is
(A) +1.5 (B) –1.5 (C) +6.67 (D) –6.67

3. A ray of light passes through four transparent media with refractive indices μ_1, μ_2, μ_3 and μ_4 as shown in the figure.
The surfaces of all media are parallel. If the emergent ray CD is parallel to the incident ray AB, we must have

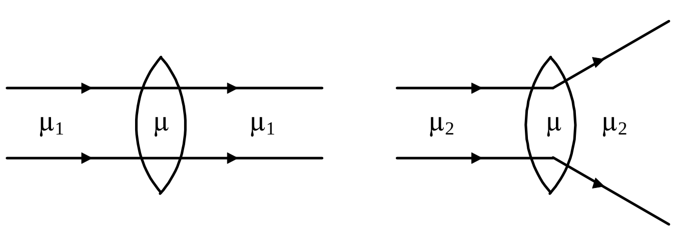


(A) $\mu_1 = \mu_2$ (B) $\mu_2 = \mu_3$ (C) $\mu_3 = \mu_4$ (D) $\mu_4 = \mu_1$

4. A hollow double concave lens is made of very thin transparent material. It can be filled with air or either of two liquids L_1 or L_2 having refractive indices μ_1 and μ_2 respectively ($\mu_2 > \mu_1 > 1$). The lens will diverge a parallel beam of light if it is filled with
(A) air and placed in air (B) air and immersed in L_1
(C) L_1 and immersed in L_2 (D) L_2 and immersed in L_1

5. A point object is placed at the centre of a glass sphere of radius 6 cm and refractive index 1.5. The distance of virtual image from the surface is
(A) 6 cm (B) 4 cm (C) 12 cm (D) 9 cm

6. What is the relation between the refractive indices μ_1 and μ_2, if the behaviour of light ray is as shown in the figure.



(A) $\mu_1 > \mu_2$ (B) $\mu_1 < \mu_2$ (C) $\mu_1 = \mu_2$ (D) None of these

7. Which of the following lens can form image of an object on screen.
(A) Concave (B) Convex

EXERCISE-IV

SECTION-A

- **Multiple choice question with one correct answers**

1. A convex lens A of focal length 20 cm and a concave lens B of focal length 5 cm are kept along the same axis with a distance 'd' between them. If a parallel beam of light falling on a leaves B as a parallel beam, then d is equal to

(A) 25 cm (B) 20 cm (C) 15 cm (D) 10 cm

2. A thin rod of length f/3 is placed along the principal axis of a concave mirror of focal length f such that its image which is real and elongated, just touches the rod. The magnification is

(A) 2/3 (B) 3/2 (C) 3/5 (D) 5/3

3. Two thin lenses, when in contact, produce a combination of power +10 diopters. When they are 0.25 m apart, the power reduces to +6 diopters. The focal length of the lenses are

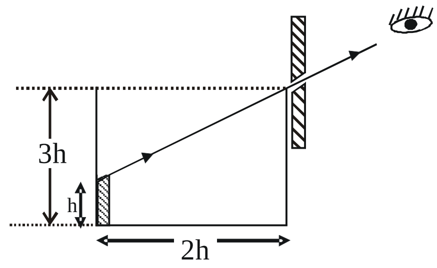
(A) 0.125 m. 0.5 m (B) 0.25 m, 0.5 m (C) 0.25 m, 0.75 m (D) none of these

4. A diminished image of an object is to be obtained on a screen 1.0 m from it. This can be achieved by appropriately placing.

(A) A convex lens of focal length more than 0.25 m(B) A convex mirror of suitable focal length

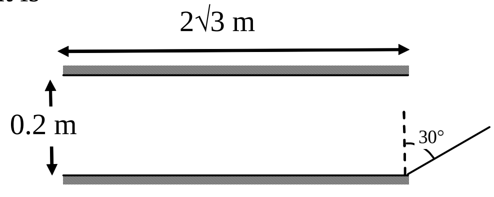
(C) A convex lens of focal length less than 0.25 m (D) A concave lens of suitable focal length

5. An observer can see through a pin-hole the top end of a thin rod of height h, placed as shown in the figure. The beaker height is 3h and its radius h. When the beaker is filled with a liquid up to a height 2h, he can see the lower end of the rod. Then the refractive index of the liquid is



(A) $\frac{5}{2}$ (B) $\sqrt{\frac{5}{2}}$ (C) $\sqrt{\frac{3}{2}}$ (D) $\frac{3}{2}$

6. Two plane mirrors A and B are aligned parallel to each other as shown in the figure. A light ray is incident at an angle 30° at a point just inside one end of A. The plane of incidence coincides with the plane of the figure. The maximum number of times the ray undergoes reflections (including the first one) before it emerges out is



(A) 28 (B) 30 (C) 31 (D) 34

7. The size of the image of an object, which is at infinity, as formed by a convex lens of focal length 30 cm is 2 cm. If a concave lens of focal length 20 cm is placed between the convex lens and the image at a distance of 26 cm from the convex lens, calculate the new size of the image.

(A) 1.25 cm (B) 1.67 cm (C) 1.05 cm (D) 2 cm

SECTION-D

- **Match the following (one to many)**

  Column-I and **column-II** contains **four** entries each. Entries of column-I are to be matched with some entries of column-II. One or more than one entries of column-I may have the matching with the same entries of column-II and one entry of column-II may have one or more than one matching with entries of column-I

1.

Column I	Column II
(A) Straight line which is normal to the mirror at its pole (p)	(P) will passes through principal focus (F)
(B) A ray, parallel to the principal axis of concave mirror after reflection	(Q) Focal length (f)
(C) The distance between the pole and the principle focus of a mirror	(R) principal axis
(D) A straight line passing through the pole (p) and the centre of curvature (c)	(S) Half of radius of curvature (c)

Answers

TRY YOURSELF

1. (D) 2. (D) 3. (A)

4. (i) 7/9 m (ii) 2/9 (iii) Virtual, erect and diminished

5. $n_g = 3/2$ 6. 125/94 7. 5/18

8. (i) $h_i = 5$ cm (ii) v = –10 cm (iii) virtual, erect & diminished (iv) –5 D

9. f = 25 cm, P = 4D

EXERCISE-I

1. Light waves are electromagnetic waves. 2. The radius of a plane mirror is infinity.

3. The angle of reflection is 0° 4. Focal length = $\frac{\text{Radius of curvature}}{2}$ or f = R/2

5. If the rays of light after reflection or refraction actually meet at a point, the image is known as real image.

6. If the rays do not actually meet but appear to meet when produced backwards, the image is known as virtual image.

7. (i) virtual image and (ii) real image

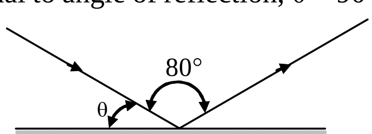
8. $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ (u = objective distance, v = image distance and f = focal length)

9. Convex mirror 10. Convex mirror 11. At C, centre of curvature

12. (i) Between pole P and focus F and (ii) At focus F

13. The virtual image of a concave mirror is always magnified whereas the virtual image of a convex mirror is diminished.

14. Since angle of incidence is equal to angle of reflection, θ = 90° – 40° = 50°



10. Focal length, f = –50 cm (concave lens)

Now, power, P = $\frac{1}{f(in\ metre)} = \frac{1}{-50/100\ m} = -\frac{100}{50} = -2D$

Thus, the power of this concave lens is –2 dioptres.

12. h_i = –2 cm, real, inverted and enlarged v = –30 cm
13. 21 cm
14. v = 10 cm, virtual, erect and diminished
15. virtual, erect and smaller in size by a factor of 0.23
16. inverted and enlarged
17. Refractive index of glass, $n = \frac{\sin 45°}{\sin 30°} = \frac{1/\sqrt{2}}{1/2} = \sqrt{2}$
18. 5×10^{14} Hz 19. 0.75
20. refractive index of glass with respect to water is 9/8.
21. (i) 2×10^8 m/s (ii) 9×10^{14} Hz (iii) λ_m = 333.33 nm
22. f = +30 cm, convex lens 23. v = –7.5 cm, h_i = 5/8 cm
24. f = 10 cm
25. virtual, erect and enlarged, v = –200 cm, h_i = 25 cm
26. (i) the image is situated 60 cm on the other side of the lens. (ii) the image is real
27. real, inverted and enlarged, v = 30 cm, h_i = –4 cm, m = –2

EXERCISE-III

SECTION-A

1. 2×10^8 m/s, 0.4×10^{-6} m

SECTION-B

1.	(A)	2.	(B)	3.	(D)	4.	(D)	5.	(B)	6.	(B)
7.	(B)	8.	(C)	9.	(B)						

SECTION-C

1.	(D)	2.	(A)	3.	(A)	4.	(A)	5.	(C)

SECTION-D

1. (A)-(Q), (B)-(R), (C)-(P), (D)-(S)

EXERCISE-IV

SECTION-A

1.	(C)	2.	(B)	3.	(A)	4.	(C)	5.	(B)	6.	(C)
7.	(B)	8.	(A)	9.	(D)	10.	(D)				

SECTION-B

1. (B,D) 2. (B,C)

SECTION-C

1.	(B)	2.	(A)	3.	(A)	4.	(B)

SECTION-D

1. (A)-(R), (B)-(P), (C)-(Q,S), (D)-(P,R)

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