

Physics Chapter - 01

*** Students are Advised to Solve the Questions of Exercises in the same Sequence 'or' as Directed by the Faculty Members. ***

Conceptual Short Notes for NTSE/KVPY/Olympiad/Board

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❖ Key Concept ❖

➤ Introduction of Light

Light is a form of energy (optical energy) which helps us in seeing objects by its presence.

(A) Theories about Nature of light :

(i) Particle nature of light (Newton's corpuscular theory) :

According to Newton light travels in space with a great speed as a stream of very small particles called corpuscles. This theory was **failed to explain** interference of light and diffraction of light. So wave theory of light was discovered.

(ii) Wave nature of light :

Light waves are electromagnetic waves so there is no need of medium for the propagation of these waves. They can travel in vacuum also. The speed of these waves in air 'or' in vacuum is maximum i.e., 3×10^8 m/s.

Photoelectric effect was **not explained** with the help of wave theory, so Plank gave a new theory which was known as **quantum theory of light**.

(iii) Quantum theory of light :

When light falls on the surface of metals like caesium, potassium etc., electrons are given out. These electrons are called 'photo-electrons' and phenomenon is called 'photo-electric effect'. This was explained by **Einstein**. According to plank light consisted of packets or quanta's of energy called **photons**. Each quanta carries energy $E = h\nu$.

$h \rightarrow$ Planck's constant $= 6.6 \times 10^{-34}$ J-s.

$\nu \rightarrow$ Frequency of light

Some phenomenon's like interference of light, diffraction of light are explained with the help of wave theory but wave theory was **failed to explain** the photo electric effect of light. It was explained with the help of **quantum** theory. So, light has **dual nature** (study in class 12th).

(i) Wave nature (ii) Particle nature

(B) Sources of light:

- ◆ The objects which emit (give) light are called **luminous objects**. It may be natural or man-made. Sun is a natural source of light and electric lamp are man-made source .
- ◆ The **Non-luminous objects** do not emit light. However, such objects become visible due to the reflection of the light falling on them. Moon does not emit light. It becomes visible due to the reflection of the sunlight falling on it.

(C) Propagation of light :

- Light travels along straight lines in a medium or in vacuum. The path of light changes only when there is an object in its path or where the medium changes.
- ◆ **Transparent medium** : A medium in which light can travel freely over large distances is called a transparent medium. Examples: Water, glycerine, glass are transparent.
- ◆ **Opaque** : A medium in which light cannot travel is called opaque. Examples : Wood, metals, bricks etc.
- ◆ **Translucent** : A medium in which light can travel some distance, but its intensity reduces rapidly. Such materials are called translucent. Examples : Oil

(D) Characteristics of light:

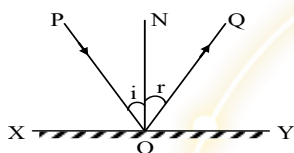
1. Light is an electromagnetic wave.
2. Light travels in a straight line.
3. Light is a transverse wave, and does not need any medium to travel. Light can travel through vacuum. Its speed through vacuum is 3×10^8 m/s.
4. The velocity of light changes when it travels from one medium to another.
5. The wavelength (λ) of light changes when it goes from one medium to another.
6. The freq.(ν) of the light wave remains same in all media.
7. Light gets reflected back from polished surfaces, such as mirrors, polished metal surfaces, etc.
8. Light undergoes refraction (bending) when it travels from one transparent medium to another.

➤ Reflection of light

Definition. When light rays are incident on an opaque polished surface (medium), these are returned back in the same medium.

This phenomenon of returning of ray of light in the same medium, is called reflection of light.

Definition of some associated terms :



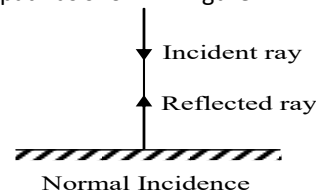
1. **Reflecting surface** : The surface from which the light is reflected, is called the reflecting surface. In diagram, XY is the reflecting surface.
2. **Point of incidence** : The point on the reflecting surface at which a ray of light strikes, is called the point of incidence. In diagram, O is the point of incidence.
3. **Normal** : A perpendicular drawn on the reflecting surface at the point of incidence, is called the normal. In diagram, ON is the normal.
4. **Incident ray** : The ray of light which strikes the reflecting surface at the point of incidence is called the incident ray. In diagram, PO is the incident ray.
5. **Reflected ray** : The ray of light reflected from the reflecting surface from the point of incidence, is called the reflected ray. In diagram, OQ is the reflected ray.
6. **Angle of incidence** : The angle that the incident ray makes with the normal, is called the angle of incidence. It is represented by the symbol i . In diagram, angle PON is the angle of incidence.
7. **Angle of reflection** : The angle that the reflected ray makes with the normal, is called the angle of reflection. It is represented by the symbol r . In diagram, $\angle QON$ is the angle of reflection.
8. **Plane of incidence** : The plane in which the normal and the incident ray lie, is called the plane of incidence. In diagram, plane of the book page, is the plane of incidence.
9. **Plane of reflection** : The plane in which the normal and the reflected ray lie, is called the plane of reflection.

➤ Laws of reflection of light

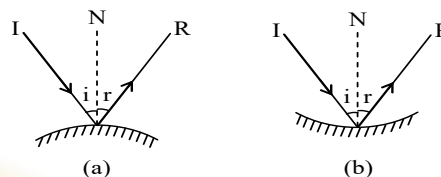
- ◆ **First law** : The incident ray, the reflected ray and the normal at the point of incidence, all lie in the same plane.
- ◆ **Second law** : The angle of reflection ($\angle r$) is always equal to the angle of incidence ($\angle i$). i.e., $\angle r = \angle i$ (For normal incidence, $i = 0$, $r = 0$. The ray is reflected back along normal).

(i) A ray of light striking the surface normally retraces its path

When a ray of light strikes a surface normally, then angle of incidence is zero i.e., $\angle i = 0$. According to the law of reflection, $\angle r = \angle i$, $\therefore \angle r = 0$ i.e. the reflected ray is also perpendicular to the surface. Thus, an incident ray normal to the surface (i.e. perpendicular to the surface) retraces its path as shown in figure.

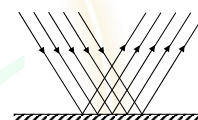


- (ii) Laws of reflection are also obeyed when light is reflected from the **spherical or curved surfaces** as shown in figure (a) and (b)



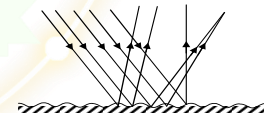
(iii) Regular and Irregular Reflection :

- ◆ **Regular Reflection** – The phenomenon due to which a parallel beam of light travelling through a certain medium, on striking some smooth polished surface, bounces off from it, as parallel beam, in some other fixed direction is called Regular reflection.



Regular reflection takes place from the objects like looking glass, still water, oil, highly polished metals, etc. Regular reflection is useful in the formation of images, e.g., we can see our face in a mirror only on account of regular reflection. However, it causes a very strong glare in our eyes.

- ◆ **Irregular reflection or Diffused reflection** :



The phenomenon due to which a parallel beam of light, travelling through some medium, gets reflected in various possible directions, on striking some rough surface is called irregular reflection or diffused reflection. The reflection which takes places from ground, walls, trees, suspended particles in air, and a variety of other objects, which are not very smooth, is irregular reflection.

- ◆ **Note** : Laws of reflection are always valid no matter whether reflection is regular or irregular.

➤ Nature of image

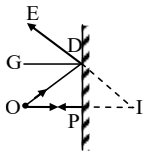
- ◆ **Definition** : Incident rays starting from a point object, and reflected from a mirror, either actually meet at or appear to come from a point. The other point is called the **image** of the point object.

Real Image	Virtual Image
1. A real image is formed when two or more reflected rays meet at a point in front of the mirror.	1. A virtual image is formed when two or more rays appear to be coming from a point behind the mirror.
2. A real image can be obtained on a screen.	2. A virtual image cannot be obtained on a screen.
3. A real image is inverted	3. A virtual image is erect with

➤ Reflection from the plane mirror

Relation between the distances of the object and the image from the plane mirror is that they are equal.

To verify this, consider the geometrical construction shown in figure. Rays OP and OD, starting from the object O, fall on the mirror. The ray OP is perpendicular to the mirror and hence, reflects back along PO. The incident ray OD and the reflected ray DE make equal angles with the normal DG. The two reflected rays when produced backwards meet at I, producing a virtual image there.



Now, $\angle EDG = \angle DIO$ ($DG \parallel IO$),

$\angle EDG = \angle GDO$ (law of reflection),

and $\angle GDO = \angle DOI$ ($DG \parallel IO$).

Hence, $\angle DIO = \angle DOI \therefore OD = DI$

Now $OP^2 = OD^2 - DP^2$, and $PI^2 = DI^2 - DP^2$

From (i), since $OD = DI$, $OP^2 = PI^2$ or $OP = PI$.

So, in the case of a plane mirror, the image is formed as far behind the mirror at the same distance as the object is in front of it.

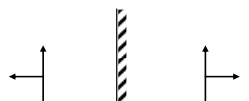
◆ Some important results about Reflection from plane surfaces

◆ **Lateral inversion** : When you see your image in a vertical plane mirror such as that fixed to an almirah, the head in the image is up and the feet are down, the same way as you actually stand on the floor. Such an image is called an **erect image**. However, if you move your right hand, it will appear as if the left hand of your image is moving. If you keep a printed page in front of a plane mirror, the image of the letters appear erect but inverted laterally or sideways. Such an inversion is called lateral inversion.



◆ Relative motion of object and image :

Case I : If an object moves towards (or away from) a plane mirror at speed v



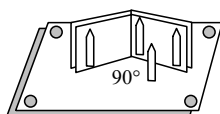
The image will also approach (or recede) at speed v

The speed of image relative to object will be $v - (-v) = 2v$.

Case II : If the mirror is moved towards or (away from) the object with speed ' v '

The image will move towards (or away from) the object with a speed ' $2v$ '.

◆ **Multiple Reflection** : Number of images formed by combination of plane mirrors depends upon angle between mirrors.

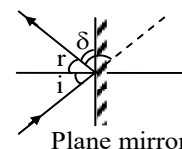


If there are two plane mirrors inclined to each other at an angle 90° , The no. of images of a point object formed are 3.

◆ **Deviation** : δ is defined as the angle between directions of incident ray and emergent ray. So if light is incident at an angle of incidence i ,

$$\delta = 180^\circ - (\angle i + \angle r) = (180^\circ - 2i)$$

$$[\text{as } \angle i = \angle r]$$



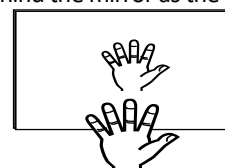
So if light is incident at angle of 30° ,

$$\delta = (180^\circ - 2 \times 30^\circ) = 120^\circ \text{ and for normal incidence}$$

$$\angle i = 0^\circ, \delta = 180^\circ$$

Characteristics of the image formed by a plane mirror :

- The image formed by a plane mirror is virtual.
- The image formed by a plane mirror is erect.
- The size of the image formed by a plane mirror is same as that of the size of the object.
For Example- If object is 10 cm high, then the image of this object will also be 10 cm high.
- The image formed by a plane mirror is at the same distance behind the mirror as the object is in front of it.

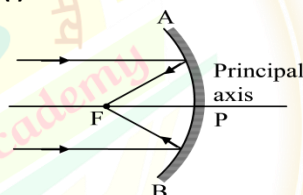


Lateral Inversion

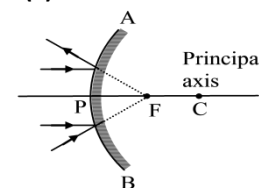
➤ Reflection from Spherical mirror

There are two types of spherical mirrors:

(i) Concave mirror :



(ii) Convex mirror :



◆ Some terms associated with Spherical mirrors:

- Aperture**. The diameter of the circular rim of the mirror. In diagram AB is the aperture of the mirror.
- Pole** : The centre of the spherical surface of the mirror is called the pole of the mirror. It lies on the surface. In diagram, P is the pole of the mirror.
- Centre of curvature** : The centre of the spherical shell, of which the mirror is a section, is called centre of curvature of the mirror. It lies outside the surface. Every point on mirror surface lies at same distance from it. In diagram, C is the centre of curvature of the mirror.
- Principal axis** : The straight line passing through the pole and the centre of curvature of the mirror, is called principal axis of the mirror.
- Principal focus** : It is a point on the principal axis of the mirror, such that the rays incident on the mirror parallel to the principal axis after reflection, actually meet at this point (in case of a concave mirror) or appear to come from it (in case of a convex mirror). In diagram, F is the principal focus of the mirror.
- Radius of curvature** : The distance between the pole and the centre of curvature of the mirror, is called the radius of curvature of the mirror. It is equal to the radius of the spherical shell of which the mirror is a section. In diagram, PC is the radius of curvature of the mirror. It is represented by the symbol R.
- Focal length** : The distance between the pole and principal focus of the mirror, is called the focal length of

the mirror. In diagram, PF is the focal length of the mirror. It is represented by the symbol f .

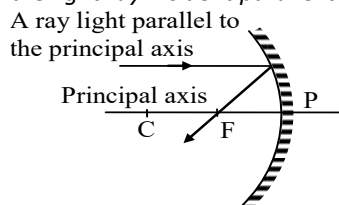
$$f = +\frac{R}{2} \text{ for convex} \quad \& \quad f = -\frac{R}{2} \text{ for concave}$$

8. **Principal section** : A section of the spherical mirror cut by a plane passing through its centre of curvature and the pole of the mirror, is called a principal section of the mirror. It contains the principal axis.

➤ Rules for image form. by Ray diagram method

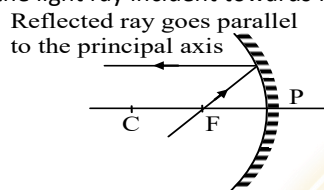
◆ Rules for image formation from Concave Mirror:

(a) When the light ray incident parallel to the principal axis.

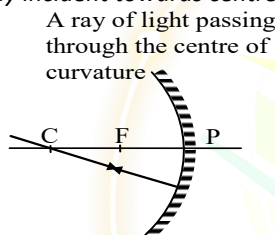


OR

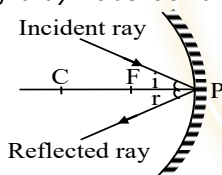
When the light ray incident towards focus.



(b) When the light ray incident towards centre of curvature.

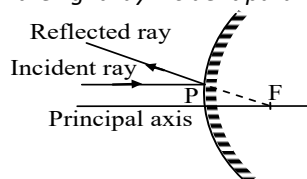


(c) When the light ray incident on the pole of the mirror.



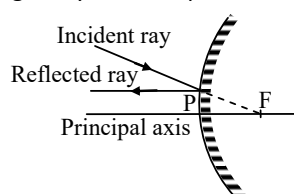
◆ Rules for image formation from Convex Mirror:

(a) When the light ray incident parallel to the principal axis.



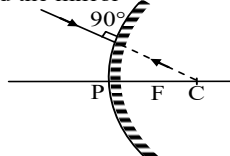
OR

When the light ray incident parallel to the principal axis.



(b) When the light ray incident on the mirror directing towards centre of curvature.

Rays traveling towards C behind the mirror



◆ Sign Convention:

Description : It is a convention which fixes the signs of different distances measured. The sign convention to be followed is the **New Cartesian** sign convention. It gives the following rules :

1. All distance are measured from the **pole** of the mirror
2. The distances measured in the **same** direction as the direction of incident light from pole are taken as **positive**.
3. The distances measured in the direction **opposite** to the direction on incident light from pole are taken as **negative**.
4. Distances measured **upward** and perpendicular to the principal axis, are taken as **positive**.
5. Distances measured **downward** and perpendicular to the principal axis, are taken as **negative**.

➤ Image formation by Spherical mirror in diff Cases

Introduction : From mirror formula, we find that for a mirror of a fixed focal length f , as object distance u changes, image distance v also changes.

(A) By Concave mirror :

(1) Object at Infinity

A point object lying on the principal axis. Rays come parallel to the principal axis and after reflection from the mirror actually meet at the focus F .

The image is formed at F . It is real and point sized (fig.)

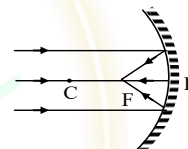
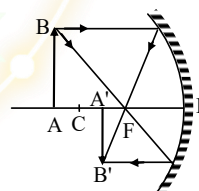


Fig. Concave mirror : point object at infinity, image at focus

(2) Object Beyond Centre of Curvature

Real object AB has its image $A'B'$ formed between focus and centre of curvature. The image is real-inverted and diminished.

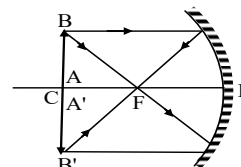


Concave mirror : object beyond centre of curvature, image between focus and centre of curvature.

(3) Object at Centre of Curvature

Real object AB , has its image $A'B'$ formed at centre of curvature.

Image is real-inverted & has same size as the object. (fig.).

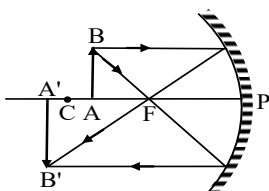


Concave mirror : object at centre of curvature, image at centre of curvature

(4) Object between Centre of Curvature and Focus

Real object AB has its image $A'B'$ formed beyond centre of curvature.

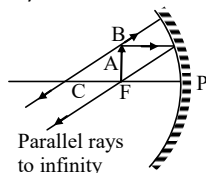
The image is real-inverted and enlarged (bigger in size than the object). (Fig.)



Concave mirror : object between centre of curvature and focus, image beyond centre of curvature.

(5) Object at Focus

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



Concave mirror : object at focus image at infinity.

(6) Object between Focus and Pole

Real object AB has its image A'B' formed behind the mirror. The image is virtual-erect and enlarged.

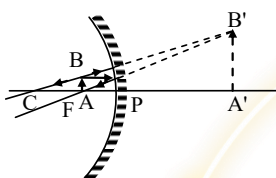
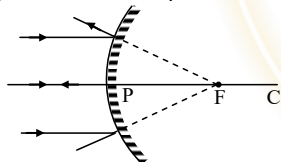


Fig. Concave mirror : Object between pole and focus, image behind the mirror.

(B) By Convex mirror :

(1) Object at infinity

A point object lying on the principal axis. Rays come parallel to the principal axis and after reflection from the mirror, appear to diverge from focus F behind the mirror. So, The image is formed at F. The image is virtual and point sized. [fig.]



Convex mirror : point object at infinity, virtual image at focus.

(2) Object at anywhere on principle axis

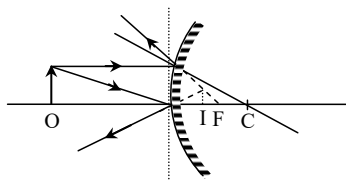


Image is virtual & point sized

Numerical method in Spherical mirror

(A) Mirror formula:

Definition : The equation relating the object distance (u) the image distance (v) and the mirror focal length (f) is

called the mirror formula.
$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

Assumptions made :

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

(B) linear magnification For spherical mirrors-

Definition : The ratio of the size of the image, as formed by reflection from the mirror to the size of the object, is called linear magnification produced by the mirror. It is represented by the symbol m.

$$m = -\frac{v}{u} = \frac{\text{height of image}}{\text{height of object}}$$

(C) Power of mirror-

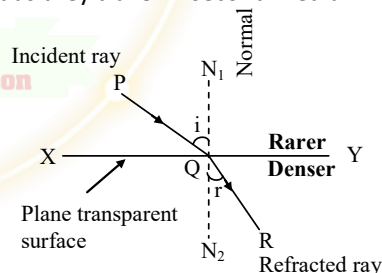
$$\text{Power of a mirror [in Diopters]} = \frac{1}{f \text{ (in metre)}}$$

Summary of images by Spherical mirror

	Position of object	Position of Image	Size of Image	Nature of Image
Concave mirror	At infinity	At focus F	Highly diminished	Real and inverted
	Beyond C	Between F and C	Diminished	Real and inverted
	At C	At C	Same size	Real and inverted
	Between F and C	Beyond C	Enlarged	Real and inverted
	At F	At infinity	Highly enlarged	Real and inverted
	Between P and F	Behind the mirror	Enlarged	Virtual and erect
convex mirror	at infinite	at focus	highly diminished	virtual point size
	anywhere on principal axis	between pole & focus	diminished	virtual erect

Refraction of light

Definition : When light rays travelling in a medium are incident on a transparent surface of another medium they are bent as they travel in second medium.



Refraction of light from a plane transparent denser surface.

Some associated Terms:

- Transparent surface** : The plane surface which refracts light, is called transparent surface. In diagram, XY is the section of a plane transparent surface.
- Point of incidence** : The point on transparent surface, where the ray of light meets it, is called point of incidence. In diagram, Q is the point of incidence.
- Normal** : Perpendicular drawn on the transparent surface at the point of incidence, is called normal. In diagram, N_1QN_2 is the normal on surface XY.
- Incident ray** : The ray of light which strikes the transparent surface at the point of incidence, is called incident ray in diagram PQ is the incident ray.
- Refracted ray** : The ray of light which travels from the point of incidence into the other medium, is called refracted ray. In diagram, QR is the refracted ray.
- Angle of incidence** : The angle between the incident ray and the normal on the transparent surface at the point of

incidence, is called the angle of incidence. It is represented by the symbol i . In diagram, angle PQN_1 is the angle of incidence.

- **Angle of refraction** : The angle between the refracted ray and the normal on the transparent surface at the point of incidence, is called angle of refraction. It is represented by symbol r . In diagram angle RQN_2 is the angle of refraction.
- **Plane of incidence** : The plane containing the normal and the incident ray, is called plane of incidence. For the diagram, plane of book page is the plane of incidence.
- **Plane of refraction** : The plane containing the normal and the refracted ray, is called plane of refraction. For the diagram, plane of book page is the plane of refraction.

➤ Law of Refraction of light

- ◆ **First Law** : The incident ray, the normal to the transparent surface at the point of incidence and the refracted ray, all lie in one and the same plane.
- ◆ **Second Law** : The ratio of sine of angle of incidence to the sine of the angle of refraction is constant and is called refractive index of the second medium with respect to the

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

➤ Refractive index

(a) Refractive Index in terms of Speed of Light:

The refractive index of a medium may be defined in terms of the speed of light as follows :

$$\text{Refractive index} = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}} \quad \text{or} \quad \mu = \frac{c}{v}$$

(b) Refractive Index in terms of Wavelength :

Since the frequency (ν) remains unchanged when light passes from one medium to another, therefore,

$$\mu = \frac{c}{v} = \frac{\lambda_{\text{vac}} \times \nu}{\lambda_{\text{med}} \times \nu} = \frac{\lambda_{\text{vac}}}{\lambda_{\text{med}}}$$

(c) Relative Refractive Index :

The relative refractive index of medium 2 with respect to medium 1 is defined as the ratio of speed of light (v_1) in the medium 1 to the speed of light (v_2) in medium 2 and is denoted by ${}_1\mu_2$.

$$\text{Thus, } {}_1\mu_2 = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{\mu_2}{\mu_1}$$

As refractive index is the ratio of two similar physical quantities, so it has **no unit and dimension**.

◆ Factor on which the refractive index of a medium depend are :

- Nature of the medium.
- Wavelength of the light used.
- Temperature
- Nature of the surrounding medium.

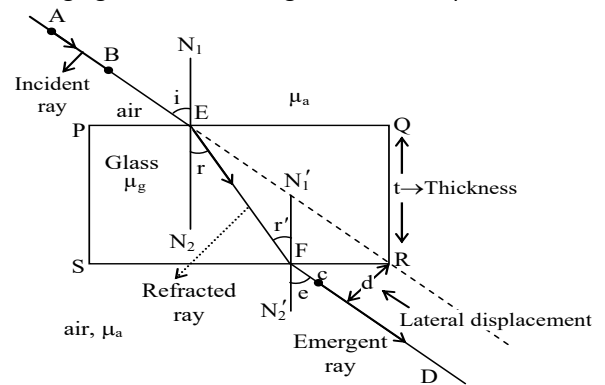
➤ Refraction through glass slab

(a) Refraction through a rectangular glass slab and principle of reversibility of light :

Consider a rectangular glass slab, as shown in figure. A ray AE is incident on the face PQ at an angle of incidence i . On entering the glass slab, it bends towards normal and travels along EF at an angle of refraction r . The refracted ray EF is incident on face SR at an angle of incidence r' . The emerged ray FD bends away from the normal at an angle of refraction e .

Thus the emergent ray FD is parallel to the incident rays

AE, but it has been laterally displaced with respect to the incident ray. There is shift in the path of light on emerging from a refracting medium with parallel faces.



Proof for $i = e$

Case-I : For light going from air to glass at point E.

$$\mu_a \sin i = \mu_g \sin r \quad \dots (1)$$

Case-II : For light going from glass to air at point F.

$$\mu_g \sin r = \mu_a \sin e \quad \dots (2)$$

From (1) & (2) we can say that $i = e$

⇒ incident & emergent rays are parallel to each other.

➤ Spherical Lens

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

◆ **Types** : There are two types of spherical lenses:

(i) **Convex or Converging Lenses** : These are thick in the middle and thin at the edges.

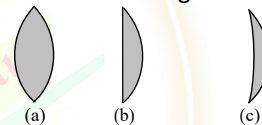


Fig. Three types of convex lenses

(a) **Double Convex Lens** : It has both the surfaces convex

(b) **Plano-Convex Lens** : It has one surface plane and the other surface convex.

(c) **Concavo-Convex Lens** : It has one surface concave and the other surface convex.

(ii) **Concave or Diverging Lenses** : These are thin in the middle and thick at the edges.

There are three types of concave lenses :

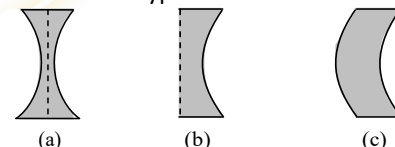


Fig. Three types of concave lenses

(a) **Double Concave Lens** : It has both the surfaces concave.

(b) **Plano-Concave Lens** : It has one surface plane and the other surface concave. (fig.)

(c) **Convexo-Concave Lens** : It has one surface convex and the other surface concave. (fig.)

◆ Some Associated Terms :

(i) **Centre of curvature (C)** :

The centre of curvature of the surface of a lens is the centre of the sphere of which it forms a part, because a lens has two surfaces, so it has two centres of curvature. In figure (a) & (b) points, C_1 & C_2 are centres of curvature.

(ii) **Radius of curvature (R)** :

The radius of curvature of the surface of a lens is the radius of the sphere of which the surface forms a part. R_1 & R_2 in the figure (a) & (b) represents radius of curvature.

(iii) **Principal axis (C_1C_2)** :

It is the line passing through the two centres of curvature

(C_1 and C_2) of the lens.

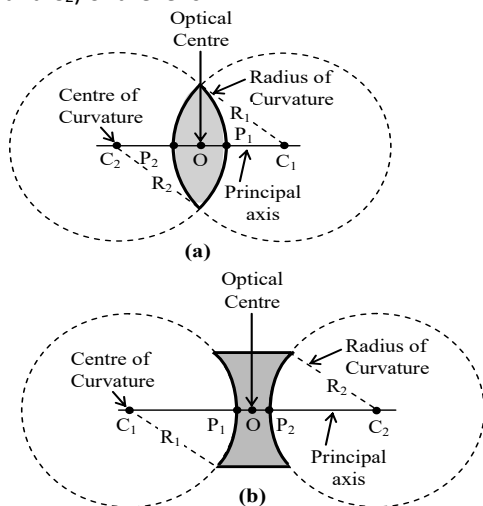


Figure : Characteristics of convex and concave lenses

(iv) Optical centre :

If a ray of light is incident on a lens such that after refraction through the lens the emergent ray is parallel to the incident ray, then the point at which the refracted ray intersects, the principal axis is called the optical centre of the lens.

$$\frac{OP_1}{OP_2} = \frac{P_1C_1}{P_2C_2} = \frac{R_1}{R_2}$$

(v) Principal foci and focal length :

(A) First principal focus and first focal length :

It is a fixed point on the principal axis such that rays starting from this point (in convex lens) or appearing to go towards this point (concave lens), after refraction through the lens, become parallel to the principal axis. It is represented by F_1 .

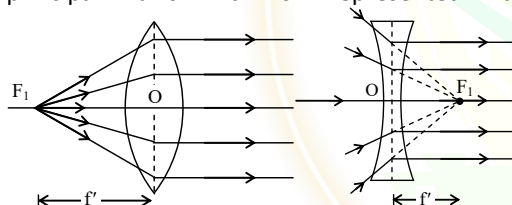


Figure : Ray diagram showing first principal focus

(B) Second principal focus and second focal length :

It is a fixed point on the principal axis such that the light rays incident parallel to the principal axis, after refraction through the lens, either converge to this point (in convex lens) or appear to diverge from this point (in concave lens). It is denoted by F_2 .

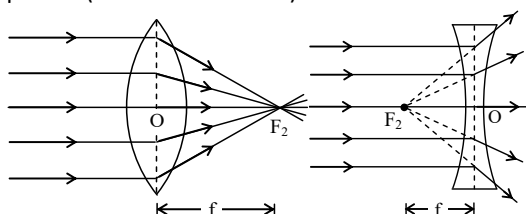


Figure : Ray diagram showing second principal focus

If the medium on both sides of a lens is same, then the numerical values of the first and second focal lengths are equal. Thus $f = f'$

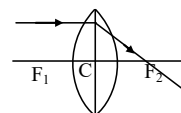
(vi) Aperture :

It is the diameter of the circular boundary of the lens.

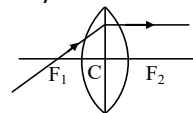
➤ Rule for image formation by ray diagram method

◆ Three special rays for Convex lens

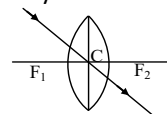
1. When light ray incident parallel to principal axis.



2. When light ray incident from focus.

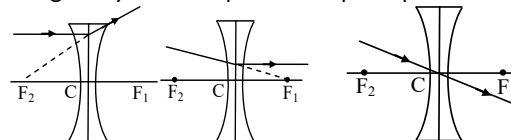


3. When light ray incident on the pole.



◆ Three special rays for Concave lens

When light ray incident parallel to principal axis.



➤ Image formation by lens

Introduction : From lens formula, we find that for a lens of a fixed focal length as object distance u changes, image distance v also changes. Moreover, as u decreases or increases, this changes the position, the nature and the size of the image.

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

◆ Convex lens in different Cases:

Case 1 : Object at Infinity

1. A point object lying on the principal axis

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

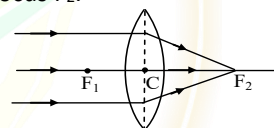
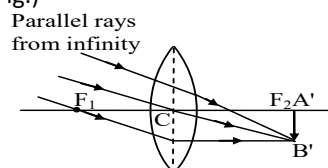


Fig. Convex lens point object at infinity, image at focus. The image is formed at focus F_2 . It is real and point sized.

2. A big size object with its foot on the principal axis

Parallel rays come inclined to the principal axis. Image of foot is formed at the focus.

Image is formed at the second principal focus F_2 . It is real inverted and diminished (smaller in size than the object). (Fig.)

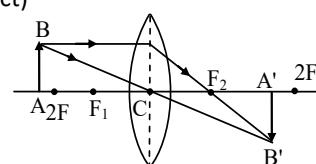


Convex lens : big size object at infinity, image at focus

Case2 : Object at distance more than twice the Focal Length

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

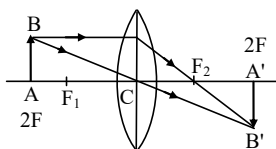
The image is real inverted and diminished (smaller in size than the object)



Convex lens : object beyond $2f$, image between f and $2f$.

Case 3. Object at distance twice the Focal Lengths

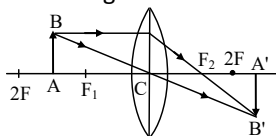
Real object AB has its image $A'B'$ formed at distance $2f$.



Convex lens : object at distance $2f$, image at distance $2f$.
The image is real, inverted and has same size as the object.

Case 4 : Object at distance more than Focal Length and less than twice is Focal Length

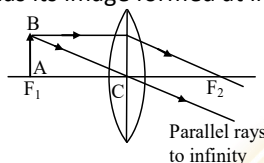
Real object AB has its image $A'B'$ formed beyond distance $2f$



Convex lens : object at distance between f and $2f$, image beyond $2f$.
The image is real inverted and enlarged (bigger in size than the object).

Case 5 : Object at Focus

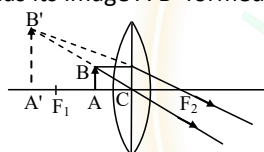
Real object AB has its image formed at infinity.



Convex lens : object at focus, image at infinity.
The image is imaginary inverted (refracted rays to downward) and must have very large size.

Case 6 : Object between Focus and Optical Centre

Real object AB has its image $A'B'$ formed in front of lens.



◆ **Concave lens in different Cases:**

Case 1 : Object at infinity

1. A point object lying on the principal axis.

Rays come parallel to the principal axis and after refraction from the lens, appears to come from the second principal focus F_2 .

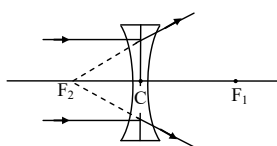


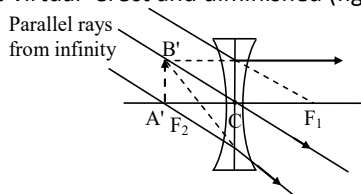
Fig. Concave lens point object at infinity, image at focus.
The image is formed at focus F_2 . It is virtual and point sized

2. A big size object with its foot on the principal axis.

Parallel rays come inclined to the principal axis. Image of foot is formed at focus.

The image is formed at the second principal focus F_2 .

It is virtual-erect and diminished (fig.)



Concave lens : big size object at infinity image at focus.

Case 2 : Object at a Finite Distance

Real object AB has its image $A'B'$ formed between second principal focus F_2 optical centre C.

The image is virtual-erect and diminished.

➤ **Numerical method in lens**

(A) lens formula :

Definition : The equation relating the object distance (u), the image distance (v) and the focal length (f) of the lens is called the lens formula.

◆ **Assumptions made :**

1. The lens is **thin**.
2. The lens has a **small aperture**.
3. The object lies **close** to principal axis.
4. The incident rays make **small angles** with the lens surface or the principal axis.

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

(B) Linear magnification for lens:

◆ **Linear magnification:**

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

If I be the size of the image and O be the size of the object,

then
$$m = \frac{I}{O} = \frac{v}{u}$$

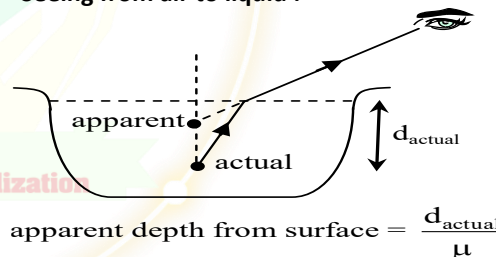
(C) Power of lens:

Definition : It is the capacity or the ability of a lens to deviate (converge or diverge) the path of rays passing through it. A lens producing more converging or more diverging, is said to have more power.

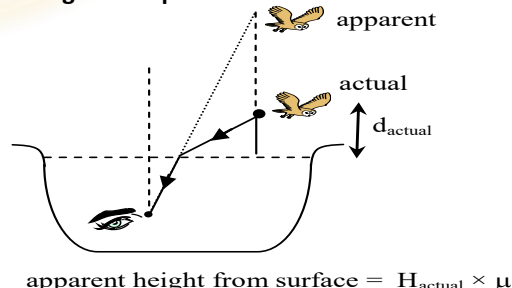
Power of lens (in diopter) $\propto \frac{1}{f(\text{in metre})}$

➤ **Real & Apparent depth & height**

(A) Seeing from air to liquid :



(B) Seeing from liquid to air



➤ **Problem based on Reflection**

Ex.1 An insect is at a distance of 1.5m from a plane mirror. Calculate the following?

- (i) Distance at which image of the insect is formed.
- (ii) distance between the insect and its image.

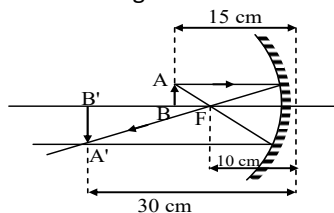
Sol. (i) The distance of insect from the mirror = 1.5 m
 $\therefore$ The distance of insect from the mirror is also equal to 1.5 m. Image is formed at 1.5 m behind the mirror.
 (ii) The distance between the insect and image = 1.5 + 1.5 = 3m

Ex.2 A concave mirror is made up by cutting a portion of a

hollow glass sphere of radius 30 cm. Calculate the focal length of the mirror.

Sol. The radius of curvature of the mirror = 30 cm
Thus, the focal length of the mirror = $\frac{30\text{cm}}{2} = 15\text{cm}$

Ex.3 An object is placed at a distance of 15 cm from a concave mirror of focal length 10 cm. Find the position of the image.



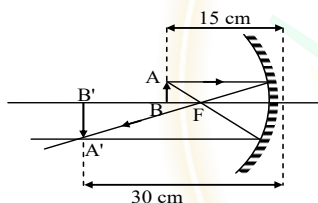
Sol. We have $u = -15\text{ cm}$ and $f = -10\text{ cm}$

Using the relation, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ we get

$$\frac{1}{v} + \frac{1}{-15} = \frac{1}{-10} \quad \text{or} \quad \frac{1}{v} = \frac{1}{15} - \frac{1}{10} = -\frac{1}{30} \quad \text{or} \quad v = -30\text{ cm}$$

So the image will be formed 30 cm from the mirror. Since v has a negative sign, the image is formed to the left of the mirror, i.e. in front of the mirror.

Ex.4 A 3 cm long object is placed perpendicular to the principal axis of a concave mirror. The distance of the object from the mirror is 15 cm, and its image is formed 30 cm from the mirror on the same side of the mirror as the object. Calculate the height of the image formed.



Sol. Here $u = -15\text{ cm}$ and $v = -30\text{ cm}$
Size of the object, $h = 2\text{ cm}$

$$\text{Magnification, } m = \frac{h'}{h} = \frac{v}{u} = -\frac{(-30)}{(-15)} = -2$$

$$\text{or } h' = -2 \times h = -2 \times 3 = -6\text{ cm}$$

So the height of the image is 6 cm. The minus sign shows that it is on the lower side of the principal axis, i.e. the image is inverted.

Ex.5 A 1 cm high object is placed at 20 cm in front of a concave mirror of focal length 15 cm. Find the position and nature of the image.

Sol. $u = -20\text{ cm}$, $f = -15\text{ cm}$, $h_o = 1\text{ cm}$

Using mirror formula,

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \quad \text{we get} \quad \frac{1}{v} + \frac{1}{-20} = \frac{1}{-15}$$

$$\text{or } \frac{1}{v} = -\frac{1}{15} + \frac{1}{20} = -\frac{1}{60} \quad \therefore v = -60\text{ cm}$$

The image is formed 60 cm from the mirror. Since, the signs of u and v are the same, the object and image are formed on the same side of the mirror. Therefore, the image is real.

$$\text{Now magnification, } m = \frac{h'}{h} = \frac{v}{u} = \frac{-60\text{ cm}}{-20\text{ cm}} = -3$$

$$\therefore h' = -3h = -3 \times 1\text{ cm} = -3\text{ cm}$$

The negative sign shows that the image is inverted. Thus, the image is real, inverted and of size 3 cm and

formed 60 cm in front of the mirror.

Ex.6 An object 5 cm high is placed at a distance of 20 cm from a convex mirror of radius of curvature 30 cm. Find the position, nature and size of image.

Sol. Here, $u = -20\text{ cm}$, $h = 5\text{ cm}$

Radius of curvature, $r = +30\text{ cm}$

$$\therefore \text{Focal length, } f = \frac{r}{2} = +\frac{30}{2} = +15\text{ cm}$$

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

$$\frac{1}{v} + \frac{1}{-20} = \frac{1}{+15} \quad \text{or} \quad \frac{1}{v} = \frac{1}{15} + \frac{1}{20} = \frac{7}{60} \quad \text{or} \quad v = \frac{60}{7}\text{ cm}$$

The image is formed 8.5 cm from the mirror. The positive sign shows that the image is formed on the other side or behind the mirror. So the image is

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

$$\text{or } \frac{h'}{5} = -\frac{60/7}{(-20)} = +\frac{60}{7 \times 20} = \frac{3}{7} \quad \text{or } h' = 5 \times \frac{3}{7} = \frac{15}{7}\text{ cm}$$

The height of the image is 2.1 cm. Positive sign shows that the image is erect.

Ex.7 A convex mirror used on a automobile has 3 m radius of curvature. If a bus is located 5 m from this mirror, find the position, nature and size of image.

Sol. Here, $u = -5\text{ m}$, $r = +3\text{ m}$ $\therefore f = \frac{r}{2} = +\frac{3}{2} = 1.5\text{ m}$

Using the relation, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$, we get

$$\text{or } \frac{1}{v} + \frac{1}{-5} = \frac{1}{1.5} \quad \text{or } \frac{1}{v} = \frac{1}{1.5} + \frac{1}{5} = +1.15\text{ m}$$

The image is 1.15 m behind the mirror.

$$\text{Magnification, } m = \frac{h'}{h} = -\frac{v}{u} = -\frac{1.15}{(-5)} = +0.23$$

Thus, the image is virtual, erect and smaller in size than the object.

➤ Problem based on Refraction

Ex.1 Speed of light in water is $2.25 \times 10^8\text{ m/s}$. Calculate the refractive index of water.

Sol. Refractive index is given by

$$n = \frac{\text{speed of light in vacuum}(c)}{\text{speed of light in water}(v)} = \frac{3 \times 10^8\text{ m/s}}{2.25 \times 10^8\text{ m/s}} = 1.33$$

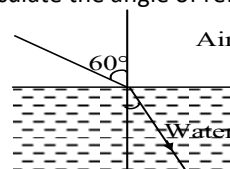
Ex.2 Refractive index of diamond is 2.42. Calculate the speed of light in diamond.

Sol. We know that refractive index,

$$n = \frac{c}{v} = \frac{\text{speed of light in vacuum}}{\text{speed of light in diamond}}$$

$$\text{or } 2.42 = \frac{3 \times 10^8}{v} \quad \text{or } v = \frac{3 \times 10^8}{2.42} = 1.24 \times 10^8\text{ m/s.}$$

Ex.3 A ray of light travelling in air falls on the surface of water. The angle of incidence is 60° with the normal to the surface. The refractive index of water = $4/3$. Calculate the angle of refraction.



Sol.

$$\text{We know that } \frac{\sin i}{\sin r} = n$$

Here, $i = 60^\circ$, $n = 4/3$ $\therefore \frac{\sin 60^\circ}{\sin r} = \frac{4}{3}$

or $\frac{\sqrt{3}/2}{\sin r} = \frac{4}{3}$ or $\sin r = \frac{3\sqrt{3}}{8} = 0.65$ $\therefore r = \sin^{-1} 0.65$

Ex.4 A ray of light is incident on the plane surface of a transparent medium at an angle 60° with the normal. The angle of refraction is 30° . Calculate the refractive index of the transparent material.

Sol. Here, Angle of incidence, $i = 60^\circ$
Angle of refraction, $r = 30^\circ$

Refractive index, $n = \frac{\sin i}{\sin r} = \frac{\sin 60^\circ}{\sin 30^\circ} = \frac{\sqrt{3}/2}{1/2} = \sqrt{3}$

Ex.5 A 2 cm long pin is placed perpendicular to the principal axis of a lens of focal length 15 cm at distance of 25 cm from the lens. Find the position of image and its size.

Sol. Here, $u = -25$ cm, $f = +15$

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

$\frac{1}{v} - \frac{1}{-25} = \frac{1}{+15}$ or $\frac{1}{v} = \frac{1}{15} - \frac{1}{25} = \frac{2}{75}$ or $v = 37.5$ cm

The positive sign shows that the image is formed on the right-hand side of the lens.

Magnification is given by $m = \frac{h'}{h} = \frac{v}{u} = \frac{37.5}{-25} = -1.5$

$\therefore h = -1.5 \times h = -1.5 \times 2$ cm $= -3$ cm

The image of the pin is 3 cm long. The negative sign shows that it is formed below the principal axis, i.e. the image is inverted.

Ex.6 A convex lens forms an image of the same size as the object at a distance of 30 cm from the lens. Find the focal length of the lens. Also find power of the lens. What is the distance of the object from the lens?

Sol. A convex lens forms the image of the same size as the object only when the object is placed at a distance $2f$ from the lens. In this case the image is also equal to $2f$ from the lens.

Hence, $2f = 30$ cm or $f = 15$ cm $= 0.15$ m

Power of the lens, $P = \frac{1}{f} = \frac{1}{0.15}$ D $= 6.6$ D

The distance of the object from lens is also $2f = 30$ cm.

Ex.7 A 3 cm high object is placed at a distance of 80 cm from a concave lens of focal length 20 cm. Find the position and size of the image.

Sol. Here, $u = -80$ cm, $f = -20$ cm Using the lens formula,

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, we get or $\frac{1}{v} - \frac{1}{-80} = \frac{1}{-20}$

or $\frac{1}{v} = -\frac{1}{20} - \frac{1}{80} = \frac{-5}{80} = -\frac{1}{16}$ or $v = -16$ cm

Magnification, $m = \frac{h'}{h} = \frac{v}{u} = \frac{-16}{-80} = \frac{1}{5}$ or $h' = \frac{h}{5} = \frac{3.0}{5} = 0.6$ cm

Length of image is 0.6 cm. Positive sign shows that the image is erect.

➤ Multiple Choice Questions

Q.1 The critical angle for light going from medium X into medium Y is θ . The speed of light in medium X is v . The speed of light in medium Y is -
(A) $v(1 - \cos \theta)$ (B) $v/\cos \theta$ (C) $v \cos \theta$ (D) $v/\sin \theta$

Q.2 One surface of a lens is convex and the other is concave. If the radii of curvature are r_1 and r_2 respectively, the lens will be convex, if-

(A) $r_1 > r_2$ (B) $r_1 = r_2$ (C) $r_1 < r_2$ (D) $r_1 = 1/r_2$

Q.3 R.I. of glass w.r.t. air is $3/2$, then the R.I. of air w.r.t. glass is-

(A) $3/4$ (B) $2/3$ (C) $1/3$ (D) 3

Q.4 Refractive index of glass with respect to air is 1.5 and refractive index of water with respect to air is $4/3$. What will be the refractive index of glass with respect to water?

(A) 1 (B) 1.5 (C) 1.125 (D) -10

Q.5 The refractive index of a medium depends upon-

(A) Nature of material of the medium
(B) Optical density of the medium
(C) Wavelength of light
(D) All of these

Q.6 A child walks towards a fixed plane mirror at a speed of 5 km h^{-1} . The velocity of the image with respect to mirror is -

(A) 5 km h^{-1} (B) -5 km h^{-1} (C) 10 km h^{-1} (D) -10 km h^{-1}

Q.7 The letter that does not show lateral inversion-

(A) Z (B) M (C) O (D) W

Q.8 In a plane mirror, an object is 0.5 m in front of the mirror. The distance between object and image is -

(A) 0.5 m (B) 1 m (C) 0.25 m (D) 0.75 m

Q.9 An object 0.5 m tall is in front of a plane mirror at a distance of 0.2 m. The size of the image formed is-

(A) 0.2 m (B) 0.5 m (C) 0.1 m (D) 1 m

Q.10 A plane mirror is approaching you at 10 cm s^{-1} . Your image shall approach you with a speed of-

(A) $+10 \text{ cm s}^{-1}$ (B) -10 cm s^{-1} (C) $+20 \text{ cm s}^{-1}$ (D) -20 cm s^{-1}

Q.11 The path along which light travels in a homogeneous medium is called a-

(A) beam of light (B) ray of light
(C) pencil of light (D) none of these

Q.12 The image formed by a concave mirror is real, inverted and of the same size as that of the object. The position of the object should be-

(A) Beyond C (B) Between C and F
(C) At C (D) At F

Q.13 A boy is standing in front of a plane mirror at a distance of 3m from it. What is the distance between the boy and his image?

(A) 3 m (B) 4.5 m (C) 6 m (D) none

Q.14 The magnification of an object placed 10 cm from a convex mirror of radius of curvature 20 cm will be-

(A) 0.2 (B) 0.5 (C) 1 (D) infinity

Q.15 A ray of light is incident on a plane mirror at an angle θ . If the angle between the incident and reflected rays is 80° , what is the value of θ .

(A) 40° (B) 50° (C) 45° (D) 55°

Q.16 A swimming pool appears to be 2m deep. Its actual depth is (μ for water = 1.33)-

(A) 2.66 m (B) 2 m (C) 2.34 (D) 2.54 m



1-D	2-C	3-B	4-C	5-D	6-B	7-A	8-B
9-B	10-C	11-B	12-C	13-C	14-B	15-B	16-A



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*** With Best Wishes ***