MODULUS
MAKES EVERYONE POSITIVE

AN INITIATIVE BY IITian

MODULUS
STUDY MATERIAL

TARGET YOUR JEE WITH IITians

PHYSICS

RAY OPTICS & HUMAN EYE

www.modulushyd.com

Ph. 7 99 33 74 333 , 7 99 33 75 333 , 7 99 33 76 333

MODULUS
MAKES EVERYONE POSITIVE

Do you know how much percentage of marks a student has to score in IITJEE advanced exam to get a rank in top 100 ? a seat getting rank in IITs ?

Unbelievably they are just 75% and 35% (avg of last 10 years data)
Many students who score 10/10 in boards are not able to score 35% in JEE advanced but an average student can make it to IIT if the coaching institute has

- ✓ Expert faculty - Excellent teaching
- ✓ Meticulous planning - Long-term strategy
- ✓ Constant motivation - Continuous support
- ✓ Rigorous practice - Accuracy and Speed

Previous Years JEE ADVANCED Rank VS % of Marks

RANK	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Avg %	2021 (M. Marks 360) Marks	Rank	2021 (M. Marks 360) Marks	Rank
1	85.48	91.67	96.01	92.22	92.78	93.06	86.02	92.62	93.61	93.01	88.89	91.40	348	1	196	1544
10	81.39	85.42	88.48	85.83	86.94	83.92	78.49	86.88	86.11	82.80	81.06	84.99	324	8	185	2043
100	70.76	79.79	78.68	76.39	77.50	69.84	68.61	83.33	74.72	72.85	71.72	74.93	323	13	178	2395
500	62.17	72.08	69.36	66.67	68.61	60.32	54.57	77.32	64.44	61.02	59.34	65.08	313	25	160	3542
1000	57.87	68.13	64.46	61.67	63.33	56.75	49.46	72.95	58.59	55.65	53.28	60.22	310	27	154	4137
2000	52.97	62.50	58.33	55.56	57.22	49.21	43.55	67.48	53.06	50.00	46.46	54.21	302	46	145	5005
3000	49.69	59.17	54.41	51.94	53.61	45.44	42.74	63.38	49.17	46.77	42.42	50.79	297	66	135	6180
4000	47.03	56.67	51.72	49.17	51.11	42.66	37.90	60.38	46.39	44.09	39.39	47.86	296	70	131	6750
5000	44.99	54.38	49.51	47.22	48.89	40.48	36.02	57.65	43.89	41.94	37.12	45.64	286	94	126	7516
6000	43.35	52.17	47.55	45.56	47.22	38.69	34.41	55.45	41.94	40.32	35.10	43.85	266	201	121	8494
7000	41.92	51.04	45.83	43.89	45.56	37.10	33.33	53.55	40.28	38.71	33.59	42.25	254	299	109	10848
8000	40.49	49.79	43.38	42.50	44.44	35.91	31.99	51.63	38.61	37.63	32.32	40.79	245	395	102	12874
9000	39.47	48.54	43.14	41.11	43.06	34.52	30.91	50.27	37.22	36.29	30.81	39.58	239	471	100	13215
10000	38.85	47.71	41.91	40.00	41.94	33.33	29.84	48.90	36.11	35.22	29.80	38.51	231	600	85	18547
QUAL%	38.85	47.71	34.55	33.88	35.00	23.81	20.16	22.50	25.00	25.00	17.42	29.44	212	1006	79	21157

For query Call : 7993376333, 7993375333, 7993374333
Visit : www.modulushyd.com

Chapter 7

Light

Remember

Before beginning this chapter you should be able to:

- Define light, sources of light, etc.
- Learn about laws of reflection and images formed by plane mirror and their applications

Key Ideas

After completing this chapter you should be able to:

- Discuss different terms related to the study of light
- Study reflection of light by plane mirror and spherical mirrors
- Understand the phenomenon of bending of light rays and their applications
- Observe spliting of white light into its constituent colours and its applications

INTRODUCTION

The branch of physics which deals with nature, source, properties and the effects of light is called optics. When rays of light coming from an illuminated object strike the eye, an object is seen. Thus, light is necessary to see an object. During the day time, we see objects due to light from the sun. Sun is the main and a natural source of light. At night we receive light from stars, moon, bulbs, candles, etc.

Moon does not emit light on its own but the moon is visible due to the light falling on it. Moon is a non luminous body. Thus, bodies which emit light on their own are called luminous bodies and bodies which do not emit light on their own but are visible, when light falls on them are called non-luminous bodies.

Examples: ***Luminous Bodies*** Sun, stars, electric fish, some species of fish and insects.

Examples: ***Non-luminous Bodies*** Moon, planets, etc.

Artificial sources of light are fluorescent bulb, incandescent bulb, candles, etc. Incandescent bulb and candles emit light when they are heated whereas fluorescent bulb, neon bulb, sodium vapour lamp emit light without a rise in temperature. Thus, sources which emit light due to rise in temperature are called hot sources and sources which emit light without rise in temperature are called cold sources.

When a light emitted from a candle is viewed or seen through a pinhole made in a cardboard, the light emerges only through a pinhole. This pinhole acts like a point source of light.

When a candle is seen without a card board, light emerges from all points of the flame of the candle. Thus, the flame of candle is an extended source. Other examples of extended sources are bulb, tube light, etc. If a source of light is bigger than a point source, then the source is an extended source.

Light does not require a material medium to travel, it can travel through vacuum. This is best illustrated by light travelling from the sun to the earth through vast spaces. Apart from vacuum and gases, light also travels through solids and liquids. The medium which allows most of the incident light to pass through is called transparent medium.

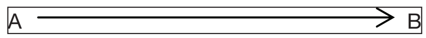
Example: glass.

When a bulb is seen through an oiled paper or a stained glass the intensity of the emerging light is reduced. The oiled paper or the stained glass allows only a part of the light to travel through it. Oiled paper, stained glass are examples of translucent bodies.

The bodies which allow only a part of the incident light to travel through them are called translucent bodies. Light does not travel through wood, stone, walls, etc., such bodies are known as opaque bodies. Opaque bodies are bodies which do not allow light to pass through them.

Light passing through an open window or a door can be easily made out due to the minute particles present in air which receive light. When we observe the path of these minute particles, we observe that they travel in a straight line. Thus, light travels from point

A to point B in a given homogeneous medium along a straight line. This property of light is known as rectilinear propagation of light. The straight line from A to B is called a ray of light. A small bundle of these rays is known as a pencil of rays and large bundles of these rays are known as beams of light.



A bundle of rays in which rays are parallel to one another is called parallel beam of light.

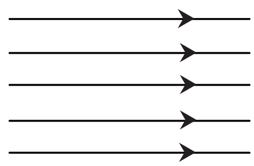


FIGURE 7.1 Parallel beam

The rays of light which are not parallel to each other and which proceed towards a point or meet at a point are known as convergent rays.

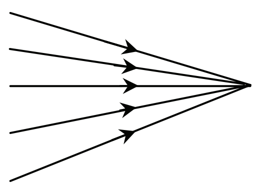


FIGURE 7.2 Convergent beam

The rays of light which are not parallel to each other and which spread out from a point are called divergent rays.

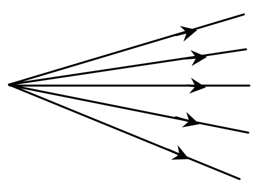


FIGURE 7.3 Divergent beam

Properties of Light

1. Light does not require any material medium to propagate. It can travel through vacuum.
2. It travels with a very high velocity of about 3×10^8 m s^{-1} in air or vacuum.
3. It always travels in a straight line. This property is known as the rectilinear propagation of light.
4. Light does not change the properties of the medium through which it passes.
5. The velocity of light decreases as it travels from a rarer medium to denser medium.

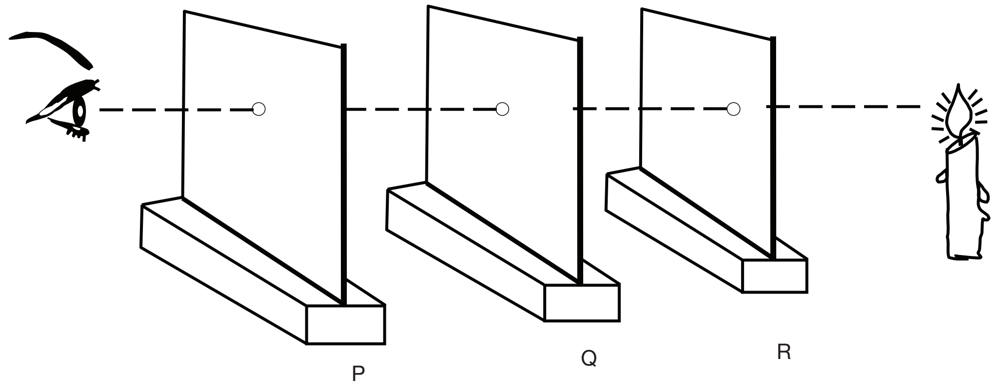


FIGURE 7.4 Experimental arrangement to observe rectilinear propagation of light

The path of the light in a straight line changes only when the medium changes or it is obstructed by an obstacle. The rectilinear propagation of light can be proved experimentally.

Consider a simple experiment. Take three wooden uprights *P*, *Q* and *R*. Make a small hole at the same height from the base on each of *P*, *Q* and *R* such that the holes are in a straight line. Place a lighted candle towards the upright *P* facing the hole. Look through the hole of upright *R*. The candle flame is clearly visible which would disappear if one of the upright is moved proving that light has rectilinear propagation. The casting of shadows and eclipses are due to the rectilinear propagation of light.

SHADOWS

When an opaque or translucent object is brought between a lighted candle and a wall, a dark patch is formed on the wall. This dark patch is known as the shadow. A shadow may consist entirely of a dark patch called umbra or it may be surrounded by a less darker patch called penumbra, depending on the nature of the source and the size of the object. Thus, a shadow is formed when rays of light are stopped by an opaque object.

If a point source of light is used to cast the shadow of an opaque body, only umbra is formed, but if an extended source of light is used, both umbra and penumbra are formed.

Formation of Shadow by a Point Source

Consider a cardboard having a pinhole at its centre. Place the card board in front of a light source (candle). The pinhole on the card board acts as a point source. Place a screen on the other side of the cardboard. If an object AB is placed between the pinhole and the screen, a totally dark patch is formed on the screen. This region is known as an umbra. If the distance between the cardboard (point source) and the object is increased, the size of the dark patch decreases. By varying the distance between the point source and the opaque object, the size of the dark patch can be varied.

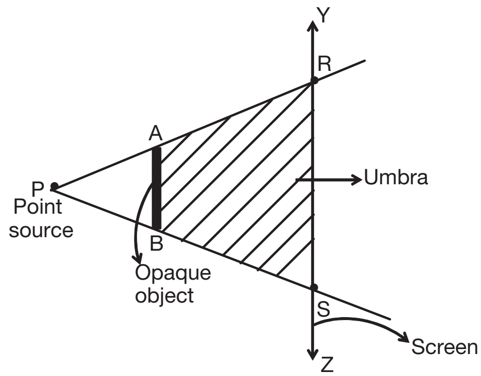


FIGURE 7.5 Shadow formed by point source

NOTE

In conducting the above experiment, the flame of the candle, the pinhole and the object should be in the same straight line.

Formation of the Shadow by An Extended Source

An extended source PP^1, an object *EF* and a screen *XY* are arranged as shown in (Fig. 6).

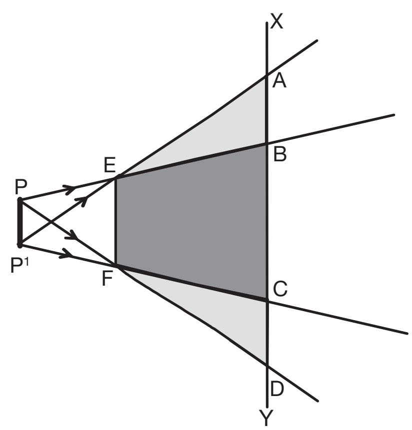


FIGURE 7.6 Shadow formed by extended source

The light rays starting from point *P* and point P^1 of an extended source along an opaque object meet the screen *XY* at points *B*, *D* and *A*, *C*, respectively. It is observed that the regions, *AB* and *CD* are partly illuminated by *P* and P^1, respectively. Hence, the regions *AB* and *CD* form penumbra while the region, *BC* forms umbra, where the light is not incident from any part of the source. Hence, an extended source of light forms both umbra and penumbra when an opaque object is placed in its path. To increase the regions of umbra and penumbra, either the screen is moved away from the opaque body or the source is moved towards the opaque body.

If the extended source is bigger than the opaque body, the region of umbra is smaller than that of penumbra. The region of umbra, can be further decreased until it completely disappears by either moving the source of light towards the opaque body or by moving the screen away from the opaque body.

The above discussion explains why a tube light forms very faint shadow and also why shadows of flying objects like aeroplane are not formed on the earth.

ECLIPSES

The phenomenon in which the moon's shadow falls on the earth or the earth casts its shadow on the moon is known as an eclipse. When the moon comes in between the earth and the sun and if all the three are in the same straight line, some part of the earth does not receive light from the sun at all and some other regions of the earth receive partial light. This is known as solar eclipse.

When the earth comes between the sun and the moon and if all the three are in the same straight line, then the shadow of the earth falls on the moon. As a result some part of the moon is not visible. This is known as lunar eclipse.

REFLECTION OF LIGHT

When we enter a dark room, we cannot see objects in the room but when the room is illuminated with a candle, objects are visible. This is due to the turning or the bouncing of light by an object. This bouncing of light into the same medium, from which the light ray is incident, is called reflection.

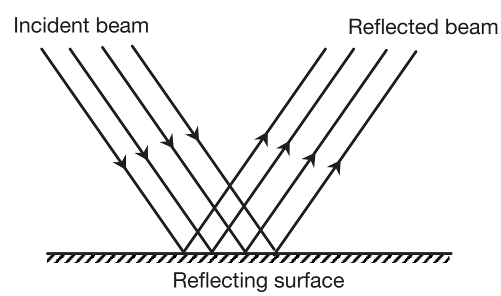


FIGURE 7.7 Regular reflection

Moon is visible to us because the light which falls on it is reflected. Reflection can be classified as regular reflection and irregular reflection.

1. **Regular reflection:** If a parallel beam of light is incident on a surface such that the reflected light rays also form a parallel beam of light, then such a reflection is known as regular reflection (Fig. 7). Regular reflection takes place when light is incident on highly polished and plane surfaces. It is regular reflection that a plane mirror produces, which helps us see our image in the mirror.
2. **Irregular reflection:** If a parallel beam of light is incident on a surface such that the reflected light rays are not parallel, such a reflection of light is called irregular reflection of light (Fig. 8). Reflection which take place on an uneven surface is irregular. This is the reason why we cannot see our image on a cardboard even though it reflects light.

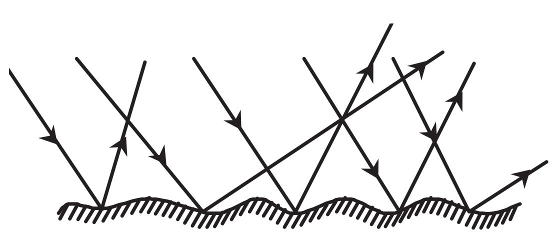


FIGURE 7.8 Irregular reflection

Even though the rays are parallel the angles of incidence are different due to the unevenness of the surface. As a result, they are reflected at different angles, and therefore, are not parallel to each other.

Definitions Related to Reflection

Consider an object at a point P. Let MM^1 be a highly polished plane surface which we refer to as a mirror (Fig. 9).

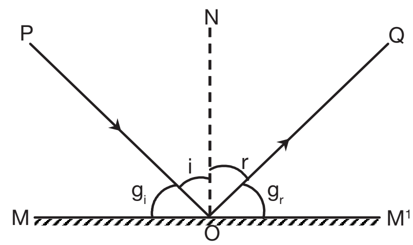


FIGURE 7.9 Reflection by a plane mirror

1. The ray PO from the object, travelling towards the mirror is called the **incident ray**.
2. The point 'O' at which the incident ray meets the mirror is called the **point of incidence**.
3. The ray OQ which bounces off the surface of the mirror when the incident ray strikes the mirror is called the **reflected ray**.
4. The perpendicular (ON) drawn to the surface of the mirror at the point of incidence is called the **normal ray**.
5, The angle between the incident ray (PO) and the normal (ON) is called the **'angle of incidence'** and is denoted by 'i', i.e., $\angle PON$
6. The angle between the reflected ray (OQ) and the normal (ON) is called the **'angle of reflection'** and is denoted by 'r', i.e., $\angle QON$
7. The angle between the incident ray (PO) and the reflecting surface (MM^1) is called the **'glancing angle of incidence'** and is denoted by 'g_i'.
8. The angle between the reflecting surface (MM^1) and the reflected ray (OQ) is called the **'glancing angle of reflection'** and is denoted by 'g_r'.

LAWS OF REFLECTION

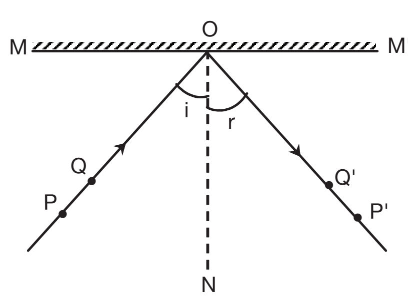


FIGURE 7.10 Reflection of light from a mirror

The reflection of light rays at a particular point always satisfies the following laws.

1. The incident ray, the reflected ray and the normal, all lie in the same plane.
2. The angle of incidence is equal to the angle of reflection. $\angle i = \angle r$

Experiment I

The experiment to verify laws of reflection.

Apparatus required

Plane mirror, four pins, scale and protractor, white paper, drawing board.

Procedure

1. Draw a straight line MM^1 on a white paper fixed to a drawing board.
2. Draw a perpendicular line ON to MM^1.
3. Draw a line PO such that it makes suitable acute angle with the normal.
4. Place a plane mirror on MM^1.
5. Fix two pins P^1 and Q^1 on the line PO. PO is the incident ray.
6. Looking from the other side of the normal observe the image of the pins P and Q.
7. Fix two more pins P^1 and Q^1 in line with the images of the pins P and Q.
8. Remove the plane mirror.
9. Join P^1 and O. OP^1 gives the reflected ray.
10. Measure $\angle PON$ and $\angle P^1ON$. $\angle PON$ gives the angle of incidence. $\angle P^1ON$ gives the angle of reflection.
11. Repeat the experiment for different angles of incidence and tabulate the results.

Observation

Trial no.	$\angle PON =$	$\angle P^1ON = r$

Result

1. The incident ray, the reflected ray and the normal all lie in the plane of the paper (same plane).
2. It is found that the angle of incidence is equal to the angle of reflection. $\angle i = \angle r$
   This proves the laws of reflection.

Reflection by Plane Mirrors

Plane mirror is a looking glass which is highly polished on one surface and is silvered on the other surface. When a light ray strikes the polished surface, it is reflected by the silvered surface.

An 'image' is defined as the impression of an object carried over and formed by light reflected from it. An image is said to be a **real image** if it can be caught on a screen, and a **virtual image** if it cannot be caught on the screen. For example, the image on the screen in a theatre is a real image and the image observed in a plane mirror is a virtual image.

1. **Reflection of a point object in a plane mirror:** Consider a point object '*O*' placed in front of a plane mirror, as shown in (Fig.7.11). To get the position of its image, we take two divergent rays from the object and consider the reflection of those two rays. The two reflected rays are divergent and do not meet each other. Hence, when we produce them back, they appear to meet at point '*I*'. The position where two divergent reflected rays that are produced appear to meet is the position where the image is formed.

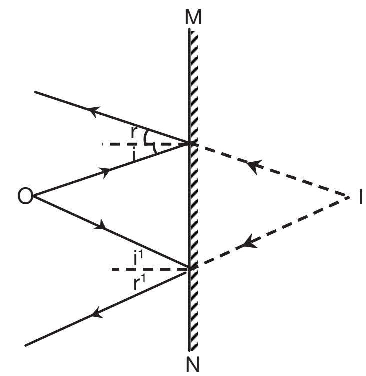


FIGURE 7.11 Reflection of a point object in a plane mirror

2. **Reflection of an extended object in a plane mirror:** Consider an extended object '*AB*' placed in front of a plane mirror *MN* as shown in (Fig. 7.12). Consider the light ray '*AC*' from position '*A*' incident on the mirror at '*C*'. Since the angle of incidence is zero, the angle of reflection is also zero and the light ray retraces its path and travels along '*CA*'. Another light ray '*AD*' from position '*A*' of the object is incident on the mirror at '*D*' and gets reflected along '*DE*'. The two reflected rays, '*CA*' and '*DE*' when produced back, intersect at position 'A^1'.

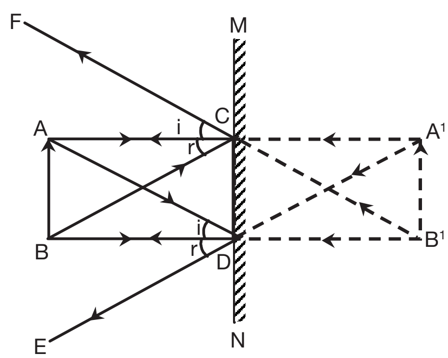


FIGURE 7.12 Reflection of an extended object in a plane mirror

The image of the point '*A*' of the object is formed at 'A^1'. Similarly, the reflection of the extended object takes place throughout the body '*AB*' and similar rays are plotted for the bottom-most position of the object '*B*'. The light rays through '*B*' viz, '*BC*' and '*BD*' are reflected along '*CF*' and '*DB*', respectively, and when these two reflected rays are produced, they appear to meet at position 'B^1'. If the lengths of the object *AB* and the image *A'B'* are measured, it is found to be equal. Similarly the measure of *DB* and *DB'* are found to be equal.

Hence, the total image of the object 'AB' is formed as 'A^1B^1'. The distance of the object 'AB' from the plane mirror is equal to the distance of the image from the mirror.

The distance of the object from the mirror is known as 'object distance', denoted by 'u' and the distance of the image from the mirror is known as 'image distance', denoted by 'v'. The image formed is erect but is laterally inverted when compared to the object, i.e., if you face a plane mirror, your left side will appear as the right side of the image and vice versa. The image formed by a plane mirror cannot be obtained on a screen. Such images are called **'virtual images'** whereas the images which can be obtained on a screen are called **'real images'**.

Hence, the image formed by a plane mirror is

1. of the same size as that of the object.
2. at the same distance behind the mirror as the object is in front.
3. erect but laterally inverted.
4. virtual.

Image Formed by Two Mirrors

Consider two mirrors that are placed such that they make an angle 'θ' with each other and their reflecting surfaces face towards each other. If an object is placed between them as shown in the (Fig. 13), formation of more than one image takes place.

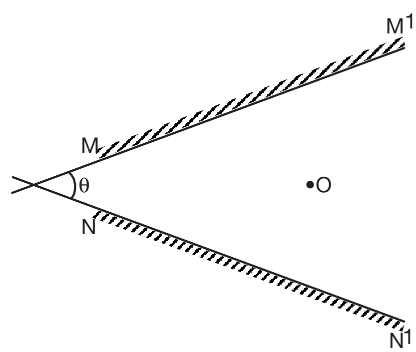


FIGURE 7.13 Reflection by two mirrors placed facing towards each other

'MM^1' and 'NN^1' are two plane mirrors placed such that the angle between them is 'θ'. 'O' is a point object placed between them as shown in (Fig. 13). Multiple images are formed in each of the mirrors, as the image of the object in the first mirror acts as an imaginary object for the second mirror and vice versa. The total number of images (n) formed is given by the expression,

$$n = \left[\frac{360^{\circ}}{\theta} - 1\right]$$

If $\theta = 90°$, the number of images formed is $n = \frac{360}{90} - 1 = 3$

If θ = 0°, i.e., the mirrors are parallel to each other, infinite images are formed but their brightness decreases.

EXAMPLE

Find the number of images formed by two mirrors whose reflecting surfaces intersect at an angle of 60°.

SOLUTION

In the given problem the angle of intersection of the reflecting surfaces, $\theta = 60°$

The number of images formed, $n = \dfrac{360}{\theta} - 1$

$\therefore\ n = \dfrac{360}{60} - 1 = 6 - 1 = 5$

5 images are formed.

Uses of Plane Mirrors

1. Plane mirrors are primarily used as looking glasses.
2. Since a combination of mirrors can produce multiple images, they are used to provide false dimensions, in showrooms.
3. They are also used as reflectors in solar cookers.
4. Plane mirrors are used in the construction of periscopes.

PERISCOPE

Plane mirrors are used in the construction of a reflecting periscope. A reflecting periscope works on the principle of the reflection of light. It consists of a cylindrical cardboard or wooden tube bent twice at right angles as shown in (Fig. 14). Two plane mirrors are fixed at the bends of the tube at an angle of 45° with the side of the tube. The inner side of the cylindrical tube is blackened to avoid any reflection of light.

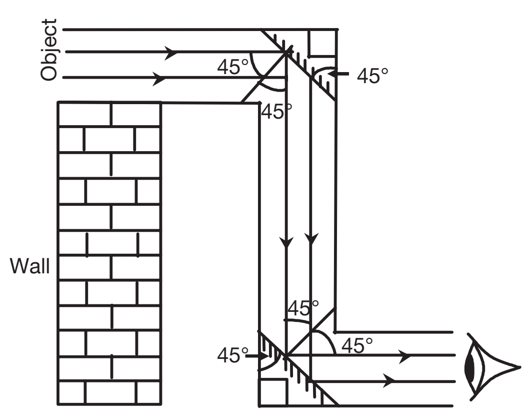


FIGURE 7.14 Reflecting periscope

The parallel rays entering the cylindrical tube from the upper end from an object strike the plane mirror at an angle of 45°, and hence are reflected through an angle of 45° (using principle of reflection). These reflected rays strike the second mirror at an angle of 45° and are further reflected through an angle of 45°. Finally the reflected rays reach the eye and the image of the object can be viewed from the other end.

Periscopes are used in submarines to see the objects on the surface of water and by soldiers present in a trench warfare to observe the movement of the enemy.

KALEIDOSCOPE

Three rectangular plane mirrors of the same size are placed such that the reflecting surfaces face each other. The mirrors are bound together by a string. The system is placed in cylindrical tube of suitable size. One end of cylindrical tube is closed with plane mirror. Glass bangle pieces or paper bits of different, bright colours are placed in the tube. Looking through the open end of the tube, we find different, beautiful patterns that are obtained on rotating the tube.

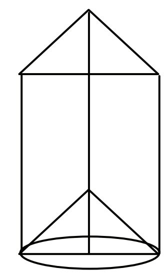


FIGURE 7.15 Kaleidoscope

SPHERICAL MIRRORS

Mirrors which are used by dentists, mirrors used as rear view mirrors in automobiles, and mirrors used for shaving are not plane mirrors. These are called spherical mirrors. Spherical mirrors form a part of a sphere. Consider a hollow glass sphere as shown in (Fig. 16), with its centre at '*O*'.

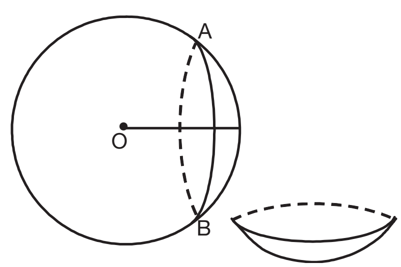
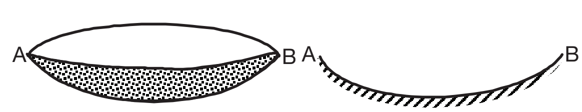


FIGURE 7.16 Hollow glass sphere and a section of it

When the hollow glass sphere is cut along '*AB*' as shown in above given figure, the part that is cut off appears to be like a dish. If the cut off portion is silver coated at the bottom, i.e., on the convex side or the bulged out side or the outer side, the inner side or the concave side becomes the reflecting surface and the mirror thus obtained is called as a 'concave mirror' or 'converging mirror' given in (Fig. 17).



(a) Concave mirror formed by silver coating the outer side

(b) Symbolic representation of a concave mirror

FIGURE 7.17 Concave mirror

If the cut-off part of the glass sphere is silver coated on the inside surface (concave side), the reflecting surface is the outer one and such a spherical mirror formed is called a 'convex mirror' or a 'diverging mirror'. (Fig. 18)

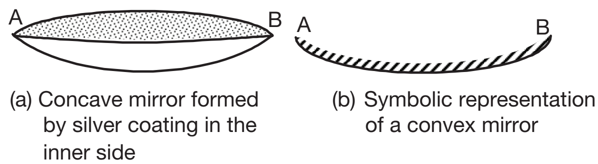


FIGURE 7.18 Convex mirror

Some of the terms related to spherical mirror are as follow:

1. **Pole (*P*):** It is the geometrical centre of the spherical mirror. *P* is the pole of the mirror.

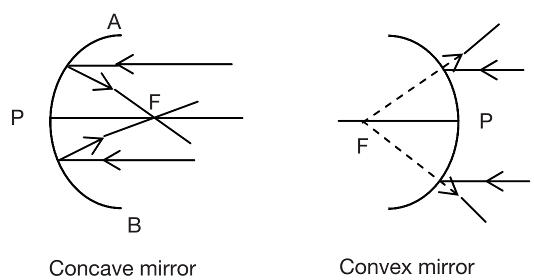


FIGURE 7.19 Images showing Pole and Focus of spherical mirrors

2. **Centre of curvature (*C*):** It is the centre of the sphere of which the mirror is a part. *C* is the centre of curvature.
3. **Radius of curvature (*R*):** It is the radius of the sphere of which the spherical mirror is a part. *PC* is the radius of curvature.
4. **Principal axis:** It is the line passing through the pole and the centre of curvature. *PM* is the principal axis.
5. **Principal focus (*F*):** Incident rays close to and parallel to the principal axis, after reflection converge at a fixed point on the principal axis in the case of a concave mirror or appear to diverge from a fixed point on the principal axis in the case of convex mirror. This fixed point is known as the principal focus. *F* is the principal focus.
6. **Focal length (*f*):** It is the distance between the pole and the principal focus. The distance between *P* and *F* is the focal length. Focal length is denoted by *f*.

Path of the Reflected Rays in Spherical Mirrors

Draw an arc of a circle of convenient radius with the centre at *C*. Draw the line *PC*. The line passing through *P* and *C* is the principal axis. *CB* and *CY* are the normal to the spherical surface at point *B* and *Y*, respectively. Draw two lines *AB* and *XY* parallel to the principal axis. Determine by geometrical construction the direction of the reflected rays, *BD* and *YG*, i.e., from the laws of reflection.

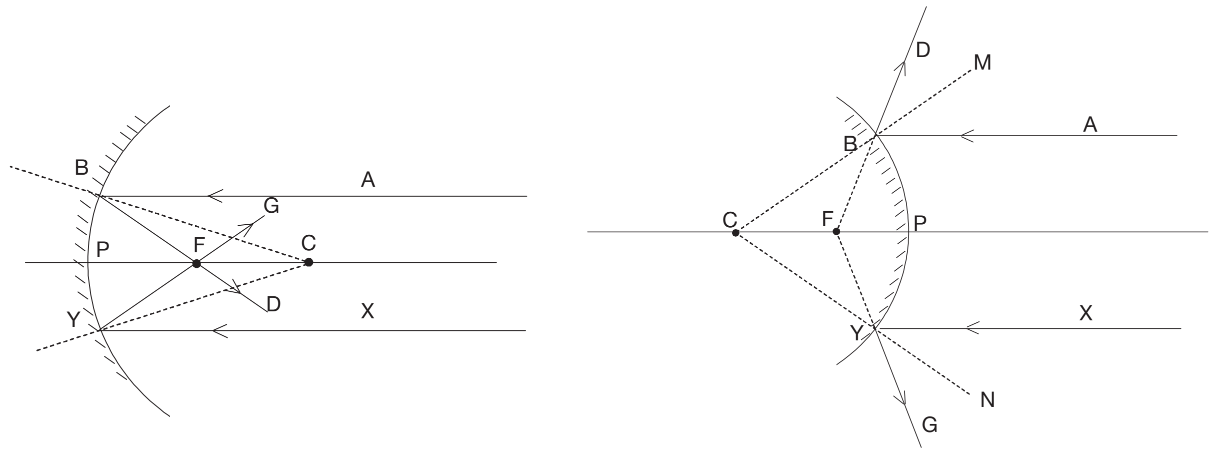


FIGURE 7.20 Figure showing the reflection of light rays which pass through or appear to pass through the focus of Concave or Convex mirrors

$\angle CBD = \angle ABC$ and $\angle CYG = \angle XYC$ in (Fig. 20) and $\angle MBD = \angle ABM$ and $\angle GYN = \angle NYX$ in figure 21 (The angle of incidence is equal to the angle of reflection).

By construction we can find that the two reflected rays meet at a fixed point F in the case of concave mirror and in convex mirror they appear to diverge from the fixed point F on the principal axis.

The incident rays parallel to the principal axis after reflection from the spherical mirror passes through principal focus in the case of concave mirror and appears to diverge from the principal focus in case of convex mirror. Conversely, an incident ray passing through the principal focus in the case of concave mirror or an incident ray that is directed towards the principal focus in the case of convex mirror is reflected parallel to the principal axis.

Rules for Construction of Ray Diagrams Formed in Spherical Mirrors

To know the position and the nature of the image of an object placed in front of a spherical mirror, any two of the following light rays coming from a point on the object are drawn.

1. A light ray parallel to the principal axis incident on a spherical mirror, after reflection, passes through the principal focus in the case of a concave mirror and appears to come from the principal focus in the case of a convex mirror (Fig. 21).

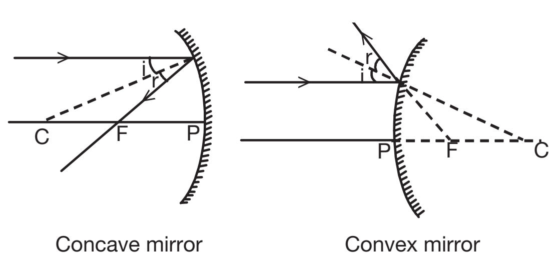


FIGURE 7.21 Figure showing the reflection of light rays which are parallel to the Axial line of Concave or Convex mirrors

2. A light ray passing through the principal focus and incident on a concave mirror or a light ray which is directed towards principal focus and incident on a convex mirror is reflected parallel to its principal axis (Fig. 22).

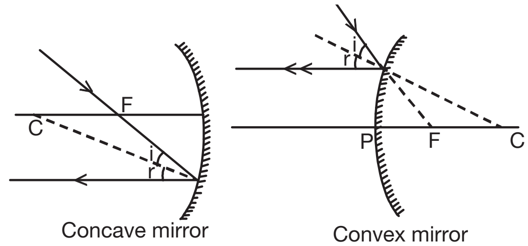


FIGURE 7.22 Figure showing the reflection of light rays which pass through or appear to pass through the focus of Concave or Convex mirrors

3. A light ray passing through the centre of curvature and incident on a concave mirror or a light ray which is directed towards the centre of curvature and incident on a convex mirror after reflection retraces its path (Fig. 23).

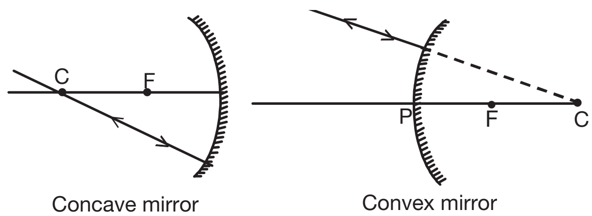


FIGURE 7.23 Figure showing the reflection of light rays which pass through or appear to pass through the center of curvature of Concave or Convex mirrors

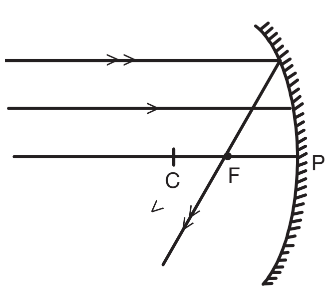
MAGNIFICATION

If the size of the image is larger than the size of the object such an image is called a magnified image. The ratio of the size of an image to the size of its object is known as magnification and is denoted by 'm'. It is just a number and does not have any units. Magnification can be expressed in terms of the distances of the object and the image from the mirror.

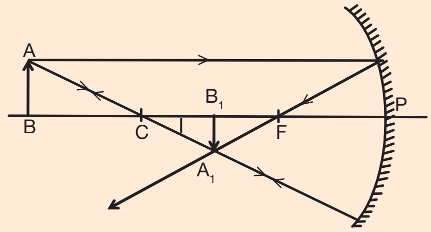
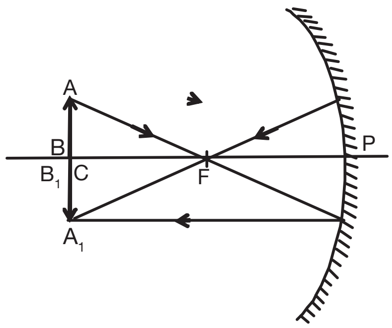
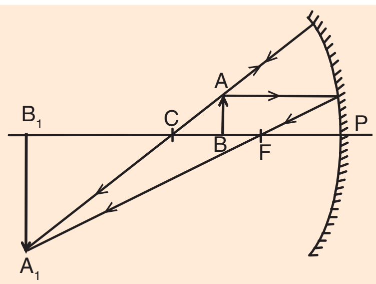
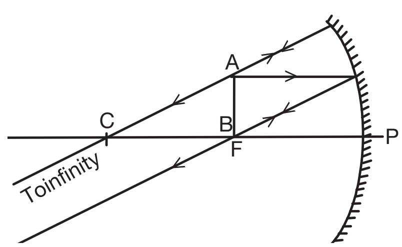
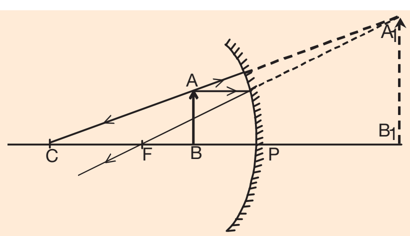
$$\text{Magnification, } m = \frac{\text{size of the image } (h_i)}{\text{size of the object } (h_0)} = -\frac{v}{u} = \frac{-\text{images distance}}{\text{object distance}}$$

If the image size is smaller than the object, it is called a 'diminished image'.

Formation of Images in Concave Mirror

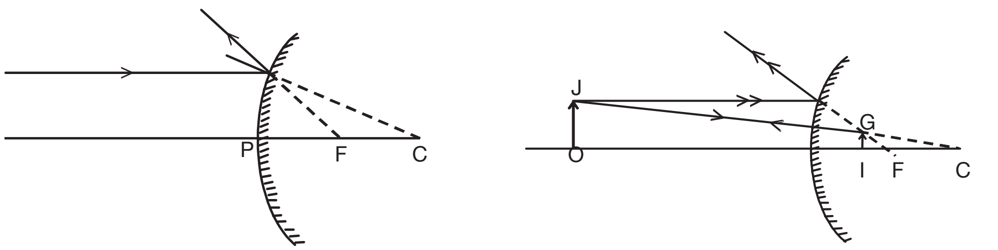
Diagram	Object distance	Image distance	Nature of the image
	Infinity, i.e., $u = \infty$	Image distance = Focal length, i.e., on principal focus	Real, inverted and highly diminished

(*Continued on following page*)

Diagram	Object distance	Image distance	Nature of the image
	Beyond C but not at ∞ ($\infty > u > R$)	Image lies between F and C	Real, inverted and diminished
	At C, i.e., $u = R$	at C, i.e., $v = R$	Real, inverted and of same size as that of the object.
	Between C and F ($R > u > f$)	Beyond C ($v > R$)	Real, inverted and magnified
	At F, $u = f$	At infinity ($v = \infty$)	Real, inverted and highly magnified
	Between F and P ($u < f$)	Beyond the mirror	Virtual, erect and magnified and formed on the opposite side of the mirror as that of the object.

Formation of Images by Convex Mirror

When the object is at infinity, or it is nearer to the mirror, the nature of the image is almost similar. Wherever the object is placed, the image formed by a convex mirror is always, erect, virtual and diminished. The only difference is, when the object is at infinity, the image is highly diminished and formed at the principal focus. When the object is placed at any other position, the position of the image lies between the principal focus and the pole of the mirror as shown in the following figures.



(a) When object is at infinity (b) When object is at any position other than infinity

FIGURE 7.24 Figure showing the position of images formed by convex mirror for various positions of object

Mirror Formula and Cartesian Sign Convention

The mirror formula is given by, $\frac{1}{f}-\frac{1}{v}+\frac{1}{u}$; where f, u and v are the focal length of spherical mirror, the object distance and the image distance, respectively. In order to solve numerical problems related to images formed by spherical mirrors, in an easy manner; positive and negative signs are adopted to the spherical mirror systems. These are known as the rules of sign convention to be followed to solve the problems (Fig. 25).

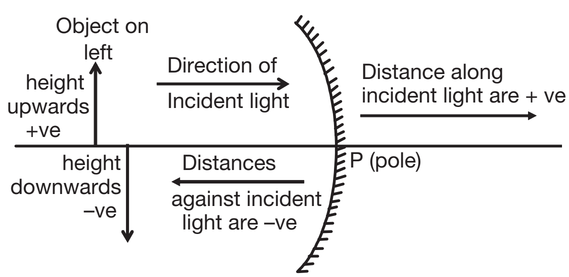


FIGURE 7.25 Cartesian sign convention

They are as follows:

1. All distances parallel to the principal axis are measured from the pole of the spherical mirror.
2. The distances measured in the direction of incident light are taken as positive.
3. The distances measured in a direction opposite to the direction of incident light are taken as negative.
4. The height of objects or images measured upwards (above the principal axis) and perpendicular to the principal axis are considered as positive.
5. The heights of objects or images measured downwards (below the principal axis) and perpendicular to the principal axis are considered as negative.

Formation of Images by Concave Mirror—an Experiment

Apparatus required: Mirror stand, screen, scale and concave mirror.

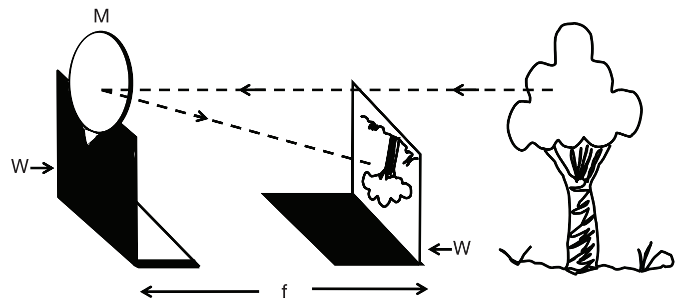


FIGURE 7.26 Formation of the image of a distant object on a screen placed at focus

Procedure

1. Mount a concave mirror on the mirror stand.
2. Focus the mirror to a distant object.
3. Introduce a screen and adjust the position of the screen such that a clear, sharp image of the distant object is formed on it.
4. Measure the distance between the screen and the concave mirror. This distance gives the focal length of the given mirror. Parallel beams from the distant object after reflection converges at the principal focus.

Observation

1. The image formed on the screen is smaller in size to that of the object.
2. The image obtained on the screen is inverted.
3. It is real image because it is caught on the screen.

Image Obtained Experimentally When the Object is at a Small Distance

Apparatus required: Concave mirror, mirror stand, screen, scale and object (candle)

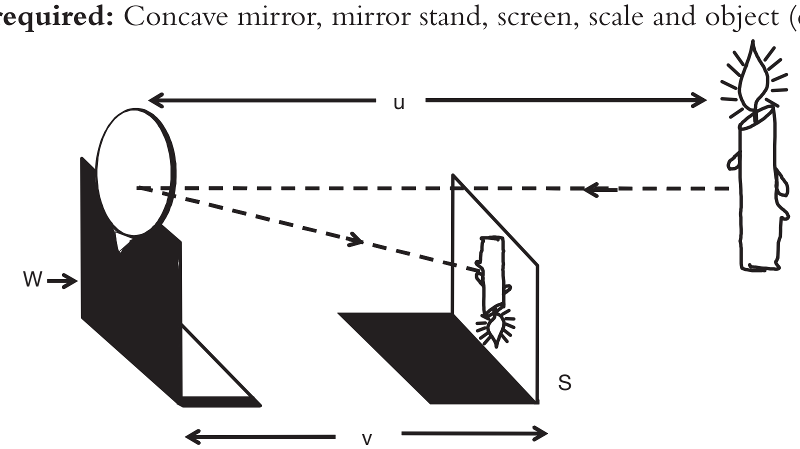


FIGURE 7.27 Formation of image due to a concave mirror-object at finite distance

Procedure

1. Mount a concave mirror on the mirror stand.
2. Place the mirror in front of an object (lighted candle) at a certain distance.
3. Place the screen between the object and mirror but not in line with them.
4. Adjust the position of the screen and the mirror until a bright and sharp image is obtained on the screen.
5. Measure the distance between the object and the mirror. This distance gives the object distance u.
6. Measure the distance between the concave mirror and the screen. This gives the image distance v.
7. Repeat the experiment for different values of object distance and tabulate the results.
8. The focal length of the given concave mirror can be found out using the mirror formula.

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

Trial no	'u' (in m)	v (in m)	$= f \frac{uv}{u+v} (m)$

Observation

1. The image obtained on the screen is inverted.
2. It is a real image, since it is caught on the screen.
3. The size of the image depends on the object distance.
4. If the object distance is greater than $2f$ of the concave mirror, the image will be smaller in size.
5. If the object distance is greater than the focal length but lesser than the radius of curvature of a given mirror, magnified image is obtained.

If a spherical mirror is given, we can easily identify whether the given mirror is concave or convex.

Concave mirror forms an enlarged and erect image of an object when it is much nearer to the object and if the object is moved further away from the mirror, the image becomes smaller. The convex mirror forms an erect and diminished image of the object.

Uses of Spherical Mirrors

1. A convex mirror is a diverging mirror and it forms a diminished image. So it is used as a side view mirror in vehicles so that the driver can observe a wide range of vehicles coming behind his vehicle (Fig. 28).
2. Convex mirrors, at times, are placed at the traffic junctions where signals are not provided so that during the day time, drivers of the vehicles moving along one direction can be aware of any vehicles moving across their path.
3. Convex mirrors are also placed in some of the ATM centres above the machine at some height. This is done as a security measure. The person operating the ATM machine will be aware of others who are behind him by being able to observe them in the convex mirror.

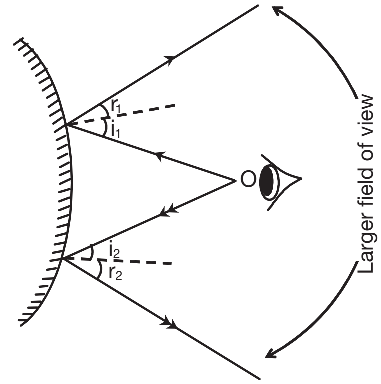


FIGURE 7.28 Increase in field view due to the presence of convex mirror

4. Concave mirrors are used to produce magnified virtual images. So these can be used as shaving mirrors.
5. Due to the ability of concave mirrors to produce magnified, virtual images they are used by dentists and E.N.T. specialists to view the interior portions of a body clearly.
6. Concave mirrors can be used as reflectors of light. When a bulb is kept at the focus of the mirror, we obtain a parallel beam of light reflected from the mirror (Fig. 29).

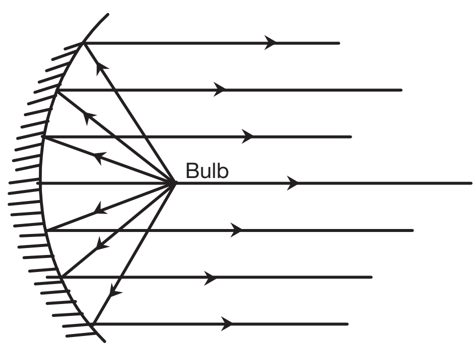


FIGURE 7.29 Figure to show how a concave mirror can be used to obtain parallel beam of light rays

Spherical mirrors are also used in reflecting telescopes.

EXAMPLE

Find the position of the image of an object placed at a distance of 12 cm from a convex mirror of focal length 10 cm.

SOLUTION

In the given problem object distance $u = -12$ cm (by using sign convention). The focal length of the convex mirror, $f = 10$ cm.

From mirror formula,

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

$$\frac{1}{10} = \frac{1}{-12} + \frac{1}{v}$$

$$\therefore \frac{1}{v} = \frac{1}{10} + \frac{1}{12}$$

$$\frac{1}{v} = \frac{12+10}{120}$$

$$\frac{1}{v} = \frac{22}{120}$$

$$v = \frac{120}{22} = 5.45 \text{ cm.}$$

The image distance is 5.45 cm.

EXAMPLE

An object of height 2 cm is placed on a principal axis at a distance of 10 cm from the pole of concave mirror. The image height is 5 cm. Find the image distance and the focal length of the concave mirror if the image is real and inverted.

SOLUTION

In the given problem,

The height of the object $h_o = 2$ cm

The height of the image $h_i = -5$ cm (using sign convention)

The object distance $u = -10$ cm (by using sign convention)

Since the image is real, image distance is negative $= -v$.

$$\therefore \text{Magnification} = \frac{hi}{h_o} = \frac{v}{u}$$

$$= \frac{-5}{2} = \frac{-v}{-10}$$

$$= \frac{-5 \times -10}{2} = -v$$

$$v = -25 \text{ cm}$$

The focal length of the mirror

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \text{ (mirror formula)}$$

$$\therefore \frac{1}{f} = \frac{1}{-10} + \frac{1}{-25}$$

$$\therefore \frac{1}{f} = \frac{-25 \times 10}{25 \times 10}$$

$$\frac{1}{f} = \frac{35}{250} \text{ or } f = \frac{250}{35} = -7.14 \text{ cm}$$

REFRACTION

Place a newspaper below a thick glass slab such that a portion of the paper lies outside the glass slab. View normally from the top of the glass slab. Portion of text lying below the glass slab appears closer than the portion outside the slab. Similarly, when a spoon is placed in a glass bowl, the spoon appears to be bent or discontinuous at air–water interface.

This perceived closeness of the text and the apparent bending of spoon is due to the refraction of a light. When light ray travels from one transparent medium to another, there is a deviation in the path of the light ray. This phenomenon is known as refraction.

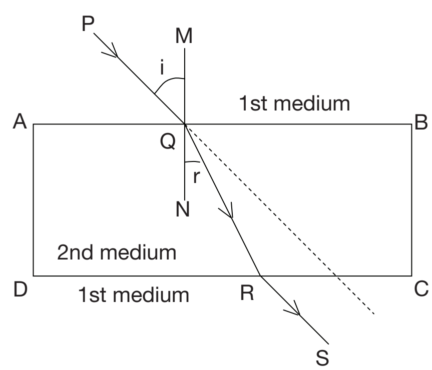


FIGURE 7.30 Refraction of a light ray traveling from air medium to glass medium

PQ is the incident ray.

QR is the refracted ray.

MN is the normal to the refracting surface *AB*.

$\angle PQM = \angle i$ which is the angle of incidence.

$\angle RQN = r$ which is the angle of refraction.

Q is the point of incidence.

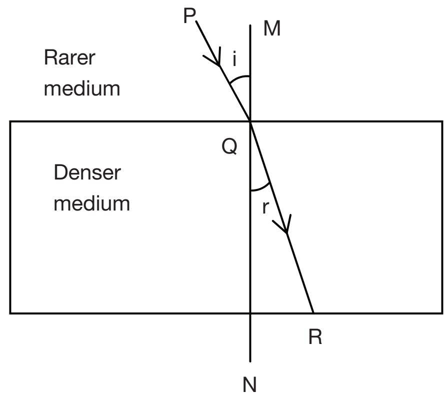


FIGURE 7.31 Refraction of a light ray traveling from rarer medium to a denser medium

When a diving board is seen from inside a pool of water, it appears to be at a greater height than it actually is. This is because light ray travelling from rarer to denser medium bends towards the normal and the object appears to be farther. The angle of incidence is greater than the angle of refraction if the light is incident from the rarer to the denser medium.

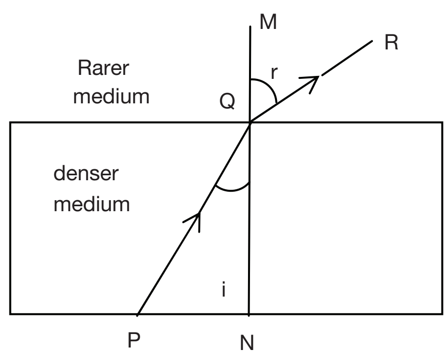


FIGURE 7.32 Refraction of a light ray traveling from a denser medium to a rarer medium

Due to the above-said reason, the sun appears to be at a higher position than its actual position during the sun rise and the sunset.

The floor of the swimming pool or a fish in water appears to be closer than they actually are when viewed from outside. This is because the light ray traveling from denser medium (water) to rarer medium (air) bends away from the normal, hence, the object appears to be nearer.

The angle of incidence is lesser than the angle of refraction $\angle i < \angle r$, when light travels from denser to rarer medium.

NOTE

When light is incide nt along the normal, the ray passes without deviation.

THE LAWS OF REFRACTION

The refraction of light occurs in accordance with the following two laws of refraction.

1. The incident ray, the refracted ray and the normal to the refracting surface at the point of incidence, all lie in the same plane.
2. For a given pair of media and for the light of a given wavelength, the ratio of the sine of the angle of incidence to the sine of angle of refraction is a constant. This law is known as Snell's law of refraction.

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

Refraction through a Glass Slab

Place a glass slab on a white paper fixed to a drawing board. Mark the boundary of the glass slab *ABCD*. Remove the glass slab. Draw a normal *MN* to the glass surface *AB*. Taking suitable acute angle, draw a line *OZ*. This forms the incident ray. Replace the glass-slab on the boundary *ABCD*. Fix two pins *P* and Q on the incident ray *OZ*. Looking through the face *CD*, find the images of pins *P* and Q. Fix two more pins *P*' and Q' in line with the images of pin *P* and Q. Remove the glass slab. Join *P*' and Q' so that it meet the line *CD* at *R*. Join *OR*. *OR* is the refracted ray and *RS* is the emergent ray. $\angle MOZ = i$, which is the angle of incidence. $\angle NOR = r$, which is the angle of refraction and $\angle TRS$ is the angle of emergence.

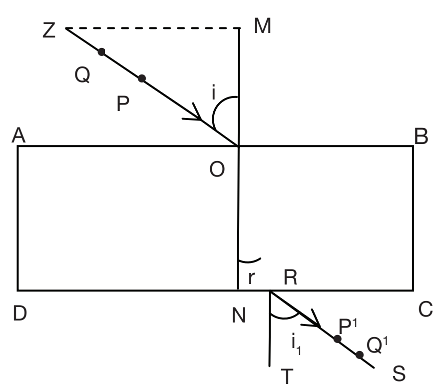


FIGURE 7.33 Refraction of light through glass slab

Measure the angle of incidence, angle of refraction and angle of emergence.

Calculate sin *i* and sin *r* and find their ratio.

The above experiment can be repeated for different angle of incidence and the result is tabulated.

Trial No.	Angle of incidence = $\angle i$	Angle of refraction = $\angle r$	sin *i*	sin *r*	$\frac{\sin i}{\sin r}$

Observation

In the above experiment it is found that

1. the incident ray, the refracted ray and the normal all lie in the plane of the paper.
2. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is found to be constant, i.e., $\frac{\sin i}{\sin r}$ = constant.
3. It is also found that the angle of emergence is equal to the angle of incidence. ($\angle i_1 = \angle i$) But the emergent ray is s lightly displaced and is parallel to the incident ray. The emergent ray is parallel to the incident ray only if the medium on both the sides of the glass slab is the same.

Refractive Index of a Medium

Light is considered to be travelling in the form of waves. A wave has characteristics like wavelength, frequency and velocity.

These three parameters (i.e., physical quantities required to be measured) are related as $v = n\lambda$ where v, n and λ are the velocity, frequency and the wavelength, respectively.

When light travels from one transparent medium to another, a change in the wavelength of the light occurs due to a change in the density (more specifically, optical density considered with reference to the motion of light) of the medium. But the frequency of light (i.e., the number of light waves produced in unit time) does not change. This results in the change in the velocity of light when it travels from one transparent medium to another.

For a given pair of media, the ratio of the velocity of light in the two media is constant, which is known as the 'refractive index' of one medium with reference to the other medium.

Consider a light ray travelling from air or vaccum to glass. Let 'c' and 'v' be the velocity of light in air or vacuum and glass respectively. Then, the ratio (c/v) is constant and is known as the refractive index of glass. The standard symbol for denoting refractive index is 'μ'.

To calculate the refractive index of any medium, the standard medium which is taken as reference is air or vacuum. The velocity of light is greater in the rarer medium when compared to the velocity of light in the denser medium.

For a given pair of media, the refractive index is calculated for the denser medium with reference to the rarer medium.

If v_1 and v_2 are the velocities of light in the 1st medium which is rarer and the 2nd medium which is denser, respectively, then the refractive index of the 2nd medium with reference to the 1st medium is given by $\mu_{21} = \frac{v_1}{v_2}$. If '$c$' is the velocity of light in air or vacuum then, the refractive index of the 1st medium with respect to air or vacuum (or simply known as the refractive index of the 1st medium) is given by $\mu_1 = \frac{c}{v_1}$ and similarly the refractive index of the 2nd medium is given by $\mu_2 = \frac{c}{v_2}$.

$$\text{Hence, } \mu_{21} = \frac{v_1}{v_2} \Rightarrow \mu_{21} = \frac{v_1}{v_2} \times \frac{c}{c}$$

$$\Rightarrow \mu_{21} = \frac{c}{v_2} \times \frac{v_1}{c} = \frac{c}{v_2} \div \frac{c}{v_1} \Rightarrow \mu_{21} = \frac{\left(\frac{c}{v_2}\right)}{\left(\frac{c}{v_1}\right)}$$

$$\Rightarrow \mu_{21} = \frac{V_1}{V_2}$$

Hence, we can define the refractive index or absolute refractive index of a material as 'the ratio of velocity of light in air or vacuum to the velocity of light in the medium'.

NOTE

1. Optical density is the property of a material and refractive index is the measure of that property.
2. The more the refractive index of a material is the more the light bends while travelling in that medium.
3. Since refractive index is the ratio of velocity, it does not have any unit and is just a number.

EXAMPLE

The velocity of light in first medium is 2.8×10^8 m s^{-1} and that in the second medium is 2.3×10^8 m s^{-1}. Find the refractive index of medium 2 with respect to medium 1.

SOLUTION

In the given problem.

Velocity of light in medium 1, v_1

$$= 2.8 \times 10^8 \text{ m s}^{-1}$$

Velocity of light in medium 2, v_2

$$= 2.8 \times 10^8 \text{ m s}^{-1}$$

Refractive index of medium 2 with respect to medium is given by

$$\mu_{21} \text{ or } {}_1\mu_2 = \frac{v_1}{v_2}$$

$$\therefore {}^1\mu_2 = \frac{2.8 \times 10^8}{2.3 \times 10^8} = 1.2$$

EXAMPLE

Find the velocity of light in a given medium. The absolute refractive index of the medium is 1.5 (given velocity of light in vacuum or air = 3×10^8 m s^{-1}).

SOLUTION

In the given problem

Velocity of light in air or vacuum,

$$c = 3 \times 10^8 \text{ m s}^{-1}$$

Velocity of light in a given medium = ?

Absolute refractive index of the medium is $\mu = 1.5$

$$\mu = \frac{c}{v}$$

$$1.5 = \frac{3\times10^8}{v}$$

$$v = 1.5 = \frac{3\times10^8}{v} = 2 \times 10^8 \text{ m s}^{-1}.$$

The velocity of light in the given medium is 2×10^8 m s^{-1}.

Apparent Depth—A Phenomenon Due to Refraction

Consider a glass slab of depth 't'; light rays travelling from the depth t, such as OA is refracted along AB and the refracted ray when produced backwards, meets at point I. The point I lies on the ray OC which travels normally to the interface and reaches the eye undeviated. Thus, the ray appears to come from I and not from O. I is the virtual image of O placed at depth 't'. CI is the apparent depth, i.e., the depth seen by us.

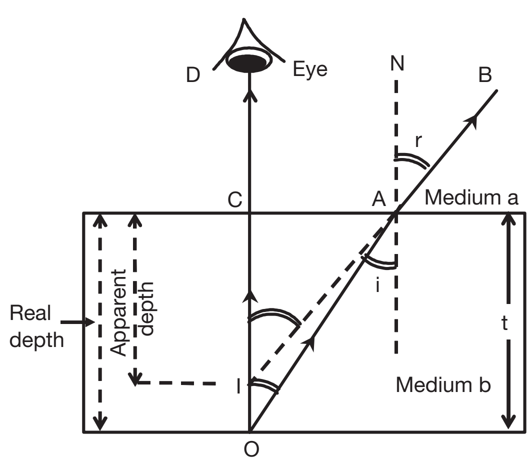


FIGURE 7.34 Apparent Depth

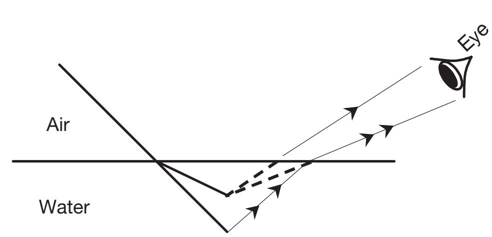


FIGURE 7.35 Apparent bent in a stick

When light enters from a denser medium to a rarer medium it bends away from the normal. As a consequence of this, the depth of a pond or the thickness of a glass slab appears to be less than the actual value (Fig. 34). It is due to the same reason that a stick partially immersed in water appears to be bent (Fig. 35) and short.

When a coin is placed in an empty beaker and water is poured into it, the coin appears to be raised. This happens due to the refraction of light. The depth of the coin due to optical illusion is known as 'apparent depth' and the actual depth is known as the 'real depth'.

Both apparent and real depths are related to the refractive index of water by the relation,

$$\mu = \frac{\text{Real depth}}{\text{Apparent depth}}$$

This equation is applicable not only to water but also to any other liquid in which refraction of light takes place.

TOTAL INTERNAL REFLECTION

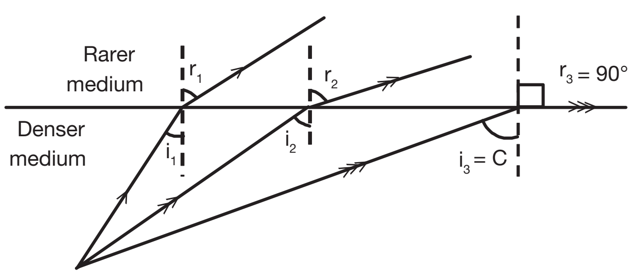


FIGURE 7.36 Critical angle

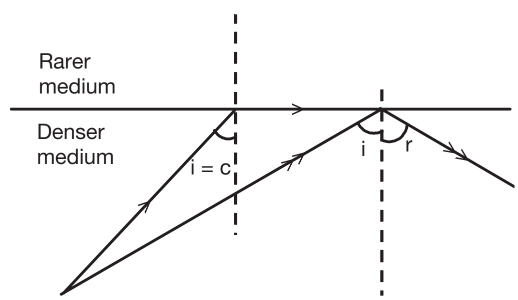


FIGURE 7.37 Total internal reflection

When a light ray travels from a denser to rarer medium, the refracted ray bends away from the normal. When the angle of incidence is further increased, the angle of refraction also increases. At a particular angle of incidence, the refracted ray just grazes the surface separating the two media or in other words the angle of refraction is equal to 90°. The angle of incidence for which the angle of refraction is 90° is called critical angle and is denoted by '*c*'. If the angle of incidence is greater than the critical angle, the light rays are not refracted but they are reflected back in the same denser medium. This phenomenon is known as total internal reflection. The conditions required for the total internal reflection to take place are :

1. light rays should travel from the denser to the rarer medium and
2. the angle of incidence should be greater than the critical angle.

Mirage

It is an optical illusion caused due to total internal reflection. In deserts or in peak summers the air above the earth surface gets heated up and it becomes rarer whereas the upper layers of in the atmosphere air are comparatively denser. Thus, the light from the sun travels from denser to rarer medium and the ray undergoes total internal reflection if the angle of incidence is greater than the critical angle of air.

This gives rise to an inverted image of a tree or any object and this creates an illusion as though the image is formed in water.

Sparkling of Diamond

Diamond is cut into a number of regular faces having appropriate angles. When light ray enters diamond, it undergoes multiple total internal reflection before it emerges out. This makes the diamond sparkle.

Bicycle Reflectors

A disc on the rear side of the bicycle which glows red when light is incident on it, works on the principle of total internal reflection. It is made up of a reflecting prism which make the disc's surface glitter which in turn makes the drivers vehicles approaching the bicycle take notice of its presence.

Optical Fibres

Optical fibres are used to transport images. An optical fibre consists of glass or plastic fibre which has a very small area of cross-section. A number of fibres are placed parallel to each other and clamped at the edges to form a cable. The ends of the cable or the fibres are highly polished. These cables or fibres are used to transport light in any desired path. Since the pipes have a small area of cross section, the incident ray strikes the fibre at a glancing angle. The light entering a fibre undergoes a series of total internal reflections before emerging out.

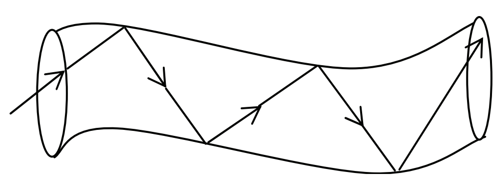


FIGURE 7.38 Optical fibre

Uses

1. Used in communication of images and sound.
2. Used by physicians to examine internal parts of the body (endoscope and fibre scopes).

Old model binoculars, telescopes, microscopes, and periscopes made up of prisms, make use of total internal reflection.

Isosceles right angled prisms are used to rotate the light through 90° and 180°.

Prism are made up of glass. The critical angle for glass is around 42°.

Refraction through a Prism

A prism is a solid with triangular surfaces at two ends and bounded by three rectangular lateral surfaces (Fig. 39). Any section perpendicular to the rectangular surface is called principal section.

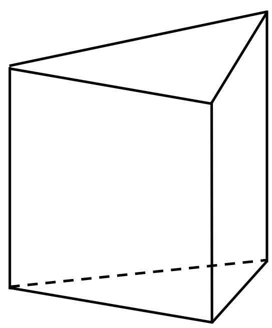


FIGURE 7.39 Prism

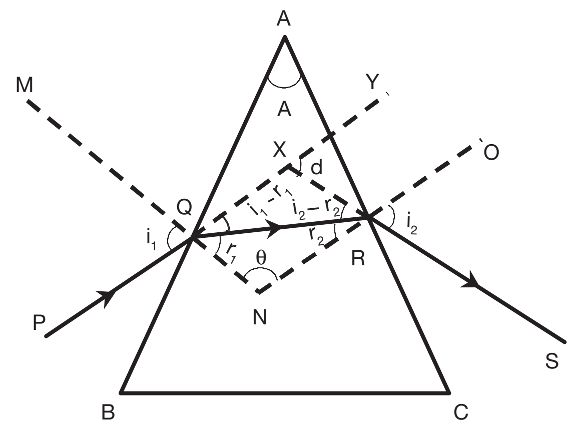


FIGURE 7.40 Refraction through glass prism

Consider the principal cross section of the prism *ABC* as shown in (Fig. 40). *BC* is the base of the prism and *AB*, *AC* are the refracting surfaces. The angle between them, i.e., $\angle BAC = A$, is the angle of the prism. '*PQ*' is the incident light ray at '*Q*' on face *AB* of the prism. '*QR*' is the refracted ray inside the prism and '*RS*' is the emergent ray emerging from face *AC*. 'i_1' is the angle of incidence, 'i_2' is the angle of emergence 'r_1' is the angle of refraction on face '*AB*' and 'r_2' is the angle of incidence inside the prism on the face '*AC*'. In the absence of the prism, the light ray would travel along the path '*PQXY*'. Due to the presence of the prism, it refracts at '*Q*' and '*R*' on the two faces and emerges in the direction '*RS*'. The angle between incident ray (*PQ*) and emergent ray (*RS*), i.e., $\angle YXR$ (= *d*) is known as the angle of deviation. '*MN*' and '*NO*' are the normals at '*Q*' and '*R*' on faces '*AB*' and '*AC*', respectively. From the figure, in the quadrilateral *AQNR*, $A + \theta = 180°$, and in ΔQRN, $r_1 + r_2 + \theta = 180°$.

Thus, $$A + \theta = r_1 + r_2 + \theta$$

∴ $$A = r_1 + r_2 \quad (7.1)$$

In ΔXQR, $$d = (i_1 - r_1) + (i_2 - r_2)$$
$$= i_1 - r_1 + i_2 - r_2$$
$$= (i_1 + i_2) - (r_1 + r_2)$$
$$= (i_1 + i_2) - A$$

Thus, we have $$i_1 + i_2 = A + d \quad (7.2)$$

Rotation of Light Eays using Different Prisms

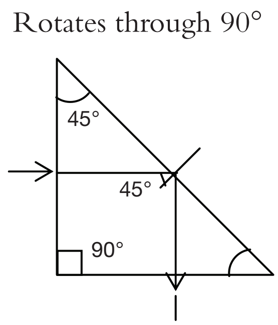


FIGURE 7.41

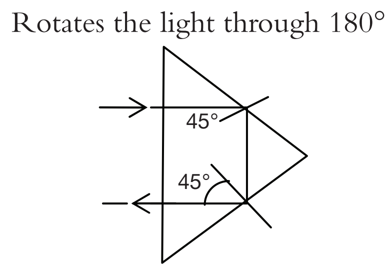


FIGURE 7.42

Right angled isosceles prism and Equilateral prism

EXAMPLE

A light ray incidents on an equilateral triangle with an angle of 30°. Find the angle of deviation of the emergent light ray if the angle of emergence from the second surface is 70°.

SOLUTION

Angle of incidence $(i_1) = 30°$

Angle of emergence $(i_2) = 70°$

Angle of prism $(A) = 60°$

since the primis an equilateral prism.

$$i_1 + i_2 = A + d$$

$$d = i_1 + i_2 - A$$

$$\Rightarrow d = 7 + 30 - 60$$

$$\Rightarrow \text{Angle of deviation } (d) = 40°$$

Dispersion of Light

When sunlight (white light) is made to pass through a prism, it is found that the ray of white light splits into its constituent colours. This phenomenon is called dispersion.

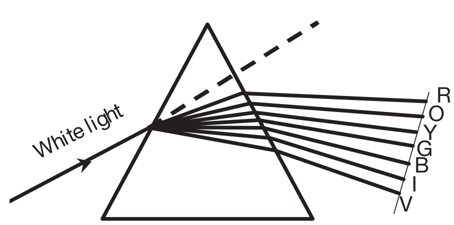


FIGURE 7.43 Dispersion of light

As discussed earlier the refractive index of a medium is different for different wavelengths (colours). When a ray of white light falls on a refracting surface like a prism, although the angle of incidence is the same for all colours, the angle of refraction is different for different colours. This causes the white light to split into its constituent colours (Fig. 43).

Spectrum

The visible light consists of seven colours. The band of these seven colours is called the visible spectrum.

Rainbow

The formation of a rainbow is due to the dispersion of the sunlight by water droplets. When sunlight falls on water droplets, light undergoes dispersion. Water droplets act as a dispersive medium. Some times two rainbows appear together. The inner rainbow is called the primary rainbow and the outer rainbow is called the secondary rainbow. The primary rainbow is narrower and brighter than the secondary rainbow.

Scattering of light

When light falls on dust and other minute particles present in the atmosphere it undergoes irregular reflection and spreads. This is called scattering of light.

Blue Colour of the Sky

The colour of the sky is blue due to dispersion and scattering. When sunlight passes through atmosphere it undergoes refraction. When light gets refracted, the blue light is scattered more than are the other colours by the air molecules. Hence, the sky appears blue.

Lenses

A lens is a transparent medium bound by two refracting surfaces. A lens can be bounded by two curved surfaces or one plane surface and one curved surface. There are many types of lenses, viz., biconvex (or simply, convex) lens (*d*), biconcave (or simply, concave) lens (*c*), plano-convex lens (*a*), plano – concave lens (*b*) and convex – concave lens (*e*) (Fig. 44).

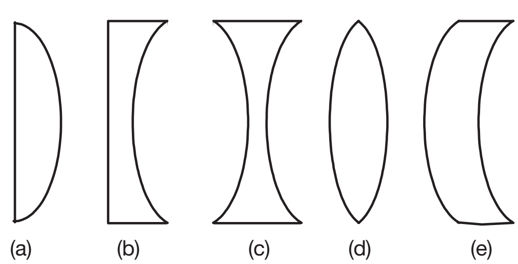


FIGURE 7.44 Kinds of lenses

A biconvex lens can be considered to be formed from the combination of two glass spheres, as shown in (Fig. 45). Since it is formed from two spheres, it will have two centres of curvature and correspondingly two radii of curvature (whose values need not always be equal). A convex surface having a larger radius of curvature is less curved. (If the curvature is zero, i.e., if the surface is plane, the radius of curvature is infinity). An imaginary line passing through the two centres of curvature of the two surfaces of a lens is known as the '**principal axis**' of the lens.

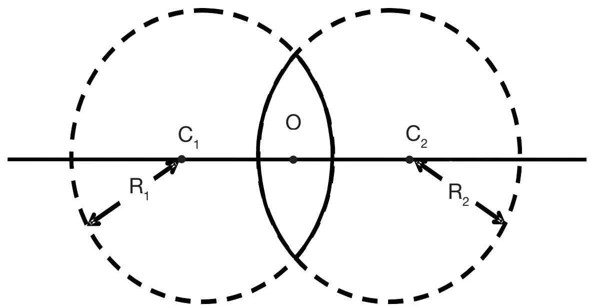


FIGURE 7.45 Formation of a convex lens

The mid-point of the line segment 'C_1C_2' (shown as '*O*' in Fig. 45) is known as the **optic centre** of the lens. For a thin lens and for all practical purposes, the distance from the optic centre to the centre of curvature is treated as the **radius of curvature**.

A biconcave lens is considered to be formed by filling the space between two imaginary spheres with glass, as shown in (Fig. 46).

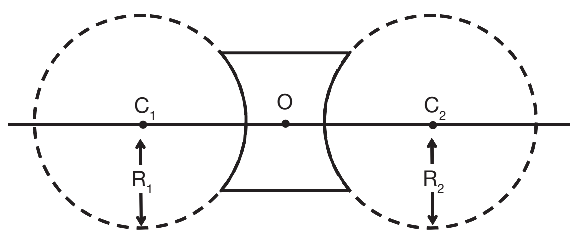


FIGURE 7.46 Formation of a concave lens

Similar to a convex lens, the centres and the radii of curvature of the two concave surfaces and the optic centre and principal axis are shown in (Fig. 46).

When a beam of light parallel to the principal axis is incident on a lens, it refracts at the two surfaces and after refraction at the two surfaces, it converges at (in the case of a convex lens) or appears to diverge from (in the case of a concave lens) a point on the principal axis, which is known as the **principal focus (*F*)**.

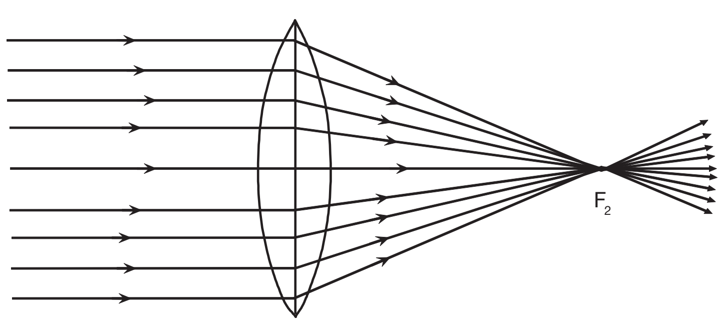


FIGURE 7.47 Figure to show the Focus of a convex lens

Thus, a convex lens is also known as a converging lens and a concave lens is also known as a diverging lens. Converging lenses are generally thickest in the middle while diverging lens are thinnest in the middle.

The distance of an object from the optic centre of a lens is known as the **object distance** (denoted by '*u*'), the distance of an image from the optic centre of a lens is known as the **image distance** (denoted by '*v*') and the distance of principal focus from the optic centre of a lens is known as the '**focal length**' (denoted by '*f*').

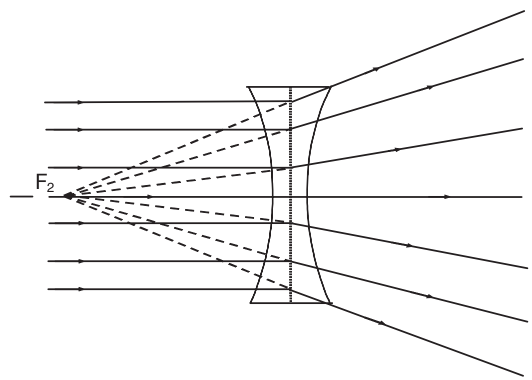


FIGURE 7.48 Figure to show the Focus of a concave lens

Since a lens has two refracting surfaces, like two centres and radii of curvature, it has two principal foci and focal lengths, each on either side of the lens.

Refraction by Spherical Lenses

Any two of the following rays coming from an object placed in front of a lens are taken into consideration to know about the image formation in lenses.

1. A light ray from an object parallel to the principal axis after refraction at the two surfaces of a lens converges at (in a convex lens) or appears to diverge from (in a concave lens) the second principal focus (Fig. 49).

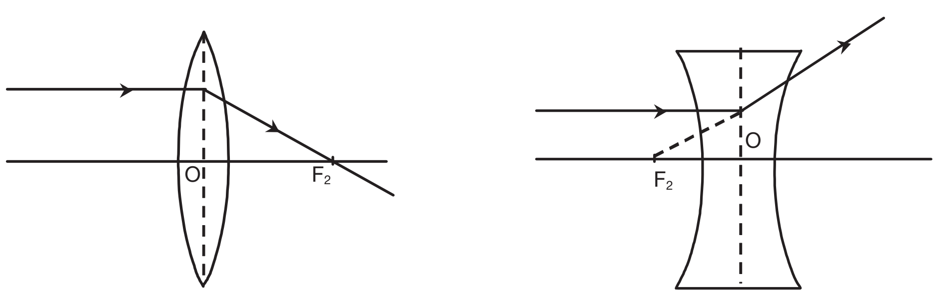


FIGURE 7.49 Figure showing the refraction of light rays through lenses when incident parallel to principal axis

2. A light ray passing through the first principal focus (in a convex lens) or appearing to meet at it (in a concave lens) emerges parallel to the principal axis after refraction at the two surfaces of a lens (Fig. 50).

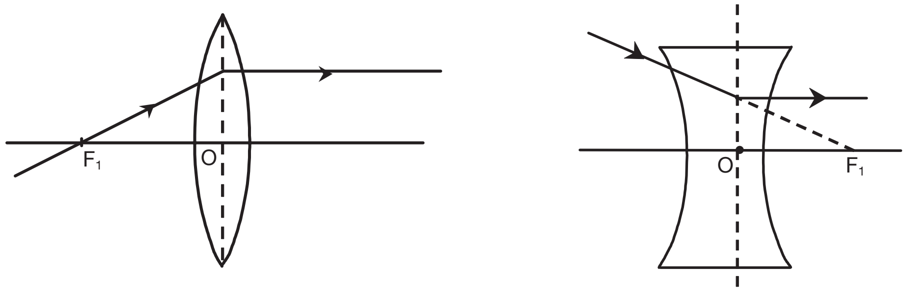


FIGURE 7.50 Figure showing the refraction of light rays through lenses when incident light rays pass through or appear to pass through focus

3. A ray of light passing through the optical centre of a lens, emerges without any deviation after refraction at the two surfaces of the lens (Fig. 51).

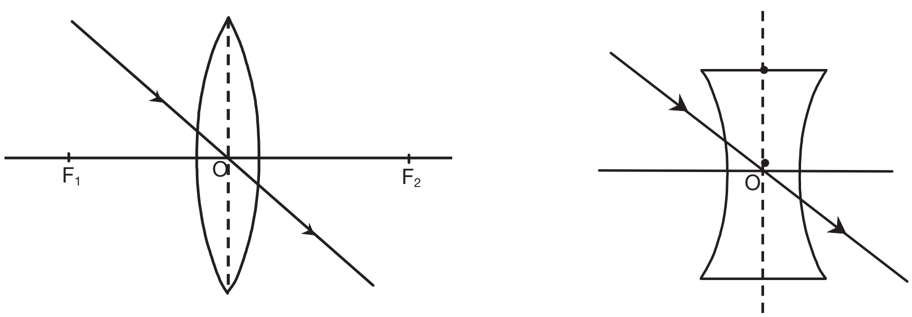


FIGURE 7.51 Figure showing the refraction of light rays through lenses when incident light rays pass through Optic center

Sign Convention for Lenses

1. All distances parallel to the principal axis are measured from the optic centre of the lens.

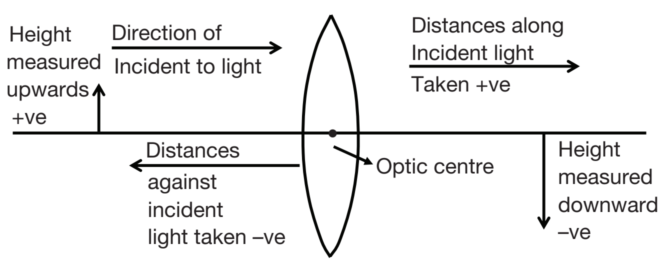


FIGURE 7.52 Sign convention in lenses

2. The distances measured in the direction of incident light are considered to be positive.
3. The distances measured in the direction opposite to the direction of incident light are taken as negative.

4. The heights of objects or images measured upwards (above the principal axis) and perpendicular to it are considered as positive.
5. The height of objects or images measured downwards (below the principal axis) and perpendicular to it are considered as negative.

Lens Formula

The relation between object distance (u), image distance (v) and focal length of a lens (f) is given by the expression $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$. This expression is known as lens formula, and is applicable to both convex as well as concave lenses.

Magnification in case of spherical lens is given by,

$$m = \frac{h_i}{h_0} = \frac{v}{u}$$

Formation of Images by a Convex Lens

The image of an object placed in front of a convex lens depends on the distance of the object from the lens. The distances of the object and its image from the lens are measured from optic centre of the lens.

When the object is at infinite distance from the lens, the image is formed on the other side of the lens, highly diminished, real and inverted. As the object moves nearer to the lens, the image moves away from the lens gradually and even the size of the image formed increases.

The following figures illustrate the formation of images by a convex lens when an object is at different positions.

Symbols used:

$OF_1 = OF_2 =$ Focal length $= f$

$OA =$ object distance $= u$

$OA_1 =$ image distance $= v$

1. **When the object is at infinite distance**

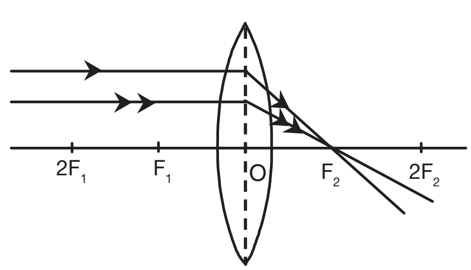


FIGURE 7.53 Figure showing the formation of an image by a convex lens when the object is placed at infinity

The image is

(i) formed at the focus (F_2),

(ii) real,

(iii) inverted and

(iv) Nhighly diminished (Fig. 53).

2. When the object is beyond the centre of curvature

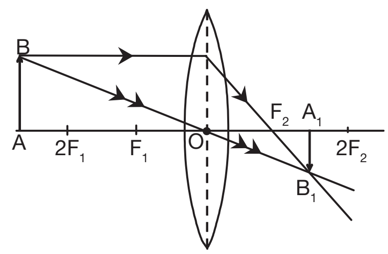


FIGURE 7.54 Figure showing the formation of an image by a convex lens when the object is placed at the center of curvature

The image is

(i) formed between F_2 and $2F_2$,

(ii) real,

(iii) inverted and

(iv) diminished (Fig. 54)

3. When the object is at the centre of curvature

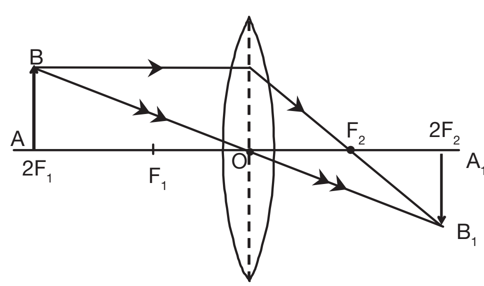


FIGURE 7.55 Figure showing the formation of an image by a convex lens when the object is placed at the center of curvature

The image is

(i) formed at $2F_2$,

(ii) real,

(iii) inverted and

(iv) same size as that of the object (Fig. 55).

4. When the object is between the principal focus and centre of curvature

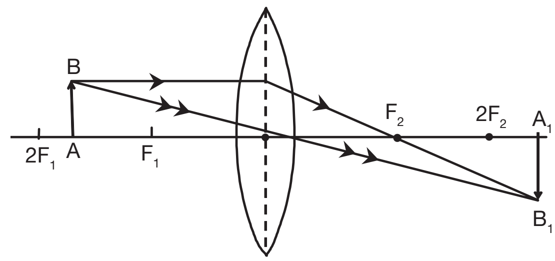


FIGURE 7.56 Figure showing the formation of an image by a convex lens when the object is placed between focus and the center of curvature

The image is

(i) ormed beyond $2F_2$,

(ii) real,

(iii) inverted and

(iv) magnified (Fig. 56)

5. When the object is at the principal focus

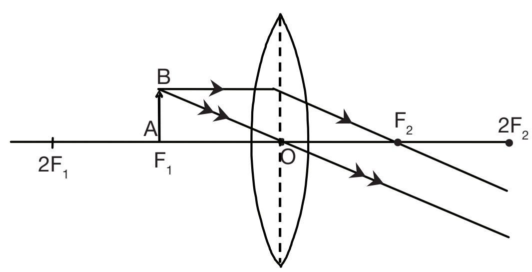


FIGURE 7.57 Figure showing the formation of an image by a convex lens when the object is placed at the focus of the lens

The image is

(i) formed at infinity

(ii) real

(iii) inverted

(iv) highly magnified (Fig. 57)

6. When the object is placed between the optic centre and the principal focus

In this case the refracted rays are diverging, and hence, a real image cannot be formed. When the diverging rays are produced backward, they meet at a point and the position where these divergent rays appear to meet is the position of the image. Hence, the image is erect, virtual and magnified. Here the image is formed on the same side of the lens, i.e., on the side where the object lies. (Fig. 58).

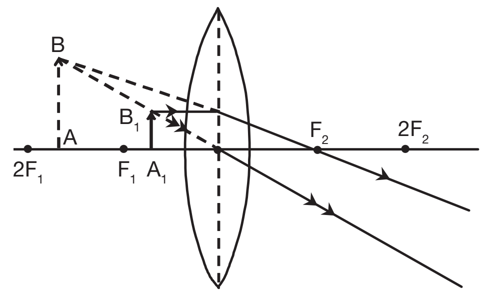


FIGURE 7.58 Figure showing the formation of an image by a convex lens when the object is placed in between focus and the optic center

The above information can be summarized in the following table.

Object distance	Image distance	Nature of image
$u = \infty$	$v = f$	Real, inverted and highly diminished
$2f < u < \infty$	$f < v < 2f$	Real, inverted and diminished
$u = 2f$	$v = 2f$	Real, inverted and of the same size as that of the object
$f < u < 2f$	$v > 2f$	Inverted, real and magnified
$u = f$	$v = \infty$	Real, inverted and highly magnified
$u < f$	–	Virtual, erect, magnified and formed on the same side of the lens on the side where the object lies.

Formation of Image by a Concave Lens

In the case of a concave lens, the nature of the image does not change with a change in the object distance, as illustrated in the following Figs, 59 and 60 except that there will be a slight difference in the magnification. When the object is at infinity the image is highly diminished and is formed at F_2. When the object is at other places, it is diminished, and is formed between O and F_2.

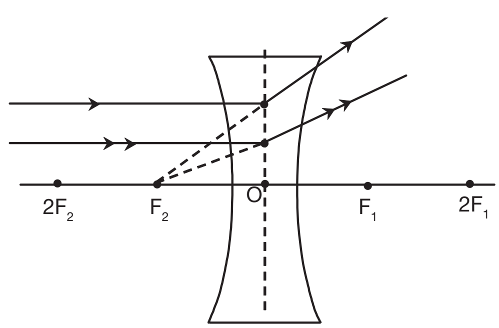


FIGURE 7.59 When the object is at infinite distance

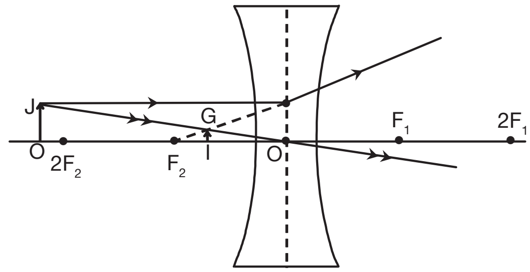


FIGURE 7.60 When the object is not at infinity

The nature of the image is always virtual, diminished, erect and formed on the same side of the lens as the object. Due to this nature of a concave lens, it is used in Galileo telescope and for correcting short sightedness.

Detearmination of the Focal Length of a Convex Lens

Using a distant object

Mount a convex lens and a screen on an optical bench. Hold the lens so that the rays of light from the sun fall directly upon it. Focus the image on the screen (Fig. 61).

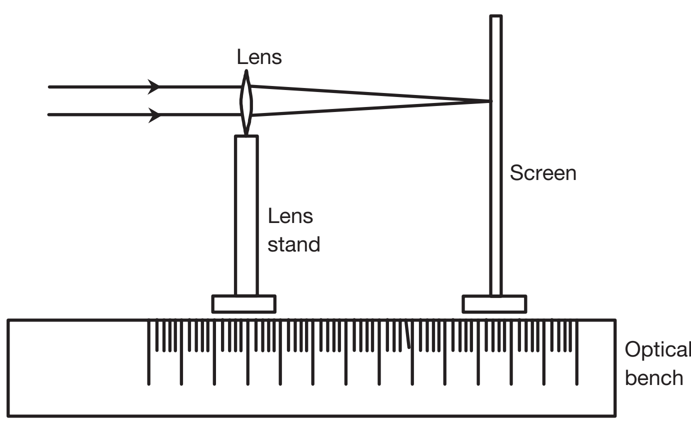


FIGURE 7.61 Experimental arrangement to determine the focal length of a particular convex lens

Measure the distance of the image from the optic centre of the lens. Since the object distance is infinity, the image distance would be equal to the focal length.

Uses of Lenses

1. A convex lens having short focal length can be used to focus light coming from the sun at a point and can be used for burning.
2. A convex lens is used in photographic cameras.
3. A convex lens can be used in a terrestrial telescope to make the inverted images erect, and is known as an erecting lens.

4. A combination of convex and concave lenses are used in cinema projectors and L.C.D projectors.
5. Convex lenses can be used in search lights used by miners. They produce a parallel beam of light when a bulb is placed at the principal focus.
6. A convex lens is used by palmists to view a magnified image of the hand and to study it.
7. A convex lens of short focal length can be used as a simple microscope or a hand-lens to read fine prints.
8. We can observe the weaving pattern of clothes by using a convex lens.
9. A convex lens of appropriate focal length can be used for correcting long sightedness.
10. Similarly a concave lens of appropriate focal length can be used for correcting short-sightedness.
11. A concave lens is also used as an eye lens in a Galileo telescope.

HUMAN EYE

The human eye has some limitations, a few of which are listed below.

1. Inability to see clearly far off objects like stars.
2. Inability to see very small objects like bacterial cells.
3. The images formed are temporary and cannot be stored permanently.

Also due to ageing and due to several other reasons, a person may be unable to see nearby or distant objects clearly.

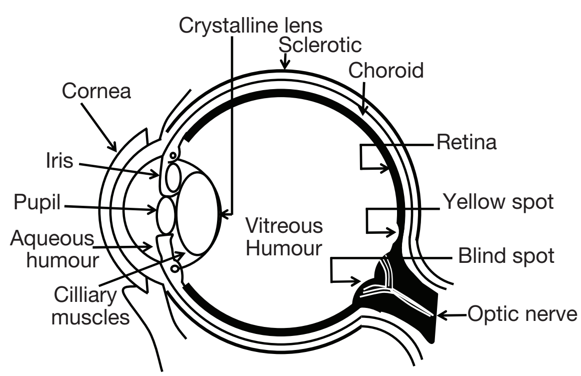


FIGURE 7.62 Human Eye

To overcome these limitations and defects, several optical instruments like spectacles, microscopes, telescopes and camera were invented.

These optical instruments help us to see better. Before we discuss how different optical instruments help us in doing that, we discuss the functioning of a human eye.

A normal human eye is a spherical ball having a diameter of about 2.5 cm, with a slight bulge in the front portion.

The table given below gives the different parts of an eye, their description and their function.

Part of eye	Description	Function
Sclerotic	A thick, white and opaque fibrous tissue covering the exterior part of the eye ball.	Gives a definite shape to the eye and protects the interior parts.
Choroid	A dull grey membrane between sclerotic and retina.	Keeps the interior part of the eye ball dark by preventing internal reflections.
Cornea	Tough and transparent membrane covering the front part of the eye.	Allows the light to enter the eye.
Aqueous humor	A transparent liquid present in the region behind cornea.	Keeps the cornea moist and gives definite shape to the eye ball.
Crystalline lens	A capsule containing a fibrous jelly. Hard at the centre and softer at outer portions.	Acts as a double convex lens and helps focusing the image on the retina.
Ciliary muscles	A ring of muscles which hold the lens in place.	Relax and contract, thereby changing the focal length of the lens.
Vitreous humor	Thin jelly like fluid consisting largely of water. Present behind the lens.	Prevents the eye ball from collapsing.
Optic nerve	A bunch of thousands of nerves which originate from the brain.	Helps in transmitting optical impulses to the brain.
Retina	The ends of thousands of nerves of optical fibres form a hemispherical delicate film on the inner surface of the eye. This film is called retina.	Converts the image that is formed on it into optical impulses.
Rods and cones	Special type of cells on retina which are rod shaped and cone shaped.	Rod cells respond to the intensity of incident light, whereas cone cells are sensitive to colours.
Yellow spot or Macula	Slight depression in the retina at the centre of which is a minute region called fovea centralis which is largely made of cones.	Most sensitive part of the eye, the lens adjusts itself such that the image of an object under observation falls on fovea.
Blind spot	Portion of retina which does not contain any light sensitive cells.	No specific function.
Iris and pupil	Iris comprises of several muscles which can contract and relax, thereby adjusting the size of an aperture called pupil.	Control the amount of light entering the eye.

Formation of Image on the Retina

The rays coming from an object enter the eye through the pupil. The size automatically dilates if the brightness is low and decreases when brightness is high. This ability of the eye to adapt to changes in brightness is called **adaptation of the eye**. The light entering through the eye falls on the lens, which being a converging lens, converges the rays on to the retina, forming an inverted and real image. The optical nerves convert the image into optical impulses and then pass on the image to the brain.

As discussed earlier, a human eye has a unique ability to adjust its focal length. The focal length of the lens is varied by relaxing or contracting the ciliary muscles. This process of altering the focal length of the lens is known as the **accommodation of eye**.

When objects near the eye are being viewed, the ciliary muscles contract, making the lens more convex, this helps in decreasing the focal length of the lens.

When distant objects are being viewed, the ciliary muscles relax; this makes the lens less convex, and hence increases the focal length, of the lens.

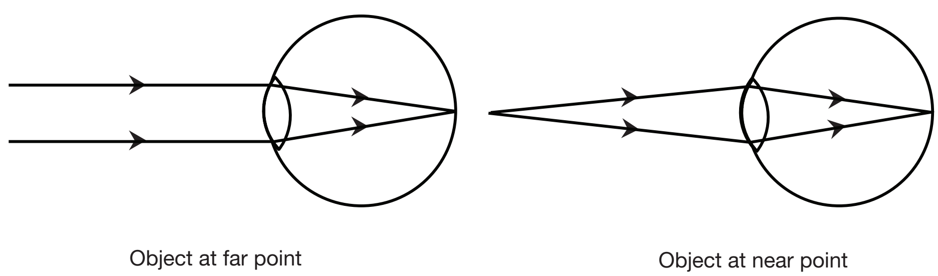


FIGURE 7.63 Focusing of ray for normal eye

But the variations in focal length of the eye is limited, the minimum distance at which an object can be clearly viewed is called the **near point**. Similarly, the farthest point at which an object can be viewed clearly is called the **far point**. The far point for a normal human eye is at infinity. The near point for a normal human eye or the least distance of distinct vision is approximately 25 cm.

DEFECTS OF EYE

If the cilary muscles are unable to alter the focal length of the eye lens, the eye lens cannot focus either near objects or far off objects clearly on the retina. Then the eye is said to be defective.

Long-Sightedness or Hypermetropia

Hypermetropia is a defect due to which a person can see distant objects clearly but is unable to see objects which are near to the eye clearly. This happens as the rays from a near object are focused behind the retina.

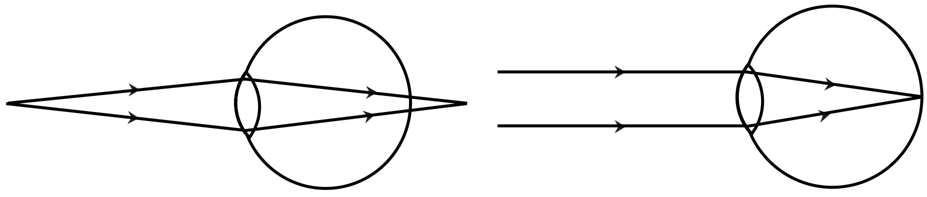


FIGURE 7.64 Image formation in a person's eyes having hypermetropia

Hypermetropia can be corrected by using a convex lens of suitable focal length, this helps in decreasing the combined focal length, thus forming the image on the retina.

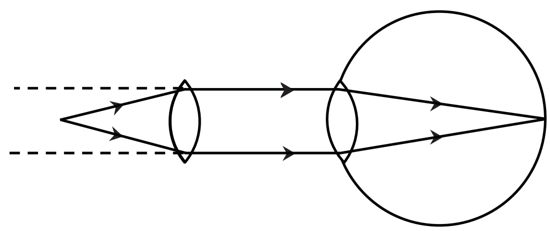


FIGURE 7.65 Correction of hypermetropia

Causes for Long-Sightedness

1. As we grow old or due to some disease, ciliary muscles becomes hard, and hence, they cannot contract. As a result the curvature and the focal length of the eye lens cannot be decreased as required. The image is formed behind the retina.
2. The eyeball shortens or the focal length of the eye lens increases due to some disease, and hence, the image is formed behind the retina.

EXAMPLE

A person has least distance of distinct vision of 57 cm. What should be the focal length of the lens that is required for him to read a news paper at a distance of 25 cm?

SOLUTION

The person near point is 75 cm, i.e., he could not see objects never than 75 cm. This defect is called hypermetropia and this can be rectified using convex lans.

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

$$u = -25 \text{ cm} = {}^{-}0.25 \text{ m}$$

$$v = -75 \text{ cm} = -0.75 \text{ m}$$

Short-Sightedness or Myopia

Myopia is a defect due to which a person can see the objects nearby clearly but is unable to see the objects at a distance clearly. This happens as the rays from a distant object are focused before they reach the retina.

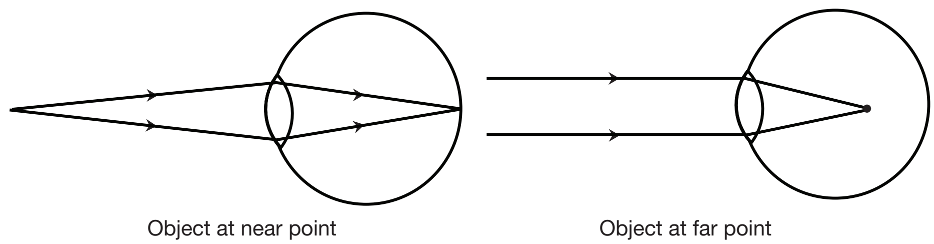


FIGURE 7.66 Image formation in a person's eyes having myopia

Myopia can be corrected by using a concave lens of suitable focal length, this helps in increasing the combined focal length thus forming the image on the retina.

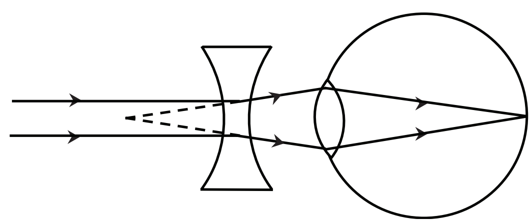


FIGURE 7.67 Correction of myopia

Causes of short-sightedness

1. Ciliary muscles become weak as a result of some disease or age. The focal length of the eye lens does not increases sufficiently due to the inability of ciliary muscles to pull outward. Hence, the image of the far off objects is formed in front of the retina.
2. If the eyeball gets bulged, then the focal length of the eye lens becomes short. As a result, the image of a distant object is formed in front of the retina.

When we see the eyes of cat and cattle in the dark, their eyes sparkle due to reflection of light. This is due to the presence of a reflecting layer called tapetum which is present behind the retina.

NOTE
Care and precautions should be taken to protect the eyes against any possible damages or injuries.

PHOTOGRAPHIC CAMERA

A camera is an optical instrument which helps us to create permanent images of objects. A photographic camera consists of a convex lens, a dark chamber and a photosensitive film.

The convex lens is fitted at the front portion of the dark box and at the other end is the photographic film. The distance between the lens and the film can be changed using a knob. The box is blackened from inside to prevent internal reflections. Behind the lens, a circular plate having an aperture called diaphragm is placed.

The diameter of the aperture can be adjusted to control the light entering the camera. In dim light, the size of the aperture is increased to obtain a clear image. To control the exposure time, a shutter is provided whose speed can be controlled.

To take the photograph of an object, the distance between the lens and the film is adjusted, so as to get a clear image in the view finder. The size of the aperture and the shutter speed is adjusted depending upon the intensity of the light. When the 'click' button is pressed, the shutter opens briefly and the light enters the camera through the lens and falls on the film. The exposed film is then treated chemically in a process known as development and then prints are taken on a photographic paper.

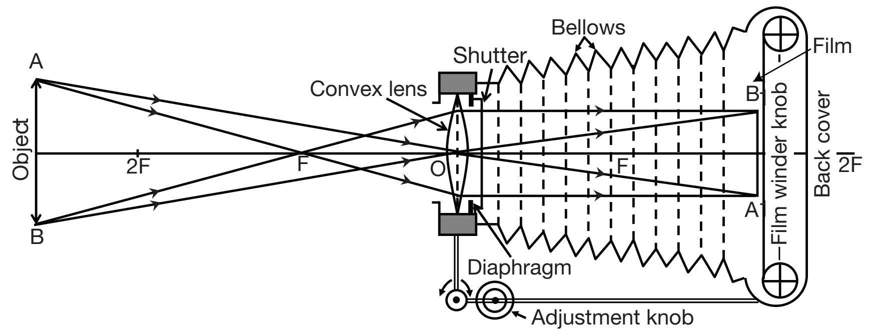


FIGURE 7.68 Camera

Similarities between the Eye and the Camera

1. In both the cases, the image formation takes place by means of a convex lens.
2. The image is real and inverted in both the cases.
3. The amount of light entering the dark chamber can be controlled in both cases. In the case of the eye, the pupil controls the light entering the eye whereas in the case of a camera, the diaphragm plays a similar role.
4. Incase of eye, eyelid controls the time of exposure of light whereas in a camera, the time of exposure is controlled by the shutter.

Dissimilarities between the Eye and the Camera

1. The eye lens can adjust its focal length, whereas the lens in a camera cannot vary its focal length.
2. Focussing in the case of an eye is done by changing the shape of the lens, whereas in the case of a camera, focusing is done by changing the distance between the lens and the film.

3. Image formed on the retina is temporary whereas in a camera, the image formed is permanent.
4. The eye lens is made up of a transparent and flexible substance whereas the camera lens is made up of glass.

MICROSCOPES

A microscope is an instrument which is used to obtain magnified images of minute objects which cannot be otherwise viewed clearly by the naked eye.

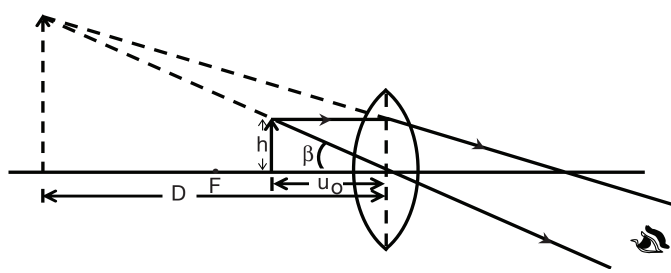


FIGURE 7.69 Simple microscope

A convex lens of short focal length can be used to observe small objects, this lens is known as a **simple microscope** or a magnifying glass. A simple microscope works on the principle of angular magnification. By placing a convex lens of short focal length between the eye and the object, such that the object lies within the focal length of the lens, the rays coming from the object can be made to form a larger angle than that which would have formed without the use of the lens. The image obtained by using a simple microscope is virtual, erect and magnified.

COMPOUND MICROSCOPE

A simple microscope can produce images having magnification up to a certain limit. It is not possible for a simple microscope to produce images of greater magnification. When images of greater magnification are required, we use another convex lens in combination with the one used as a simple microscope. The combination of these two lenses which is used to obtain images of greater magnification is called 'compound microscope'.

Construction and Working

The two lenses that are used in a compound microscope are each fixed to the outer ends of two hollow tubes that can slide one over the other such that their principal axes coincide. The lens that faces the object is called an 'objective' and is of smaller focal length when compared to the focal length of the other lens which faces the eye and is called the 'eye-piece'.

A screw is provided so that on rotating, the distance between the objective and the eye-piece can be adjusted.

An object AA_1 is placed beyond the principal focus of the objective and its image BB_1 is formed between the objective and the eye-piece. The first image formed (BB_1) is inverted, real and magnified with respect to the object. This first image acts as an object to the second convex lens, i.e., eye-piece. The distance of the first image 'BB_1' from the eye-piece is less than the focal length of the eye-piece. So it is further magnified and a third and final image 'CC_1' is formed beyond 'BB_1'. The final image is inverted with respect to the object and virtual. It is magnified when compared to the first image.

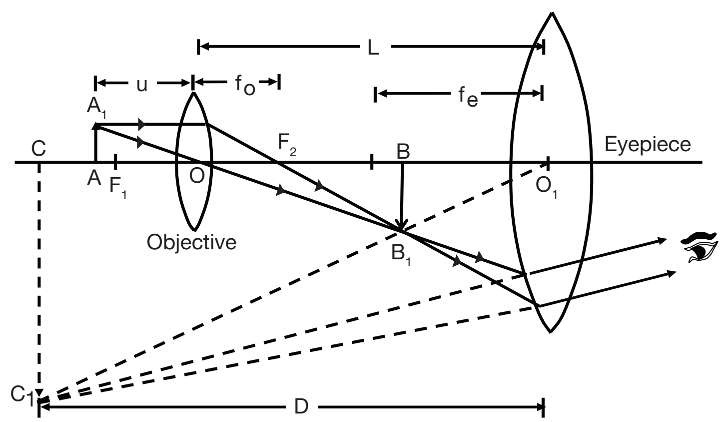


FIGURE 7.70 Compound microscope

TELESCOPES

When an object is very far from the eye, the angle it subtends at the eye is very small and so it appears to be small. To make the object appear nearer to the eye, the angle it subtends at the eye should be increased. To make the distant objects appear nearer, the optical instrument used is called a telescope.

There are two types of telescopes, viz., the astronomical telescopes and the terrestrial telescopes. The astronomical telescopes are used to observe the celestial bodies, like planets, comets, etc., and the terrestrial telescopes are used to observe distant objects on the earth's surface, like distant mountains, etc.

ASTRONOMICAL TELESCOPE

An astronomical telescope has the same construction as that of a compound microscope, but the focal length of the objective is larger compared to the focal length of the eye-piece.

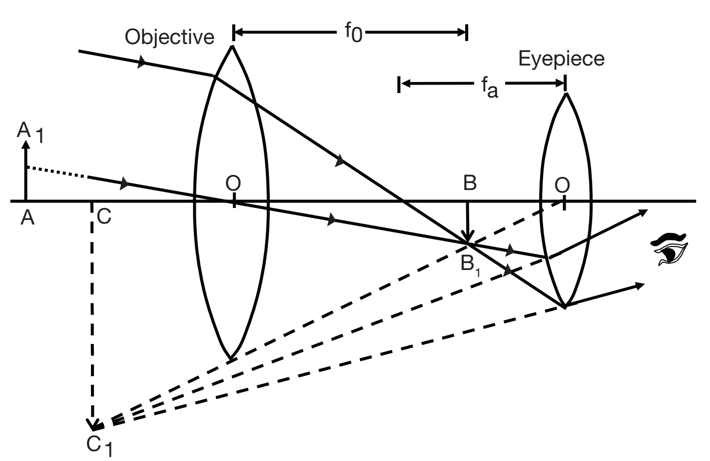


FIGURE 7.71 Astronomical Telescope

Working of Telescope

A parallel beam of light rays from a distant object (AA_1) almost parallel to the principal axis of the objective is incident on the objective and an image (BB_1) of the object is formed between the objective and the eye piece. This first image which is diminished, inverted and real acts as an object for the eye-piece. The distance between the first image and the eye-piece is less than the focal length of the eye-piece. So, a magnified and a virtual image (CC_1) is formed on the same side of the eye-piece as the first image. The final image is erect with respect to the first image but is inverted with respect to the object. The angle subtended by the final image at the eye-piece, and so at the eye, is larger than that of the angle subtended by the object at the eye. So the final image is magnified and appears to be having larger size than that of the object.

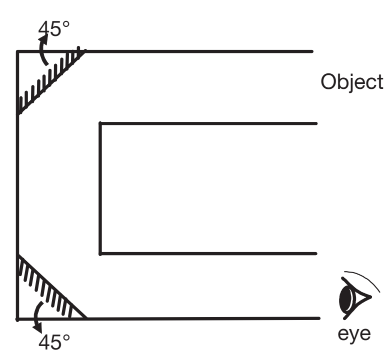
TEST YOUR CONCEPTS

Very Short Answer Type Questions

1. What is a divergent beam of light?
2. What is an eclipse?
3. Is it possible to have a magnified image with a concave mirror?
4. The __________ telescope is used to observe distant objects on the earth's surface.
5. What is total internal reflection?
6. What is a luminous body?
7. Define the focal length of a spherical mirror.
8. An object appears ______ when viewed through a concave lens.
9. State Snell's law.
10. Define irregular reflection of light.
11. What is magnification?
12. Glow worm is an example of ______ source of light.
13. What are optical fibres?
14. What is a translucent medium?
15. Define the principal focus of a spherical mirror.
16. What is the function of the ciliary muscles?
17. Formation of shadows is a consequence of ______ light.
18. The degree to which the light bends as it passes from one medium to another medium depends on the __________.
19. Are the laws of refraction applicable to the refraction taking place at curved surfaces?
20. What is a shadow?
21. Define refraction.
22. Define the principal focus of a lens.
23. Kaleidoscope works on the principle of ______ of plane mirrors.
24. Why is a concave lens called a diverging lens?
25. Define refractive index.
26. Why is a concave mirror called a converging mirror?
27. Size of the image obtained by using a simple microscope is__________ than the size of the object.
28. What is meant by the far point of the eye?
29. What is the nature of the image of an object formed by a convex mirror?
30. What is a lens?

Short Answer Type Questions

31. Explain the principle of a photographic camera.
32. Describe the construction and working of a periscope.
33. Why does it take some time to see surroundings clearly in a dark cinema hall when a person enters from bright sunlight?
34. Draw the ray diagrams to show the defective eye and the corrected eye for long sightedness.
35. Why does the sky appear blue?
36. If a plane mirror and an object placed in front of it, both move towards each other by 10 cm, find the shift in the position of the image.
37. When two plane mirrors are placed at an angle of 30° with their reflecting surfaces towards each other, and an object is placed between them, how many images of the object can be observed?
38. A student has constructed a reflecting periscope by arranging two plane mirrors as shown in the figure. What is the nature of the image of an object viewed through this periscope?



39. State and explain the rules for construction of ray diagrams for lenses.

40. A thin single glass plate is transparent. If number of such glass plates are arranged in the form of a stack, is the arrangement still transparent? Explain.

41. How does a concave lens help to correct the short sightedness in a person?

42. State and explain the formation of images in a convex mirror with the help of ray diagrams.

43. In which of the following cases, a bright image is produced (1) the image formed by a concave mirror (2) the image formed by a convex lens (3) the image formed due to total internal reflection of light.

44. Velocity of light in air is 3×10^8 m s^{-1} and of that in a given medium is 1.875×10^8 m s^{-1}. Find the refractive index of the given medium.

45. State the laws of reflection.

Essay Type Questions

46. Describe an experiment to find the focal length of a concave mirror and to find the nature of the image when the object is at finite distance.

47. Explain the construction and working of a compound microscope.

48. Describe an experiment to verify laws of reflection.

49. What is a point source of light?

50. Bring out the differences between myopia and hypermetropia.

CONCEPT APPLICATION

Level 1

Directions for questions 1 to 7:
State whether the following statements are true or false.

1. Virtual images are formed by diverging rays.

2. When a ray of light travels from water ($\mu = 4/3$) to glass ($\mu = 1.5$), it bends towards the normal.

3. The size of the images produced by any mirror is of the same as that of the object.

4. The focal length of a lens is same for all the colours in visible spectrum.

5. The nearest point upto which an eye can see objects clearly is called the near point of the eye.

6. Transparent objects do not cast shadows.

7. Rainbow formation is due to combined effect of refraction, total internal reflection and dispersion.

Directions for questions 8 to 14:
Fill in the blanks

8. A ray of light travelling in a medium of refractive index μ_1 is incident obliquely at the boundary of a medium of refractive index μ_2. The ray may reflect back totally only when μ_1 is ______________ μ_2.

9. The size of the umbra region can be varied by varying the distance between the __________, __________ and ______.

10. ______________ helps in transmitting optical impulses to the brain.

11. The portion of a mirror from which reflection of light actually takes place is ________________.

12. Lateral displacement depends on ________ of the glass slab.

PRACTICE QUESTIONS

13. The ratio of velocity of light in first medium to that of velocity of light in second medium is ________.

14. Irregular reflection ________ laws of reflection.

Directions for question 15:
Match the entries in Column A with the appropriate ones in Column B.

15.

Column A			Column B
A. Myopia	( )	(a)	Fire-fly
B. Hypermetropia	( )	(b)	Linear magnification < 1
C. Umbra	( )	(c)	Concave lens
D. Penumbra	( )	(d)	Convex lens
E. Total internal reflection	( )	(e)	Permanent image
F. Telescope	( )	(f)	Magnification > 1
G. Microscope	( )	(g)	Total darkness
H. Camera	( )	(h)	House-fly
I. Luminous body	( )	(i)	Mirage
J. Non-luminous body	( )	(j)	(Partial) less darkness

Directions for questions 16 to 45:
For each of the questions, four choices have been provided. Select the correct alternative.

16. When an object is moved away from a convex mirror, the image
(a) becomes smaller
(b) moves closer to the focus
(c) becomes inverted
(d) Both (a) and (b)

17. Light travels in straight line because
(a) its velocity is very high.
(b) bending effect is negligible, due to its small wavelength.
(c) it is not absorbed by atmosphere.
(d) it consist of all wave lengths

18. A man stands in front of a mirror and finds that his image is larger than himself. The mirror is a ________ mirror.
(a) convex (b) concave
(c) plane (d) Both (a) and (b)

19. Total internal reflection may occur when light travels from _______.
(a) vacuum to air (b) water to glass
(c) air to glass (d) glass to water

20. Real images are formed by______.
(a) converging rays
(b) diverging rays
(c) Both (a) and (b)
(d) Neither (a) nor (b)

21. Velocity of light in medium 1 is 2.4×10^7 m s^{-1} and velocity of light in medium 2 is 1.8×10^7 m s^{-1}, then the refractive index of medium 2 with respect to medium 1 is
(a) $\frac{3}{4}$ (b) $\frac{4}{3}$
(c) $\frac{1}{3}$ (d) $\frac{1}{4}$

22. A ray of light passing through the principal focus of a convex lens after refraction
(a) passes through the optic centre.
(b) emerges parallel to the principal axis.
(c) emerges without any deviation.
(d) None of these

23. The sun is seen before the actual sun rise because of ______.
(a) reflection
(b) refraction
(c) scattering of light
(d) rectilinear propagation of light

24. In a convex lens, we get virtual image when the object is_______.
(a) between F and $2F$
(b) beyond $2F$
(c) between F and optic center
(d) None of these

25. When white light is incident on a hollow prism,
(a) the light emerges from the prism and gives rise to spectrum.
(b) the light emerges giving no spectrum.

(c) the light doesn't emerges from the prism and spectrum is not observed.

(d) the light emerges from the prism and gives spectrum, but all colours bend towards the base.

26. By using a concave mirror, image of a tree is focused on a screen. The distance between the screen and the mirror is ______.

(a) equal to radius of curvature of the mirror.

(b) equal to half the radius of curvature of the spherical mirror.

(c) equal to twice the focal length of the mirror.

(d) equal to one fourth the focal length of the mirror.

27. The object or image distance is taken as positive

(a) if the length is measured opposite to the direction of the incident ray.

(b) if the length is measured in the direction of the incident ray.

(c) if the length is measured opposite to the direction of the refracted ray.

(d) None of these

28. The convex lens of larger focal length used in a compound microscope is called

(a) objective. (b) eye piece.

(c) erector lens. (d) None of these

29. A concave mirror forms an erect image twice the size of a object. The object distance from the mirror is ________.

(a) $\frac{f}{2}$ (b) $2f$

(c) $\frac{3f}{2}$ (d) $\frac{2f}{3}$

30. If the real depth of a coin in water ($\mu = 4/3$) is 4 cm, the apparent depth is

(a) 3 cm (b) $\frac{1}{3}$ cm

(c) $\frac{16}{3}$ (d) None of these

31. Five spherical mirrors are made from the same sphere. The uncommon thing among the mirrors is _______.

(a) radius of curvature (b) focal length

(c) pole (d) None of these

32. When an extended source of light moves towards a stationary opaque body, where the extended source is bigger than the opaque body, then on a stationary screen placed behind the object the

(a) penumbra and umbra, both increase.

(b) penumbra and umbra, both decrease.

(c) penumbra increases and the umbra decreases.

(d) penumbra decreases and the umbra increases.

33. A concave mirror produces a virtual, erect image when the object is ________.

(a) between F and C (b) at F

(c) beyond C (d) between pole and F

34. The heights of objects or images are taken as negative when they are measured

(a) downwards, perpendicular to the principal axis.

(b) along the direction of incident rays.

(c) upwards, perpendicular to the principal axis.

(d) None of these

35. Arrange the following steps in sequential order to verify laws of reflection of light.

(a) Place a mirror on MM' and looking at the pins P and Q from the other side of the normal, observe their images.

(b) Fix a white paper to a drawing board and draw a straight line MM' and a line ON perpendicular to MM' on the paper.

(c) Fix two more pins P' and Q' in line with the images of the pins P and Q.

(d) Draw a line PO such that it makes suitable acute angle with the normal and fix two pins P and Q on the line, which is the incident ray.

(e) Measure $\angle PON$, the angle of incidence and $\angle P'ON$, the angle of reflection.

(f) Remove the plane mirror and join P' and O. OP' is the reflected ray.

(g) Repeat the experiment for different angles of incidence and tabulate the results.

(1) b a e c d f g (2) b d a c f e g

(3) b a d c e f g (4) b d c e f a g

36. Arrange the following steps of an experiment in sequential order to prove the rectilinear propagation of light.

(a) Place a lighted candle towards the wooden upright C facing the hole.

(b) The candle flame is clearly visible which would disappear if one of the uprights is moved.

(c) Take three wooden uprights A, B and C and make a small hole at the same height from the base on each of A, B and C such that they are in a straight line.

(d) Now, look through the hole of upright A.

(1) c a d b (2) c d a b

(3) a c b d (4) a d c b

37. Arrange the following steps of an experiment in sequential order to calculate the focal length of a concave mirror when the object is at a small distance.

(a) Mount a concave mirror on the mirror stand and place an object in front of it at a certain distance.

(b) Adjust the position of the screen and the mirror until a bright and sharp image is obtained on the screen.

(c) Measure the distance between the object and the mirror. This distance gives the object distance u.

(d) Place the screen between the object and mirror but not in line with them.

(e) Measure the distance between the concave mirror and the screen. This gives the image distance v.

(f) The focal length of the given concave mirror can be found out using the mirror formula with proper signs.

(g) Repeat the experiment for different values of u and v and tabulate the results.

(1) a d b c e g f (2) a c e b d g f

(3) a b c d e f g (4) a b d e c g f

38. Long-sightedness is caused due to

(a) eye ball being too short.

(b) eye ball being too long.

(c) the blind spot on the retina.

(d) None of the above.

39. If an object is placed at the principal focus of a convex lens, the image formed is real, inverted and

(a) magnified

(b) diminished

(c) of same size as that of object

(d) highly magnified.

40. The image obtained by using a simple microscope is

(a) real, erect and magnified.

(b) virtual, erect and magnified.

(c) virtual, inverted and magnified.

(d) real, inverted and magnified.

41. Just before the time of sunset the sun appears to be bigger because

(a) sun changes its shape at that time.

(b) of the scattering of light.

(c) of the effect of refraction.

(d) of reflection.

42. Myopia is caused due to

(a) the high diverging power of the eye lens.

(b) the high converging power of the eye lens.

(c) the blind spot on the retina.

(d) None of the above

43. **Assertion (A):** Convex mirrors are used as rear view mirrors in vehicles.

Reason (R): The field view of convex mirrors is maximum and they form diminished images.

(a) Both A and R are correct, and R is the correct explanation of A.

(b) Both A and R are correct, but R is not the correct explanation of A.

(c) A is correct but R is incorrect.

(d) Both A and R are incorrect.

44. **Assertion (A):** A rainbow is formed when white light is incident on raindrops.

Reason (R): White light contains seven colours and it undergoes dispersion inside a raindrop.

(a) Both A and R are correct, and R is the correct explanation of A.

(b) Both A and R are correct, but R is not the correct explanation of A.

(c) A is correct but R is incorrect.

(d) Both A and R are incorrect.

45. Read the following statements and choose the correct option.

(A) Only a point source forms a complete umbra.

(B) An extended source of light forms both umbra and penumbra.

(1) Only A is true

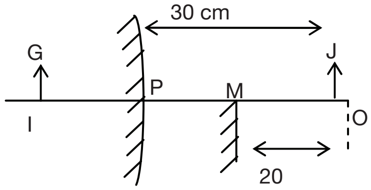
(2) Only B is true

(3) Both A and B are true

(4) Both A and B are false

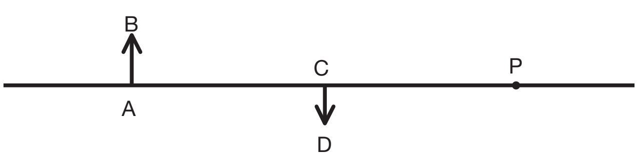
Level 2

46. A convex mirror and a plane mirror are arranged facing an object as shown in the figure below. If there is no parallax between the images formed by the two mirrors, then find the radius of curvature of the convex mirror?



47. If a plane mirror shifts through a distance of 5 cm towards an object and the object shifts through 10 cm towards the mirror, then find the shift in the position of an image.

48. In the given figure below, AB is the object and CD is its image. If a spherical mirror is used to get the image, name the type of spherical mirror used and locate the position of focus of the mirror by drawing a ray diagram. 'P' is the pole of the mirror.



49. Two convex lenses, of focal lengths 20 cm and 10 cm, respectively are separated by a distance of x cm. If a parallel beam of light remain parallel after refraction through both the lenses find x.

50. Are all animals equally sensitive to same intensity of light? Explain.

51. A jar contains two immiscible liquids A and B with a coin at its bottom. The depths of liquid A and liquid B are 6 cm and 8 cm, respectively. If the apparent depth of the coin is 9 cm and refractive index of liquid A is 1.5, what is the refractive index of liquid B?

52. For a person sitting near a fire, why the objects like trees and houses on the other side of the fire appear shifting?

53. An object is placed in front of a concave mirror and it produces a real image of magnification 1.5. If the object distance is decreased by 5 cm, the magnification of the real image is increased to 4. Find the focal length of the concave mirror.

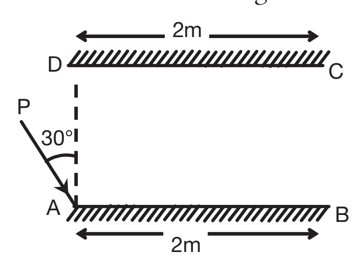
54. A man places a rectangular glass slab of thickness 9 cm on a newspaper. On the top of the glass slab he places a glass beaker of negligible wall thickness containing water up to a height of 6 cm. If refractive index of glass is 1.5 and refractive index of water is (4/3), what is the apparent depth of the newspaper?

55. A source of light and screen are separated by a distance of 50 cm. A sharp image of the source is produced by lens when placed at two positions between the source and the screen. If the distance of separations of the lens between the two positions is 20 cm, find the focal length of the lens.

56. Does an air bubble inside a water behave like a lens? If so, what type of lens is it? Expalin?

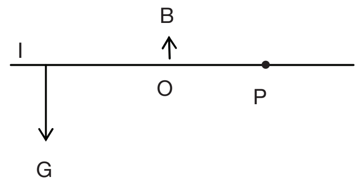
57. Two plane mirrors are inclined at an angle of 50°. A ray is incident on one of the mirrors with certain angle of incidence. The reflected ray from this mirror is incident on the second mirror such that it gets reflected parallel to the first mirror. Find the angle of incidence at the two mirrors. Also show that the sum of angles of incidence on first and second mirrors is equal to the angle of inclination between the two mirrors.

58. Two plane mirrors AB and CD each of length 2 m are arranged parallel to each other $\sqrt{3}$ m apart and a ray of light is incident at 'A' as shown in the figure. How many reflections does the ray of light undergo? What is the distance travelled by the ray of light between the two mirrors? What is the angle of deviation?



59. A concave mirror and a plane mirror are arranged facing each other and an object AB is placed between them as shown in the figure.
What is the distance between the object and its inverted, virtual image formed in plane mirror?

60. In the figure given below, OB is the object and IG is the image formed. A spherical mirror with P as the pole of the mirror is used to form image IG. Identify the type of spherical mirror used and also locate the position of focus of the mirror using the ray diagram.



61. If the mirror moves away from the object with speed v units, then find the speed of the image that moves away from the object.

62. Mahesh wanted to know whether the decrease in the number of images of an object placed between two mirrors would vary proportionally to the rate at which the angle between them increases. So he arranged two plane mirrors facing each other in such a way that they were inclined at an angle of 5°. They were arranged such that the angle between them increased uniformly at 1° per second. What is his inference?

63. Siddharth wanted to see his inverted image in a plane mirror. So, he stood between a concave mirror and a plane mirror facing each other as shown in the figure. Knowing the focal length of the concave mirror, he found the distance between him and his inverted virtual image, formed in the plane mirror. What is his answer?

64. A concave mirror of focal length 'f' forms an erect image twice the size of an object. Find the object distance from the mirror.

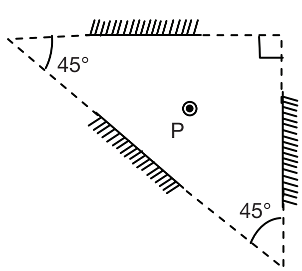
65. Srikar focussed separately on two objects of different sizes using a photographic camera. He found that the sizes of the images of the two objects, one kept at a distance of 200 m and the other at a distance of 2 m is the same. How did he achieve this? Explain.

Level 3

66. A thin rectangular silver sheet acts as a plane mirror. A person who can see his face in it, holds it vertically, such that the length of the sheet is perpendicular to the ground. How does his image in the silver sheet change if the sheet is bent in a semi-circular way,
    (a) along the length such that it bulges towards the face.
    (b) along the length such that it bulges away from the face.
    (c) along the breadth such that it bulges towards the face.
    (d) along the breadth such that it bulges away from the face.

67. 'Objects in the mirror are closer than they appear'. This statement is printed on the rear view mirrors of vehicles. What is its significance?

68. Three plane mirrors are mounted on three walls forming an isosceles right triangle as shown in the figure. How many images are formed in all? Draw a diagram and indicate the positions of the images.



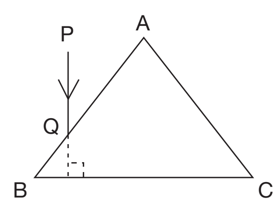
69. If v is the velocity of light in air or vacuum, find the time taken by the light to travel through a glass slab of thickness x and having refraction index μ.

70. 'An opaque paper when oiled becomes translucent'. Give reasons.

71. A ray of light changes its wavelength from 6000 A° to 3000 A°, when it travels from one medium to another medium. What is the critical angle of the denser medium with respect to the rarer medium?

    [Given $\sin 0 = 0$, $\sin 30 = \frac{1}{2}$, $\sin 45 = \frac{1}{\sqrt{2}}$, $\sin 60 = \frac{\sqrt{3}}{2}$, $\sin 90 = 1$]

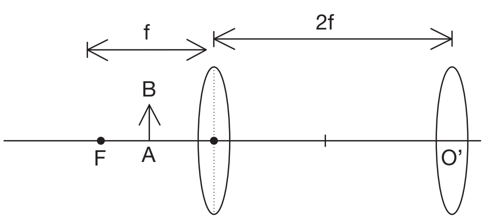
72. A ray of light PQ is incident on the face AB of an equilateral glass prism ABC as shown in the figure. Show that angle of emergence = angle of deviation. Also, with a ray diagram, trace the path of the emergent ray.



PRACTICE QUESTIONS

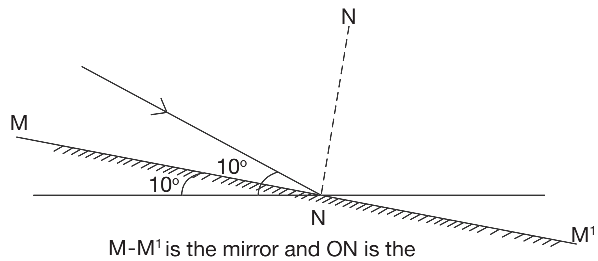
73. The face *AC* of the prism *ABC* of refracting angle 30° and refractive index 2 is silvered. A ray of light, after refraction from face *AB*, strike the face *AC* at 90°. Find the angle of incidence and path traced by the ray after reflecting from the silvered surface.

74. An object *AB* is placed on the principal axis of two lenses of equal focal length (*f*). The lenses are separated by a distance 2*f*, as shown in the fi gure. Using ray diagram locate the image formed by each lens and state their nature.



75. An object 10 cm tall is placed on the principal axis of a concave lens of focal length 10 cm at a distance of 15 cm from it. Find the position and nature of the image formed by the lens and draw the ray diagram.

76. A ray of light making an angle 50° with the horizontal is incident on a plane mirror, which itself is inclined to the horizontal at an angle 10°as shown in the figure. Determine the angle made by the reflected ray with the horizontal _______.



M-M[1] is the mirror and ON is the

77. An object is placed in front of a convex mirror at a distance equal to the focal length of the mirror. If its focal length is 20 cm, the distance of the image from the mirror is _______ cm.

(a) 10 (b) 20

(c) 40 (d) infinity

78. An object is first placed at a distance of 24 cm from the lens and then at a distance of 16 cm from the lens. If the magnification of the image formed in both the cases is same, determine the focal length of the lens

79. In the spectrum of visible light which colour of light deviates the maximum?

80. A convex mirror of radius of curvature 20 cm forms an image which is half the size of the object. Determine the position of the object from the pole of the mirror.

PRACTICE QUESTIONS

CONCEPT APPLICATION

Level 1

True or false

1. True **2.** True **3.** False **4.** False **5.** True **6.** True **7.** True

Fill in the blanks

8. $\mu_1 > \mu_2$ **9.** source, opaque object, screen. **10.** optic nerve
11. aperture **12.** thickness **13.** refractive index of second medium with respect to first medium.
14. obeys

Match the following

15. A : c B : d C : g D : j E : i F : b G : f H : e I : a J : h

Multiple choice questions

16. (d) **17.** (b) **18.** (b) **19.** (d) **20.** (a) **21.** (b) **22.** (b) **23.** (b) **24.** (c) **25.** (b)
26. (b) **27.** (b) **28.** (a) **29.** (a) **30.** (a) **31.** (c) **32.** (c) **33.** (d) **34.** (a) **35.** (c)
36. (a) **37.** (a) **38.** (a) **39.** (d) **40.** (b) **41.** (c) **42.** (b) **43.** (a) **44.** (a) **45.** (c)

Solutions for questions 31 to 45:
Multiple choice questions

31. As spherical mirror is a part of sphere, the focal length and radius of curvature for all the mirrors will remain same, but depending on the length of (arc of sphere) mirror, the position of pole changes.

32. In case an extended source of light is bigger than an opaque body, and the extended source moves towards the opaque body or screen moves away from the opaque body, the umbra decreases and penumbra increases. When the extended source moves away from the opaque body or the screen moves towards the opaque body, umbra increases and penumbra decreases.

33. When an object is placed between the pole and the focus, i.e., within focus the image produced is virtual and erect.

34. The heights of objects or images are taken as negative when they are measured downwards perpendicular to the principal axis.

35. (a) Fix a white paper to a drawing board and draw a straight line *MM'* and a line *ON* perpendicular to *MM'* on the paper (*b*).

(b) Place a mirror on *MM'* and looking at the pins *P* and Q from the other side of the normal, observe their images (*a*).

(c) Draw a line *PO* such that it makes suitable acute angle with the normal and fix two pins *P* and Q on the line, which is the incident ray (*d*).

(d) Fix two more pins *P'* and *Q'* in line with the images of the pins *P* and Q (*c*).

(e) Measure *FPON*, the angle of incidence and *FP'ON*, the angle of reflection (*e*).

(f) Remove the plane mirror and join *P'* and *O*. *OP'* is the reflected ray (*f*).

(g) Repeat the experiment for different angles of incident and tabulate the results (*g*).

36. (a) Take three wooden uprights *A*, *B* and *C* and make a small hole at the same height from the base on each of *A*, *B* and *C* such that they are in a straight line.(*c*)

(b) Place a lighted candle towards the upright *C* facing the hole (*a*).

(c) Now, look through the hole of upright A (*d*).

(d) The candle flame is clearly visible which would disappear if one of the uprights is moved (*b*).

37. (a) Mount a concave mirror on the mirror and place an object in front of it at a certain distance (*a*).
(b) Place the screen between the object and mirror but not in line with them (*d*).
(c) Adjust the position of the screen and the mirror until a bright and sharp image is obtained on the screen (*b*).
(d) Measure the distance between the object and the mirror. This distance gives the object distance *u* (*c*).
(e) Measure the distance between the concave mirror and the screen. This gives the image distance *v* (*e*).
(f) Repeat the experiment for different values of u and v and tabulate the results (*g*).
(g) The focal length of the given concave mirror can be found out using the mirror formula with proper signs (*f*).

38. Long sightedness is caused due to low converging power of eye lens or due to the eye ball being too short.

39. If an object is placed at the principal focus of a convex lens, then the image formed is real, inverted and highly magnified.

40. The image obtained by a simple microscope is virtual, erect and magnified.

41. Just before the time of sunset the sun appears to be bigger as the light rays passing through the atmosphere undergo refraction.

42. Myopia arises due to focusing of light rays before retina from a distant object, i.e., the eye lens converges the light rays more, due to which light is focused before retina. That is myopia arises due to the more converging power of the eye lens.

43. Convex mirrors are used as rear view mirrors in vehicles because the field view of a convex mirror is large and it forms a diminished image so that the vehicles coming from behind can be observed. So, *A* and *R* are correct, and '*R*' is the correct explanation of *A*.

44. White light contains all the seven colours of light. When white passes through light raindrops, under certain conditions it undergoes dispersion and forms a rainbow. So, *A* and *R* are correct and *R* is the correct explanation of *A*.

45. Only a point source of light forms a complete dark patch on a screen, i.e., umbra. An extended source of light forms both umbra and penumbra.

Level 2

46. (a) Relation between object distance and image distance for a plane mirror.
(b) Mirror formula for a convex mirror
(c) Relation between focal length and radius of curvature.

47. (i) Identify the position of mirror object and its corresponding images, respectively.
(ii) Find the shift in the image by using the characteristics of a plane mirror.

48. (i) Rules for the ray diagrams
(ii) Observe the position of the object and the type of image formed.
Recall the nature of image formed by different mirrors.
Which mirror is used here–concave mirror or convex mirror?
Draw the ray diagram to obtain the type of image shown in the question. Compare this ray diagram with the given figure and analyze to locate the position of the principal focus.

49. (a) Condition for emergent beam to remain parallel after refraction through both the lens in terms of their foci.
(b) Foci of two lens coincide.

50. (a) Relation between refractive index and wavelength of light.
(b) Which part of the eye is responsible for the sensitivity towards the light rays?
Is it the same for all animals?

51. $\mu = \dfrac{\text{real depth}}{\text{appaarent depth}}$

52. (i) Relation between refractive index and wavelength of light.
(ii) ${}^{2}\mu_1 = \dfrac{\mu_2}{\mu_1} = \dfrac{\lambda_1}{\lambda_2}$
Find $\angle i$

53. (i) Mirror formula.

(ii) By using the relation between object-distance, image-distance and the magnification, $m = \frac{v}{u}$. In both cases find u, then find the image-distance. Use the relation between focal length, object-distance and the image-distance and find the focal length of the mirror using the mirror formula $\left(\frac{1}{f} = \frac{1}{u} + \frac{1}{v}\right)$.

54. (i) Displacement = real depth − apparent depth.

(ii) Use the relation, $\mu = \frac{\text{Real depth}}{\text{Apparent depth}}$.

(iii) The position of the image shifts twice, when the light rays pass through the two media.

55. (i) Identifying the lens that produces conjugate positions of object and image.

(ii) The image is formed in two positions of the convex lens where these two positions are conjugate positions.

56. (i) Compare the refractive index of water with air.

(ii) In which direction does the light ray deviate when passing from a denser medium into a rarer medium?

57. (i) Draw a ray diagram.

(ii) Using a ray diagram, find the incident rays of the light ray on two mirrors and also find the sum of these incident rays.

58. (1) Laws of reflection of light

(2) Equilateral triangle

59. (i) Mirror formula

(ii) Find the image-distance formed by the concave mirror using the formula $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

(use Cartesian signs)

(iii) Is the image formed by the concave mirror inverted?

(iv) The inverted image of the concave mirror acts as virtual object to the plane mirror.

(v) Find the distance of the virtual object from the plane mirror $(50 + 30 - v) = u_1$

(vi) Now find the image distance, (v_1) formed by plane mirror $(v_1 = u_1)$

(vii) Now find the distance between the original object and the image formed in the plane mirror.

60. Using the rules for constructing ray diagrams drawing the ray diagram.

61. If the mirror moves away from the object with a speed v units, then the image moves away from the object with a speed of $2v$ units.

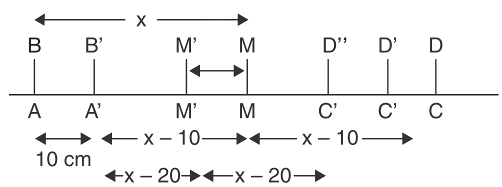
$\therefore OI' = x + v + x + v = 2x + 2v$

$OI = x + x = 2x$

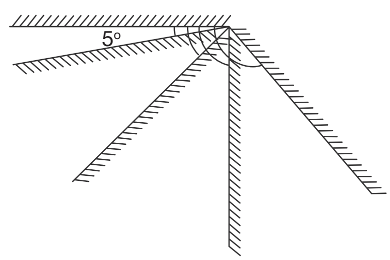
As v is the velocity of the mirror, it travels through a distance 'v' in one second.

$\therefore$ Distance moved by image from object in one second $= 2x + 2v - 2x = 2v$ units.

Thus, the speed of the image $= 2v$.



62.

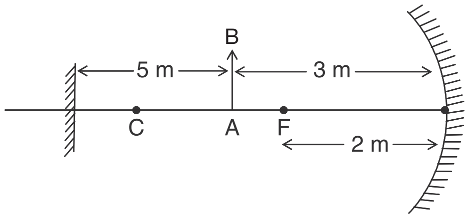


Time in second	Angle between mirrors	Number of images	Decrease in number of images
0	5°	71	–
5	10°	35	36
10	15°	23	12
15	20°	17	6

From the above table, it can be concluded that, the decrease in the number of images formed is not equal in equal intervals of time; whereas the angle between the mirrors increases uniformly. So the decrease in the number of images is not proportional to the rate at which the angle between the mirrors increase.

HINTS AND EXPLANATION

63.



Given $f = -2\text{m}$, $u = -3\text{m}$

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \Rightarrow \frac{-uf}{u-f} = \frac{-3 \times 2}{3-2} = \frac{-6}{1} = 6\text{m}$$

An inverted, magnified and real image forms at 6 m from the concave mirror and this acts as an object to the plane mirror. Hence, the inverted virtual image is formed at a distance of 5 + 3 − 6 = 2 m, behind the plane mirror. So the distance of the object and its virtual, inverted image is 2 + 5 = 7 m.

64. For concave mirror: $h_i = 2 \times h_o$

$$\frac{h_1}{h_0} = 2 = \text{m} = \frac{-v}{u} \Rightarrow v = -2u.$$

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

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

($\because$ Applying sing convention)

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

negative sign indicates that the object is placed along the side of principal focus of the mirror.

$\therefore$ object distance from the mirror $\frac{f}{2}$.

65. Given that an object is placed at 200 m and another object at 2 m, respectively. The size of the images formed due to two objects are also equal. The distance between the lens and the images formed due to the two objects are also equal, i.e., image distance (v) is equal. Hence, let m_1 be the magnification of 1st object at 200 m and m_2 be the magnification of 2nd object at 2 m.

$$\therefore m_1 = \frac{h_i}{h_{o_1}} = \frac{v}{u_1} \Rightarrow \frac{h_1}{h_{o_1}} = \frac{v}{200} \quad (1)$$

$$\therefore m_2 = \frac{h_i}{h_{o2}} = \frac{v}{u_2} \Rightarrow \frac{h_1}{h_{o2}} = \frac{v}{2} \quad (2)$$

Dividing (1) by (2)

$$\frac{h_i}{h_{o1}} \times \frac{h_{o2}}{h_i} = \frac{v}{200} = \frac{2}{v} \Rightarrow \frac{h_{o2}}{h_{o1}} = \frac{1}{100} (or)$$

$$ho_1 = 100\ ho_2$$

$\therefore$ The height or the size of 1st object is 100 times more than the size or the height of 2nd object.

Level 3

66. (i) Identify the shape of the mirror in each case after it is bent.

(ii) Characteristics of the nature of the images for concave and convex mirrors.

67. Recall the nature of the image formed by different mirrors.

Which mirror can produce a diminished real image of a distant object?

What is the relation between the image distance and the magnification?

68. (i) Find the number of images formed when two plane mirrors are placed at some angle in each case.

(ii) Add all the images excluding the images that have overlapped.

(iii) Number of images formed $= \frac{360}{\theta} - 1$

69. (i) $\mu = \frac{v_1}{v_2}$

(ii) Find the velocity of light in glass in terms of velocity of light in air and refractive index.

Using the formula $\mu = \frac{c}{v}$ (1)

Relate the velocity of light in glass with the distance traveled and the time taken using the formula

$v = \frac{x}{t}$ (2)

Find t by comparing (1) and (2)

70. (i) Amount of light getting absorbed, reflected transmitted in case of opaque and translucent objects.

(ii) Difference in transmission of light from pores of oiled paper to that of ordinary paper.

71. When light ray passes from one medium to another there is a change in the wavelength of light. The change in the velocity changes the wavelength of light. Velocity of light, V = $n\lambda$, where n is the frequency of light.

Let V_1 and V_2 be the velocity of light in two media. λ_1 and λ_2 be the corresponding wavelengths.

$V_1 = n\lambda_1$

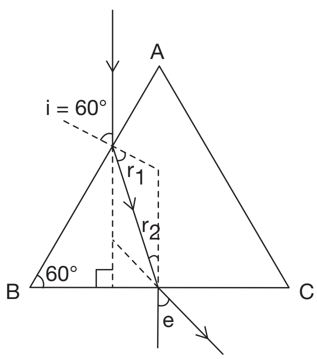
$V_2 = n\lambda_2$

$$\frac{V_1}{V_2} - \frac{\lambda_1}{\lambda_2} - \frac{6000}{3000} = 2$$

Refractive in index of medium

$$= \frac{V_1}{V_2} = 2. \text{ Sin } c = \frac{1}{\mu}\frac{1}{2} \Rightarrow c = 30^o$$

72.



Here, B is the vertex of the prism and $\angle B$ is the angle of prism.

$i + e = B + D.$

From geometry we have $B = 60°$, $i = 60°$.

$\therefore\ e = D.$

73. PQ is the incident ray incident at an angle i, QR the refracted ray refracted at an angle r.

From geometry (in triangle AQR)

$\angle AQR = 60°$

$\angle$ angle of refraction $r = 90° - 60° = 30°$

From Snell's law

$$\mu = \frac{\sin i}{\sin r}$$

$(\mu = \sqrt{2}$ given)

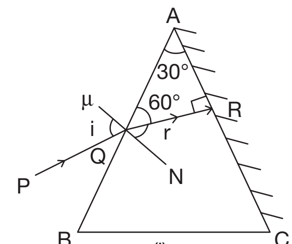
$$\sqrt{2} = \frac{\sin i}{\sin 30}; \sqrt{2} = \frac{\sin i}{\frac{1}{2}}$$

$$\sin i = \frac{\sqrt{2}}{2} = \frac{1}{\sqrt{2}}$$

$i = 45^o$

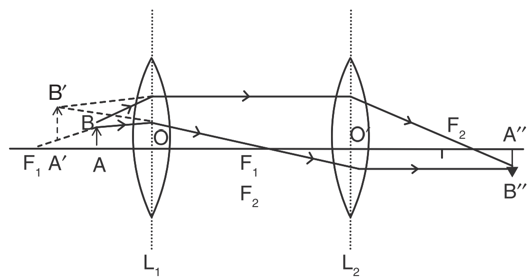
$\therefore$ angle of incidence = 45°

Since the ray strikes the mirror normally, it retraces its path.



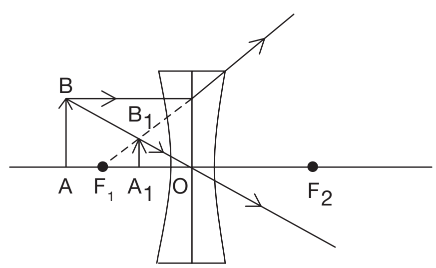
(i)

74.



Let F_{11} and F_{12} be the principal foci of the first lens L_1, and F_{21} and F_{22} be the principal foci of the second lens L_2. From the construction of the ray diagram it is evident that two images would be formed, $A'B'$ image formed by the first lens which would become the object for the second lens, and $A''B''$, final image formed by the second lens. $A'B'$ – virtual, erect, on the same side as object AB, and magnified. $A''B''$ – real, inverted, diminished (compared to $A'B'$) and on the far side of the combination of lens.

75.



Object size h_0 = 10 cm

Object distance fromlens, u = –15 cm.

Focal length of lens, f = –10 cm.

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

f = –10 cm; u = –15 cm

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

$$\frac{1}{v} = -\left[\frac{1}{10} + \frac{1}{15}\right] = -\left[\frac{25}{150}\right] \Rightarrow v = -6\text{cm}$$

Magnification, m = $\frac{v}{u} = \frac{-6}{-15} = \frac{2}{5}$

$\Rightarrow m = \frac{h_i}{h_o} \Rightarrow \frac{2}{5} = \frac{h_i}{10}$

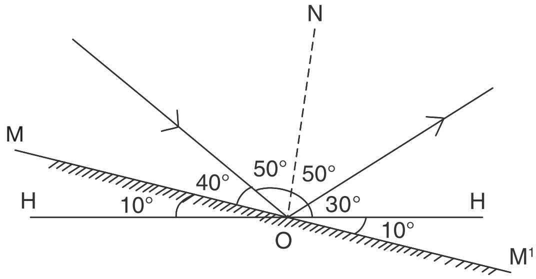
$\Rightarrow h_i = \frac{20}{5} = 4$ cm

∴ image distance, $v = -6$ cm.

The nature of images formes is virtual, erect and diminished compared to the object size.

Explation for questions 76 to 80:

76.



77. $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}, f = 20 \text{ cm}, u = 20 \text{ cm}$

$\frac{1}{20} = \frac{-1}{20} + \frac{1}{v}, \frac{1}{v} = \frac{1}{20} + \frac{1}{20} = \frac{2}{20}$

$v = 10$ cm

78. In the first case the image is real

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

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

$m = \frac{f}{u-f}, \; m = \frac{f}{24-f}$

(1)

In the 2 nd case the image is virtual

$u = -ve, v = -ve$

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

$\frac{1}{m} = \frac{u}{v} = \frac{f-v}{f}, \; m = \frac{f}{f-u}, \; m = \frac{f}{f-16}$ (2)

$\frac{f}{24-f} = \frac{f}{f-16}, \; f - 16 = 24 - f, \; 2f = 24 + 16$

$f = \frac{40}{2} = 20$ cm

79. In the spectrum of visible light, deviation is the maximum the violet colour. The deviation increases with the refractive index. The refractive index is maximum in the case of violet as its wave length is the least.

80. Since convex mirror always forms a virtual image, magnification, m is positive.

$m = -\frac{v}{u} = \frac{1}{2}\frac{v}{u} = \frac{h_i}{h_o}$ where v is image distance, u is object distance, h_i is height of the image and h_0 is height of the object.

$$v = -\frac{u}{2} \quad (1)$$

Radius of curvature, $R = 20$cm

Focal length, $f = \frac{R}{2} = \frac{20}{2}$ 10cm

From mirror formula

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

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

$\frac{1}{10} = \frac{1-2}{u}$

or u -10 cm

Therefore, the object is at 10 cm from the pole of the mirror.

MODULUS
MAKES EVERYONE POSITIVE

Do you know how much percentage of marks
a student has to score in IITJEE advanced exam to get
a rank in top 100 ?
a seat getting rank in IITs ?

Unbelievably they are just 75% and 35% (avg of last 10 years data)
Many students who score 10/10 in boards are not able to score 35% in
JEE advanced but an average student can make it to IIT if the coaching institute has

- ✓ Expert faculty - Excellent teaching
- ✓ Meticulous planning - Long-term strategy
- ✓ Constant motivation - Continuous support
- ✓ Rigorous practice - Accuracy and Speed

Previous Years JEE ADVANCED Rank VS % of Marks

RANK	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Avg %	2021 (M. Marks 360) Marks	Rank	2021 (M. Marks 360) Marks	Rank
1	85.48	91.67	96.01	92.22	92.78	93.06	86.02	92.62	93.61	93.01	88.89	91.40	348	1	196	1544
10	81.39	85.42	88.48	85.83	86.94	83.92	78.49	86.88	86.11	82.80	81.06	84.99	324	8	185	2043
100	70.76	79.79	78.68	76.39	77.50	69.84	68.61	83.33	74.72	72.85	71.72	74.93	323	13	178	2395
500	62.17	72.08	69.36	66.67	68.61	60.32	54.57	77.32	64.44	61.02	59.34	65.08	313	25	160	3542
1000	57.87	68.13	64.46	61.67	63.33	56.75	49.46	72.95	58.59	55.65	53.28	60.22	310	27	154	4137
2000	52.97	62.50	58.33	55.56	57.22	49.21	43.55	67.48	53.06	50.00	46.46	54.21	302	46	145	5005
3000	49.69	59.17	54.41	51.94	53.61	45.44	42.74	63.38	49.17	46.77	42.42	50.79	297	66	135	6180
4000	47.03	56.67	51.72	49.17	51.11	42.66	37.90	60.38	46.39	44.09	39.39	47.86	296	70	131	6750
5000	44.99	54.38	49.51	47.22	48.89	40.48	36.02	57.65	43.89	41.94	37.12	45.64	286	94	126	7516
6000	43.35	52.17	47.55	45.56	47.22	38.69	34.41	55.45	41.94	40.32	35.10	43.85	266	201	121	8494
7000	41.92	51.04	45.83	43.89	45.56	37.10	33.33	53.55	40.28	38.71	33.59	42.25	254	299	109	10848
8000	40.49	49.79	43.38	42.50	44.44	35.91	31.99	51.63	38.61	37.63	32.32	40.79	245	395	102	12874
9000	39.47	48.54	43.14	41.11	43.06	34.52	30.91	50.27	37.22	36.29	30.81	39.58	239	471	100	13215
10000	38.85	47.71	41.91	40.00	41.94	33.33	29.84	48.90	36.11	35.22	29.80	38.51	231	600	85	18547
QUAL%	38.85	47.71	34.55	33.88	35.00	23.81	20.16	22.50	25.00	25.00	17.42	29.44	212	1006	79	21157

For query Call : 7993376333, 7993375333, 7993374333
Visit : www.modulushyd.com

WHY MODULUS JUNIOR COLLEGE ?

Best IITJEE Faculty : Team led by an Alumni of IIT Delhi,**MODULUS** has expert faculty to provide IITJEE coaching, mentoring and counselling to the students to reach their goal.

Exceptional Teaching Methodology : Concept Oriented Teaching rather than Rote Learning. Sufficient self-study time is given to grasp the concepts and to apply them to solve the difficult problems. Classes will be interactive to keep students curious and interested in subject.

"I listen - I forget,
I read -I remember,
I do - I understand"

following this saying, measures like asking students to teach some subtopic will be taken.

Scientifically Researched Program : IITJEE experts /toppers recommend for every one hour of teaching, one hour of self study should be given. Triumph program is designed keeping this in mind.

Optimum Batch Size : Batch size of 30-35 students to provide individual attention to each and every student.

Excellent Study material : Complete, well structured and comprehensive study material prepared by our Subject Matter Experts will be provided.

Regular Exams : IITJEE(JEE MAINS/ADVANCE), BITSAT & EAMCET pattern exams will be conducted weekly to test students followed by test analysis to diagnose the students weak areas.

Students Mentorship Program : Students will be assigned Mentors to resolve their day to day problems. MENTORS will follow up with students on regular basis to monitor their progress and will help them to stay focused on their goal.

Overall Personality Development : Regular sessions of YOGA, MEDITATION, SPORTS, Moral and Ethical Behavior will be conducted for students holistic development.

Regular PTM & Motivational seminars: Regular Parent - Teacher meetings will be conducted to discuss the performance of their ward. Regular motivational seminars by IIT Alumni , IIT JEE Experts to instigate the deep desire in students to work hard to get admissions into world class institutes.

Career Guidance to students after completion of their Intermediate course.

Transport Facility: Transport Facility will be provided to needy students.

Hostel Facility: Separate hostel facility for BOYS and GIRLS will be provided.

MODULUS Junior College

WEEK DAYS / WEEKENDS
Class Room Programs

7th
For 7th Class Students
ENRICH TWO YEAR

8th
For 8th Class Students
ENRICH ONE YEAR

The main aim of the programme is to enrich logical thinking, IQ besides laying strong foundation in MATHS, PHYSICS, CHEMISTRY.
This program also helps students to excel in school exams.

9th
For 9th Class Students
REFINE TWO YEAR

10th
For 10th Class Students
REFINE ONE YEAR

The goal of this program is to lay strong foundation for the most prestigious competitive exams like NTSE, IIT-JEE, KVPY, NSEJS and other Olympiads.
This also helps students to perform exceptionally in board exams.

11th
For 11th Class Students
TRIUMPH TWO YEAR

12th
For 12th Class Students
TRIUMPH ONE YEAR

The above programs will help the student to perform well in IIT-JEE Mains and Advanced exams. This also equip the student excel in other engineering and board exams.

ADDRESS
OPP. ZENAS INTERNATIONAL SCHOOL , Near Miyapur Metro First Pillar ,
Mathrusri Nagar , Miyapur ,Hyderabad.

www.modulushyd.com www.facebook.com/modulushyd modulushyd@gmail.com