Refraction of Light

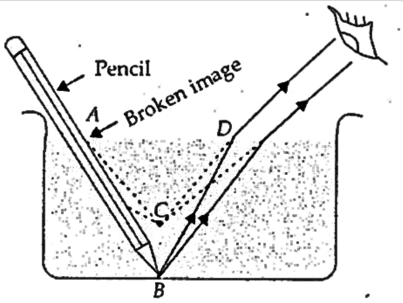
Physics – X CBSE

Refraction of Light

The bending of light rays when they pass obliquely from one medium to another medium is called refraction of light.
In other words when light rays traveling in one medium are incident on a transparent surface (medium), they are bent as they enter in second transparent medium. This phenomenon of bending of ray of light in second medium is called refraction of light.
This phenomenon of light can be easily demonstrated by the following activity.

ACTIVITY CORNER

A pencil appears bent and short, when immersed obliquely (at an angle) in water. Take a pencil and dip it obliquely in a beaker, half filled with water. The pencil appears to be bent or displaced at the surface of separation between the two media (water - air interface). This apparent bending or displacement of pencil is due to the refraction of light. The ray coming from the portion of the pencil is due to the refraction of light. The ray coming from the portion of the pencil above and below the water reaches our eyes from different directions and the pencil appears to be bent or broken



The pencil inside the water appears to be broken

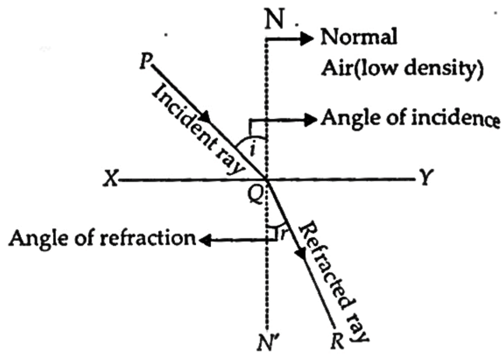
Explanation: Consider a ray of light starting from the end point P or the pencil passing from water to air at point D and reaching the eye. It appears to be coming from a different point C. The point C is therefore the virtual image of the end point B of the pencil and lies exactly above point B. In the same way each point on the portion AB (dipped in water) of the pencil has a corresponding virtual image above the point. Thus the virtual image of the portion AB of the pencil appears at AC due to refraction of light.

Cause of Refraction

Light rays get deviated from their original path, while entering from one transparent medium to another medium of different density. This deviation (change in direction) in the path of light is due to the change in velocity of light in the different medium. The velocity of light depends on the nature of the medium in which it travels. Velocity of light in a rarer medium (low optical density) is more than in a denser medium (high optical density).

Refraction of light from a plane transparent surface

In diagram, XY is section of a plane transparent surface of a denser medium.
A ray of light PQ strikes the surface at Q and goes along QR in denser medium. It is bent towards normal. This bending of ray of light when it travels in different medium, is called refraction. The surface is said to have refracted the light.



(i) Transparent surface: The plane surface which refracts light/ is called transparent surface.
In diagram, XY is the section of a plane transparent surface.
(ii) Point of incidence: The point Q on the boundary of two media where the incident ray strikes is called the point of incidence.

(iii) Normal: A perpendicular drawn at the point of incidence is called normal. In diagram, NQN' is the normal on surface XY.

(iv) Incident ray: The ray of light which strikes the transparent surface at the point of incidence is called incident ray. Here the ray PQ is the incident ray.

(v) Refracted ray: The ray of light on entering the second medium is called refracted ray. In diagram, QR is the refracted ray.

(vi) Angle of incidence: The angle between the incident ray and the normal is called angle of incidence $(\angle i)$

(vii) Angle of refraction: The angle between the refracted ray and the normal is called angle of refraction $(\angle r)$

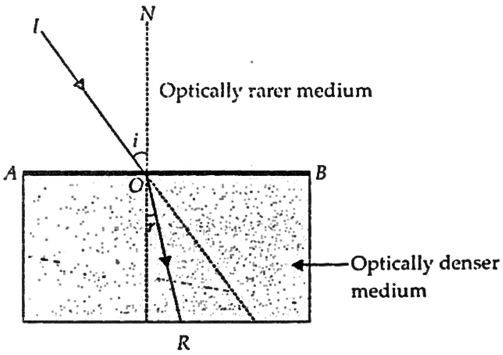
(viii) Plane of incidence: The plane containing the normal and the incident ray is called plane of incidence. For the diagram, plane of paper is the plane of incidence.

(ix) Plane of refraction: The plane containing the normal and the refracted ray is called plane of refraction. For the diagram/ plane of paper is the plane of refraction.

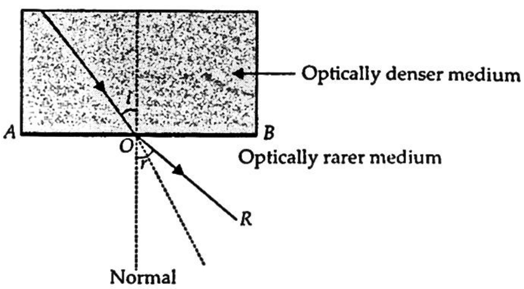
Characteristics of Refraction of Light

The bending of light follows the following rules:

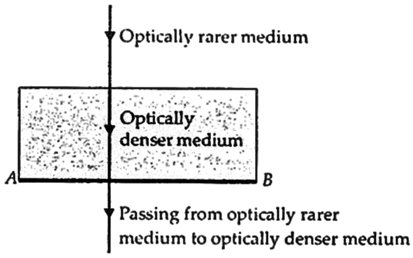
(i) In going from a rarer to a denser medium: A ray of light passing obliquely from an optically rarer medium to an optically denser medium, bends towards the normal. In this case the angle of refraction is always less than the angle of incidence.

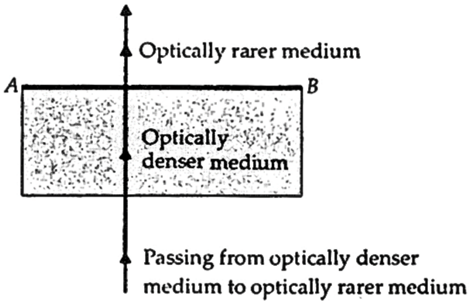


(ii) In going from a denser to a rarer medium: A ray of light passing obliquely from an optically denser medium to an optically rarer medium bends away from the normal. In this case the angle of refraction is always greater than the angle of incidence.



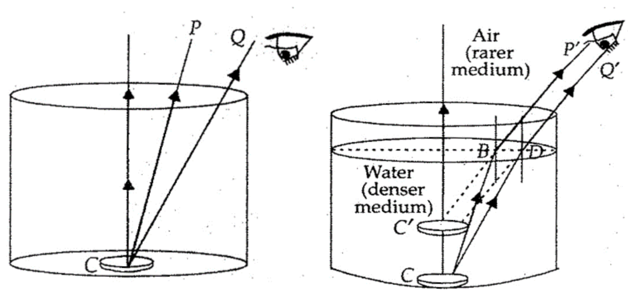
(iii) When light is incident normally on a optically denser medium: A ray of light passing normally, i.e./ at right angles from one optical medium to another optical medium, does not bend or deviate from its path. In this case, angle of incidence and angle of refraction both are equal to zero.





ACTIVITY CORNER

Place a coin C at the bottom of an empty metallic vessel as shown in figure (a). Now slowly move away from the vessel until you reach a place where the coin just disappears. Now ask somebody to slowly fill the vessel with water without disturbing the position of the coin. Maintain a steady gaze at the coin. The coin gradually begins to appear and can be seen completely from the same position of the eye after the level of water reaches a certain height.



(a) Coin not visible in an empty metallic vessel

(b) Coin now visible and also appears to be raised inwater

As shown in figure (b), rays like CP and CQ cannot reach the eye, so the coin was not visible. A ray of light, CB coming from the lower end C of the coin passes from water in to air at a point B arid gets refracted away from the normal in the direction BP'. Another ray of light, CD gets refracted in the direction DQ'. There refracted rays BP' and DQ' reach the eye of the observer, who sees the coin raised to C. Thus the coin, which was not visible earlier, come's in to view. C is the apparent position of the coin C, which appears to be raised up due to refraction of light.

Laws of Refraction of Light

Refraction of light follows the following two laws:

- **First Law:** The incident ray, the normal to the transparent surface at the point of incidence and the refracted ray, all lie in one and the same plane.
- Second Law: The ratio of sine of the incidence angle ($\angle i$) to the sine of the refracted angle ($\angle r$) is constant and is called refractive index of the second medium with respect to the first medium. It is denoted by n.

  i.e., . $\frac{\sin i}{\sin r} = n$ ...(i)

  Refractive index of second medium with respect to the first medium is denoted by ${}_2n_1$

  Thus, eqn. (i) can be written as ${}_2n_1 = \frac{\sin i}{\sin r}$

  This law is called Snells' law as it was stated by Prof. Willenbrord Snell (Dutch mathematician and astronomer).

Refractive index

Light travels the fastest in vacuum with the highest speed of 3×10^8 m s^{-1}. In air, the speed of light is only marginally less, compared to that in vacuum. But for all practical purposes, we considerthe speed of light in air equal to the speed of light in vacuum. However speed of light decreases in denser media like water, glass etc. It means when light goes from air to some other medium like water and glass, its speed decreases. The amount of change in the speed of light in a medium depends upon the property of the medium. This property is known as refractive index of the medium. Refractive index is a measure of how much the speed of light changes when it enters a medium from air.

Absolute Refractive index

Absolute refractive index of a medium is defined as the ratio of the speed of light in vacuum or air to the speed of light in the medium. It is denoted by n.

Then, $n = \frac{\text{speed of light in air}}{\text{speed of light in water}} = \frac{c}{v}$

It has no unit.

ILLUSTRATION

1. The speed of light in air is 3×10^8 m s^{-1} and the speed of light in water is 2.26×10^8 m s^{-1}. Find the refractive index of water.

Sol: Given, $c = 3\times10^8$ m s^{-1}, $v = 2.26\times10^8$ m s^{-1}

Using, $n = \frac{c}{v}$ we have

$$n = \frac{3\times10^8\, m s^{-1}}{2.26\times10^8\, m s^{-1}} = 1.33$$

Thus, refractive index of water = 1.33

Relative Refractive index

When light passes from medium 1 to another medium 2, the refractive index of medium 2 with respect to medium 1 is written as ${}_2n_1$,and is called relative refractive index.

$$\frac{\text{speed of light in medium 1}}{\text{speed of light in medium 2}} = \frac{v_1}{v_2}$$

Multiply and divide R.H.S. of eq. (i) by c (speed of light in air), we get

$${}_2n_1 = \frac{cv_1}{cv_2} = \left(\frac{c}{v_2}\right)\times\left(\frac{v_1}{c}\right) = \left(\frac{c/v_2}{c/v_1}\right)$$

But $\frac{c}{v_1} = n_1$ (absolute refractive index of medium. 1)

and $\frac{c}{v_2} = n_2$ (absolute refractive index of medium 2)

Hence, eqn. (ii) can be written as ${}_2n_1 = \frac{n_2}{n_1}$

Thus, relative refractive index of medium 2 with respect to medium 1 is defined as the ratio of absolute refractive index of medium 2 to the absolute refractive index of medium 1.

Also ${}_2n_1 = \frac{\sin i}{\sin r}$

Comparing eqns. (iii) and (iv), we get $\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$ or

$n_1 \sin i = n_2 \sin r$

We know, refractive index of medium 2 with respect to medium 1 is given by, ${}_2n_1 = \frac{v_1}{v_2}$

Similarly, refractive index of medium 1 with respect to 2 is given by, ${}_1n_2 = \frac{v_2}{v_1}$

Multiplying eqn. (vi) and (vii), we get, ${}_2n_1 \times {}_1n_2 = \frac{v_1}{v_2}\times\frac{v_2}{v_1} = 1$ or ${}_2n_1 = \frac{1}{{}_1n_2}$

i.e., refractive index of medium 2 with respect to medium 1 is the reciprocal of refractive index of medium 1 with respect to medium 2.

For example, refractive index of water with respect to air,

For water, ${}_{\omega}n_a = \frac{4}{3}$ or 1.33 for glass ${}_{g}n_a = \frac{3}{2} = 15$

When light goes from water to glass,

Refractive index of glass with respect to water, ${}_{g}n_{\omega} = \frac{3/2}{4/3} = \frac{9}{8} = 1.125$

Values of Refractive Indices of Some Transparent media

Names of Substance	Refractive Index	Names of Substance	Refractive Index
Air	1.0003	Glycerine	**1.47**
Hydrogen	1.00013	Benzene	**1.501**
Carbon dioxide	1.00045	Crown glass	**1.52**
Ice	1.31	Rock salt	**1.54**
Water	1.333	Carbon disulphide	**1.63**
Alcohol	1.36	Flint glass	**1.66**
Kerosene	1.44	Ruby	**1.71**
Carbon tetrachloride	1.46	Diamond	**2.42**
Turpentine oil	1.47		

Do You Know

Refractometer is a device used to measure the refractive index of a substance.

ILLUSTRATION

2. Light travels from a rarer medium 1 to a denser medium 2. The angle of incidence and refraction are respectively 45°and 30°. Calculate the refractive index of second medium with respect to the first medium.

Sol: Given, angle of incidence, i = 45°angle of refraction, r = 30°

From relation, $n = \frac{\sin i}{\sin r}$

Putting values, we get ${}_{2}n_{1}$

$${}_{2}n_{1} = \frac{\sin i}{\sin r} = \frac{\sin 45°}{\sin 30°} = \frac{1\sqrt{2}}{\frac{1}{2}} = \sqrt{2} = 1.414$$

3. In above problem, calculate the refractive index of first medium with respect to second medium.

Sol: From relation ${}_{1}n_{2} = \frac{1}{{}_{2}n_{1}}$

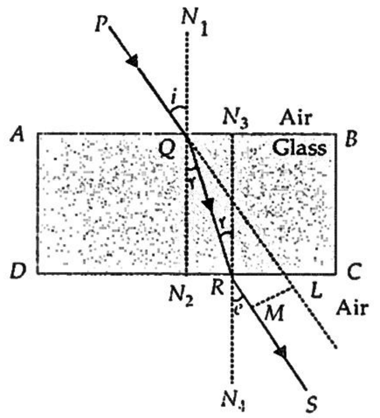
Putting values, we get ${}_{1}n_{2} = \frac{1}{{}_{2}n_{1}} = \frac{1}{\sqrt{2}}$

Multiplying and dividing eqn.(i) by $\sqrt{2}$

$${}_{1}n_{2} = \frac{1}{\sqrt{2}} \times \frac{\sqrt{2}}{\sqrt{2}} = \frac{\sqrt{2}}{2} = \frac{1.414}{2} = 0.707$$

Refraction Through a Rectangular Glass Slab

Consider a rectangular glass slab ABCD. Ray PQ is incident on it on face AB at point Q, making angle PQN_1= i, called angle of incidence. It refracts in glass slab and goes along QR as refracted ray and becomes incident on face DC at point R from inside the slab. Angle RQN_2 = angle QRN_3 = r and is called angle of refraction.



Refraction of light through a rectangular glass slab

The ray emerges (comes out) from the slab along RS making $\angle SRN_4$= e, called angle of emergence. For refraction at Q (from air to glass),

According to Snell's law, $n = \frac{\sin i}{\sin r}$ ... (i)

For refraction at R (from glass to air), $\frac{1}{n} = \frac{\sin r}{\sin e}$ or

$n = \frac{\sin e}{\sin r}$ ... (ii)

From eqns. (i) and (ii), $\sin i = \sin e$

i.e., $i = e$

angle of incidence = angle of emergence

It means that in refraction through a rectangular glass slab the incident ray and emergent ray of light are parallel to each other.

Lateral Displacement

The perpendicular distance between the original path of incident ray and the emergent ray coming out of a glass slab is called lateral displacement of the emergent ray of light.

In above diagram, LM represents lateral displacement for a glass slab.

Factors on which lateral displacement depends

(a) Lateral displacement is directly proportional to the thickness of glass slab.
(b) Lateral displacement is directly proportional to the incident angle.
(c) Lateral displacement is directly proportional to the refractive index of glass slab.
(d) Lateral displacement is inversely proportional to the wavelength of incident light.

ACTIVITY CORNER

To verify the laws of refraction and determine the refractive index of the glass

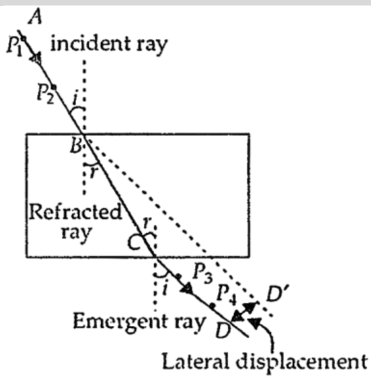
Materials required: Rectangular glass slab. White sheet of drawing paper. Drawing board. Drawing pins and all-purpose pins.

Procedure: Fix a plain sheet of paper on a drawing board with the help of drawing pins. Place a rectangular glass slab in the middle of the paper and draw its boundary with a sharp pencil.

Fix two pins (P_1 and P_2) vertically along a straight line AB. Now look through the glass slab from the other side and fix two pins (P_3 and P_4) so that those pins and the images of the pins P_1 and P_2 are in a straight line (when seen through the glass slab). Remove the glass and all the pins. Mark the positions of the pins.

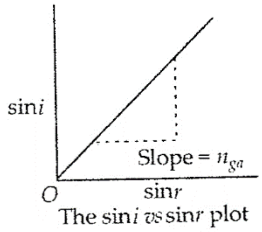
Join the points P_1 and P_2 and extend the line to meet one face of the slab (Pointer B). Similarly, extend the line obtained by joining the points P_3 and P_4 to meet the other face of the slab (point C). Also the points B and C. Draw perpendiculars to the two faces of the slab at point B and point C. Measure and record the angle of incidence (i) and the angle of refraction (r).

Repeat the experiment for different angles of incidence and determine the corresponding angles of refraction.



Refraction of light through a glass slab

Calculations: (i) Calculate the ratio $\sin i/\sin r$ for all the observations.
Calculate the average of all these values.
(ii) Plot a graph of $\sin i$ vs $\sin r$. Determine the slop of the plot.



The sin$i$ vs sin$r$ plot

Results: From the calculations, following results are obtained
(i) The ratio $\sin i/\sin r$ for all observations is constant.
(ii) The plot of $\sin i$ vs $\sin r$ is a straight line passing through the origin.
The slope of $\sin i$ vs $\sin r$ plot is equal to the ratio $\sin r$.

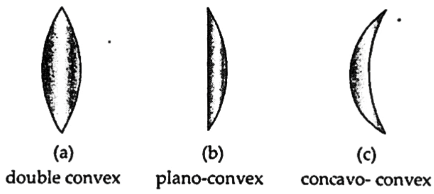
Conclusions: (i) The constant value of the ratio $\sin i/\sin r$ and the straight line plot between sin i and $\sin r$ verify the first law of refraction or Snell's law.
(ii) The incident ray, refracted ray and the normal, all lie in the same plane, i.e., plane of the paper.
This verifies the second law of refraction.
(iii) The average value of the $\sin i/\sin r$ ratio is equal to the refractive index of the glass of the slab.
(iv) The slop of $\sin i$ vs $\sin r$ plot is equal to the refractive index of the glass of the slab.

Spherical Lenses

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

Lenses are of two types:
(i) Convex or converging lenses.
(ii) Concave or diverging lenses

- **Convex Lens**
  A lens having both spherical surfaces or one spherical surface and other plane surface such that it is thick in the middle and thin at the edges is known as convex lens.

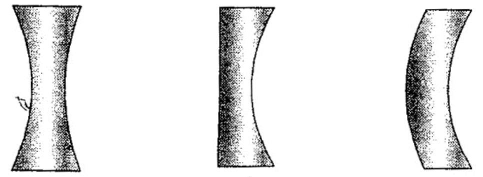


There are three types of convex lenses:
(i) Bi-convex or double convex lens: It has both the surfaces convex as shown in figure (a).
(ii) Plano-convex lens: It has one surface plane and the other surface convex as shown in figure (b).
(iii) Concavo-convex lens: It has one surface concave and the other surface convex as shown in figure (c).

- **Concave Lens**

  A lens which is thicker at the edges and thin at the centre i.e., curved inwards is known as concave lens. Concave lens are of three types:

  (i) Double concave lens: It has both the surfaces concave as shown in figure (a).



(a) double concave (b) plano-concave (c) convexo-concave

(ii) Plano-concave lens: It has one surface plane and the other surface concave as shown in figure (b).

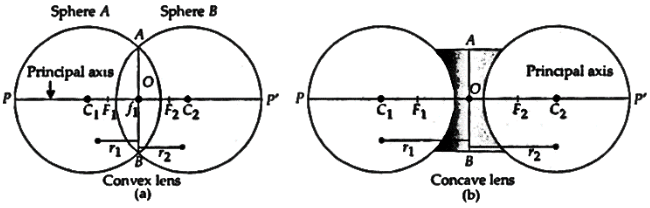
(iii) Convexo-concave lens: It has one surface convex and the other surface concave as shown in figure (c).

- **Terms Associated with Spherical Lenses**

(i) Aperture: The diameter of the circular edge of the lens, is called the aperture of the lens. In diagram, AB is the aperture of the lens.

(ii) Centre of curvature: The centre of curvature of a lens is defined as the centre of the spherical surface from which the lens has been cut. Thus, each surface of the lens is a part of a sphere. There will be two centres of curvature. In figures (a) and (b), C_1 and C_2 are the centres of curvature of the two lens surfaces.

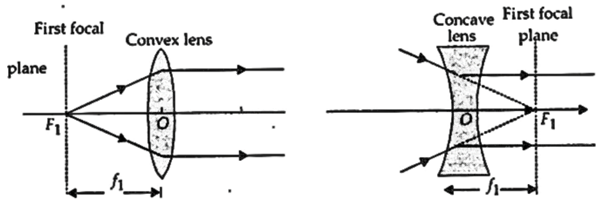
(iii) Principal axis: An imaginary straight line passing through the two centers of curvature of two spherical surfaces of the lens (or through one centre of curvature of one spherical surface and normal to the other plane surface), is called the principal axis of the lens. For a plane concave or plane convex lens, the principal axis is a line, which is normal to the plane surface and passing through the centre of curvature of the curved surface.



(iv) Optical centre: It is a point on the principal axis of the lens, such that a ray of light passing through it goes undeviated. In diagram '0' is optical centre of the lens.

(v) First principal focus (F_1): The position of a point on the principal axis of a lens so that the rays of light starting from this point after passing through the lens travel parallel or appear to travel parallel to the principal axis is called first principal focus (F_1)

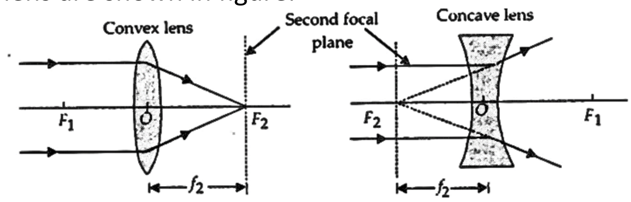
First principal focus (F_1) of a convex lens and a concave lens are shown in figure.



1(a)

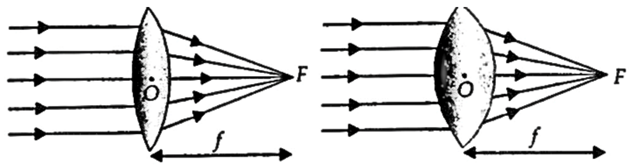
(vi) Second Principal focus (F_2): The position of a point on the principal axis of a lens where a beam of light parallel to the principal axis meets or appears to meet after passing through the lens is called second principal focus (F_2).

Second principal focus (F_2) of a convex and a concave lens are shown in figure.



1(b)

(vii) Focal length: The distance between the optical centre of the lens and the principal focus (first or second) of the lens, is called focal length of the lens. It is represented by the symbol f. In diagram, OF = f.



Thinner lens (Convex) Thicker lens (Convex)

(viii) Focal plane: A vertical plane perpendicular to the principal axis, passing through the principal focus of the lens is called a focal plane. As shown in figure 1 (a) and 1(b), the plane passing through the first principal focus is called first focal plane and that passing through the second principal focus is called second focal plane.

Do You Know

For concavo-convex and convexo-concave lens, optical
centre may be outside the lens.

Activity Corner

Activity to determine the principal focus and rough focal length of a convex lens.

Fix a convex lens in a holder. Allow sunlight to fall on the convex lens. Now take a sheet of paper and adjust its position on the other side of the lens till a small but bright spot of light is formed on the paper as shown in

figure. This spot of light is the principal focus of the given convex lens. Measure the distance of the paper from the lens.
This distance is equal to the rough focal length of the lens.

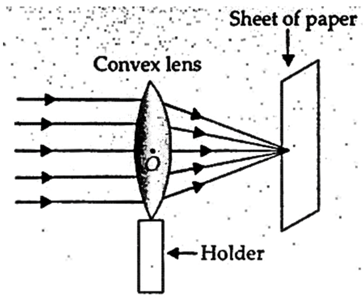
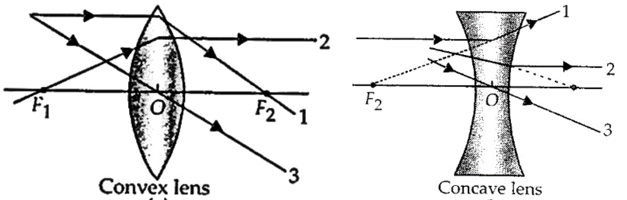


Image Formation in Lenses Using Ray Diagrams

For geometrical construction of an image formed by a lens, any of three of following rays of light are used:



Convex lens (a) Concave lens (b)

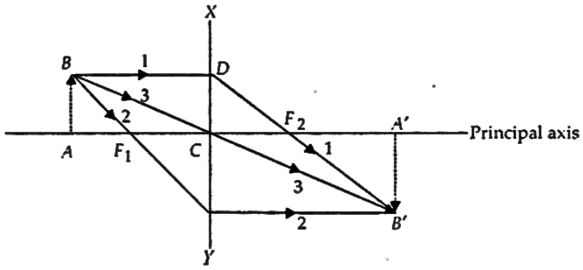
- **Incident on the lens parallel to principal axis:** After refraction from the lens, it actually passes through second principal focus F_2 (in case of a convex lens) or appears to come from the second principal focus F_2, (in case of a concave lens).
[Object at infinity, image at focus F_2]
- **Incident on the lens through first principal focus F_1 (in case of a convex lens) or in direction of first principal focus F_1 (in case of a concave lens):** After refraction from the lens, it goes parallel to the principal axis.
[Object at focus F_1, image at infinity]
- **Incident on the lens in direction of optical centre:** It passes undeviated through the lens.
- These special rays are very useful in drawing ray diagram in different cases.

Image Formation of Big Objects

The object is divided into many points. Point to point images are obtain. By combining the point images, the image of the whole object is obtained. Real point images give real image and virtual point images give virtual image of the complete object.

Note: Since lenses used are supposed to have a small aperture, their surfaces can be taken as plane and their principal sections can be represented by a straight line.

Example: In figure, XY represent principal section of a convex lens. It is taken plane due to its small aperture.



AB is a real object having bottom A on the principal axis and top B upwards. Three special rays are shown coming from top B, incident on the lens and refracted as shown. They actually meet at a point B', which becomes real image of B.A' lies perpendicularly below B', on the principal axis.

A' must represent image of bottom A of the object. A'B' represents real image of complete object AB. For small distances and sizes involved, the ray diagram can be drawn on same scale. For bigger distances and sizes, the diagram has to be drawn on a chosen scale.

Sign Convention

Description: It is a convention which fixes the signs of different distances measured. The sign convention to be formed is the new cartesian sign convention. It gives the following rules.

- The principal axis of the lens is taken along the X-axis of the rectangular coordinate system, and optical centre of the lens is taken as the origin.
- All distances are measured from the optical centre of the lens.
- The distances measured in the same direction as the direction of incident light, are taken as positive.
- The distances measured in the direction opposite to the direction of incident light, are taken as negative.
- Distances measured upward and perpendicular to the principal axis, are taken as positive.
- Distances measured downward and perpendicular to the principal axis, are taken as negative.
- In short:
Right $\rightarrow$ positive Left $\rightarrow$ negative
Upward $\rightarrow$ positive Downward $\rightarrow$ negative.

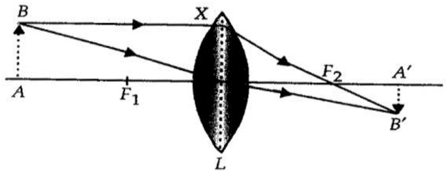
Lens Formula

The equation relating the object distance, the image distance and the focal length, is called the lens formula.
Assumptions made

- The lens is thin.
- The lens has a small aperture.
- The object lies close to principal axis.
- The incident rays make small angles with the lens surface or the principal axis.

Lens Formula for Convex Lens

The diagram shows the principal section of a convex lens L, forming a real and inverted image A'B' of a real and erect object AB. The object is beyond distance 2f, while the image is between distance f and 2f.



Ray diagram for a convex lens forming a real image

Object distance (measured from C to A), $CA = -u$ (object on the left of the lens)

Image distance (measured from C to A'), $CA' = +v$ (image on right of the lens)

Focal length (measured from C to F_2), $CF_2 = +f$ (focus on right of the lens)

In similar triangles A'B'F, and CFX_2,

$$\frac{A'B'}{CX} = \frac{F_2A'}{CF_2} = \frac{CA' - CF_2}{CF_2} = \frac{v-f}{f}$$

In similar triangles A'B'Cand ABC,

$$\frac{A'B}{AB} = \frac{CA'}{CA} = \frac{v}{-u}$$

But since CX = AB

$$\frac{A'B'}{CX} = \frac{A'B'}{AB} = \frac{v}{-u}$$

Hence/ from eqns. (i) and (ii),

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

$$-uv + uf = vf$$

$$uf - vf = uv$$

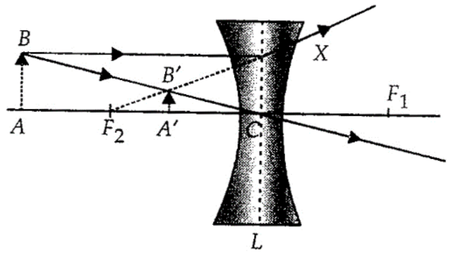
Dividing by uvf, we get,

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

This is the required lens formula.

Lens Formula For Concave Lens

The diagram shows the principal section of a concave lens L forming a virtual and erect image A 'B' of a real and erect object AB. The object is beyond distance If, while the image is in between focus and optical centre on same side as the object.



Ray diagram for a concave lens forming a image which is always virtual

Here,

Object distance (measured from C to A), $CA = -u$ (object on the left of the lens)

Image distance (measured from C to A'), $CA' = -v$ (image on left of the lens)

Focal length (measured from C to F_2) $CF_2 = -f$ (focus on left of the lens)

In similar triangles and CXF_2

$$\frac{A'B'}{CX} = \frac{F_2A'}{CF_2} = \frac{F_2C - A'C}{CF_2} = \frac{-f-(-v)}{-f} = \frac{f-v}{f}$$

In similar triangles A'B' C and ABC

$$\frac{A'B'}{AB} = \frac{CA}{CA} = \frac{-v}{-u} = \frac{v}{u}$$

But since CX=AB

Hence/ from eqns. (i) and (ii),

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

$$uf - uv = vf$$

$$uf - vf = uv$$

Dividing by uvf, we get,

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

This is the required lens formula.

Linear Magnification

The ratio of the size of the image as formed by refraction from the lens to the size of the object, called linear magnification produced by the lens. It is represented by the symbol m.

If I be the size of the image and 0 be the size of the object/ then $m = \frac{I}{O}$

If we represent size of the object by h_1 and size of image by h_2,

Then, $I = h_2$ and $O = h_1$

Hence, $m = \frac{h_2}{h_1}$

Expression:

(i) For convex lens forming real image in figure (1).

$I = A'B' = -h_2$ (inverted image)

$O = AB = +h_1$ (erect object)

Then, $m = \frac{-h_2}{h_1} = \frac{-A'B'}{AB}$

In similar triangles A'B'C and ABC, $\frac{A'B'}{AB} = \frac{CA'}{CA}$

Then, $m = -\frac{CA'}{CA} = \frac{-v}{-u}$ i.e., $m = \frac{v}{u}$

(ii) For concave lens forming virtual image,

$I = A'B' = -h_2$ (erect image)

$O = AB = +h_1$ (erect object)

Then $m = \frac{-h_2}{h_1} = \frac{A'B'}{AB}$

In similar triangles A'B'C and ABC, $\frac{A'B'}{AB} = \frac{CA'}{CA}$

Then, $m = -\frac{CA'}{CA} = -\frac{v}{-u}$ i.e., $m = \frac{v}{u}$

Hence we concluded that the linear magnification produced by a lens is equal to the ratio of the image distance to the object distance with a plus sign.

Note: For mirror, $m = -\frac{v}{u}$. It is so because for an inverted image v is negative in case of mirrors while it is positive in case of lenses.

ILLUSTRATION

4. A 4.0 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 20 cm. If the distance of the bisect is 30cmfrom the lens, find the position, nature and size of the image. Also find its magnification,

Sol.: Here, $h_1 = ? v = ?, m = ?$

Step 1. Determination of v

Using lens formula $-\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ we have

$-\frac{1}{(30)} + \frac{1}{v} = \frac{1}{20}$ or $\frac{1}{v} = \frac{1}{20} - \frac{1}{30}$

Or $\frac{1}{v} = \frac{1}{60}$ or $v = +60$ cm

Thus, the image is formed at 60 cm on other side

(i.e., right side) of the lens.

Step 2. Determination of h_2

Using $\frac{h_2}{h_1} = \frac{v}{u}$ we have

$h_2 = \frac{v}{u} h_1 = \frac{60}{-30} \times 4 = -8.0$ cm

Thus, size of the image is 8.0 cm. Negative sign shows that the image is inverted.

So, a real and inverted image of large size is formed.

Step 3. Determination of magnification

Using $m = \frac{h_2}{h_1}$ we get

$m = \frac{-8.0\,cm}{4.0\,cm} = -2$

Image Formation By a Convex Lens

From lens formula, we find that for a lens of a fixed focal length *f*, as object distance u changes, image distance v also changes. Moreover, as u decreases, v increase. This change the position, thenature and the size of the image.

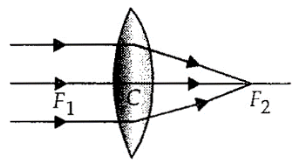
Different cases, are as given below with their ray diagram

- **Object at infinity:**

A point object lying on the principal axis:

Rays come parallel to the principal axis and after refraction from the lens, actually meet at the second principal focus F_2

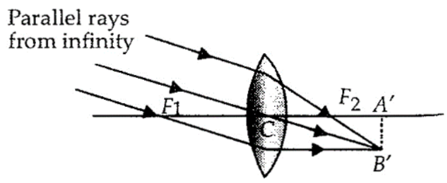
The image is formed at focus F_2. It is real and point sized.



Convex lens; Point object at infinity, image at focus

- **A big size object with its foot on the principal axis**

Parallel rays come inclined to the principal axis. Image is formed at the second principal focus F_2.It is real, inverted and diminished (smaller in size than the object)

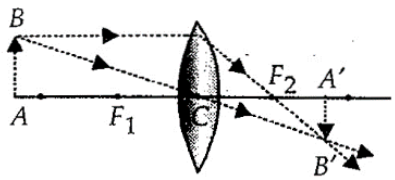


Convex lens; Big object at infinity, image at focus

- **Object at distance more than twice the focal length**

Real object AB has its image A'B' formed between distance f and 2f.

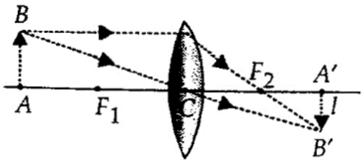
The image is real, inverted and diminished (smaller in size than the object).



Convex lens; object beyond 2*f*, image between *f* and 2*f*

- **Object at distance twice the focal length**

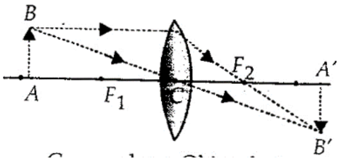
Real object AB has its image A'B' formed at distance If.
The image is real, inverted and has same size as the object.



Convex lens; object beyond $2f$, image between f and $2f$

- **Object at distance more than focal length and less than twice the focal length**

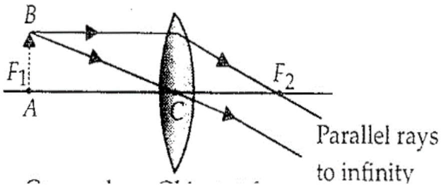
  Real object AB has its image A'B' formed beyond distance If.
  The image is real, inverted and enlarged (bigger in size than the object)



Convex lens; object between f and $2f$ image beyond $2f$

- **Object at focus**

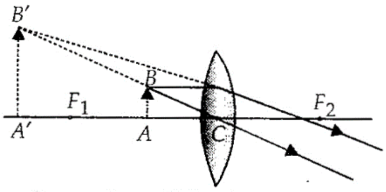
Real object AB has its image formed at infinity.
The image is real and, inverted (refracted rays go downward) and must have very large size.



Convex lens; object at focus, mage at infinity

- **Object between focus and optical centre**

Real object AB has its image A'B' formed in front of the lens.
The image is virtual erect and enlarged.



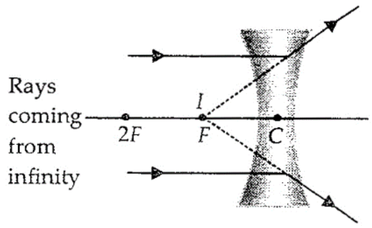
Convex lens; Object between focus and optical centre, image in front of the lens

Image Formation by a Concave Lens

Different cases, are as given below with their ray diagrams.

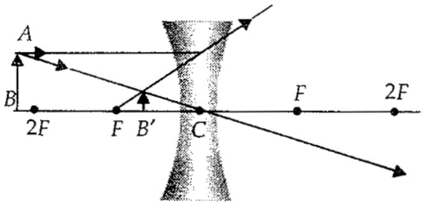
- **When the object is at infinity.**

Appears to be formed at the focus (F), virtual, erect arid very small on the same side as the object.



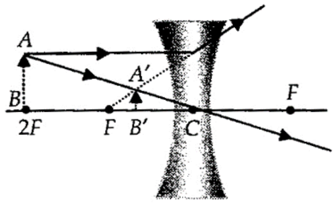
- **When the object is beyond 2F.**

Appears to be formed between F and C, virtual, erect and smaller than the object on the same side as the object.



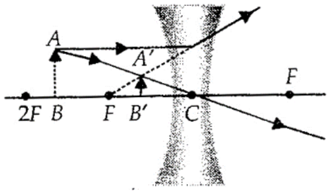
- **When the object is at 2F.**

Virtual, erect, diminished and on the same side as the object,



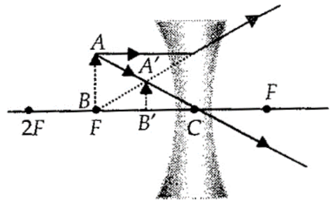
- **When the object is between F and 2F.**

Virtual, Erect, Diminished and on the same side of the lens.



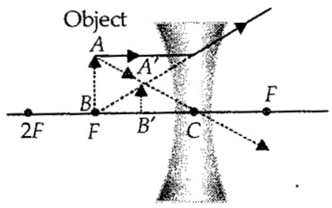
- **When the object is at F.**

Virtual, erect, diminished and on the same side of the object.



- **When the object is anywhere near the lens, i.e., between F and C.**

Virtual, erect, diminished and on the same side of lens.



ILLUSTRATION

5. A concave lens of focal length 20 cm form an image at a distance of 10 cm from the lens. What is the distance of the object from the lens? Also draw ray diagram.

Sol:

Here, $f = -20\,\text{cm}$(Sign convention)

$u = -10$ ($\because$ Image formed by concave lens is virtual)

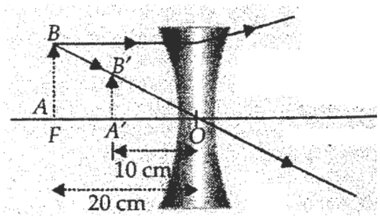
Step 1. Using, $-\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ we have

$-\frac{1}{u}-\frac{1}{10}=-\frac{1}{20}$ or $-\frac{1}{20}+\frac{1}{10}=\frac{1}{20}$

or $u = -20\,\text{cm}$

Thus, the object is placed at 20 cm from the concave lens.

Step 2.



- **Distinction Between a Plane Glass Sheet, a Convex and a Concave Lens (without touching Surface)**

  The glass sheet is placed over a printed page and the virtual image of the print is seen. The magnification of the image is observed. Then make an idea of the magnification.

  If magnification is one, glass sheet is plane. If magnification is more than one, it's a convex lens.

  If magnification is less than one, it's a concave lens.

Power of a Lens

A convex lens converges (brings closer) and a concave lens diverges (spreads) the light rays incident on it. More is the convergence or divergence produced by a lens, more powerful the lens is said to be. It is the capacity or the ability of a lens to deviate (converge or diverge) the path of rays passing through it. A lens producing more convergence or more divergence, is said to have more power. It is represented by the symbol P.

Do You Know

(i) Power of convex lens is positive because its focal length is positive.

(ii) Power of concave lens is negative because its focal length is negative.

- **Relation of Power with Focal Length**

A lens of less focal length focuses a parallel beam of light at near point. It produces more convergence or more divergence. It is said to have more power.

Hence, Power $\propto \frac{1}{\text{focal length}}$ i.e., $P \propto \frac{1}{f}$

We have, $P = \frac{1}{f}$

- Units of power is dioptre (D). One dioptre is the power of a lens or focal length 1 m.

  In general, P (dioptre) $= \frac{1}{f\,(metre)} = \frac{100}{f\,(cm)}$

ILLUSTRATION

6. What will be the focal length of a lens whose power is given as +2.0 D?

Sol: Here, P = 2 D

Using $P = \frac{1}{f\,(in\,m)}$ we get

$f = \frac{1}{P} = \frac{1}{2} = 0.5m = 50cm$

7. What is the power of a convex lens o local length 40 cm

Sol. Here, $f = 40$ cm

Using, $P = \frac{100}{f\,(in\,cm)}$

We have $P = \frac{100}{40} = +2.5\,\text{D}$

Number of a Lens

(i) A convex lens of focal length +50 cm (+0.5 m), has power +2 dioptre. Its number is +2.

(ii) A concave lens of focal length – 20 cm (-0.2 m), has power -5 dioptre. Its number is – 5.

- **Focal Length and Power of a Lens Combination**

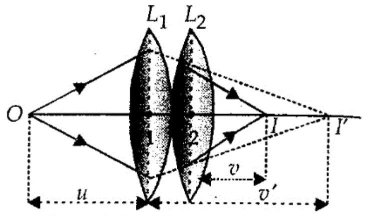
  The power of the combination of a number of thin lenses placed in contact is equal to the algebraic a sum of the powers of the individual lenses.

- **For a Two Lens Combination**

  Let lenses L_1 and L_2 'have focal lengths $f_1$and f_2 and powersP_1 and P_2 respectively. They are very thin so that their optical centers C_1 and C_2 lie very close.

  Let for the combination/ focal length = F, Power = P

Lens L_1, forms real image of point object 0 at point I'. acts as virtual object for lens L_2 which makes final real image at I.



Two thin lenses in contact

For lens $L_1, C_1O = -u, C_1I' = +v'$
For lens $L_2, C_2I' = C_1I' = v', C_2I = +v$

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

For lens $L_1, \frac{1}{v'} - \frac{1}{u} = \frac{1}{f_1}$

For lens $L_2, \frac{1}{v} - \frac{1}{v'} = \frac{1}{f_2}$

Adding equations (i) and (ii) $\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2}$

For the combination, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Hence, from equation (iii) and (iv), $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$ or

$P = P_1 + P_2$

Note:

- For a number of thin lenses having very close optical centers $P = P_1 + P_2 .... + P_n$ or $P = \sum P_n (n = 1 \; to \; n)$
- P is positive for convex lens and negative for concave lens.
  Then P = algebraic sum of power.

ILLUSTRATION

8. Two lenses one of focal length 20 cm (convex lens) and another of focal length -15 cm (concave lens) are placed in contact. What is the focal length and power of the combination?

Sol: Here, f_1=+20cm=+0.2m

$f_2 = -15cm = -0.15m$

F =?

P =?

From relation, $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$

Putting values, we get

$\frac{1}{F} = \frac{1}{0.2} + \frac{1}{-0.15} = \frac{3-4}{0.6} = -\frac{1}{0.6}$

Or F = - 0.6 m

From relation, $P = \frac{1}{F} = -\frac{1}{0.6} = -1.67$

i.e., $p = -1.67$ D

ESSENTIAL POINTS For COMPETITIVE EXAMS

- Refraction of light: The bending of light when it passes obliquely from one transparent medium to another is called refraction of light.
- Medium: A transparent substance in which light travels is known as a medium. A medium in which the speed of light is more is known as an optically rarer medium. A medium in which the speed of light is less is known as an optically denser medium.
- Laws of refraction: (i) The incident ray, the refracted ray and the normal to the surface separating two medium all lie in the same plane.
  (ii) The ratio of the sine of the incident angle ($\angle$i) to the sine of the refracted angle ($\angle$r) is
  i.e., $n = \frac{\sin i}{\sin r}$ = constant.
  This constant is known as the refractive index of second medium with respect to the first medium.
- Lateral shift (displacement): The perpendicular distance between the original path of the incident ray and the emergent ray coming out of a glass slab is called lateral shift.
- Lens: It is a transparent medium bounded by two spherical refracting surfaces or by one spherical and other plane refracting surfaces.
- Power of a lens: It is defined as the reciprocal of the focal length of a lens.
- Dioptre: It is the S.I. unit of power. One dioptre is the power of a lens where focal length is one metre.
- Lens formula: $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$
- Magnification: $m = \frac{h'}{h} = \frac{v}{u}$
- Power of lens: $P = \frac{1}{\text{focal length (in meters)}}$
- Power of a convex lens is positive.
- Power of a concave lens is negative.

SOLVED EXAMPLES

1. Find the refractive index of a material if angle of incidence of ray of light is 45° and angle of refraction in a material is 30°.

Sol. Given, $i = 45°, \; r = 30°$

Using $n=\frac{\sin i}{\sin r}$, we have

$$n=\frac{\sin 45^\circ}{\sin 30^\circ}=\frac{0.7071}{0.5000}\left(\because \begin{array}{l}\sin 45^\circ=0.7071\\ \sin 30^\circ=0.5000\end{array}\right)$$

Thus, refractive index of the material is 1.414.

2. The speed of light in air is $3\times10^8\ m\,s^{-1}$. Calculate the speed of light in glass if the refractive index of glass is 1.5.

Sol: Given, $c=3\times10^8 m\,s^{-1},\ n=1.5$

Using, $n=\frac{c}{\upsilon}$, we have

$$\upsilon=\frac{c}{n}=\frac{3\times10^8 ms^{-1}}{1.5}=2\times10^8 ms^{-1}$$

Thus, velocity of light in glass $=2\times10^8 m\,s^{-1}$

3. Light of wavelength 600 nm in air enters a glass slab of refractive index 1.5. Calculate (a) speed (b) frequency and (c) the wavelength of light in glass slab.

Sol: Here, $\lambda=600nm=600\times10^{-9}m=6\times10^{-7}m$

$(\because 1nm=10^{-9}m)$

$n=1.5$

$c=3\times10^8 m\,S^{-1}$ (Speed of light in air)

(a) Using, $n=\frac{c}{\upsilon}$, we get

$$\upsilon=\frac{c}{n}=\frac{3\times10^8 ms^{-1}}{1.5}=2\times10^8 ms^{-1}$$

Thus, speed of light in glass slab is $2\times10^8 ms^{-1}$

(b) Using, $c=f\lambda$, we get

$$f=\frac{c}{\lambda}=\frac{3\times10^8 ms^{-1}}{6\times10^{-7}m}=5\times10^{14}s^{-1}\text{ (or Hz)}$$

The frequency of light in glass is $10^7\,Hz$ or s^{-1}

(c) Using, $n=\frac{\lambda}{\lambda_m}$, we get

$$\lambda_m=\frac{\lambda}{n}=\frac{6\times10^{-7}n}{1.5}=4\times10^{-7}m$$

Thus, wavelength of light in glass slab decreases and becomes 400 nm.

4. The refractive index of water is 4/3 and for glass it is 3/2 with respect to air. What is the refractive index of glass with respect to water?

Sol. Here,

Refractive index (R.I.) of water with respect to air, ${}_\omega n_a=\frac{4}{3}$

R.I. of glass with respect to air, ${}_g n_a=\frac{3}{2}$

R.I. of glass with respect to water, ${}_g n_w=?$

From relation,

For successive refraction, ${}_w n_a\times{}_g n_w\times{}_a n_g=1$

$$\left(As\frac{n_\omega}{n_a}\times\frac{n_g}{n_\omega}\times\frac{n_a}{n_g}=1\right)$$

We have, ${}_g m_w=\frac{1}{{}_w n_a\times{}_a n_g}=\frac{{}_g n_a}{{}_w n_a}$

Putting value, we get,

$${}_g n_w=\frac{3/2}{4/3}=\frac{3}{2}\times\frac{3}{4}=\frac{9}{8}=1.125$$

5. A convex lens has focal length of 20 cm. Calculate at what distance from the lens should the object be placed so that the image is formed at 40 cm on the other side of the lens? Also state the nature of the image formed.

Sol. Here, $f=20m$

$\upsilon=40cm$

$u=?$

Step 1. Using $-\frac{1}{u}+\frac{1}{\upsilon}=\frac{1}{f}$, we have

$$-\frac{1}{u}=\frac{1}{f}-\frac{1}{\upsilon}=\frac{1}{20}-\frac{1}{40}$$

or $-\frac{1}{u}=\frac{1}{40}$ or $u=-40cm.$

Thus, the object should be placed at a distance of 40 cm in front of the convex lens.

Step 2. $m=\frac{\upsilon}{u}=\frac{40}{-40}$

Negative sign shows that the image is real and inverted.

6. An object 4 cm high is placed at a distance of 27 cm in front of a convex lens of focal length18 cm. Find the position, nature and size of the image formed.

Sol. Here, $u=-27\ cm$ (sign convention)

$f=18cm,\ h_1=4cm$

Step 1. Determination of υ

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

$$-\frac{1}{(-27)}+\frac{1}{\upsilon}=\frac{1}{18}\text{ or }\frac{1}{\upsilon}=\frac{1}{18}-\frac{1}{27}=\frac{1}{54}$$

$\therefore \upsilon=54cm$ (Position of image)

Step 2. Determination of h_2

Using, $\frac{h_2}{h_1}=\frac{\upsilon}{u}$, we get

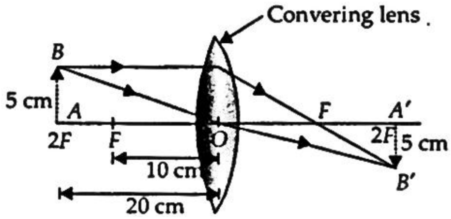
$$h_2=\frac{\upsilon}{u}\times h_1=\frac{54}{-27}\times4=-8cm$$

Thus, size of image is 8 cm, negative sign shows that the image is inverted.

7. An object of 5 cm is placed 20 cm away from a converging lens of focal length 10 cm. Draw the ray diagram to produce the image and find the position, size and the nature of the image formed.

Sol. In this case, $f = +10cm,\ u = -20cm,\ h_1 = 5cm$

Here, object is placed 20 cm away from the lens of focal length 10 cm, so object is at 2F. So the image of the object will be formed at 2F on right side of the lens. The image formed will be real, inverted and of the same size as that of the object as shown in the diagram.



$h_1 = 5cm,\ u = -20cm,\ f = 10cm$

Step 1. Using $-\frac{1}{u} + \frac{1}{\upsilon} = \frac{1}{f}$, we have

$-\frac{1}{(-20)} + \frac{1}{\upsilon} = \frac{1}{10}$ or $\frac{1}{\upsilon} = \frac{1}{10} - \frac{1}{20} = \frac{1}{20}$

$\therefore \quad \upsilon = +20cm$

Positive sign shows that a real image is formed.

Step 2. Using, $\frac{h_2}{h_1} = \frac{\upsilon}{u}$, we have

$h_2 = \frac{\upsilon}{u} h_1 = \frac{20}{-20} \times 5 = -5cm$

Negative sign shows that the image formed is inverted.

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

8. A convex lens forms a real and inverted image of a needle at a distance of 25 cm from the lens. If the image is of the same size as that of the needle, then where should the needle be placed in front of the lens. Also calculate the power of the lens.

Sol. **Step 1.** We know, if the size of the real and inverted image is same as that of the object, then the object is at 2F and image is also formed at 2F on the other side of the convex lens.

$\therefore \quad u = -25cm$

Also $\frac{h_2}{h_1} = \frac{\upsilon}{u}$ or $\frac{\upsilon}{u} = 1 \qquad (\because h_2 = h_1)$

or $\upsilon = u = 25\ cm$

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

$\frac{1}{f} = \frac{1}{25} + \frac{1}{25} = \frac{2}{25}$ or $f = \frac{25}{2} = 12.5cm$

In this case. If $2f = 25\ cm$ or $f = 12.5\ cm$

Thus, needle must be placed at a distance of 25 cm in front of the convex lens.

Step 2. Now, power of lens, $P = \frac{100}{f\,(in\ cm)} = \frac{100}{12.5} = +8.0D$

9. Find the focal length of a lens of power -1.0 D. What type of lens is this?

Sol. Using $P = \frac{100}{f\,(in\ cm)}$,

Here, $P = -1.0D$

$\therefore f = \frac{100}{P} = \frac{100}{-1} = -100cm$

Since the power and focal length are negative, so the given lens is concave lens.

10. A lens used in spectacles has power + 2.0 D. What is the focal length of the lens? Is the lens a converging or diverging?

Sol. Here, $P = +2.0\ D$

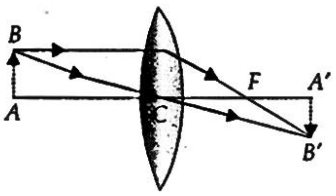
Using, $P = \frac{100}{f\,(cm)}$ we get

$f = \frac{100}{P} = \frac{100}{2} = 50$

Since power and focal length of the lens are positive, so the given lens is converging.

11. An object 5 cm high is held 25 cm away from a converging lens of focal length *f* = 10 cm. Draw a suitable scale diagram and find the position and size of the image formed. Is the image real or virtual?

Sol. In figure AB is real object. A' B' is the real image.



Also, in measurement

Object distance, $CA = 25cm$ i.e., $u = 25cm$

Focal length, $CF = 10\ cm \ \ f = 10\ cm$

Object size, $AB = 5cm$ i.e., $h_1 = 5cm$

From lens formula $\frac{1}{\upsilon} - \frac{1}{u} = \frac{1}{f}$

We have, $\frac{1}{\upsilon} = \frac{1}{f} + \frac{1}{u}$

Putting values, we get

$\frac{1}{\upsilon} = \frac{1}{10} + \frac{1}{-25} = \frac{5-2}{50} = \frac{2}{50}$ or

$\upsilon = \frac{50}{3} cm = 16.7cm$

From relation, $m = \frac{h_2}{h_1} = \frac{\upsilon}{u}$

We have, $h_2 = h_1 \frac{\upsilon}{u}$

Putting values, we get $h_2 = 5 \times \frac{50/3}{-25} = -\frac{10}{3}$

Or $h_2 = -\frac{10}{3}$ or $-3.3cm$

h_2 negative means image is inverted, hence real.

12. A 2.0 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 10 cm. The distance of the object from the lens is 15 cm. Find the nature, position and size of the image. Also find the magnification.

Sol. Here, (using sign convention)

Focal length, $f = +10\ cm$ (focus on the right of the lens)

Object distance, $u = -15\ cm$ (object on the left of the lens)

Object size, $h_1 = 2\ cm$ (erect object)

(i) Position of image

From lens formula, $\frac{1}{\upsilon} - \frac{1}{u} = \frac{1}{f}$

We have, $\frac{1}{\upsilon} = \frac{1}{f} + \frac{1}{u}$

Putting values, we get,

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

$\upsilon = +30cm$

Image is 30 cm away on the right of the lens.

(ii) Image size

From relation, $m = \frac{h_2}{h_1} = \frac{\upsilon}{u}$

We have, $h_2 = h_1 \frac{\upsilon}{u}$

Putting value, we get, $h_2 = 2 \times \frac{+30}{-15} = -4cm$

$h_2 = -4cm$

Image size is -4 cm. It is real and inverted

(iii) Magnification

From relation, $m = \frac{h_2}{h_1} = \frac{\upsilon}{u}$

Putting values, we get, $m = \frac{+30cm}{-15cm} = -2$

The real image is twice enlarged in size as that of the object.

13. If an object of 7 cm height is placed at a distance of 12 cm from a convex lens of focal length8 cm, find the position, nature and height of the image.

Sol. Here, object distance, $u = -12\ cm$ (object on left of the lens)

Focal length $f = +8$ (focus on right of the lens)

Object size, $h_1 = +7$ (object erect)

(i) Image position

From lens formula $\frac{1}{\upsilon} - \frac{1}{u} = \frac{1}{f}$

We have, $\frac{1}{\upsilon} = \frac{1}{f} + \frac{1}{u}$

Putting values, we get,

$\frac{1}{\upsilon} = \frac{1}{8} + \frac{1}{-12} = \frac{3-2}{24} = \frac{1}{24}$

$\upsilon = +4cm$

The image is formed at distance 24 cm from the lens on its right.

(ii) Image height

From relation, $m = \frac{h_2}{h_1} = \frac{\upsilon}{u}$

We have, $h_2 = h_1 \frac{\upsilon}{u}$

Putting values, we have, $h_2 = 7 \times \frac{24}{-12}$

Since h_2 is negative, the image is real and inverted.

Its height is 14 cm

14. A convex lens of focal length 10 cm is placed at a distance of 12 cm from a wall. How far from the lens should an object be placed so as to form its real image on the wall?

Sol. Since a real image is to be formed on the wall, the wall must be on the right of the convex lens.

Here, image distance, $\upsilon = +12\ cm$ (image on the right of the lens)

Focal length, $f = +10\ cm$ (focus on the right of the lens)

Object distance, $u = ?$

From lens formula, $\frac{1}{\upsilon} - \frac{1}{u} = \frac{1}{f}$

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

Putting values, we get,

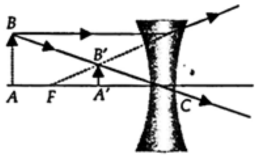
$\frac{1}{u} = \frac{1}{12} - \frac{1}{10} = \frac{5-6}{60} = -\frac{1}{60}$

$u = -60cm$

The object should be placed at distance 60 cm from the lens on its left.

15. A diverging lens or a concave lens of focal length, $f = 15\ cm$ forms an image 10 cm from the lens. Draw a scale diagram and prove that the object is placed 30 cm away from the lens. Use a scale of 1: 5.

Sol.



In figure, A'B' is the image AB is the real object. Also by measurements.

Image distance $CA' = 2\ cm$ $i.e.,\ \upsilon = 10\ cm$

Focal length, $CF = 3\ cm$ $i.e.,\ f = 15\ cm$

As $\frac{1}{\upsilon} - \frac{1}{u} = \frac{1}{f}$ or

$\frac{1}{u} - \frac{1}{\upsilon} = \frac{1}{f} = \frac{1}{10} - \frac{1}{15} = \frac{3-2}{30} = \frac{1}{30}$

or $u = 30\ cm$ CA comes to be 6 cm.

Hence, object distance $= 30\ cm$.

16. A concave lens has focal length of 15 cm. At what distance should be object from the lens be placed so that it forms an image at 10 cm from the lens? Also find the magnification of the image.

Sol. Here, (using sign convention)

Focal length, $f = -15\ cm$ (focus on left of the lens)

Image distance, $\upsilon = -10\ cm$ (image on left of the lens)

(i) Object position

From lens formula, $\frac{1}{\upsilon} - \frac{1}{u} = \frac{1}{f}$

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

Putting values, we get,

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

Object must be placed at distance 30 cm on the left of the lens.

(ii) Magnification

From relation, $m = \frac{h_2}{h_1} = \frac{\upsilon}{u}$

Putting value, we get, $m = \frac{-10cm}{-30cm} = \frac{1}{3}$

The virtual image has $\left(\frac{1}{3}\right)^{rd}$ size as that of the object.

17. An object is placed at a distance of 50 cm from a concave lens of focal length 20 cm. Find the nature and position of the image.

Sol. Here, object distance, $u = -50\ cm$ (object on the left of the lens)

Focal length, $f = -20\ cm$ (focus on the left of the lens)

Image distance, $\upsilon = ?$

From lens formula, $\frac{1}{\upsilon} - \frac{1}{u} = \frac{1}{f}$

We have, $\frac{1}{\upsilon} = \frac{1}{f} + \frac{1}{u}$

Putting values, we get,

$\frac{1}{\upsilon} = \frac{1}{-20} + \frac{1}{-50} = \frac{-5-2}{100} = \frac{-7}{100}$

or $\upsilon = -\frac{100}{7} cm = -14.3cm.$

Image is formed at distance 14.3 cm on the left of the lens.

From relation, $m = \frac{h_2}{h_1} = \frac{\upsilon}{u}$

We have, $h_2 = h_1 \frac{\upsilon}{u}$

Putting values, we get $h_2 = h_1 \times \frac{-100}{-50} = +\frac{2}{7} h_1$

Since h_1 is positive (erect object), h_2 is also positive. The image is erect and virtual.

18. An object placed 50 cm from a lens produces a virtual image at a distance of 10 cm in front of the lens. Calculate the focal length of the lens.

Sol. Here, object distance, $u = -50\ cm$ (object on the left of the lens)

Image distance, $\upsilon = -10\ cm$ (image on the left of the lens)

Focal length $f = ?$

From lens formula $\frac{1}{\upsilon} - \frac{1}{u} = \frac{1}{f}$

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

Putting values, we get,

$\frac{1}{f} = \frac{1}{-10} - \frac{1}{-50} = \frac{-5+1}{50} = \frac{-4}{50}$

or $f = -\frac{50}{4} = -12.5cm$

The lens has focal length 12.5 cm.

It is a concave lens.

19. An object lies at distance of 2f from a concave lens of focal length f. Find the image distance in terms of f

Sol. Here, object distance, $u = -2f$ (object on the left of the lens)

Focal length, $f = -f$ (focus on the left of the lens)

Image distance, $\upsilon = ?$

From lens formula, $\frac{1}{\upsilon}-\frac{1}{u}=\frac{1}{f}$

We have, $\frac{1}{\upsilon}=\frac{1}{f}+\frac{1}{u}$

Putting values, we get, $\frac{1}{\upsilon}=\frac{1}{-f}+\frac{1}{-2f}=\frac{-2-1}{2f}=-\frac{3}{2f}$

The image is formed at a distance $\frac{2f}{3}$ from the lens on its left (υ is negative).

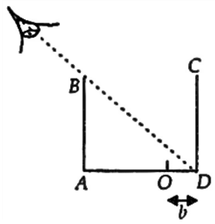
20. A ray of light travelling in air falls on the surface of a rectangular slab of a plastic material whose refractive index is 1.6. If the incident ray makes an angle of 53° with the normal (sin 53° = 4/5), find the angle made by the refracted ray with the normal.

Sol. The angle of incidence is 53° and the refractive index, is $n=1.6$

We have $\frac{\sin i}{\sin r}=n \Rightarrow \frac{\sin 53°}{\sin r}=1.6$

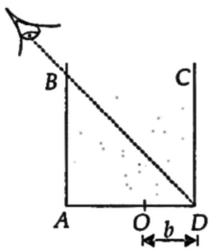
$\sin r=\frac{\sin 53°}{1.6}=\frac{4}{5\times 1.6}=\frac{1}{2}\ \therefore r=30°$

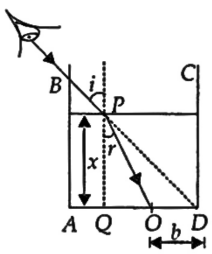
21. A cubical vessel with opaque walls, is so placed that the eye of an observer cannot see its bottom but can see the entire wall CD. A small object is placed at O at a distance $b=10cm$ from corner D. What minimum depth of water $\left(\mu=\frac{4}{3}\right)$ should be poured into the vessel which will enable the observer to see the object?



Sol. Let the minimum depth of water be x. Since the vessel is cubical (AB = AD), it is clear that angle $i=45°$. From Snell's law, the angle of refraction is given by

$\sin r=\frac{\sin i}{n}=\frac{\sin 45°}{4/3}=0.5303\ \therefore\ r=32.03°$





Since $\angle QPD=45°, PQ=x=QD$

Hence, $QO=x-b$

Now, $\Delta PQO, QO=x\tan r$

$\Rightarrow x-b=x\tan r \Rightarrow x=\frac{b}{1-\tan r}$

Substituting for b and r, we get

$x=26.7\ cm$

22. Does the critical angle for total internal reflection is greater when a ray of light travels from glass to water than when it travels from glass to air.

Sol. Here, refractive index of glass, ${}^{a}n_g=\frac{4}{3}$

Refractive index of water, ${}^{a}n_w=\frac{3}{2}$

Now, ${}^{a}n_w\times{}^{w}n_g={}^{a}n_g$

Therefore, refractive index of glass with respect to water,

$\therefore {}^{w}n_g=\frac{{}^{a}n_g}{{}^{a}n_w}=\frac{3/2}{4/3}=1.125$

Further, the angle of incidence, $i=30°$

If r is the angle of refraction, then

$\frac{\sin i}{\sin r}=1.125\Rightarrow \sin r\frac{\sin 30°}{1.125°}=\frac{0.5}{1.125}=-.4444$

i.e., $\sin^{-1}(0.4444)=26.38$

23. 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.

Sol. Here, $f=-20\ cm, h=5\ cm, \upsilon=-15\ cm, u=?$ and $h'=?$

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

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

$\therefore u=-60cm$

Thus, object should be placed at a distance of 60 cm from the lens to the left side.

Now, $m=\frac{h'}{h}=\frac{\upsilon}{u}\Rightarrow h'=\frac{-15}{-60}\times 5cm=1.25cm$

$\therefore$ Size of the image $=1.25\ cm$

24. A ray of light travels from ethanol into air. If the angle of incidence of the ray at the boundary is 30° and the refractive index of ethanol is 13.6, what is the angle of refraction of the ray as it emerges out of ethanol?

Sol. $\angle i=30°,\ {}^{a}n_e=1.36$

$\therefore {}^{e}n_a=\frac{\sin i}{\sin r}\Rightarrow \sin\ r=\sin\ i\times{}^{a}n_e$

$\Rightarrow \sin\ r=\sin 30°\times 1.36=0.68$

$\therefore\ r=\sin^{-1}(0.68)=42.84°$

25. The refractive index of glass is 1.5 and that of water is 1.3. If the speed of light in water is $2.25 \times 10^8 ms^{-1}$, what is the speed of light in glass?

Sol. Here, ${}^a n_g = 1.5,\ {}^a n_g = 1.3$

Let υ_1 and υ_2 be the speeds of light in glass and water respectively. If c is the speed of light in air, then

$\frac{c}{\upsilon_1} = 1.5$ and $\frac{c}{\upsilon_2} = 1.3 \therefore \frac{c}{\upsilon_2} \times \frac{\upsilon_1}{c} = \frac{1.3}{1.5}$

or

$$\upsilon_1 = \frac{1.3}{1.5} \times \upsilon_2 = \frac{1.3}{1.5} \times 2.25 \times 10^8 = 1.95 \times 10^8 ms^{-1}$$

26. A 4.0 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 20 cm. If the distance of the object is 30 cm from the lens, find the position, nature and size of the image. Also find its magnification.

Sol. Here, $h = 4.0\ cm,\ \ f = 20\ cm, u = -30\ cm,$
$h' = ?, m = ?$

Using lens formula,

$$\frac{1}{f} = \frac{1}{\upsilon} - \frac{1}{u} \quad \Rightarrow \quad \frac{1}{\upsilon} = \frac{1}{f} + \frac{1}{u} = \frac{1}{20} - \frac{1}{30} = \frac{1}{60}$$

$\therefore \qquad \upsilon = 60\ cm$

Thus, the image is formed at 60 cm on other side (i.e., right side) of the lens.

Now, $\frac{h'}{h} = \frac{\upsilon}{u} \Rightarrow h' = \frac{\upsilon}{u} \times h = \frac{60}{-30} \times 4 = -8.0 cm$

Thus, size of the image is 8.0 cm. Negative sign shows that the image is inverted.

So, a real and inverted image of large size is formed.

Now, $m = \frac{h'}{h} = \frac{-8.0 cm}{4.0 cm} = -2$

NCERT SECTION

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.: When a ray of light travels from air into water obliquely, it bends towards the normal. This is because water is optically denser than air. On entering water, speed of light decreases and the light bends towards normal.

2. Light enters from air to glass having refractive index 1.5. What is the speed of light in glass? The speed of light in vacuum is 3 x 10^8 m s^{-1}.

Ans.: Here, refractive index, $n = 1.5$, speed of light in vacuum = c = 3 x 10^8 m s^{-1} speed of light in glass, $\upsilon = ?$

From, $n = \frac{c}{\upsilon} \ \Rightarrow\ \upsilon = \frac{n}{c} = \frac{3 \times 10^8}{1.5} = 2 \times 10^8\ m s^{-1}$

3. Give the medium having highest optical density. Also, give the medium with lowest optical density.

Ans.: The medium with highest optical density is diamond and its refractive index is maximum (= 2.42), also, the medium with lowest optical density is air and its refractive index is minimum (= 1.0003).

4. You are given kerosene, turpentine and water. In which of these does the light travel fastest?

Ans.: We know from the definition of refractive index, that the speed of light is higher in a medium with lower refractive index. So, the light travels fastest in water relative to kerosene and turpentine.

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

Ans.: This statement means that the speed of light in diamond is lower by a factor of 2.42 relative to that in vacuum.

6. Define 1 dioptre of power of a lens.

Ans.: The power of a lens whose focal length is one metre (1 m) is one dioptre.

7. A convex lens forms a real and inverted image of a needle at a distance of 50 cm from it. Where is the needle placed in front of the convex lens if the image is equal to the size of the object?
Also, find the power of the lens.

Ans.: Distance of the image from the lens, $\upsilon = 50\ cm$

Distance of the object from the lens, $u = ?$

Size of the image, $I =$ Size of the object, O

From the definition, if h is the height of the image and that of the object,

$$magnification = \frac{I}{O} = \frac{-h}{h} = -1$$

$[\because \text{ The image is inverted}]$

For a lens, $magnification = \frac{\upsilon}{u}$

So, $\frac{\upsilon}{u} = -1 \Rightarrow\ u = -\upsilon = -50\ cm$

So, the needle (the object) is placed at a distance of 50 cm in front of the lens.

Using the lens formula $\frac{1}{f} = \frac{1}{\upsilon} - \frac{1}{u}$

$$\Rightarrow \frac{1}{f} = \frac{1}{50 cm} - \frac{1}{-50 cm}$$

$$= \frac{1}{50 cm} + \frac{1}{50 cm} = \frac{2}{50\ cm} = \frac{1}{25\ cm}$$

Then, power of the lens $= \frac{100}{f(cm)} D = \frac{100}{25cm} D = 4D$

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

Ans.: Focal length of the concave lens = - 2 m

So, power of the concave lens $= \frac{1}{-2} D = -0.5D$

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

(a) Water (b) Glass

(c) Plastic (d) Clay

Ans.: The correct answer is (d), because clay is opaque.

10. Which of the following lenses would you prefer to use while reading small letters found in a dictionary?

(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.: For reading small letters in a dictionary, we need to use a convex lens of smaller focal length. Choice (c) is correct.

11. 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.: Yes, it will produce a complete image of the object, as shown in figure. This can be verified experimentally by observing the image of a distance object like tree on a screen, when lower half of the lens is covered with a black paper. However, the intensity or brightness of image will reduce.

12. An object 5 cm in length is held 25 cm away from a converging lens of focal length 10 cm. Draw the ray diagram and find the position, size and the nature of the image formed.

Ans.: Here, object size, $h_1 = 5cm$

object distance, $u = -25\ cm$

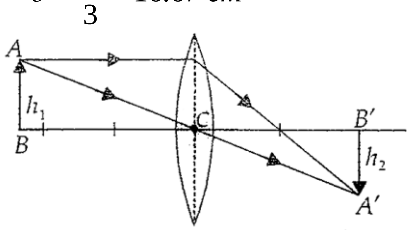
focal length of lens, $f = 10\ cm$

image distance, $\upsilon = ?$

image size, $h_2 = ?$

As $\frac{1}{\upsilon} - \frac{1}{u} = \frac{1}{f}$ $\therefore$ $\frac{1}{\upsilon} = \frac{1}{f} + \frac{1}{u} = \frac{1}{10} - \frac{1}{25} = \frac{5-2}{50}$

$\Rightarrow$ $\upsilon = \frac{50}{3} = 16.67\ cm$



As υ is positive, the image formed is real; on the right side of the lens, as shown in figure above.

As $m = \frac{h_2}{h_1} = \frac{\upsilon}{u}$

$\therefore$ $\frac{h_2}{5} = \frac{50/3}{-25} = \frac{-2}{3} \Rightarrow h_2 = -\frac{10}{3} = -3.3\ cm$

Negative sign shows that the image is inverted.

13. A concave lens of focal length 15 cm forms an image 10 cm from the lens. How far is the object placed from the lens? Draw the ray diagram.

Ans.: Here, focal length of lens, *f* = - 15 cm

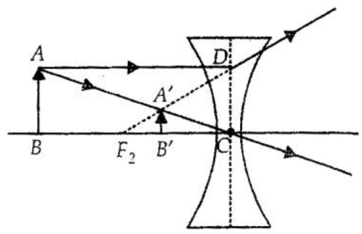
Image distance, $\upsilon = -10\ cm$

object distance, $u = ?$

As $\frac{1}{f} = \frac{1}{\upsilon} - \frac{1}{u} \Rightarrow$

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

Now, ray diagram of image:



14. Find the focal length of a lens of power -2.0 D. What type of lens is this?

Ans.: Here, focal length, *f* = ?, power, P = - 2.0 D

As $f = \frac{100}{P}$ $\Rightarrow$ $f = \frac{100}{-2.0} = -50\ cm$

As power of lens is negative, the lens must be concave.

15. 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.: Power of the lens, P = + 1.5 D = + 1.5 m^{-1}

$\therefore$ Focal length of the lens,

$f = \frac{1}{+1.5m^{-1}} = 0.667m = 66.7\ cm$

Thus, the focal length of the lens is 66.7 cm

Since the focal length of the lens is positive, hence the given lens is a converging lens.

NCERT EXEMPLAR PROBLEMS-SOLUTIONS

Multiple Choice Questions (MCQs)

1. Which of the following can make a parallel beam of light when light from a point source is incident on it?

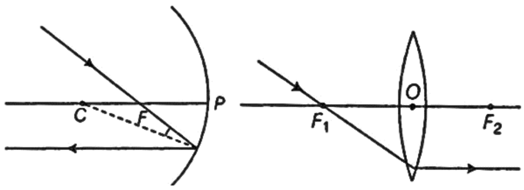
(a) Concave mirror as well as convex lens

(b) Convex mirror as well as concave lens

(c) Two plane mirrors placed at 90° to each other

(d) Concave mirror as well as concave lens

Ans. **(A)** A ray passing through the principal focus of a concave mirror or convex tens, after reflection/refraction, will emerge parallel to the principal axis.



2. 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. The focal length of this mirror is

(a) -30 cm (b) -20 cm

(c) - 40 cm (d) -60 cm

Ans. **(B)** Given, object size, $h = +10.0$ mm ($\because$ 1 cm= 10 mm)

= + 1.0cm

Image size, h' =5.0 mm = 0.5 m

Image distance, v = -30 cm (For real image)

Focal length, f = ?

Also, magnification, $m = \frac{h'}{h}\frac{\text{(Image Size)}}{\text{(object size)}}$

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

$\frac{0.5}{1} = \frac{-30}{u} \Rightarrow u = -60$ cm

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

$\Rightarrow \frac{1}{f} = \frac{1}{-30} - \frac{1}{60} = \frac{-2-1}{60} = \frac{-3}{60}$

$\Rightarrow f = -20$ cm

3. Under which of the following conditions, a concave mirror can form an image larger than the actual object?

(a) When the object is kept at a distance equal to its radius of curvature.

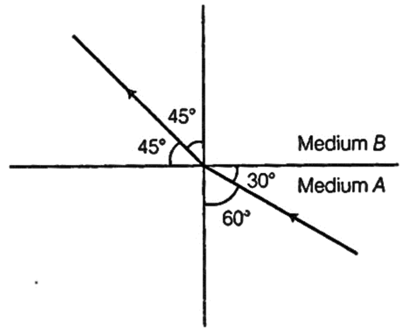
(b) When object is kept at a distance less than its focal length

(c) When object is placed between the focus and centre of curvature

(d) When object is kept at a distance greater than its radius of curvature

Ans. **(C)** A concave mirror can form an image enlarged, real and inverted than the actual object, beyond centre of curvature (C) when object is placed between the focus (F) and centre of curvature.

4. Figure shows a ray of light as it travels from medium A to medium B. Refractive index of the medium B relative to medium A is



(a) $\frac{\sqrt{3}}{2}$ (b) $\frac{\sqrt{2}}{\sqrt{3}}$

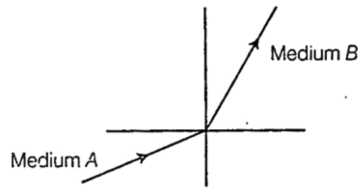
(c) $\frac{1}{\sqrt{2}}$ (d) $\sqrt{2}$

Ans. **(A)** Given, angle of incidence, i = 60°, angle of refraction, r = 45°

Refractive index of the medium B relative to medium A,

$$\mu_{BA} = \frac{\sin i}{\sin r} = \frac{\sin 60°}{\sin 45°} = \frac{\left(\frac{\sqrt{3}}{2}\right)}{\left(\frac{1}{\sqrt{2}}\right)} = \frac{\sqrt{3}}{\sqrt{2}}$$

5. A light ray enters from medium A to medium B as shown in the figure. The refractive index of medium 6 relative to A will be



(a) greater than unity

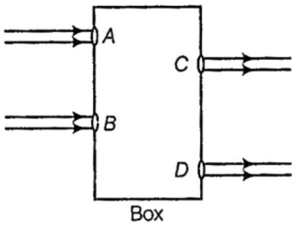
(b) less than unity

(c) equal to unity

(d) zero

Ans. **(A)** Since light rays in the medium 6 goes towards normal. So it has greater refractive index and lesser velocity of light w.r.t. medium/A. So refractive index of medium B w.r.t. medium A is greater than unity.

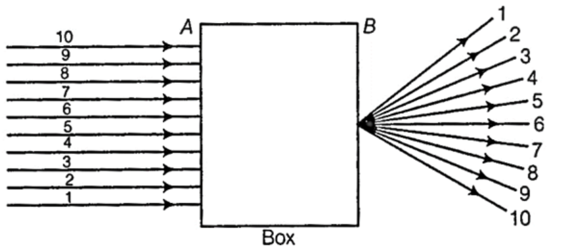
6. Beams of light are incident through the holes A and B and emerge out of box through the holes C and D respectively as shown in the figure. Which of the following could be inside the box?



(a) A rectangular glass slab
(b) A convex lens
(c) A concave lens
(d) A prism

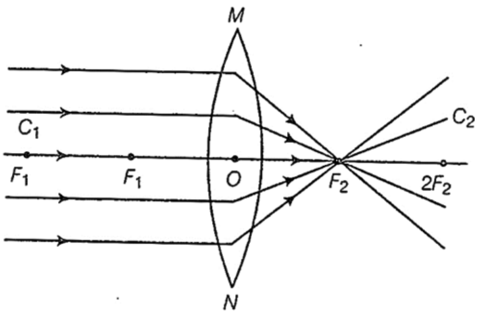
Ans. **(A)** Here, the emergent rays are parallel to the direction of the incident ray. Therefore, a rectangular glass slab could be inside the box as the extent of bending of light ray at the opposite parallel faces AB (air-glass interface) and CD (glass-air interface) of the rectangular glass slab are equal and opposite, This is why the ray emerges parallel to the incident ray.

7. A beam of light is incident through the holes on side A and emerges out of the holes on the other face of the box as shown in the figure. Which of the following could be inside the box?



(a) Concave lens
(b) Rectangular glass slab
(c) Prism
(d) Convex lens

Ans. **(D)** Since in the diagram all the parallel rays converge at a point. So inside the box there will be a convex lens.



8. Which of the following statements is true?
(a) A convex lens has 4 dioptre power having a focal length 0.25 m
(b) A convex lens has 4 dioptre power having a focal length -0.25 m
(c) A concave lens has 4 dioptre power having a focal length 0.25 m
(d) A concave lens has 4 dioptre power having a focal length - 0.25 m

Ans. **(A)** The power P of a lens of focal length f is given by $P = \frac{1}{f}$, where f is the focal length in metre and power in dioptre.

$P = \frac{1}{f}$ or $f = \frac{1}{P} = \frac{1}{4} = 0.25$ m

9. Magnification produced by a rear view mirror fitted in vehicles
(a) is less than one
(b) is more than one
(c) is equal to one
(d) can be more than or less than one depending upon the position of the object in front of it.

Ans. **(A)** The convex mirror forms virtual, erect and diminished image of the object And rear view mirror also form some type of image. Therefore, magnification (m) produced by a rear view mirror fitted in vehicles is less than one i.e., m < 1.

10. Rays from sun converge at a point 15 cm in front of a concave mirror. Where should an object be placed so that size of its image is equal to the size of the object?
(a) 15 cm in front of the mirror
(b) 30 cm in front of the mirror
(c) between 15 cm and 30 cm in front of the mirror
(d) more than 30 cm in front of the mirror

Ans. **(B)** The rays from sun i.e., from infinity, are parallel to principal axis after reflection converge at a point, known as focus. Therefore, focal length (F) of concave mirror is 15 cm. And we know that, same size, real and inverted image is formed by concave mirror when object is placed at focus 2 F or centre of curvature so to form same size image object will be placed at 15 x 2 = 30 cm.

11. A full length image of a distant tall-building can definitely be seen by using
(a) a concave mirror
(b) a convex mirror
(c) a plane mirror
(d) both concave as well as plane mirror

Ans. **(B)** The convex mirror forms virtual, erect and diminished image of the objects. So, it can form full length image of a distant tall building.

12. In torches, search lights and headlights of vehicles, the bulb is placed
(a) between the pole and the focus of the reflector

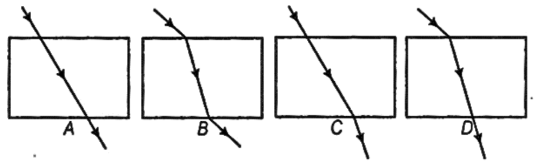
(b) very near to the focus of the reflector
(c) between the focus and centre of curvature of the reflector
(d) at the centre of curvature of the reflector

Ans. **(B)** Concave mirrors are commonly used in torches, search lights and vehicles headlights to get powerful parallel beams of light.
Here the bulb is placed very near to the focus of the reflector as the incident rays, which passes-through the focus of concave mirror, after reflection become parallel to the principal axis of the mirror.

13. The laws of reflection hold good for
(a) plane mirror only
(b) concave mirror only
(c) convex mirror only
(d) all mirrors irrespective of their shape

Ans. **(D)** The laws of reflection holds good-for light reflected from any smooth surface i.e., all mirrors regardless of its shape.

14. The path of a ray of light coming from air passing through a rectangular glass slab traced by four students shown as A, B, C and D in the figure.
Which one of them is correct?



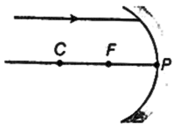
(a) A (b) B
(c) C (d) D

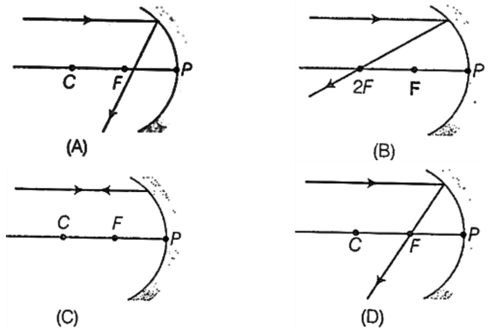
Ans. **(B)** In a rectangular glass slab, the emergent rays are parallel to the direction of the incident ray, because the lateral daviation of bending of the ray of light at the opposite parallel faces (air-glass interface) and (glass-air interface) of the rectangular glass slab are equal and opposite. This is why the ray emerges are parallel to the incident ray.

15. You are given water, mustard oil, glycerine and kerosene. In which of these media, a ray of light incident obliquely at same angle would bend the most?
(a) Kerosene (b) Water
(c) Mustard oil (d) Glycerine

Ans. **(D)** The given material having their refractive index as kerosene is 1.44, water is 1.33. musterd oil is 1.46 and glycerine is 1.74. Thus, glycerine is most optically denser and hence have the largest refractive index. Therefore, ray of light bend most in glycerine.

16. Which of the following ray diagrams is correct for the ray of light incident on a concave mirror as shown in figure?

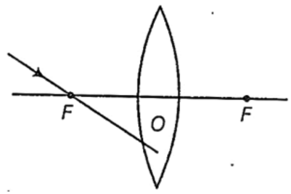


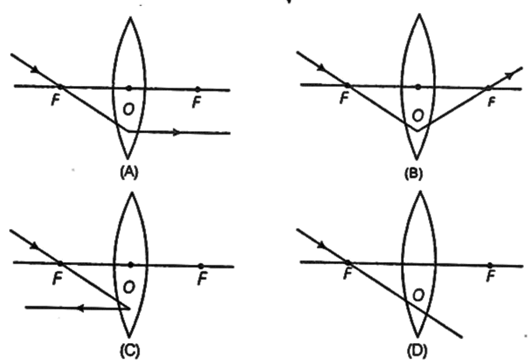


(a) A (b) B
(c) C (d) D

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

17. Which of the following ray diagrams is correct for the ray of light incident on a lens shown in figure?





(a) A (b) B
(c) C (d) D

Ans. **(A)** A ray of light passing through the principal focus of a convex lens after refraction from a convex lens, will emerge parallel to the principal axis.

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 legs smaller. The following is the order of combinations for the magic mirror from the top.
(a) Plane, convex and concave
(b) Convex, concave and plane
(c) Concave, plane and convex
(d) Convex, plane and concave

Ans. **(C)** Concave mirrors (of large focal length) can be used to see a larger image of the head, the plane mirror for middle portion to see her body of the same size and convex mirror to see the diminished image of leg. Hence, the combinations for magic mirror from the top is concave mirror, plane mirror and convex mirror.

19. In which of the following, the image of an object placed at infinity will be highly diminished and point sized?

(a) Concave mirror only

(b) Convex mirror only

(c) Convex lens only

(d) Concave mirror, convex mirror, concave lens and convex lens

Ans. **(D)** The incident rays which comes from an object placed at infinity will be parallel and the rays parallel to the principal axis, after reflection/refraction by concave mirror, convex mirror, concave lens and convex lens, will pass or appear to pass through the principal focus. Hence, image will be highly diminished and point sized.

SHORT ANSWER TYPE QUESTIONS

20. Identify the device used as a spherical mirror or lens in following cases, when the image formed is virtual and erect in each case.

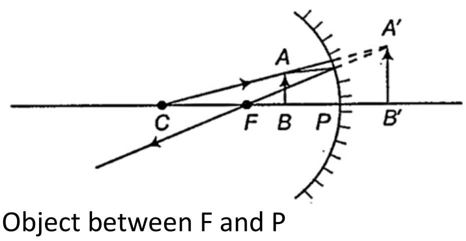
(a) Object is placed between device and its focus, image formed is enlarged and behind it

(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

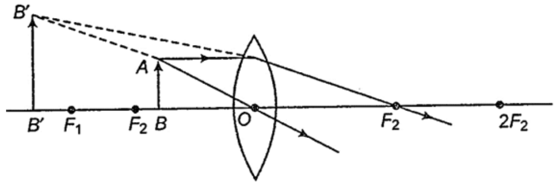
(d) Object is placed between infinity and device, image formed is diminished and between pole and focus, behind it

Ans. **(A)** The spherical mirror is used as concave mirror.



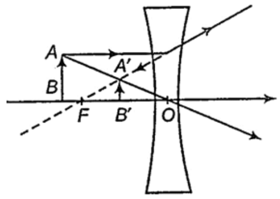
Object between F and P

(b) The spherical lens is used as convex lens.



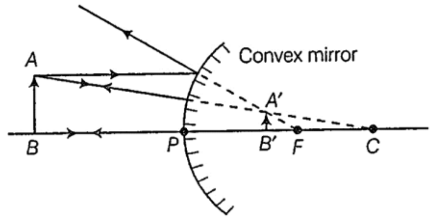
Object between focus (F) and device (O)

(c) The spherical lens is used as concave lens,



Object between infinity and device (O)

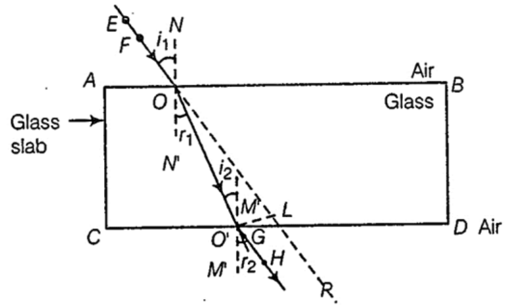
(d) The spherical mirror is used as convex mirror.



Object between infinity and device (P)

21. Why does a light ray incident on a rectangular glass slab immersed in any medium emerges parallel to itself? Explain using a diagram.

Ans. In the given figure, £0 is the incident ray, OO' is the refracted ray and O'H is the emergent ray



The extent of bending of the ray of light at the opposite parallel faces AB (air-glass interface) and CD (glass-air interface) of the rectangular glass slab is equal and opposite. This is why the ray emerges parallel to the incident ray on a rectangular glass slab. However, the light ray is shifted sideward slightly. When glass slab in immersed in any medium the interface AB (medium-glass) and CD glass medium are equal and opposite so, the emergent ray will always be parallel to the incident ray.

22. 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.

Thinking Process

As it is based on refraction of light.

Ans. A pencil partly immersed in water in a glass tumbler, it appears to be displaced at the interface of air and water. The light reaching out from the portion of the pencil inside water seems to come from a different direction, compared to the part above water due to refraction of light.

The pencil appear to be bent to the different extent, if instead of water, liquids like, kerosene or turpentine are used as their refractive indices are different which in turn produces deviation from incident ray by different extent.

23. 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?

Ans. The refractive index of the medium is defined as the ratio of speed of light in vacuum to the speed of light in the medium. It is expressed as

$$\text{Refractive index, } \mu = \frac{\text{speed of light in vacum, c}}{\text{speed of light in medium, v}}$$

$\mu_1 =$ refractive index of first medium

$\mu_2 =$ refractive index of second medium

$v_1 =$ velocity in first medium

$v_2 =$ velocity in second medium

For medium 1, we have $\mu_1 = \frac{c}{v_1}$

For medium 2, we have $\mu_2 = \frac{c}{v_2}$

$$\therefore \ \mu_{21} = \frac{\mu_2}{\mu_1} = \frac{\frac{c}{v_2}}{\frac{c}{v_1}} = \frac{v_1}{v_2}$$

24. 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. Given, refractive index of diamond with respect to glass, ${}_g\mu_d = 1.6 = \frac{\mu_d}{\mu_g}$

Absolute refractive index of glass,

${}_a\mu_g = 1.5 = \mu_g / \mu_a$

Absolute refractive index of diamond,

${}_a\mu_d = \mu_d / \mu_a = ?$

$${}_g\mu_d = \frac{{}_a\mu_d}{{}_a\mu_g}$$

$$\Rightarrow {}_a\mu_d = {}_g\mu_d \times {}_a\mu_g = 1.6 \times 1.5 = 2.4$$

25. 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?

Ans. Yes, the statement is correct. The convex lens of focal length 20 cm can produce a magnified, virtual as well as real image. The object should be placed

(i) Between focus F_1 and optical centre O (i.e., a distance less than 20 cm from the lens) for magnified, virtual and erect image.

(ii) Between (c and 2F, (;.e., at a distance between 20 cm to 40 cm) for real, inverted and enlarged image.

26. 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?

Ans. Sudha should move the screen towards the lens to obtain a sharp image of the building because window pane was lying beyond focus 2F or centre of curvature and convex lens forms its image, on the other side between F and 2F and when she tries to focus the building visible to her outside the window (i.e., at distant object at infinity), then lens forms the image of building at a distance of focal length.

The approximate focal length of this lens is 15 cm.

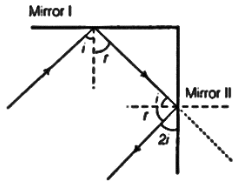
27. How are power and focal length of a lens related? You are provided with two lenses of focal length 20 cm and 40 cm, respectively. Which lens will you use to obtain more convergent light?

Ans. The power of a lens is related to its focal length as $P = \frac{1}{f\,(\text{in m})}$

For greater convergent light, lens of higher power and smaller focal length is needed i.e., the lens of focal length 20 cm is needed for the same.

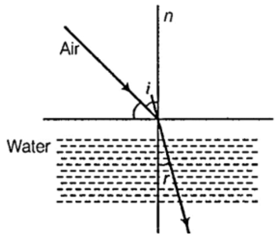
28. Under what condition in an arrangement of two plane mirrors, incident ray and reflected ray will always be parallel to each other, whatever may be angle of incidence. Show the same with the help of diagram.

Ans. When two plane mirrors are placed at right angle with each other, then incident ray and reflected ray will always be parallel to each other, whatever may be angle of incidence.

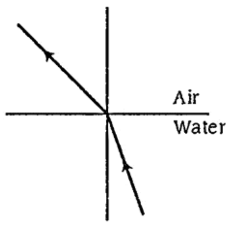


29. Draw a ray diagram showing the path of rays of light when it enters with oblique incidence (i) from air into water; (ii) from water into air.

Ans. (i) When ray of light enters with oblique incidence from air into water, then it goes from optical rarer medium to optical denser medium and velocity of light decreases which in turn bends the incident light towards the normal. Also, i > r



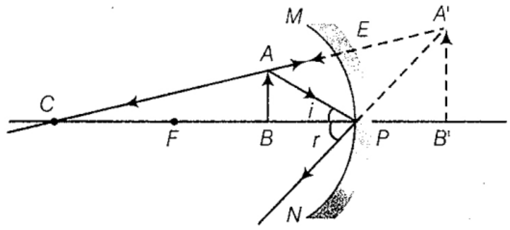
(ii) When ray of light enters with oblique incidence from water into air, then it goes from optical denser medium to optical rarer medium and velocity of light increases which in turn bends the incident light away from the normal. Also, i < r.



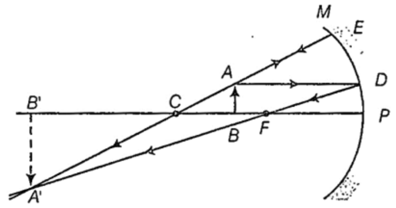
LONG ANSWER TYPE QUESTIONS

30. Draw ray diagrams showing the image formation by a concave mirror when an object is placed
(a) between pole and focus of the mirror
(b) between focus and centre of curvature of the mirror
(c) at centre of curvature of the mirror
(d) a little beyond centre of curvature of the mirror at infinity

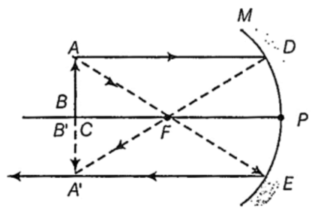
Ans. **(A)** The enlarged, virtual and erect image forms behind the mirror when the object is placed between pole and focus of the mirror.



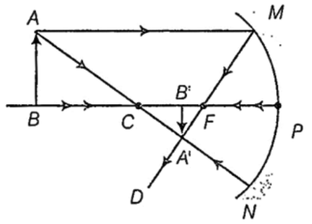
(b) The enlarged, real and inverted image forms beyond centre of curvature when the object is placed between focus and centre of curvature of the mirror.



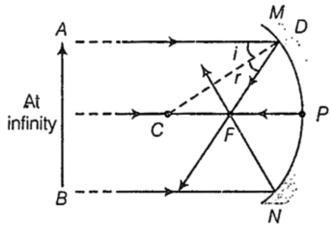
(c) The real and inverted image equal to the size of object forms at centre of curvature when the object is placed at the centre of curvature of the mirror.



(d) The diminished, real and inverted image forms between centre of curvature and focus when the object is placed a little beyond centre of curvature of the mirror.



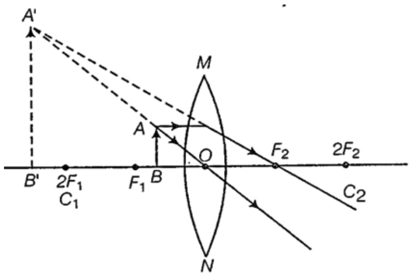
(e) The real, inverted and highly reduced image forms at focus F when the object is placed at infinity.



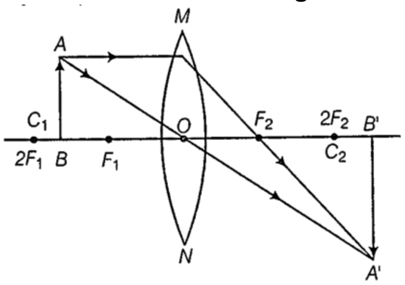
31. Draw ray diagrams showing the image formation by a convex lens when an object is placed
(a) between optical centre and focus of the lens
(b) between focus and twice the focal length of the lens
(c) at twice the focal length of the lens at infinity

(d) at the focus of the lens

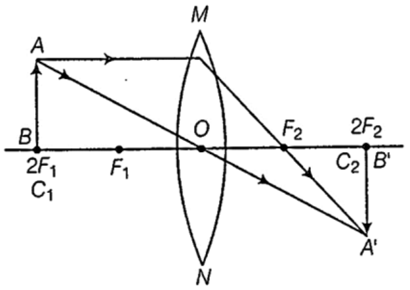
Ans. **(A)** The enlarged, virtual and erect image forms beyond $2F_1$, in the same side of object when the object is placed between optical centre and focus F_1 of the lens.



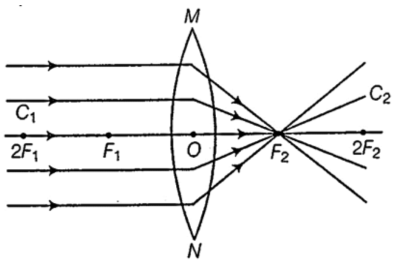
(b) The enlarged, real and inverted image forms beyond focus $2F_2$ on the other side of the object when the object is placed between focus F_1 and twice the focal length of the lens.



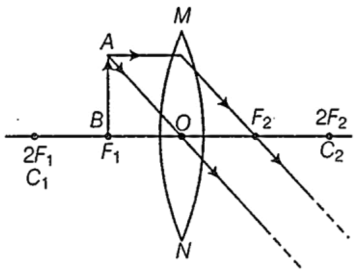
(c) The real and inverted image of equal to the size of object forms at focus $2F_2$ on the other side of the object when the object is placed at twice the focal length of the lens.



(d) The real, inverted and highly reduced image forms at focus F_2 on the other side of the object when the object is placed at infinity.



(e) The real, inverted and highly magnified image forms at infinity on the other side of the object when the object is placed at the focus of the lens.



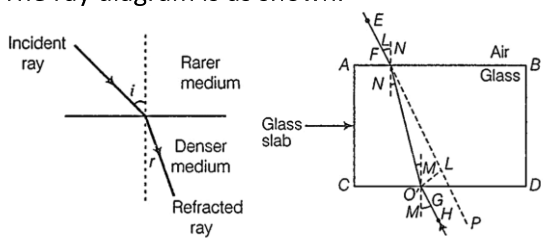
32. Write laws of refraction. Explain the same with the help of ray diagram, when a ray of light passes through a rectangular glass slab.

Ans. The following are the 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 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. And the constant is called refractive index.

The ray diagram is as shown.



In a rectangular or glass slab, the emergent rays are parallel to the incident ray because the extant of bending of the ray of light at the opposite parallel faced of rectangular glass slab are equal and opposite, so that emergent ray is parallel to incident ray.

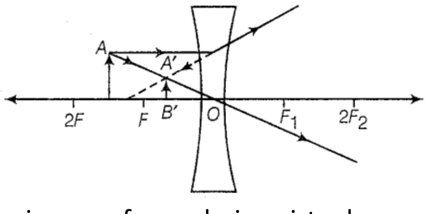
33. Draw ray diagrams showing the image formation by a concave lens when an object is placed

(a) at the focus of the lens

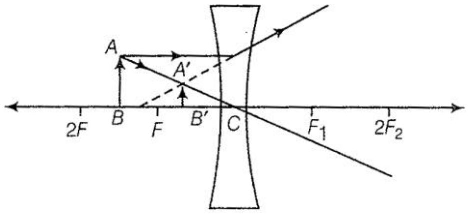
(b) between focus and twice the focal length of the lens

(c) beyond twice the focal length of the lens

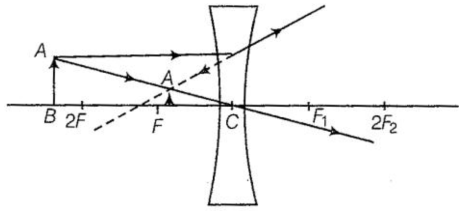
Ans. **(A)** The image formed is virtual, erect, diminished in size and between and F when the object is placed at focus



(b) The image formed is virtual, erect, diminished in size and between optical centre and focus F when the object is placed between focus and twice the focal length of the lens.

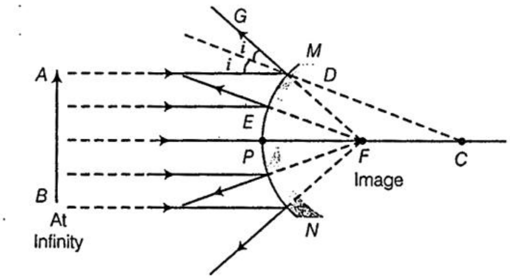


(c) The image formed is virtual, erect, diminished in size and between optical centre and focus F when the object is placed beyond twice the focal length of the lens.

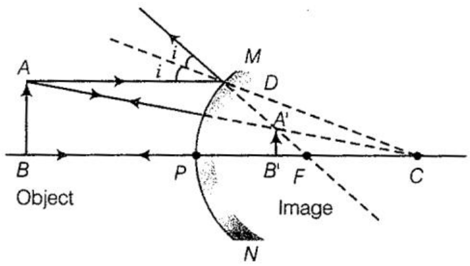


34. Draw ray diagrams showing the image formation by a convex mirror when an object is placed
(a) at infinity
(b) at finite distance from the mirror

Ans. **(A)** The virtual, erect and highly diminished image of the object forms at focus F behind the mirror when the object is placed at infinity.



(b) The virtual, erect and diminished image forms between focus F and pole P behind the mirror when the object is placed at finite distance from the mirror.



35. 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 and the lens?

Thinking Process

Using magnification find the object distance. Then, using lens formula, calculate the value of focal length. Using sign of convention nature of lens can be identified.

Ans. The image is real as only the real image can be taken on the screen.
Here, image distance v = + 80cm
Magnification, m = - 3
Object distance, u =?

Since, magnification, $m=\frac{v}{u} \Rightarrow -3=\frac{80}{u}$

Nature of image
$\rightarrow$Real, inverted
$\rightarrow$magnified
$\rightarrow$formed beyond 2F

Using lens formula, we have

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

$$\frac{1}{f}=\frac{1}{80}-\frac{3}{-80}=\frac{4}{80}=\frac{1}{20}$$

$$\Rightarrow f=20\,\text{cm}$$

Positive focal length denotes that lens is convex.

36. Size of image of an object by a mirror having a focal length of 20 cm is observed to be reduced to 1/3rd to its size. At what distance, the object has been placed from the mirror? What is the nature of the image and the mirror?

Thinking Process

Solve object distance for both concave mirror and convex mirror using the relation of magnification and mirror formula.

Ans. Here, considering (the case for both type of possible spherical mirrors

For concave mirror

Focal length, $f=-20\,\text{cm}$

Magnification, $m=-\frac{1}{3}$

Since, magnification, $m=-\frac{v}{u}$

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

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

Using mirror formula, we have

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}\Rightarrow\frac{1}{f}=\frac{1}{u}+\frac{3}{u}=\frac{4}{u}$$

$$\Rightarrow u=4f=4(-20)=-80\text{ cm}$$

The object should be placed at a distance 80 cm from the concave mirror.

For convex mirror,
Focal length, f = + 20cm

Magnification, $m = +\frac{1}{3}$

Since, magnification, $m = -\frac{v}{u}$

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

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

Using mirror formula, we have

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

$\frac{1}{f} = \frac{-3}{u} + \frac{1}{u} = \frac{-2}{u}$

$u = -2f = -2(20) = -40$ cm

The object should be placed at a distance 40 cm from the convex mirror to form virtual, erect and diminished image.

37. Define power of a lens. What is its unit? One student uses a lens of focal length 50 cm and another of -50 cm. What is the nature of the length and its power used by each of them?

Ans. Power of lense is defined as the ability of a lens to bend the rays of light. It is given by the reciprocal of focal length in metre. Its unit is dioptre.

If focal length, (f) = 50cm, then

$P = \frac{100}{f} = \frac{100}{50} = 2D$, lens is convex.

If focal length, (f) = - 50 cm, then

$P = \frac{100}{f} = \frac{100}{-50} = -2D$, lens is concave.

38. 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 as said above.

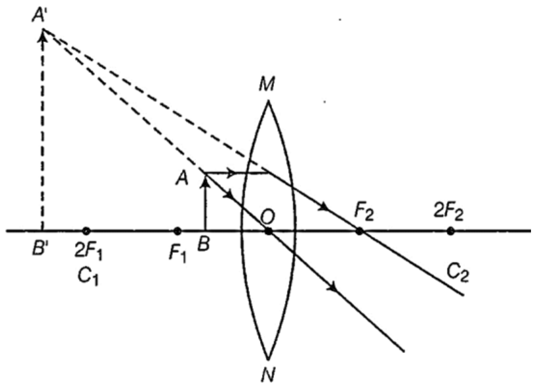
Ans. Object distance u = Position of the convex lens - Position of candle
= 50 – 12 = 38 cm
By sign convention, u = -38 cm
Similarly,' image distance, v = position of the screen - position of convex lens
= 88 – 50 = 38 cm
By sign convention, v = + 38 cm

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

$\frac{1}{f} = \frac{1}{38} - \frac{1}{-38} = \frac{2}{38} = \frac{1}{19}$

$f = 19$ cm

The focal length of the convex lens is 19 cm.
(ii) After shifting the candle towards the lens at a position of 31.0 cm, then object distance u = position of convex lens - position of candle = 50 – 31 =19
By sign convention, u = - 19cm, but here focal length of the convex lens is also 19 cm.
So, the candle lies at the focus of lens, hence its image forms at infinity.
(iii) When student further shifts the candle towards the lens i.e., candle lies between optical centre and focus of convex lens, then lens forms enlarged, virtual and erect image of the candle.
(iv) The ray diagram showing the formation of image



EXERCISE

Multiple Choice Questions

1. Incident angle of a ray of light is 30°. The angle between the incident ray and the reflected ray
(a) 30^o (b) 60^o
(c) 90^o (d) 15^o

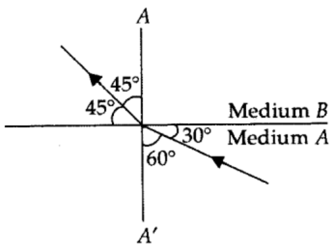
2. A letter L written on a white paper is placed in front of a plane mirror. The image of this letter in the plane mirror will appear as
(a) L (b) Γ
(c) ⅃ (d) ˥

3. To form an image twice the size of the object, using a convex lens of focal length 20 cm, the object distance must be
(a) $< 20cm$ (b) $> 20cm$
(c) $< 20cm$ and between 20 cm and 40 cm
(d) cannot say

4. The refractive index of dense flint glass is 1.65 and for alcohol, it is 1.36 with respect to air, then the refractive index of the dense flint glass with respect to alcohol is
(a) 1.31 (b) 1.21
(c) 1.11 (d) 1.01

5. Light travels from air into glass of refractive index 1.2. The time taken by the light to travel through a piece of glass of 50 cm thickness is
(a) $2.25s$ (b) $2.25\times10^{-7}s$
(c) $2.5\times10^{-8}s$ (d) $2.5\times10^{-9}s$

6. The even figure shows a ray of light as it travels from medium A to medium B. Refractive index of the medium B relative to medium A is
(a) $\frac{\sqrt{3}}{\sqrt{2}}$ (b) $\frac{\sqrt{2}}{\sqrt{3}}$
(c) $\frac{1}{\sqrt{2}}$ (d) $\sqrt{2}$



7. Refractive index of glass with respect to air is and refractive index of water with respect to air is $\frac{4}{3}$. What will be the refractive index of glass with respect to water?
(a) 1 (b) 1.5
(c) 1.125 (d) 1.4

8. Refractive index of diamond with respect to glass is 1.6 and the absolute refractive index of glass is 1.5, then the absolute refractive index of diamond is
(a) 1.4 (b) 2.4
(c) 3.4 (d) 4.4

9. Power of a convex lens of focal length 50 cm is
(a) - 2 D (b) - 0.5 D
(c) + 2 D (d) + 0.5 D

10. The sign of the power of a convex lens is
(a) negative (b) positive
(c) positive if focal length is small
(d) positive or negative depending on the focal length of the lens

11. In the case of refraction of light from a rectangular glass slab, if i be the angle of incidence and e be the angle of emergence, then
(a) $e=i$ (b) $e<i$
(c) $e>i$ (d) $i\neq e$

12. The refractive index of diamond is
(a) 1.5 (b) 1.33
(c) 2.42 (d) 1.8

13. In case of erect object having inverted image, sign of the linear magnification is
(a) positive (b) negative
(c) zero (d) no definite sign

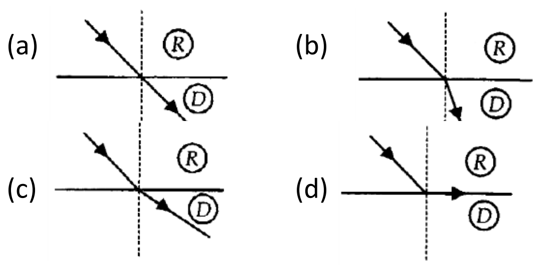
14. Two thin lenses of power, + 3.5 D and - 2.5 D are placed in contact, then the power and focal length of the lens combination is
(a)+ 1 D, + 100 cm (b) + 2 D, + 150 cm
(c)+1 D, + 200 cm (d) + 2 D, + 100 cm

15. When an object moves towards a convex lens, the size of the image
(a) decreases
(b) first decreases then increases
(c) increases
(d) remains the same

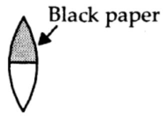
16. A ray of light travelling from air enters a liquid at an angle of 45° with the normal. If the corresponding angle of refraction is 30°, then the refractive index of the liquid with respect to air is
(a) 1.44 (b) 1.41
(c) 1.21 (d) 1.45

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

18. Which of the following shows the bending of light from rarer (R) into denser (D) medium?

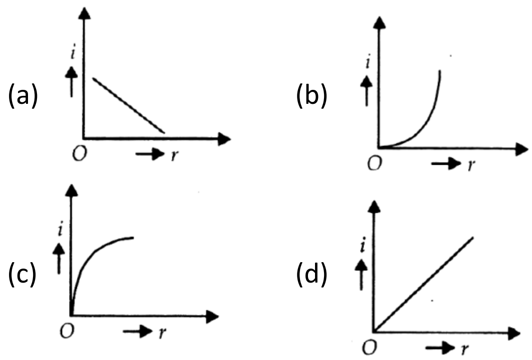


19. How will the image formed by a convex lens be affected if the upper half of the lens is wrapped with a black paper?



(a) The size of the image is reduced to one-half.
(b) The upper half of the image will be absent.
(c) The brightness of the image is reduced.
(d) There will be no effect.

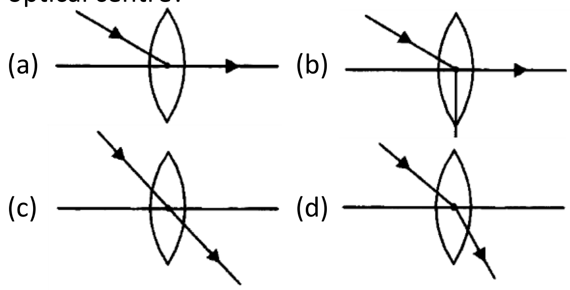
20. Which of the following correctly represents the graphical variation between very small angles of incidence (i) and refraction (r) ?



21. If f is focal length of the lens, then the power a lens is equal to

(a) $\frac{100}{f(cm)}$ (b) $\frac{10}{f(cm)}$
(c) $\frac{100}{f(m)}$ (d) $\frac{1}{100f(cm)}$

22. Which of the following diagram correctly represents the ray of light passing through the optical centre?



23. A convex lens of focal length 24 cm is placed 12 cm in front of a convex mirror. It is found that when a pin is placed 36 cm in front of the lens, it coincides with its own inverted image formed by, the lens and the mirror. Then the focal length of the mirror is

(a) 45 cm (b) 60 cm
(c) 15cm (d) 30cm

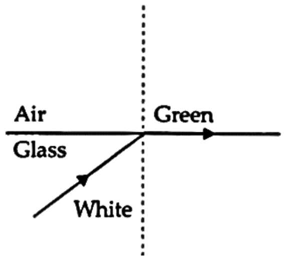
24. A concave mirror of radius of curvature 60 cm is placed at the bottom of tank containing water up to a height of 20 cm. The mirror faces upwards with its axis vertical. Sun light falls normally on the surface of water and the image of the sun is formed. If ${}^{a}n_{w}$ is $\frac{4}{3}$ then with the observer in air, the distance of the image from the surface of water is

(a) 7.5 cm below (b) 7.5 cm above
(c) 10 cm (d) 30 cm

25. A ray of light travelling inside a rectangular glass block of refractive index $\sqrt{2}$ is incident on the glass-air surface at an angle of incidence of 45°. The refractive index of air is one. Under these conditions the ray

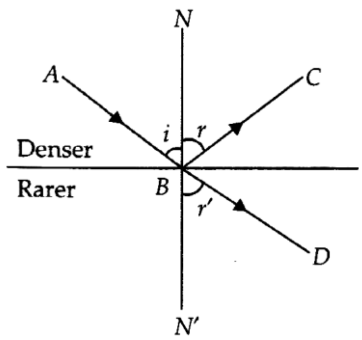
(a) will emerge into the air without any deviation
(b) will be reflected back into the glass
(c) will be absorbed
(d) will emerge into the air with an angle of refraction equal to 90°

26. White light is incident on the interface of glass and air as shown in the figure. If green light is just totally internally reflected then the emerging in air contains



(a) yellow, orange, red (b) violet, indigo, blue
(c) all colours
(d) all colours except green

27. A ray of light from a denser medium strikes a rare medium at angle of incidence i as shown in figure. The reflected and refracted rays make an angle of 90° with each other. The angles of reflection and refraction are *r* and *r'*. The critical angle is



(a) $\sin^{-1}(\tan r)$ (b) $\sin^{-1}(\tan i)$
(c) $\sin^{-1}(\tan r')$ (d) $\tan^{-1}(\tan i)$

28. A glass of thickness 4 cm contains the same number of waves as 5 cm of water when both Are traversed by the same monochromatic light. If the refractive index of water is 4/3, what is that of glass?

(a) 5/3 (b) 5/4
(c) 16/15 (d) 1.5

29. A point source of light is placed 4 m below the surface of water of refractive index 5/3. The minimum diameter of a disc, which should placed over the source, on the surface of water to cut off all light coming out of water is

(a) 1m (b) 4 m

(c) 3m (d) 6 m

30. The distance between object and the screen is D. Real images of an object are formed on the screen for two positions of a lens separated by a distance *d.* The ratio between the sizes of two images will be

(a) D/d (b) D^2/d^2

(c) $(D-d)^2/(D+d)^2$ (d) $\sqrt{(D/d)}$

31. A concave lens of focal length forms an image which is *n* times the size of the object. The distance of the object from the lens is

(a) $(1-n)f$ (b) $(1+n)f$

(c) $\left(\frac{1+n}{n}\right)f$ (d) $\left(\frac{1-n}{n}\right)f$

32. A lens behaves as a converging lens in air and a diverging lens in water. The refractive index of the material is

(a) equal to unity

(b) equal to 1.33

(c) between unity and 1.33

(d) greater than 1.33

33. A thin convex lens of focal length 10 cm and a thin concave lens of focal length 26.2 cm are in contact. The combination acts as

(a) concave lens of focal length 16.4 cm

(b) convex lens of focal length 16.2 cm

(c) concave or convex lens depends upon the material of lenses

(d) none of the above

34. A thin equiconvex lens has focal length 10 cm, refractive index 1.5. One of its faces is now silvered and for an object placed at a distance. *u* in front of it, the image coincides with the object. The value of M is

(a) 10 cm (b) 5 cm

(c) 20 cm (d) 15 cm

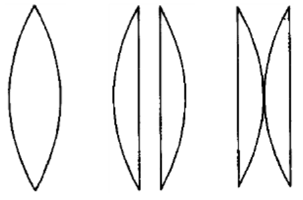
35. A convex lens of focal length 20 cm is cut into two equal parts so as to obtain two Plano-convex lenses as shown in figure. The two parts are then put in contact as shown in figure. What is the focal length of combination?

(a) zero

(b) 5 cm

(c) 10 cm

(d) 20 cm



36. 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 the distance *d* in cm will be

(a) 25 (b) 15

(c) 30 (d) 50

37. Bending of ray of light, when it enters obliquely from one medium to other is called

(a) dispersion (b) interference

(c) reflection (d) refraction

38. For light going from air to water $^{a}n_{w}=4/3$. Then $^{w}n_{a}$ has value

(a) 1 (b) 3/4

(c) 16/9 (d) 3/2

39. A ray of light passes undedicated through a point on the principal axis. The point is

(a) optical centre

(b) no where

(c) focus

(d) centre of curvature

40. For studying refraction through a lens, we keep the lens with its refracting surface towards

(a) up (b) down

(c) right (d) left

41. We put a glass piece on a printed page. Image of prints on the page has same size. The piece is a

(a) concave lens (b) prism

(c) glass slab (d) convex lens

42. The power of a glass slab is

(a) zero (b) infinite.

(c) less (d) more

43. In a lens combination of thin lenses in contact, for obtaining the power of the combination power of individual lens are algebraically

(a) multiplied (b) divided

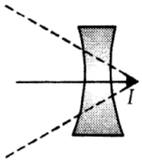
(c) added (d) subtracted

44. A thin lens has focal length f, and its aperture has diameter *d.* It forms an image of intensity I. Now, the central part of the aperture up to diameter *d/2* is blocked by an opaque paper. The focal length and image intensity will change to

(a) $f/2$ and $I/2$ (b) f and $I/4$

(c) $3f/4$ and $I/2$ (d) f and $3I/4$

45. A convergent beam is incident on a concave lens as shown in figure. Which of the following statements is not correct?



(a) The image formed is real
(b) The image formed is virtual
(c) The image formed is erect
(d) The image formed is magnified

46. A layered lens is mad of two types of transparent materials indicated by different shades. A point object is placed on its axis the object will form

(a) 1 image (b) 2 images
(c) 3 images (d) 9 images

47. A convex lens is made of two transparent materials A and B. A ray of light is incident on the lens from a point object. We will see
(a) four images (b) two images
(c) six images (d) none of these

48. When white light passes through a dispersive medium, it breaks up into various colours. Which of the following is true?
(a) Velocity of light for violet is greater than the velocity of light for red colours.
(b) Velocity of light for violet is less than the velocity of light for red.
(c) Velocity of light is the same for all colours,
(d) Velocity of light is different for different colours.

49. Focal length of a lens for red colour is
(a) same as that for violet
(b) greater than that for violet
(c) lesser than that for violet
(d) none of the above

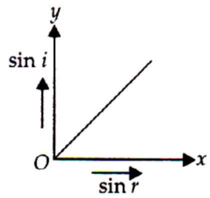
50. Even in absolutely clear water, a diver cannot see very clearly
(a) because rays of light get diffused
(b) because velocity of light is reduced in water
(c) because of ray of light passing through the water makes it turbid
(d) because the focal length of the eye lens in water gets changed and the image is no longer focused sharply on the retina

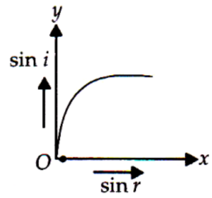
51. Due to refraction of light in atmosphere
(a) stars appear to twinkle
(b) the sun appears to be oval in morning and evening
(c) the period of visibility of the sun is increased
(d) all of these

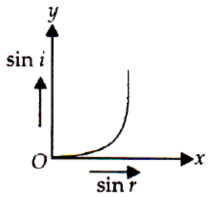
52. For prism of refractive index 1.732, the angle of minimum deviation is equal to the angle of the prism. The angle of the prism is
(a) 80° (b) 70°
(c) 60° (d) 50°

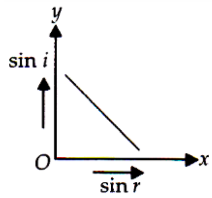
53. When white light enters a prism, it get split into its constituent colours. This is due to
(a) high density of prism material
(b) value of H is different for different λ
(c) diffraction of light
(d) velocity changes for different frequencies

54. Which of the following correctly represents graphical relation between sine of angle of incidence (i) and sine of angle of refraction (r)?

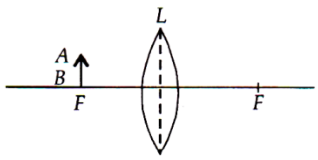
(a)


(d)


(c)


(d)


55. An object *AB* is placed in front of a convex lens at its principal focus as shown in figure below.



Which of the ray diagram below correctly depicts the detraction through the lens L

56. An object is placed at a distance of 4 cm from a concave lens of focal length 12 cm. The nature of image is
(a) 0.75 (b) 0.65
(c) 0.55 (d) 0.45

57. With regard to refraction which of the following statement is false,
(a)It is a change in direction of light when it passes from one transparent medium into another of different optical density
(b) Light is deviated away from the normal when it enters an optically dense medium from a less dense medium.
(c) the velocity of light is changed during refraction
(d) the wavelength of the light is changed during refraction

58. The following are true about the refractive index of a material

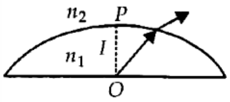
(a) the absolute refractive index of a material is always greater than its refractive index .

(b) the refractive index of a material is usually measured with ultraviolet light

(c) the refractive index of a medium differs for light of different wavelengths

(d) the deviation of light increases with the increase in refractive index of the material that it enters

59. A thick piano convex lens made of crown glass (refractive index 1.5) has a thickness of 3 cm at its centre. The radius of curvature of its curved face is 5 cm. An ink mark made at the centre of its plane face, when viewed normally through the curved face, appears to be at a distance x from the curved face. Then, *x* is equal to



(a) 2 cm (b) 2.1 cm
(b) 2.1 cm (d) 2.5 cm

60. An object is placed in front of a screen and a convex lens is placed at a position such that the size of the image formed is 9 cm. When the lens is shifted through a distance of 20 cm, the size of the image becomes 1 cm. The focal length of the lens and the size of the object are respectively,

(a) 7.5 cm and 3.5 cm (b) 7.5 cm and 4 cm
(c) 6 cm and 3 cm (d) 7.5 cm and 3 cm

61. The focal length of an equi-convex lens in air is equal to either of its radii of curvature. The refractive index of the material of the lens is

(a) 4/3 (b) 2.5
(c) 0.8 (d) 1.5

62. A concave lens of glass, refractive index 1.5, has both surfaces of same radius of curvature *R.* On immersion in a medium of refractive index 1,75, it will behave as a

(a) convergent lens of focal length 3.5R
(b) convergent lens of focal length 3.02?
(c) divergent lens of focal length 3.5R
(d) divergent lens of focal length 3.0R

63. A convergent lens made of crown glass (refractive index 1.5) has focal length 20 cm in air. If it is immersed in a liquid of refractive index 1 .60, its focal length will be

(a) 160cm (b) 100cm
(c) -80 cm (d) -160 cm

64. The plane face of a plano-convex lens of focal length 20 cm is silvered. The lens will then behave as a concave mirror of focal length

(a) 5 cm (b) 10 cm
(c) 20 cm (d) 40 cm

65. A convex lens of focal length 40 cm is in contact with a concave lens of focal length 25 cm. the power of the combination in dioptre is

(a) - 6.5 (b) -1.5
(c) +1.5 (d) +6.5

66. Concave and convex lenses are placed touching each other. The ratio of magnitudes of their powers is 2:3. The focal length of the system is 30 cm. Then the focal lengths of individual lenses are

(a) -75 cm, 50 cm (b) -15 cm, 10 cm
(c) 75 cm, 50 cm (d) 75 cm, -50 cm

67. The principal axis is also called ____ of the lens.

(a) optical axis (b) x-axis
(c) y-axis (d) none of these

68. A ray of light travelling in air is incident on the plane of a transparent medium. The angle CT incident is 45° and that of refraction is 30°. Fine the refractive index of the medium.

(a) 2 (b) $\frac{1}{\sqrt{2}}$
(c) $\frac{2}{\sqrt{2}}$ (d) $\sqrt{2}$

69. The minimum distance between an object and its real image formed by a convex lens is

(a) $\frac{2}{3}f$ (b) $2f$
(c) $\frac{5}{2}f$ (d) $4f$

70. A beam of white light passing through a prism is spilt up into its constituent colours. The light which undergoes least deviation is

(a) violet (b) yellow
(c) red (d) green

71. Under minimum deviation condition in a prism, if a ray is incident at an angle 30°, the angle between the emergent ray and the second refracting surface of the prism is

(a) 0° (b) 30°
(c) 45° (d) 60°

FILL IN THE BLANKS

1. To construct a ray diagram, you need at least........... whose path (s) after refraction through the lens are known.

2. The principal axis is also called........... of the lens.

3. The power of a lens whose focal length is one metre is .... dioptre.

4. The scattering of light depends inversely upon the fourth power of the ....of light.

5. The power of a convex lens is .... and that of a concave lens is ....

6. The relationship $\frac{1}{f}=\frac{1}{\upsilon}-\frac{1}{u}$ is called the........... formula

7. No refraction occurs when light is incident........... on a boundary of two medium.

8. Light emerges from rectangular glass slab in a direction........... to that in which it entered the glass slab.

9. Oval shape of sun at sunrise and sunset is due to........... of light.

10. The largest value of refractive index is 2.42 for…………..

11. A convex lens of smaller focal length has........... power.

12. A tank appears to be 3 m deep only then the actual depth of tank is...........

13. The effective width of a lens from which refraction takes place is called its...........

14. M. A lens having one curved surface bulged outwards and the other a plane surface is called....... lens.

15. Air is optically........... than water or glass.

16. The refractive index of vacuum is taken as...........

17. The instrument that can directly measure the power of a lens is called...........

18. A medium with higher refractive index is said to be...........

19. The critical angle for a material of refractive index $\sqrt{2}$ is............

20. ....of a lens is defined as the ability of the lens to converge a beam of light falling on the lens.

21. The power of piano convex lens, is........... when radius of curved surface is 15 cm and *n* is 1.5.

TRUE OR FALSE

1. A ray parallel to the principal axis, after reflection, will pass through the principal focus.

2. Light travels faster in glass than in air.

3. The degree of convergence or divergence of light rays achieved by a lens is expressed in terms of its power.

4. Concave lenses are used mainly in spectacles for the correction of short sightedness.

5. A ray of light passing through the optical centre of a lens does not suffer any deviation.

6. The lateral displacement during refraction does not depend on wavelength of the light.

7. Air has the highest optical density.

8. An opaque material cannot be used to make a lens.

9. One dioptre is equal to one metre.

10. Focal length of convex lens is always positive.

11. When light travels from air in to water, its speed increases.

12. Regular reflection is also called total internal reflection.

13. A real image is formed by a concave lens when the object is placed at infinity.

14. Concave lens are used as reflectors in lamps.

15. For image magnification one needs at least two convex lens.

16. If two mirrors are inclined to each other at 90°, the image seen may be four.

17. A ray passing through optical centre proceeds undedicated through the lens.

18. According to new sign convention, all distances are measured from poles.

19. The power of a lens can be measured in watt.

20. In optical instruments, the lenses are used to form images by dispersion.

21. The unit of refractive index is deportee.

Matrix Match Type

This section contains 5 questions. Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in Column - I have to be matched with statements (p, q, r, s) in Column – II

1.

Column – I	Column – II
(A) Lens formula	(p) $n\sin\theta=$ constant
(B) n_{gw}	(q) $\frac{\upsilon}{u}$
(C) Magnification by a lens	(r) $\frac{1}{f}=\frac{1}{\upsilon}-\frac{1}{u}$
(D) Snell's law	(s) $n_{ga}\times n_{aw}$

2.

Column – I	Column – II
(A) Negative	(p) Diminished image

magnification	
(B) Magnification less than 1	(q) Inverted image
(C) Positive magnification	(r) Size of image is same
(D) Magnification equal to 1	(s) Erect image

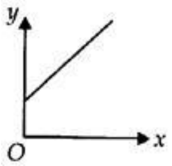
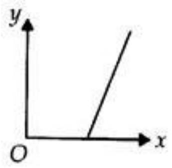
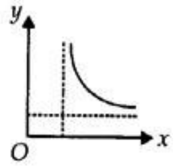
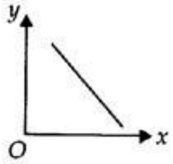
3.

Column – I	Column – II
(A) Concave lens	(p) Principal axis
(B) Line passing through optical centre	(q) Virtual image
(C) Convex lens	(r) Can be taken on a screen
(D) Real image	(s) Converging lens

4.

Column – I	Column – II
(A) 1 Angstrom unit	(p) Minimum deviation
(B) Red	(q) $10^{-10}\,m$
(C) Violet	(r) $\dfrac{1}{f\,(\text{in metre})}$
(D) Power of lens	(s) Maximum deviation

5. The graphs given apply to convex lens of focal length *f*, producing a real image at a distance *v* from the optical centre when self luminous object is at distance *u* from the optical centre. The magnitude of magnification is *m*. Identify the following graphs with the first named quantity being plotted along y-axis.

Column – I	Column – II
(A) υ against u	 (p)
(B) $\dfrac{1}{\upsilon}$ against $\dfrac{1}{u}$	 (q)
(C) m against υ	 (r)
(D) $(m+1)$ against $\dfrac{\upsilon}{f}$	 (s)

ASSERTION & REASON QUESTIONS

Directions: In each of the following questions, statement of Assertion (A) is given followed by a responding statement of Reason (R) just below Of the statements, mark the correct answer as

(a) *If both assertion and reason are true and reason is the correct explanation of assertion*

(b) *If both assertion and reason are true but reason is not the correct explanation of assertion.*

(c) *If assertion is true but reason is false.*

(d) *If assertion is false but reason is true.*

1. **Assertion:** If a plane glass slab is placed on the letters of different colours all the letters appear to be raised up to the same height.
Reason: Different colours have different wavelengths.

2. **Assertion:** An air bubble in a jar of water shines brightly due to phenomenon of refraction.
Reason: Refraction of light is the phenomenon of change in the path of light, when it goes from one medium to another.

3. **Assertion:** The diamond shines due to multiple total internal reflections.
Reason: The critical angle for diamond is 24.4°.

4. **Assertion:** Higher is the refractive index of a medium or denser the medium, lesser is the velocity of light in that medium.
Reason: Refractive index is inversely proportional to velocity.

5. **Assertion:** Convergent lens property of converging does not remain same in all mediums.
Reason: Property of lens whether the ray is diverging or converging is independent of the surrounding medium.

6. **Assertion:** Although the surfaces of a goggle lens are curved, it does not have any power.
Reason: In case of goggles, both the curved surfaces have equal radii of curvature.

7. **Assertion:** There is no dispersion of light refracted through a rectangular glass slab.
Reason: Dispersion of light is the phenomenon of splitting of a beam of white light into its constituent colours.

8. **Assertion:** A ray of white light shows no dispersion on emerging from a glass slab although there occurs dispersion inside the glass slab.
Reason: The velocity of light inside the glass slab is same for all different colours.

9. **Assertion:** A single lens produces a coloured image of an object illuminated by white light.
Reason: The refractive index of material of lens is different for different wavelength of light.

10. **Assertion:** The twinkling of star is due to reflection of light.
Reason: The velocity of light changes while going from one medium to the other.

11. **Assertion:** The luminance of an image produced by a convex lens is greater in the middle and less towards the edges.
Reason: The middle part of image is formed by unelected rays while outer part by inclined rays.

12. **Assertion:** The minimum distance between an object and its real image formed by a convex lens is If.
Reason: The distance between an object and its real image is minimum when its magnification is one.

13. Assertion: A secondary rainbow have inverted colours than the primary rainbow.
Reason: The secondary rainbow is formed by single total internal reflection.

14. Assertion: The focal length of lens does not change when red light is replaced by blue light.
Reason: The focal length of lens does not depend on colour of light used.

15. **Assertion:** The frequencies of incident, reflected and refracted beam of monochromatic light incident from one medium to another are same.
Reason: The incident, reflected and refracted rays are coplanar.

16. **Assertion:** The Sun looks bigger in size at sunrise and sunset than during day.
Reason: The phenomenon of diffraction bends light rays.

17. **Assertion:** A convex lens is made of two different materials. A point object is placed on the principal axis. The number of images formed by the lens will be two.
Reason: The image formed by convex lens is always virtual.

18. **Assertion:** Speed of light in glass of $n=1.5$ is $2\times10^{8}\,ms^{-1}$.
Reason: According to dual theory, light has particle nature and wave nature simultaneously.

19. **Assertion:** The images formed by total internal reflections are much brighter than those formed by mirrors or lenses.
Reason: There is no loss of intensity in total internal reflection.

PASSAGE

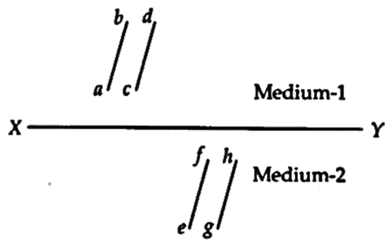
PASSAGE 1: An object of size 5 cm is kept at a distance 25 cm from the optical centre of a converging lens of focal length 10 cm

1. The image distance is ....
(a) 15.67 cm (b) 16.67 cm
(c) 15.76 cm (d) 16.01 cm

2. The size of the image is ....
(a) 2.33 cm (b) 2.32 cm
(c) 3.33 cm (d) 2.22 cm

3. The nature of image is ....
(a) inverted (b) erect
(c) enlarged (d) can't say

PASSAGE 2: The figure shows a surface XY separating two transparent media, medium-1 and medium-2. The lines ab and cd represent wave fronts of a light wave travelling in medium-1 and incident on XY. The lines ef and gh represent wave fronts of the light wave in medium-2 after refraction.



1. Light travels as a ....
(a) parallel beam in each medium
(b) convergent beam in each medium
(c) divergent beam in each medium
(d) divergent beam in one medium and convergent beam in the other medium

2. The wavelength of light after refraction will.............
(a) not change
(b) decrease
(c) increase
(d) depends on the nature of medium Speed of light is ....
(a) the same in medium-1 and medium-2

(b) more in medium-1 than medium-2
(c) more in medium-2 than in medium-1
(d) different at *b* and *d*

PASSAGE 3: A convex lens is made of glass or refractive index 1.5. The radius of curvature of each of its two surfaces is 20 cm. The lens is immersed inside a liquid of refractive index 1.25.

1. Power of lens in air is........
(a) 4 D (b) 5 D
(c) 6 D (d) 7 D

3. Power of lens inside the liquid is ......
(a) 1 D (b) 2 D
(C) 3 D (d) 4 D

4. Ratio of power in case of air to liquid is ...
(a) 2.5 (b) 3.5
(c) 4.5 (d) 5.5

PASSAGE 4: A thin convex lens of glass immersed in a liquid of refractive index *n,* behaves like a divergent lens of focal length 1 m. Refractive index at glass is 3/2 and power of the lens is 5 dioptre.

1. The focal length of lens in air is ....
(a) 5 cm (b) 10 cm
(c) 15 cm (d) 20 cm

2. The value of *n* is ......
(a) $\frac{5}{3}$ (b) $\frac{4}{3}$
(c) $\frac{2}{3}$ (d) $\frac{1}{3}$

SUBJECTIVE PROBLEMS

VERY SHORT ANSWER TYPE QUESTIONS

1. What are the conditions for no refraction of light?

2. What is the range of wavelength of visible light? Which colour has the largest wavelength and which one has the shortest wavelength?

3. A coin in a glass beaker appears to rise as the beaker is slowly filled with water. Why?

4. What is lateral magnification produced by a lens? How is it related to object distance and image distance?

5. A tank of water is 4 m deep. How deep does it appear when seen normally?

6. When is magnification positive or negative?

7. What is meant by a lens of power + 1 D?

8. A spherical mirror and a thin spherical lens have *a.* focal length of - 15 cm each. What type of lens and the mirror are referred here?

9. What is refractive index?

10. If refractive index of glass with respect to air is 3/2, what is the refractive index of air with respect to glass?

11. What is meant by optical centre of a lens?

12. What is the difference between a real image and a virtual image?

13. For the same slab of glass and the same angle of incidence, the lateral displacement for violet light is more than the red light. Generalize this observation in terms of effect of wavelength of light on the lateral displacement.

14. Does velocity of light change when it goes from one medium to another?

15. Where should an object be placed so that a real and inverted image of the same size is obtained using a convex lens?

16. For what position of the object will a convex lens form a virtual and erect image?

SHORT ANSWER TYPE QUESTIONS

1. (a) Under what condition, a convex lens will act a magnifying glass (or a simple microscope)?
(b) Draw the corresponding ray diagram.

2. A combination of a convex lens and a concave lens has a power of + 2 D. If the focal length of the convex lens is 25 cm, what will be the focal length of the concave lens used in this combination?

3. A concave lens is placed in contact with a convex lens of focal length 25 cm. The combination produces a real image at a distance of 80 cm, when an object is at a distance of 40 cm. What s the focal length of concave lens?

4. Velocity of light in glass is $2\times10^{8}s^{-1}$ and that air is $3\times10^{8}ms^{-1}$. By how much would an ink dot appear to be raised, when covered by glass plate 6.0 cm thick?

5. Two lenses of powers + 15 D and - 5D are in contact with each other forming a combination of lenses, (a) What is the focal length of this combination? (b) An object of size 3 cm is placed at 30 cm from this combination of lenses. Calculate the position and size of the image formed.

6. A concave lens is kept in contact with a convex lens of focal length 20 cm. The combination works as a convex lens of focal length 50 cm. Find the power of concave lens.

7. Find the focal length and power of a piano convex lens, when radius of curved surface is 15 cm and n = 1.5. Explain, Why?

8. A diamond glitters in a brightly lit room, but not in a dark room
(b) A crack in a window pane appears silvery.
(c) The bubbles of air rising up in a water tank appear silvery when viewed from top.

9. Why does a convex lens of glass n = 1.5 behave as a diverging lens when immersed in carbon disulphide of n = 1.65?

10. Priya 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?

11. 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 medium.

12. A, diverging lens of focal length F is cut into two identical parts, each forming a piano concave lens. What is the focal length of each part?

13. Refractive index of glass is 1.5. Calculate velocity of light in glass, if velocity of light in vacuum is $3\times10^{8}ms^{-1}$. Also, calculate critical angle for glass air interface.

14. For the same angle of incidence in medium *P, Q* and *R,* the angles of refraction are 35°, 25°, 15° respectively. In which medium will the velocity of light be minimum?

15. A convex lens of focal length 20 cm produces a real image of an object, when it is 30 cm away. Find position and magnification of image.

16. Two lenses of powers - 1.5 D and + 2.75 D are kept in contact. Find the focal length of the combination.

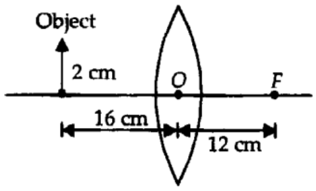
LONG ANSWER TYPE QUESTIONS

1. (i) If $f=+0.5m$, what is the power of the lens?
(ii) The radii of curvature of the faces of a double convex lens are 9 cm and 15 cm. Its focal length is 12 cm. What is the refractive index of glass?
(iii) A convex lens has 20 cm focal length in air. What is the focal length in water? (Refractive index of air-water = 1.33, refractive index of air-glass =1.5).

2. An object is placed 30 cm from a concave lens. The focal length of the concave lens is 12 cm. Find the position of the image with the help of diagram.

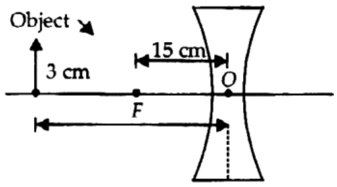
3. The object is placed in front of a concave lens of focal length 20 cm. Magnification is found to be $\frac{1}{2}$. Find the location of the object.

4. In the given figure, a 2 cm high object is placed at a distance of 16 cm from a convex lens. The focal length of the lens is 12 cm. Find the



(a) position of the image
(b) size of the image
(c) nature of the image

5. In the given figure, a 3 cm high object is placed at a distance of 30 cm from a concave lens of focal length 15 cm. Find the



(a) position of the image
(b) size of the image
(c) nature of the image

6. A ray of light travelling in air falls on the surface of a rectangular slab of a material whose refractive index is 1.2. If the incident ray makes an angle of 37° with the normal $(\sin 37^{o}=3/5)$, find the angle made by the refracted ray with the normal.

7. A light of wavelength 500 nm in air enters a glass block of refractive index 1.5. Find (a) speed (b) frequency (c) wavelength of light in glass. Velocity of light in air is $3\times10^{8}ms^{-1}$.

8. An object placed in front of a diverging mirror at a distance of 30 cm, forms a virtual and erect image which is 1/5 of the size of the object. Calculate: (i) the position of the image (ii) the focal length of the diverging mirror.

9. An object of size of 7.0 cm is placed 27 cm in front of concave mirror of focal length 18 cm. At what distance from the mirror, should a

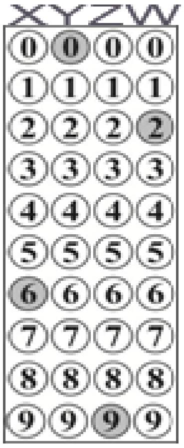
screen be place, so that a sharp focused image can be obtained? Find the size and nature of the image.

10. A convex lens is made of glass of refractive index If radius of curvature of each of its two surfaces is 20 cm, find the ratio of the power of the lens, when placed in air to its power when immersed inside a liquid of refractive index 1.25.

INTEGER ANSWER TYPE

This *section contains 5 questions, The answer to each of the questions is a single digit integer, ranging from 0 to* 9.

If the correct answers to question numbers X, Y, Z *and.* W (say) *are* 6, *0, 9 and 2 respectively, then the correct darkening of bubbles will look like the following.*



1. A beaker is filled with water to a height of 8.00 cm. The apparent depth of a needle fixed at the bottom of the beaker as measured by a travelling microscope is found to be 6.00 cm. If the height of water in the beaker is increased to 120 cm. By what distance would the microscope have to be moved to focus on the needle again?

2. An object is placed at a distance of 10 cm from a co-axial combination of two lenses A and B. the combination forms a real image three times the size of the object. If lens B is concave with a focal length of 30 cm, what is the focal length of lens A?

3. Two lenses of focal lengths 8 cm and 4 cm are placed at a certain distance apart. Calculate the distance between the lenses if they form an achromatic combination.

4. A point object is placed on the optic axis of a convex lens of focal length f at a distance of If to the left of it. The diameter of the lens is *d.* An eye is placed at a distance of $3f$ to the right of the lens and a distance *h* below the optic axis. The maximum value of *h* to see the image is *d/n.* Find the value of n.

5. An ink dot made on a paper fixed on a table top is viewed from above, from a distance of 30 cm. By what distance would the ink dot appear to be raised if it is viewed from the same distance through a 16.0 cm thick glass slab held parallel to and above the table top? The refractive index of glass is 1.6.

ANSWER – KEY

Multiple Choice Questions

1. B	**2.** C	**3.** C	**4.** B	**5.** D
6. A	**7.** C	**8.** B	**9.** C	**10.** B
11. A	**12.** C	**13.** B	**14.** A	**15.** B
16. B	**17.** D	**18.** B	**19.** C	**20.** D
21. A	**22.** C	**23.** D	**24.** B	**25.** D
26. A	**27.** A	**28.** A	**29.** D	**30.** C
31. D	**32.** C	**33.** B	**34.** B	**35.** D
36. B	**37.** B	**38.** B	**39.** A	**40.** D
41. C	**42.** A	**43.** C	**44.** D	**45.** B
46. B	**47.** B	**48.** B	**49.** B	**50.** D
51. D	**52.** C	**53.** B	**54.** A	**55.** A
56. A	**57.** B	**58.** B	**59.** D	**60.** D
61. D	**62.** A	**63.** D	**64.** B	**65.** B
66. B	**67.** A	**68.** D	**69.** D	**70.** C
71. B				

Fill in the Blanks

1. Two rays	**2.** Optical axis
3. One	**4.** Wavelength
5. Positive, negative	**6.** Lens
7. Normal	**8.** Parallel
9. Refraction	**10.** Diamond
11. Greater	**12.** 4 m
13. Aperture	**14.** Planoconvex lens
15. Less denser	**16.** One
17. dioptremeter	**18.** Optically debser
19. 45^o	**20.** Power
21. 3.33 dioptre	

True and False

1. True	**2.** False	**3.** True	**4.** True
5. True	**6.** False	**7.** False	**8.** True
9. False	**10.** True	**11.** False	**12.** False
13. False	**14.** False	**15.** False	**16.** False
17. True	**18.** False	**19.** False	**20.** False

21.	False

True and False

1.	$A \rightarrow r$; $B \rightarrow s$; $C \rightarrow q$; $D \rightarrow p$
2.	$A \rightarrow q$; $B \rightarrow p$; $C \rightarrow s$; $D \rightarrow r$
3.	$A \rightarrow q$; $B \rightarrow p$; $C \rightarrow s$; $D \rightarrow r$
4.	$A \rightarrow q$; $B \rightarrow p$; $C \rightarrow s$; $D \rightarrow r$
5.	$A \rightarrow r$; $B \rightarrow p$; $C \rightarrow q$; $D \rightarrow s$

Assertion & Reason

1. D	**2.** D	**3.** B	**4.** A	**5.** C
6. A	**7.** B	**8.** C	**9.** A	**10.** D
11. A	**12.** D	**13.** C	**14.** D	**15.** B
16. B	**17.** C	**18.** C	**19.** A	

Passage Comprehension

Passage: 1

1. B	**2.** C	**3.** A

Passage: 2

1. A	**2.** B	**3.** B

Passage: 3

1. B	**2.** B	**3.** A

Passage: 4

1. D	**2.** A

Integer Answer Type

1. 3	**2.** 6	**3.** 6	**4.** 4	**5.** 6