CHAPTER

5

Optics

SUB- TOPICS

- Introduction to optics
- Ray optics
- Reflection by Plane mirrors
- Reflection by Spherical mirrors
- Refraction and its laws
- Total internal reflection
- Prism
- Lens and Image formation
- Power and Combination of lenses
- Combination of mirror and glass or lens
- Refraction at Spherical surfaces
- Human eye, its defects and remedies
- Simple microscope
- Compound microscope
- Telescope (Astronomical)
- Atmospheric refraction
- Tyndall effect
- Formation of Rainbow
- Scattering of light
- Assignments
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- Introduction
- Huygen's Principle
- Young's double slit experiments
- Assignments
- Competitive Corner

INTRODUCTION

The branch of physics which deals with the nature of light, its sources, properties, effects and vision is called optics. Light is that form of energy which makes objects visible to our eye.

Importance of Optics :

The science of optics is by far an important part of our life and our economy. It is due to optics that we have discovered our universe from the microscopic virus to the largest galaxy. It is due to optics that we see the colours of a rainbow, sparkling of diamond, twinkling of stars, shining of air bubble in water etc.

Theories on light :

- According to **Newton** light is composed of very tiny particles called as corpuscles.
- Next **Huygen** explained that light propagates in the form of longitudinal mechanical wave with the help of wavefront.
- After that **Maxwell** proposed electromagnetic theory of light.
  But when photoelectric effect and some other phenomena associated with emission and absorption of light could not be explained by wave theory light then,
- **Planck** established quantum theory of light and was able to explain photoelectric effect by **Einstein**.
- At present it is believed that light has **dual nature**, i.e., **it propagates like a wave but interacts like a particle.**

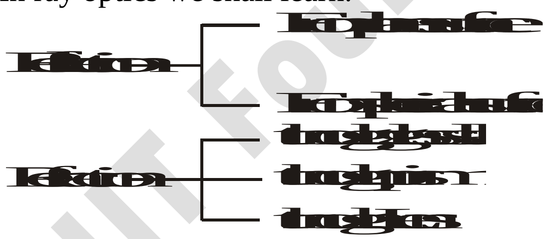
Optics is studied into two parts.

- **Geometrical or Ray Optics:** The phenomena of rectilinear propagation of light, reflection and refraction, are studied in this section.

- **Physical Optics or Wave Optics:** The wave behaviour of light (like diffraction and interference) is studied in this section.

RAY OPTICS

In ray optics we shall learn.



Other than that, we shall learn,

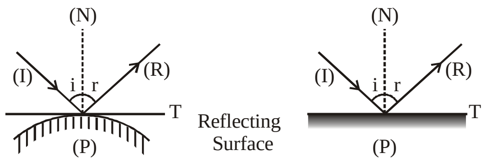
- **Optical instruments**
- **Human Eye**
- **Refraction through atmosphere.**
- **Scattering of light and Rainbow formation.**

Reflection

When light falls on the surface of a material it is either re–emitted without change in frequency or is absorbed in the material and turned into heat. When the re–emitted light is returned into the same medium from which it comes, it is called reflected light and the process is known as

reflection. If one side of a piece of glass is silvered then it becomes an ideal reflector and is called a **mirror**.
Reflecting surface is known as mirror

- **Laws of Reflection**

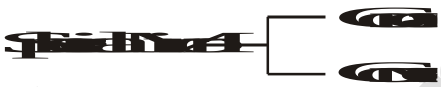


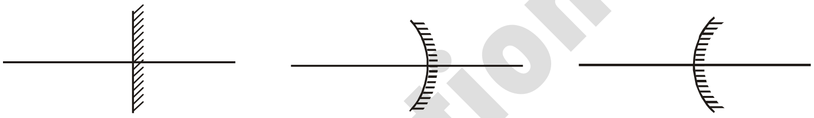
- **Note :** To apply laws of reflection draw tangent (T) and Normal (N) at the point of reflection (P)

  1st Law : Incident ray (I), normal (N) and reflected ray (R) lie in same plane.

  2nd Law : Angle of incidence = Angle of reflection
  $\Rightarrow \angle \mathbf{i} = \angle \mathbf{r}$

- **Mirrors are of two types (1) Plane (2) Spherical**
  1. Plane Mirror
  2.

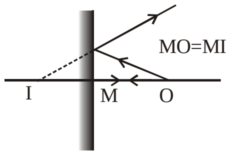




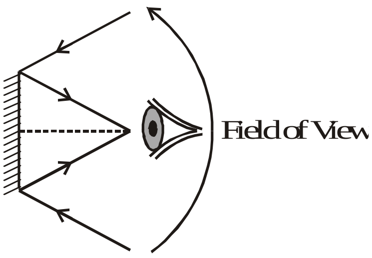
Plane Concave Convex

Reflection at Plane Surfaces

- **Image Formation of Point Object by Plane Mirror**
  Point of intersection of incident light ray is known as object.
  The point of intersection of reflected rays or refracted ray is known as image.
- **Note :** The object and image may be real or virtual
  For real object the image formed by plane mirror is virtual.

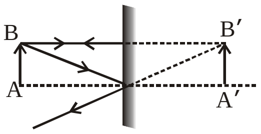


- **Field of view:** Region in which diverging rays from object or image are actually present is known as field of view.

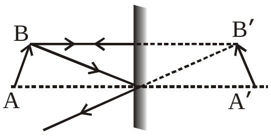


- **Image Formation Of Extended Object By Plane Mirror**

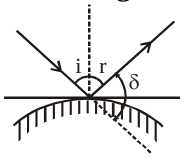
Case 1 :

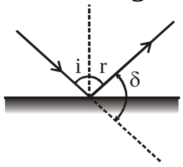


Case 2 :



- **Angle of Deviation:** The angle between the direction of incident and reflected light rays is known as angle of deviation.





angle of deviation $\delta = \pi - (i + r)$
Assume $\angle i = \angle r = \alpha$ then $\boldsymbol{\delta = \pi - (2\alpha)}$

For Normal Incidence, $\angle i = 0°$ (hence $< r = 0$)

Grazing Incidence, $\angle i = 90°$ (hence $< r = 90°$)

- **Properties of Image Formed by Plane Mirror**

For an extended Object
Size of the object = size of the image
Image is laterally inverted.

- **Rotation of Plane Mirror**

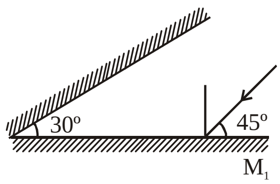
If a plane mirror is rotated through an angle θ about an axis in the plane of mirror then reflected ray, image and spot are rotated through an angle $\mathbf{2\theta}$ in the same plane.
If plane mirror is rotated about an axis perpendicular to plane of mirror then reflected ray image, spot do not rotate.

- **Combination of Plane Mirror**

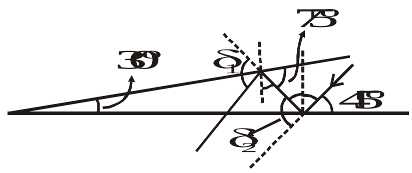
Let us find net deviation produced by combination of plane mirror and deviation produced by each mirror. While adding the deviation ensure that they must be in same direction either clockwise or anticlockwise.

For example :

Two plane mirrors are inclined at 30º as shown in figure. A light ray is incident at angle 45º. Find total deviation produced by combination of mirror after two successive reflection.



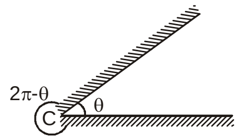
Sol. Deviation at mirror $M_1, \delta_1 = 180° - 2 \times 45° = 90° \uparrow$ – clockwise
Deviation at mirror $M_2, \delta_2 = 180º - 2 \times 15º = 150º$ – anticlockwise
Total deviation $\delta = \delta_2 - \delta_1 = 150º - 90º = 60º$ – anticlockwise



- **Images Formed By Two Mirrors**

CASE 1 : When the mirrors are parallel to each other, then number of images is infinite.
CASE 2 : (when the mirrors are inclined at angle)

1. All the images formed by two mirrors lies on circle have centre C. Here if angle between mirror is θ then image will be formed on circle at angle $(2\pi - \theta)$. If angle θ is less number of image formed will be more.
2. If n is number of images, n then



(a) $n = \frac{360}{\theta} - 1$ If $(\frac{360}{\theta}$ is even)

(b) $n = \frac{360}{\theta}$ If $(\frac{360}{\theta}$ is odd and object is kept symmetrically)

(c) If $n = \left[\frac{360}{\theta}\right]$ = fractional number then only integral part is taken.

(d) $n = \left[\frac{360}{\theta}\right]$ For all other condition .

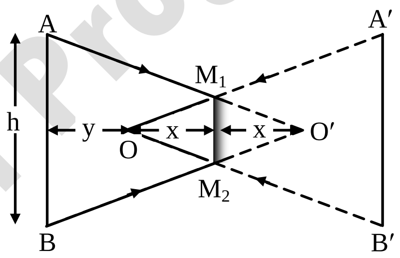
Illustration 1

A man is standing at distance x from plane mirror in front of him. He wants to see the entire wall of height h, in mirror which is at distance y behind the man. Find the size of mirror ?

Sol. From $\Delta O' M_1M_2$ and $O'AB$

$$\frac{M_1M_2}{h} = \frac{x}{2x + y}$$

size of mirror, $M_1M_2 = \frac{hx}{(2x + y)}$



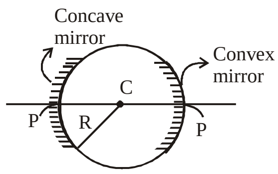
Note : If $x = y$, $M_1M_2 = \frac{h}{3}$

Illustration 2 :

Two mirrors are placed at right angle. An object is placed between them symmetrically. How many images will be formed ?

Sol. $n = \frac{360}{90} - 1 = 3$.

- **Reflection at Spherical Mirrors**
  Spherical mirrors are part of polished spherical surface



- Center of curvature (C): Center of circle of which mirror is a part.
- Radius of curvature (R): Radius of circle of which mirror is a part .
- Pole (P): Centre of mirror reflecting portion
- Principal axis: Line which join pole to the centre of curvature
- Diameter of mirror: Shortest distance between two ends of mirror.

SOME USEFUL TERMS :

- **Paraxial Ray :** Rays whose angle of incidence are small are known as paraxial rays.
- **Marginal Ray :** Rays whose angle of incidence are not small are known as marginal rays.

- **Focal Plane**
  Plane perpendicular to principal axis and passing through focus is known as focal plane
- **Centre of Curvature**
  It is the geometrical centre of the mirror. If light ray passes or appear to pass through centre of curvature then, it retraces its path.
- The focal length f and the radius of curvature r of spherical mirror of small aperture are related as $f = \frac{r}{2}$.
- **Rules For Image Formation By Spherical Mirrors**
  (a) For convex mirror a ray parallel to the principal axis diverges as if coming from its focus and for Concave mirror it passes through focus.
  (b) For convex mirror a ray falling in the direction of focus becomes parallel to the principal axis and true for concave mirror too.
  (c) For a ray falling at the poles of a convex mirror or concave mirror then the incident ray and reflected ray make equal angle with the principal axis.
  (d) In both convex mirror and concave mirror a ray passing through or in the direction of centre of curvature then it retraces its path.

For Convergent or Concave Mirror

Position of Object	Details of Image
• At infinity	Real, inverted, Diminished (m << 1 and negative) and at F
• Between infinity and 2F	Real, inverted, Diminished (m < 1 and negative) and between F and 2F
• At 2F	Real, inverted, Equal (m = –1) and at 2F
• Between 2F and F	Real, inverted, Enlarged (m > 1 and negative) and between 2F and infinity
• At F	Real, inverted, Enlarged (m >> 1 and negative) and at infinity.
• Between F and O	Virtual Erect Enlarged (m>>1 and positive) and behind the mirror.

For Divergent or Convex Mirror

Position of Object	Details of Image
• At infinity	Virtual, inverted, very small (m << 1 and positive), and at F
• For any other place	Virtual, Erect Diminished (m < 1 and positive), and between F and P

Position, nature and magnification of image

- For convex mirror images are always virtual, erect and diminished.
- For concave mirror the image is both real and virtual and may be both magnified and diminished type.
- **Sign Convention**
  Pole is taken as origin and principal axis is taken as x–axis
  Direction of incident light is taken as direction of +ve x–axis
  Object, focus, image are referred by their co–ordinates.
  Height above principal axis is taken as positive.
  Height below the principal axis is taken as negative.

- **Mirror formula**
  The relation among object distance (u), Image distance (v) and focal length (f) is, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$
  Magnification = $m=-\frac{v}{u}$
- **Uses of Spherical Mirrors**
- Convex mirrors are widely used as rear–view mirrors.
- A concave mirror can produce an erect, enlarged image, behind the mirror. A concave mirror is, therefore, used when you want to see a magnified image of the object. One such use is for shaving, where a magnified view of the face helps to get a smooth shave.

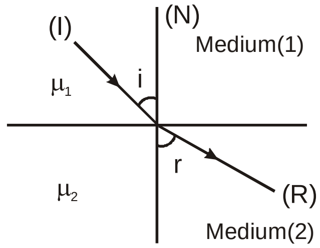
Illustration 3
A concave mirror is made by cutting a portion of a hollow glass sphere of radius 24 cm. Find the focal length of the mirror.
Sol. The radius of curvature of the mirror = 24 cm.
Thus the focal length = 24 cm/2 = 12 cm.

Illustration 4
An object is placed at a distance of 30 cm from a concave mirror of focal length 20 cm. Where will image be formed ?
Sol. We have, u = – 30 cm and f = – 20 cm.
Also, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ or $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{-20cm}-\frac{1}{-30cm}=-\frac{1}{60cm}$ or $v=-60cm$
So, the image will be formed 60 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 it, as shown in figure (b).

Illustration 5
A 2.0 cm high object is placed perpendicular to the principal axis of a concave mirror. The distance of the object from the mirror is 30 cm, and its image is formed 60 cm from the mirror, on the same side of the mirror as the object. Find the height of the image formed.
Sol. We have, u = – 30 cm and v = – 60 cm.
Thus $m=\frac{h_e}{h_0}=-\frac{v}{u}=-\frac{-60cm}{-30cm}=-2$
or $h_e=-2h_0=-2\times 2.0cm=-4.0cm$
The height of the image is 4.0 cm. The minus sign shows that it is on the other side of the axis, i.e., it is inverted.

Refraction and Its Laws, Refractive Index, Speed of Light in Different Media
- Bending of light at the interface of two mediums is called as refraction of light.
- Change in the speed of light in different medium causes refraction of light.
- Light is deviated due to medium when it is not along the normal

- **Snell's Laws**
  On refraction



First Law : For a certain pair of medium sin i / sin r = constant
This constant is known as refractive index of second medium w.r.t first medium and is denoted by ${}^1\mu_2$ or ${}^1\mu_2$ or ${}_1\mu_2$ or μ_{21}

In general, refractive index of any medium (say x) is determined w.r.t. air medium.

Also, $\mu_{21} = \frac{C_1}{C_2} = \frac{C/C_2}{C/C_1} = \frac{\mu_2}{\mu_1}$ [C = velocity of light in air = 3×10^8 ms^{-1}]
Where, C_1 and C_2 are velocity of light in first and second medium respectively.
μ_1 and μ_2 are refractive indices of first and second medium respectively.
Second Law : Incident ray, refracted ray and normal at the point of incidence lie on the same plane.

- **SNELL'S LAW IN GENERAL FORM**
  For different medium of different RI
  μ_1, μ_2 and μ_3 ……..
  $\mu_1 \sin\theta_1 = \mu_2 \sin\theta_2$ ……. = constant
  $\mu \sin\theta = \text{constant}$

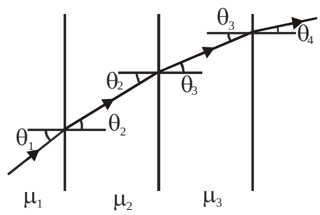


Illustration 6 :
A light ray enters a diamond from air. If the refractive index of diamond is 2.42, by what percent does the speed of light reduce on entering the diamond?

Sol. We have, $n = \frac{c}{v}$, where c is the speed of light in vacuum.

$\therefore$ The speed of light in diamond, $v = \frac{c}{\mu} = \frac{c}{2.42} = 0.41c$

The speed of light in diamond is therefore 41% of its speed in air. In other words, in diamond, the speed reduces by 59%.

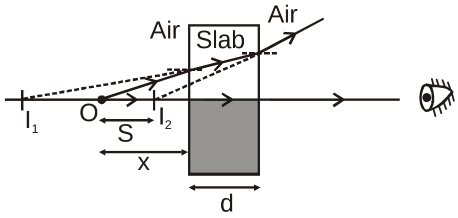
Illustration 7
A ray of light travelling in air falls on the surface of a transparent slab. The ray makes an angle of 45° with the normal to the surface. Find the angle made by the refracted ray with the normal within the slab. Refractive index of the material of the slab = $\sqrt{2}$.

Sol. We have, $\frac{\sin i}{\sin r} = \mu$ or $\frac{\sin 45°}{\sin r} = \sqrt{2}$

or $\sin r = \frac{1}{\sqrt{2}} \times \sin 45° = \frac{1}{\sqrt{2}} \times \frac{1}{\sqrt{2}} = \frac{1}{2}$ This gives r = 30°.

- **Refraction through Glass slab**

  Let us consider a slab of thickness d and R.I. μ as shown in figure.



  Consider refraction at air–slab interface

  $$\frac{1}{-x} = \frac{\mu}{v} \quad \text{or} \quad v_1 = -\mu x$$

  Now, I_1 will act as object for refraction at slab–air interface

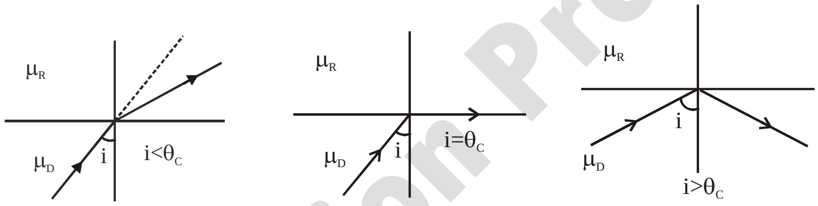
  $$\therefore \quad \frac{\mu}{-(d + \mu \cdot x)} = \frac{1}{v_2} \quad \text{or} \quad v_2 = -\left(x + \frac{d}{\mu}\right) \qquad \therefore \quad \text{shift (S)}$$

  $$= d + x - \left(x + \frac{d}{\mu}\right) = d\left(1 - \frac{1}{\mu}\right).$$

- In case when a liquid is poured in a beaker the bottom is apparently raised. Then,

  Shift = $d\left(1 - \frac{1}{\mu_{liq}}\right)$. (where d is the actual depth)

- **CRITICAL ANGLE AND TOTAL INTERNAL REFLECTION :**



  When a ray propagates from denser medium to rarer medium for 90º angle of refraction corresponding angle of incidence is known as critical angle. When angle of incidence becomes more than the critical angle the ray reflects internally. This is called as total internal reflection.

  At critical angle refraction takes place

  $$\mu_D \sin\theta_C = \mu_R \sin 90^\circ \quad \Rightarrow \quad \sin\theta_C = \mu_R / \mu_D$$

- Critical angle does not depends on angle of incidence.
- Critical angle increases with increase in temperature of a medium.
- Mirage in the desert is due to TIR.
- Working of optical fibre is based on TIR.
- For working of the optical fibre, the angle of incidence or **Launching angle** should be as follows.

  $$\sin i \le \sqrt{\left(\mu_2^2 - \mu_1^2\right)}$$

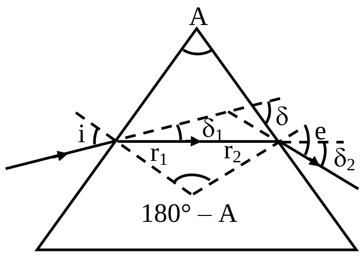
  μ_2 = R.I of the core of the pipe.

  μ_1 = R.I. of the material used for cladding the pipe.

- **Refraction through a Prism**

  Prism is a combination of two opposite plane refracting surfaces inclined at an angle called angle of prism.

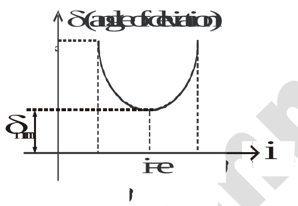
A → angle of prism
i → angle of incidence
e → angle of emergence
δ → angle of deviation
$\delta = (\mu - 1)A$
where μ is R.I. of the material of the prism.



- **Minimum Deviation**

At minimum deviation $\angle i = \angle e$ and $\angle r_1 = \angle r_2$

and $\mu = \sin\left[\frac{(\delta_{min} + A)}{2}\right] / \sin\frac{A}{2}$



δ – **i graph**

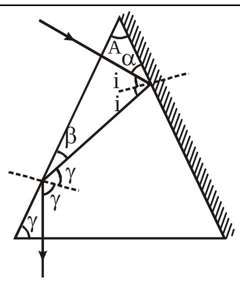
Illustration 8
A printed page is kept pressed by a glass cube $(\mu = 1.5)$ of edge 6.0 cm. By what amount will the printed letters appear to be shifted when viewed from the top?
Sol. The thickness of the cube = t = 6.0 cm. The shift in the position of the printed letters is $\Delta t = \left(1 - \frac{1}{\mu}\right)t = \left(1 - \frac{1}{1.5}\right) \times 6.0 cm = 2.0 cm$

Illustration 9
The critical angle for water is 30°. Find its refractive index.
Sol. $\mu = \frac{1}{\sin\theta_c} = \frac{1}{\sin 30°} = 2$

Illustration 10

The cross–section of the glass prism has the form of an isosceles triangle. One of the equal faces is silvered. A ray of light incident normally on the other equal face and after being reflected twice, emerges through the base of prism along the normal. Find the angle of the prism.

Sol. From the figure, $\alpha = 90° - A$
$i = 90° - \alpha = A$
Also, $\beta = 90° - 2i = 90° - 2A$
And, $\gamma = 90° - \beta = 2A$
Thus, $\gamma = r = 2A$
From geometry,
$A + \gamma + \gamma = 180°$ or $A = \frac{180}{5} = 36°$



- **Thin Lens and Its Properties**

A lens is a homogenous transparent medium (such as glass) bounded by two curved surfaces or one curved and a plane surface.

- **Types of Lens**
  (1) Concave and (2) Convex
  Each type of lens is further possible in three forms
  (i) Biconvex or Biconcave lens
  (ii) Plano convex or Plano concave lens
  (iii) Concavo convex or convexo concave lens
- Centre most point of lens is known as optical centre
- Line joining both the center of curvature and passing through optical center is called principal axis.
- Rays parallel to the principal axis converge at a point or appear to be diverging after passing through a convex or concave lens respectively. This point of convergence or divergence is known as the focus point of the respective lens.

- **Rules For Image Formation**
  The following rules are used for image formation in case of thin lenses :
  A ray passing through optical centre proceeds undeviated through the lens.
  A ray passing parallel to the principal axis after refraction through the lenses passes or appears to pass through second focal point.
  A ray passing through first focus or directed towards first focus, after refraction from the lens becomes parallel to the principal axis.

For Convergent or Convex Lens

Position of Object	Details of Image
• At infinity	Real, inverted, Diminished ($m \ll 1$) and negative and at F
• Between infinity and 2F	Real, inverted, Diminished ($m < 1$) and negative and between F and 2F
• At 2F	Real, inverted, Equal $m = -1$ at 2F
• Between 2F and F	Real, inverted, Enlarged ($m > 1$) and negative and between 2F and infinity
• At F	Real, inverted, Enlarged ($m \gg 1$) and negative and at infinity.
• Between F and O	Virtual Erect Enlarged ($m \gg 1$) and positive

For Divergent or Concave Lens

Position of Object	Details of Image
• At infinity	Virtual, erect, very small ($m \ll 1$ and positive), and at F
• At any other points	Virtual, Erect Diminished ($m < 1$ and positive), and always located between focus and optic centre.

- **Sign Convention**
  - Focal length of converging lens is taken as positive and that of the diverging lens is taken as negative, if it is kept in vacuum or in a medium whose refractive index is less than the lens.
  - Pole is taken as origin and principal axis is taken as x–axis
  - Direction of incident light is taken as direction of +ve x–axis

- Object, focus, image are referred by their co–ordinates.
- Height above principal axis is taken as positive.
- Height below the principal axis is taken as negative.

- **Len's Formula**

  The relation among object distance (u), image distance (v) and focal length (f) is called as lens formula. And it is

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

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

- **Power Of Lens**

  Power of a lens is defined as the ratio of the refractive index (μ) of the surrounding medium and the focal length (f) of the lens in that medium. The unit of power is dioptre and is denoted by D.

  Mathematically it can be written as $\mathbf{P=\frac{\mu}{f}}$. [f in metre] in air, $P=\frac{1}{f}$.

LEN'S MAKER FORMULA

$$\frac{1}{f}=\left(\frac{\mu_\ell}{\mu_s}-1\right)\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$$

$\mu_S \rightarrow$ refractive index of surrounding.

$\mu_I \rightarrow$ Refractive index of lens

- **Combination of Lenses**
- **Equivalent Focal Length of Combination of Lenses**

  If number of lenses of focal lengths are placed coaxially in contact then the equivalent focal length of the combination is given by

  $$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}+.....+\frac{1}{f_n}$$

  In terms of power $P=p_1+p_2+.....+p_n$

Illustration 11

A point object is placed at a distance of 12 cm from a convex lens on its principal axis. Its image is formed on the other side of the lens at a distance of 18 cm from the lens. Find the focal length of the lens.

Sol. According to convention, let the object be on the left of the lens. Therefore u is negative, i.e.,

u = – 12 cm. Since the image is on the other side, it is formed on the right of the lens. Thus v is positive, i.e., v = + 18 cm. (You can also say that since u is measured opposite to the direction of the incident rays, it is negative. And since v is measured along the direction of the incident rays, it is positive)

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

or $\frac{1}{f} = \frac{1}{18cm} - \frac{1}{-12cm} = \frac{5}{36cm}$

or $f = \frac{36}{5}cm = 7.2cm$

Illustration 12 :

The image of an object formed by a convex lens is of the same size as the object. If the image is formed at a distance of 40 cm. Find the power of the lens.

Sol. A same–sized image is formed when an object is placed at a distance of 2f from a convex lens. The image is formed at a distance of 2f from the lens. Here this distance is given as 40 cm. So, 2f = 40 cm or f = 20 cm

Power, $P = \frac{1}{f} = \frac{1}{0.2m} = 5D$

Illustration 13 :

A convex lens of focal length 20 cm is placed in contact with a concave lens of focal length 12.5 cm in such a way that they have the same principal axis. Find the power of combination.

Sol. $P = P_1 + P_2$

Here $P_1 = +\frac{1}{20cm} = +\frac{1}{0.20cm} = 5D$ and $P_2 = -\frac{1}{12.5cm} = -\frac{1}{0.125m} = -8D$

So the power of the combination is $P_1 + P_2 = -3D$

COMBINATION OF MIRROR AND GLASS SLAB OR LENS

Let us consider the following examples

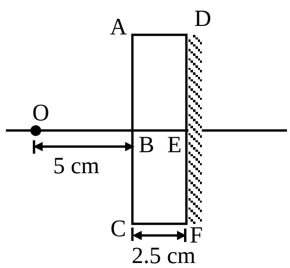
Example 1 : A plane mirror is made of glass slab ($\mu_g = 1.5$) 2.5 cm thick and silvered on back. A point object is placed 5 cm in front of the unsilvered face of the mirror. What will be the position of final image?

Sol. Let I_1, I_2 and I_3 be the images formed by

(i) Refraction from ABC

(ii) Reflection from DEF and

(iii) Again refraction from ABC



Then $BI_1 = (5)\mu_g = (5)(1.5) = 7.5$ cm

Now $EI_1 = (7.5 + 2.5) = 10$ cm

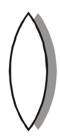
$\therefore EI_2 = 10$ cm behind the mirror

Now $BI_2 = (10 + 2.5) = 12.5$ cm

$\therefore \quad BI_3 = \frac{12.5}{\mu_g} = \frac{12.5}{1.5} = 8.33$ cm.

Example 2 :

When a lens is silvered, it behaves like a spherical mirror whose power (P_{eq}) is given by



$P_{eq} = \Sigma P_i$

where P_i is the power of lens or mirror to be taken as many times as the number of refraction or reflection. For example, let us consider silvered equiconvex lens then

$$P_{eq} = 2P_L + P_M$$

and $f_{eq} = -\frac{1}{P_{eq}}$

Example 3 : A thin bioconvex glass ($\mu = 1.5$) lens is silvered in one side. Find its focal length if its power is 1.5 D.

Sol. $P_{eq} = 2P_L + P_M$ …(i)

From $P = (\mu - 1)\left(\frac{2}{R}\right)$ [Len's maker's formula]

$$1.5 = (1.5 - 1)\frac{2}{R}$$

$$R = (2 \times 0.5)/1.5 = \frac{2}{3}\text{m}$$

$$f_M = \frac{R}{2} = \frac{1}{3}\text{m}$$

$$P_M = \frac{1}{f_M} = 3\text{D}.$$

From (i) $P_{eq} = 2 \times 1.5 + 3 = 6\text{D}$

$$f_{eq} = -\frac{1}{P_{eq}} = -\frac{1}{6}\text{m}.$$

Example 4 : Water $\left(\mu_w = \frac{4}{3}\right)$ is filled in a beaker upto a height of 20 cm. A plane mirror is fixed at a height of 5 cm from the surface of water. Find the distance of image from the mirror after reflection from it of an object O at the bottom of the beaker.

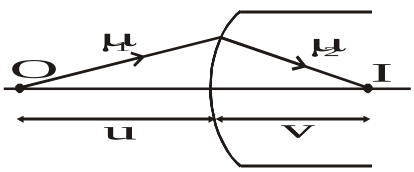
Sol. Distance of first image (I_1) formed after refraction from the plane surface of water is $\frac{20}{4/3} = 15\,\text{cm}$.

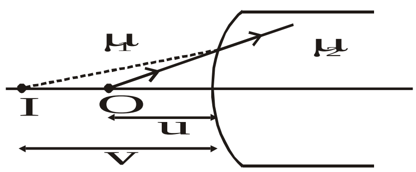
From water surface $\left(d_{app} = \frac{d_{actual}}{\mu}\right)$.

Now distance of this image is 5 + 15 = 20 cm from the plane mirror. Therefore, distance of second image (I_2) will also be equal to 20 cm from the mirror.

Refraction at Spherical Surfaces :

- For refraction from rarer to denser medium at a convex surface. The image formed may be real or virtual as shown.

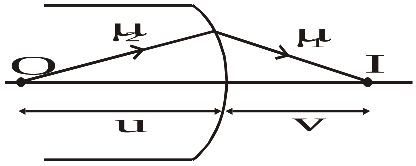




(When object is much closer)

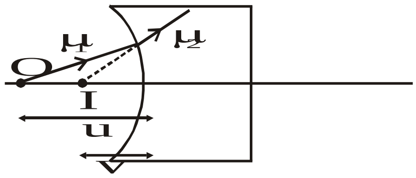
$$\frac{\mu_1}{-u} + \frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R}$$

- Refraction from rarer to denser medium at a concave surface. Image is always virtual.



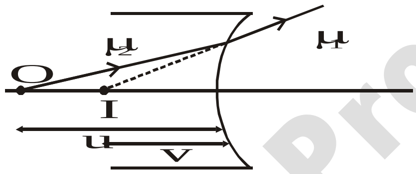
$$\frac{\mu_2}{-u} + \frac{\mu_1}{v} = \frac{\mu_2 - \mu_1}{R}$$

- Refraction from rarer to denser medium at a concave surface. Image is always virtual.



$$\frac{\mu_1}{-u} + \frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R}$$

- Refraction from denser to rarer medium at a concave surface. Image is again virtual.

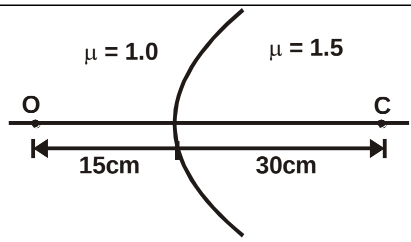


$$-\frac{\mu_2}{u} + \frac{\mu_1}{v} = \frac{\mu_1 - \mu_2}{R}$$

Magnification : $m = \frac{\mu_1 v}{\mu_2 u}$. (in each of the above cases)

Illustration 14:

Locate the image of the point object O in the situation shown in figure. The point C denotes the centre of curvature of the separating surface.



Sol. Here u = – 15 cm, R = 30 cm, $\mu_1 = 1$ and $\mu_2 = 1.5$. We have

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

or $\frac{1.5}{v} - \frac{1.0}{-15\text{cm}} = \frac{1.5-1}{30\text{cm}}$

or $\frac{1.5}{v} = \frac{0.5}{30\text{cm}} - \frac{1}{15\text{cm}}$

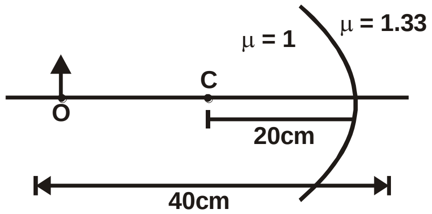
or, $v = -30\text{cm}$

The image is formed 30 cm left to the spherical surface and is virtual.

Illustration 15 :

Find the size of the image formed in the situation shown in figure.

Sol. Here u = – 40 cm, R = – 20 cm, $\mu_1 = 1, \mu_2 = 1.33$. We have,



$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

or $$\frac{1.33}{v} - \frac{1}{-40cm} = \frac{1.33 - 1}{-20cm}$$

or, $$\frac{1.33}{v} = -\frac{1}{40cm} - \frac{0.33}{20cm}$$ or,

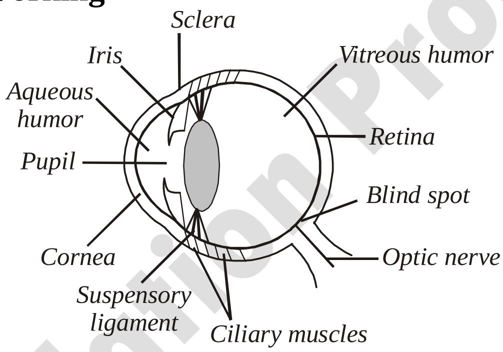
The magnification is $m = \frac{h_2}{h_1} = \frac{\mu_1 v}{\mu_2 u}$

or, $$\frac{h_2}{1.0cm} = \frac{-32cm}{1.33 \times (-40cm)}$$

or, $h_2 = +0.6cm$. The image is erect.

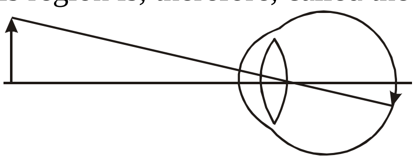
HUMAN EYE AND OPTICAL INSTRUMENTS AND COLOURFUL WORLD AROUND US :

- **Construction and Working**



- **Pupil** is the gateway of light interring the eye lens.
- **Iris** controls the size of the pupil.
- **Cilliary Muscles** changes the focal length of eye lens.
- **At retina** image is formed and then through optic nerves sent to the brain.

  The long fibres (or axons) of these nerve cells come together at a point on the retina to form an *optic nerve*. There are no rods or cones at the spot where the optic nerve leaves the eyeball. If an image is formed on this region of the retina, it is not sensed, and hence, the object is not seen. This region is, therefore, called the *blind spot* of the eye.



The image formed on the retina is much smaller than the object

- **Rod and cone cells :** These cells are found on the retina. Rod cells provides extra light and cone cells distinguish colour of light.

- **Far and Near Point**

  The fastest point up to which the eye can see properly is called the far point of the eye.

The closest point at which an object can be placed and seen clearly is called the near point of the eye. And, the distance of the closest point at which an object can be placed and seen clearly is called the least distance of distinct vision or least distance of clear vision. The standard value of distance of least distinct vision is taken as 25 cm.

- **Power of Accommodation**

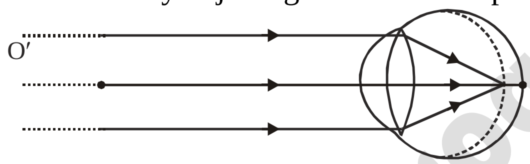
  The maximum variation in the power (1/f) of the eye–lens that can be achieved by the eye of a person is called its power of accommodation and its unit is Dioptre (D).

- **Defects of Vision**

  We shall look at three common defects of vision : near–sightedness, far–sightedness and presbyopia.

Near–sightedness (Myopia)

In certain people the eyeball becomes elongated or longer than the normal eye. As a result, the distance of the retina from the crystalline lens increases. Even for the maximum focal length of the eye–lens, i.e., when the ciliary muscles are most relaxed, parallel rays of light from faraway objects get focused at a point before the retina.

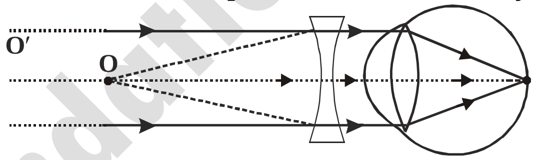


Myopic Eye

In some cases, the curvatures are such that the eye–lens has a shorter than focal length (more power) than usual. Thus, faraway objects cannot be seen clearly, although nearby objects can. This defect is called *near–sightedness, short–sightedness or myopia.*

Correcting Near–sightedness

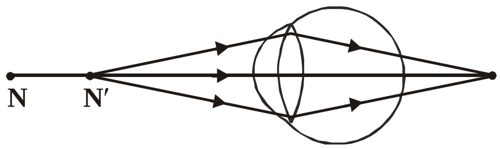
To correct this defect, concave lens is putted in front of the eye.



Correction for Myopia

Far–sightedness (Hypermetropia)

In certain people eyeball becomes shorter than that of the normal eye. As a result, the distance of the retina from the crystalline lens decrease. Even for the minimum focal length of the eye–lens, i.e., when the ciliary muscles are most contracted, a sharp image of a nearby object is not formed on the retina.

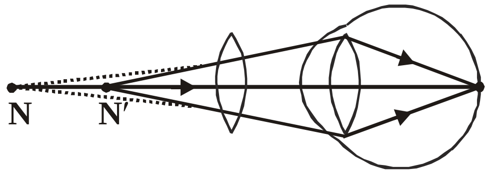


Hypermetropic Eye

Thus, nearby objects cannot be seen clearly, although faraway objects can. This defect is called *far–sightedness, long–sightedness, hypermetropia or hyperopia.*

Correcting Far–Sightedness

Suppose, the near point far an eye of a person sufferings from far–sightedness is at N′, which is kept farther away from the normal near point N.



Correction for Hypermetropic Eye

The rays coming from N′ form a sharp image on the retina when the focal length of the eye–lens is minimum. But rays coming from an object placed at the normal near point N′ (25 cm away) form an image being the retina.

Presbyopia

The power of accommodation of the eye usually decreases with ageing. For most people, the near point gradually recedes away. They find it difficult to see nearby objects comfortably and distinctly without corrective eye–glasses. This defect is called Presbyopia. It arises due to the gradual weakening of the ciliary muscles and diminishing flexibility of the eye lens. Such people often require bi–focal lenses. A common type of bi–focal lenses consists of both concave and convex lenses. The upper portion consists of a concave lens. It facilitates distant vision. The lower part is a convex lens. It facilitates near vision.

Formula for finding focal length of the correcting glass :

If f is the focal length of the required lens for correction of defect of eyes then,

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

where v is the distance where our eye is able to see.

And u is the distance that we want to see.

Illustration 16 :

A hypermetropic person whose near point is at 100 cm wants to read a book at 25 cm. Find the nature and power of the lens needed.

Sol. Here, u = –25 cm, v = – 100 cm, f = ?

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

$\therefore \frac{1}{f} = \frac{1}{25} - \frac{1}{100} = \frac{4-1}{100} = \frac{3}{100}$

f = $\frac{100}{3}\text{cm} = 33.3\,\text{cm}$.

P = $\frac{100}{f} = \frac{100}{100/3} = 3\,\text{dioptre}$.

Illustration 17 :

A person can see clearly only upto 3 metres. Prescribe a lens for his spectacles, so that he can see clearly upto 12 m.

Sol. Here, u = – 12 m, v = – 3m, f = ?

As $\frac{1}{f} = \frac{-1}{u} + \frac{1}{v} = \frac{1}{12} - \frac{1}{3} = \frac{1-4}{12} = -\frac{3}{12} = -\frac{1}{4}$

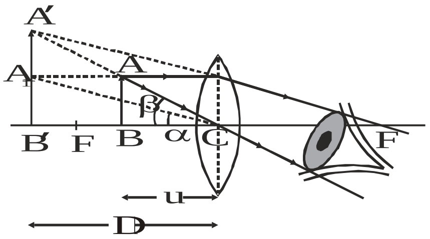
$\therefore$ f = – 4m = – 400 cm

Also, $P = \frac{100}{f} = \frac{100}{-400} = -0.25$ dioptre.

- **Simple Microscope or Magnifying Glass :**

  A simple microscope is used for observing magnified images of tiny objects. It consists of a converging lens of small focal length. A virtual, erect and magnified image of the object is formed at the least distance of distinct vision from the eye held close to the lens. That is why the simple microscope is also called a magnifying glass.

  The course of rays through a simple microscope is shown in figure.



Magnifying power of a simple microscope is defined as the ratio of the angles subtended by the image and the object on the eye, when both are at the least distance of distinct vision from the eye.

Its magnification can be expressed as,

$m = \left(1 + \frac{D}{f}\right)$ (for image at least distance of distinct vision)

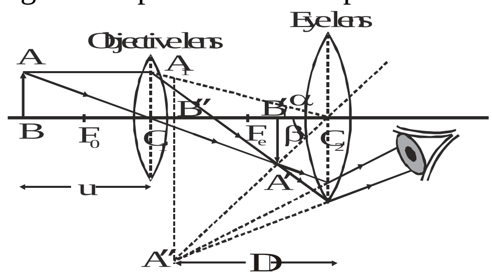
and $m = \frac{D}{f}$ (for image at infinity or for normal adjustment)

D = 25 cm (least distance of distinct vision for a normal eye)

- **Compound Microscope :**

  A compound microscope is an optical instrument used for observing highly magnified images of tiny objects.
- **Construction.** A compound microscope consists of two converging lenses (or lens systems); an objective lens O of very small focal length and short aperture and an eye piece E of moderate focal length and large aperture. The two lenses are held co–axially at the free ends of two coaxial tubes, at a suitable fixed distance from each other. The distance of the objective lens from the object can be adjusted by rack and pinion arrangement.

  The course of rays through a compound microscope is shown in figure.



- **Magnifying power** of a compound microscope is defined as the ratio of the angle subtended at the eye by the final image to the angle subtended at the eye by the object, when both the final image and the object are situated at the least distance of distinct vision from the eye.

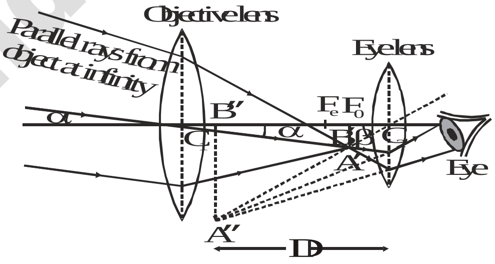
Its magnification can be expressed as,

$$m = \frac{L}{|f_0|}\left(1 + \frac{D}{f_e}\right)$$

where L = length of the tube.

- **Points to note :**
  (i) As magnifying power (m) is negative, the image seen in a microscope is always inverted i.e., upside down and left turned right.
  (ii) As intermediate image is between the two lenses, a cross–sire (or a meansuring scale) can be used.
  (iii) If final image in a microscope were at infinity (normal setting), equation would be
  $$m = \frac{LD}{f_0 f_e}$$
  (iv) For large magnifying power, f_0 and f_e both have to be small. Also, f_0 is taken to the smaller than f_e so that field of view may be increased.
  (v) As aperture of both the lenses in a microscope is small, the defects of images particularly, spherical aberration is minimized.

- **Astronomical Telescope :**
  An astronomical telescope is an optical instrument which is used for observing distinct images of heavenly bodies like starts, planets etc.
- **Construction :** It consists of two lenses (or lens systems), the objective lens O, which is of large focal length and large aperture and the eye piece E, which has a small focal length and small aperture. The two lenses are mounted co–axially at the free ends of the two tubes. The distance between these lenses can be adjusted using a rack and pinion arrangement.
  In **normal adjustment** of telescope, the final image is formed at infinity.
  The course of rays in normal adjustment of telescope is shown in figure.



- Its magnification can be expressed as,
  $$m = -\frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$$
  [When object is at infinity and image is at least distance of distinct vision (D)]
  $$m = \frac{f_0}{f_e}$$
- **Points to Note :**
  When both object and image are at infinitly at mnormal adjustment]
  (i) As magnifying power is negative, the final image in an astronomical telescope is inverted i.e., upside down and left turned right.

(ii) As intermediate image is between the two lenses, cross wire (or a measuring device) can be used.

(iii) In normal setting of telescope, final image is at infinity. Magnifying power is minimum.
When final image is at least distance of distinct vision, magnifying power is maximum. Thus

$$(M.P.)_{min} = -\left[\frac{f_0}{f_e}\right];$$

$$(M.P.)_{max} = -\frac{f_0}{f_e}\left(1-\frac{f_e}{D}\right)$$

(iv) To have large magnifying power, f_0 must be as large as possible and f_e must be as small as possible.

Illustration 18 :

A convex lens of focal length 5 cm is used as a simple microscope. What will be the magnifying power when the image is formed at the least distance of distinct vision?

Sol. Here, f = 5 cm, d = 25 cm, m = ?

$$m = \left(1+\frac{d}{f}\right) = \left(1+\frac{25}{5}\right) = 6.$$

Illustration 19 :

If we need a magnification of 375 from a compound microscope of tube length 15 cm and an objective of focal length 0.5 cm, what focal length of eye lens should be used?

Sol. M = – 375, L = 15 cm

f_0 = 0.5 cm, f_e = ? D = 25 cm

$$M = \frac{v_0}{-u_0}\left(1+\frac{D}{f_e}\right)$$

As focal length of objective lens is small $u_0 \approx f_0$.

Also, as focal length of eye lens is small, $v_0 \approx L$.

$$\therefore \quad M = \frac{L}{-f_0}\left(1+\frac{D}{f_e}\right) \Rightarrow -375 = \frac{15}{-0.5}\left(1+\frac{25}{f_e}\right)$$

$$\frac{25}{f_e} = \frac{375}{30} - 1 = 11.5;\ f_e = \frac{25}{11.5} = 2.2$$

Illustration 20 :

An astronomical telescope of magnifying power 7 consists of two thin lenses 40 cm apart, in normal adjustment. Calculate the focal lengths of the lenses.

Sol. Here, $M = \frac{f_0}{f_e} = 7$ for $f_0 = 7f_e$

In normal adjustment,

Distance between the lenses, $f_0 + f_e = 40$

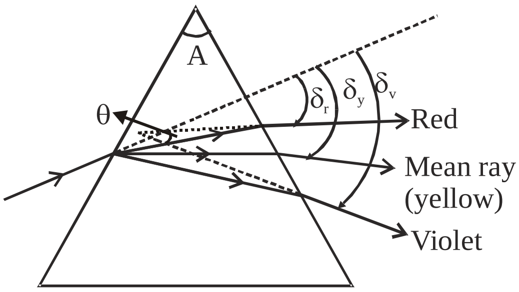
$$\therefore \quad 7f_e + f_e = 40,\ f_e = \frac{40}{8} = 5\,\text{cm}$$

$f_0 = 7f_e = 7 \times 5 = 35$ cm.

- **Dispersion of Light**

  The angular splitting of a ray of white light into a number of components and spreading in different direction is called dispersion of light.

  Angle of Dispersion :



Angle between the rays of the extreme colours in the refracted (dispersed) light is called angle of dispersion.

$\theta = \delta_v - \delta_r$

Dispersive power (w) of the medium of the material of prism is given by

$$\omega = \frac{\text{angular dispersion}}{\text{deviation of mean ray (yellow)}} = \frac{\theta}{\delta_y}$$

For small angled prism A ≤ 10°

$\delta_v = (n_v - 1)A \; \delta_R = (n_R - 1)A \quad \delta_y = (n_t - 1)A$

Here n_v, n_R and n_y refractive index of material for violet, red and yellow colours respectively.

$$\omega = \frac{\delta_y - \delta_R}{\delta_y} = \frac{(n_v - n_R)}{(n_y - 1)}$$

If n_y is not given in the problem then take $n_y = \frac{n_v + n_R}{2}$

Cause of Dispersion :

A glass medium offers different refractive indices to different components of light.

Dependence of μ on λ according to cauchy's formula $\mu(\lambda) = a + \frac{b}{\lambda^2}$.

Illustration 21 :

Find the dispersive power of flint glass. The refractive indices of flint glass for red, yellow and violet light are 1.613, 1.620 and 1.632 respectively.

Sol. The dispersive power is $\omega = \frac{\mu_0 - \mu_r}{\mu - 1} = \frac{1.632 - 1.613}{1.620 - 1} = 0.306$.

- **Atmospheric Refraction and Optical Phenomena :**

  The refractive index of air depends on its density – higher the density of air, greater its refractive index. Under standard conditions of temperature, humidity, etc., near the earth's surface, the refractive index of air has a value that is slightly greater than 1. Since density of air decreases with height above the earth's surface, the refractive index of air also decreases with height, and is very close to 1 in the outermost region of the atmosphere.

Due to atmospheric refraction,

- A planet or star appears little above our horizon. That is why Sun appears before it rises actually.
- Stars twinkle. But planets do not twinkle as they appear as large source of light and much closer as compare to star, to our eye.
- **Tyndall Effect**

  The earth's atmosphere is a heterogeneous mixture of minute particle. These particle include smoke, tiny water droplets, suspended particle of dust and molecules of air. When a beam of light strikes such fine particles, the path of the beam becomes visible. The light reaching us, after being reflected diffusely by these particles. The phenomenon of scattering of light by the colloidal particle give rise to Tyndall effect.

  The colour of the scattered light depends on the size of the scattering particle. Very fine particles scatter mainly blue light while particles of larger size scatter light of longer wavelength. If the size of the scattering particles is larger enough, then, the scattered light may even appear white.

- **Scattering of Light**

  The path of a beam of light passing through a true solution is not visible. However its path becomes visible through a colloidal solution where the size of the particles are relatively larger. When light passes through atmosphere, the components of light with high frequencies strike the atmospheric particles and get deviated from their direction of propagation. This phenomenon is known as scattering of light. According to a scientist, Rayleigh, the angle of deviation in this process increases with the increase in frequency.

Due to scattering of light :

- Sky and Sea appears Blue.
- Colour of the Sun at time of rise and set appears red.
- Clouds appear white.
- **Formation of Rainbow**

  Rainbow is formed because of the optical events known as refraction, total internal reflection and dispersion of light.

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KEY POINTS

- **For reflection** $\angle i = \angle r$
- **For spherical mirror** $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

  and $m = -\frac{v}{u}$.
- **Laws of refraction**

  $\mu_{21} = \frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} = \frac{c_1}{c_2} = \frac{\lambda_1}{\lambda_2}$.
- **Refractive index of the medium relative of vacuum** $= \sqrt{\mu_r \in_r}$
- **Deviation (d) of ray incident at** $\angle i$ **and refracted at** $\angle r$ is given by $\delta = |i - r|$
- **Principle of Reversibility of light Rays.**

  ${}_1\mu_2 = \frac{1}{{}_2\mu_1}$
- **For refraction through a parallel slab the lateral displacement**

  $d = \frac{t \sin(i - r)}{\cos r}$
- **For submerged object**

  Apparent shift $= d\left(1 - \frac{1}{n_{rel}}\right)$
- **Refraction through a composite slab**

  Apparent shift $= t_1\left[1 - \frac{1}{n_{1rel}}\right] + t_2\left[1 - \frac{1}{n_{2rel}}\right] + ... + \left[1 - \frac{n}{n_{n\,rel}}\right]t_n$
- **Critical Angle and Total Internal Reflection (T.I.R.).**

  $C = \sin^{-1}\frac{n_r}{n_d}$
- **For refraction through prism, angle of deviation.**

  $\delta = (\mu - 1)A$

  At the minimum deviation $\mu = \sin\left(\frac{A + \delta m}{2}\right) / \sin\frac{A}{2}$

  For lens $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ and $m = \frac{v}{u}$

  Lens Makers formula : $\frac{1}{f} = \left(\frac{\mu}{\mu_s} - 1\right)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$
- **Cauchy's formula.**

  $n(\lambda) = a + \frac{b}{\lambda^2}$

- **Dispersive power**

$$\omega = \frac{n_v - n_r}{n_y - 1}$$

- **Spherical Surfaces**

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

- **Transverse magnification**

$$m = \frac{v - R}{u - R} = \left(\frac{v/\mu_2}{u/\mu_1}\right)$$

- **Refraction at plane Surface**

$$v = \frac{\mu_2 u}{\mu_1}$$

- For a spherical, thin lens having the same medium on both sides.

$$\frac{1}{v} - \frac{1}{u} = \frac{\mu_m}{\mu_s}\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \qquad \ldots(a)$$

when $\mu_{rel} = \frac{\mu_{lens}}{\mu_{medium}}$

- **Transverse magnification (m)**

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

- **Lens formula**

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

- The equivalent focal length of thin lenses in contact is given by

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3}$$

- The combination of lens and mirror behaves like a mirror of focal length 'f' given by

$$\frac{1}{f} = \frac{1}{F_m} - \frac{2}{F_\ell}$$

ASSIGNMENT

Week 17 : Worksheet

1. A light ray is made to incident on a glass plate with angle of incidence 15ºand then reflected. Then the angle of deviation is
(A) 45º (B) 130°
(C) 150° (D) 90°

2. The angle between incident ray and reflected ray is 70º. What is the angle of incidence ?
(A) 45º (B) 30º
(C) 55º (D) 35º

3. How will you arrange the two mirrors so that whatever may be the angle of incidence, the incident ray and the reflected ray from the two mirrors will be parallel to each other ?
(A) 90º (B) 45º
(C) 60º (D) 180º

4. Two plane mirrors are inclined to each other at an angle . . A ray of light is reflected first at one mirror and then at the other.
(A) the total deviation of ray is 360º
(B) the total deviation produced by system of mirrors is independent of the angle of incidence on the first mirror
(C) the total deviation produced by system of mirrors depends upon the angle which the two mirror are inclined to each other.
(D) the total deviation of ray is always 90º.

5. Light is focused on the compound wall of a building with the help of vertical plane mirror. A small boy came and rotate the plane mirror with an angle of o 30 clock wise then what happens to the reflected beam when a mirror is rotated by 30º ?
(A) remains fixed (B) rotates by 15º
(C) rotates by 60º (D) rotates by 90º

6. In question no. 5 above, what happens to the normal when a mirror is rotated by 40º ?
(A) remains fixed (B) rotates by 15º
(C) rotates by 60º (D) rotates by 40º

7. In question no. 5 above, what happens to the incident angle when a mirror is rotated by 15º ?
(A) remains fixed (B) increases by 15º
(C) rotates by 60º (D) rotates by 40º

8. A light ray is made to incident on a glass plate with an angle of incidence 30º. Find the angle of reflection is
(A) 60º (B) 30º
(C) 90º (D) 0º

9. The two mirrors are inclined at an angle 90º. If a ray of light is obliquely incident on the first mirror, the deviation after two reflections is
   (A) 180º (B) 300º
   (C) 90º (D) 60º

10. A ray of light, after reflection from a plane mirror, suffers a deviation of 60º. Find the angle between the incident and reflected rays.
   (A) 130º (B) 120º
   (C) 145º (D) 60º

Week 18 : Worksheet

1. The diameter of spherical mirror in which reflection takes place is called
   (A) radius of curvature (B) centre of curvature
   (C) linear aperture. (D) focal length.

2. The image formed by a convex mirror of real object is larger than the object.
   (A) When $u < 2f$ (B) When $u > 2f$
   (C) for all values of u (D) for no value of u

3. When object is placed between principal focus and pole for a concave mirror the image is formed at
   (A) pole (B) principal focus
   (C) centre of curvature (D) behind the mirror

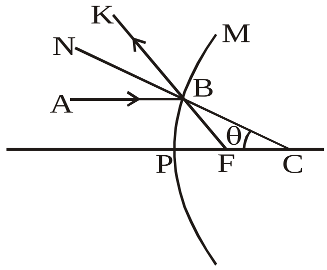
4. Which of the following forms a virtual and erect image for all positions of a real object with a greater field of view
   (A) plane mirror (B) convex mirror.
   (C) concave mirror (D) all the above

5. The point on the mirror at middle of spherical surface is
   (A) pole (B) principal axis
   (C) center of curvature (D) radius of curvature.

6. The line passing through pole and center of curvature is
   (A) pole (B) principal axis
   (C) center of curvature (D) radius of curvature.

7. The center of the hollow sphere for which the mirror is a part is
   (A) pole (B) principal axis
   (C) centre of curvature (D) radius of curvature

8. In the Figure, AB and BK represent incident and reflected rays. If angle BCF = 35º. Then ∠BFP. will be equal to ____ degrees.



(A) 70º (B) 35º
(C) 80º (D) 90º

9. A convex mirror has its radius of curvature 30cm. Find the position of the image of an object placed at a distance of 18cm from the mirror

(A) $\frac{50}{11}$cm (B) $\frac{60}{11}$cm
(C) $\frac{90}{11}$cm (D) 90 cm.

10. A ray falls at the pole of convex mirror at an angle 30º with the principal axis. The angle between the reflected ray and principle axis will be

(A) 60º (B) 15º
(C) 30º (D) not predictable.

Week 19 : Worksheet 1

1. For a concave mirror, whenever the distance of object is less than the focal length, the image is virtual. That is called virtual image, because

(A) the image is formed behind the mirror
(B) the image is not inverted
(C) the image cannot be obtained on a screen
(D) the image can be located by virtue of parallax.

2. In case of concave mirror, the minimum distance between a real object and its real image is

(A) f (B) 2f
(C) 4f (D) zero.

3. For a spherical mirror, the paraxial ray is the ray which

(A) coincides with the principal axis (B) is near the principal axis
(C) is far away from the principal axis (D) is normal to the principal axis.

4. A virtual image larger than a real object can be produced by

(A) convex mirror (B) concave mirror
(C) plane mirror (D) none of these.

5. The focal length and magnification of a plane mirror are

(A) $f = \infty, m = 0$ (B) $f = 0, m = 1$
(C) $f = \infty, m = 1$ (D) $f = 0, m = 0$.

6. Mark the wrong statement about a virtual image
   (A) a virtual image can be photographed
   (B) a virtual image can be seen
   (C) a virtual image can be photographed by exposing a film at the location of the image
   (D) a virtual image may be diminished or enlarged in size in comparison to an object.

7. Which one of the following can produce a parallel beam of light from a point source of light ?
   (A) concave mirror (B) convex mirror
   (C) plane mirror (D) concave lens.

8. A convex mirror has a focal length f. A real object placed at a distance f in front of it from the pole, produces an image at
   (A) ∞ (B) f
   (C) f/2 (D) 2f.

9. In a concave mirror an object is placed at a distance x_1 from the focus and the image is formed at a distance x_2 from the focus. Then the focal length of the mirror is
   (A) x_1x_2 (B) $\sqrt{x_1x_2}$
   (C) $(x_1 + x_2)/2$ (D) $\sqrt{x_1 / x_2}$.

10. A concave mirror of focal length f produces an image n times the size of the object. If the image is real, then the distance of the object from the mirror is
   (A) (n – 1) f (B) [(n – 1)/n] f
   (C) [(n + 1)/n] f (D) (n + 1) f.

Week 20 : Worksheet

1. The velocity of light in air is $3 \times 10\ ms^{-1}$ and in glass is $2 \times 10\ ms^{-1}$. The refractive index of glass w.r.t air is
   (A) 2/3 (B) 3/2
   (C) 4/3 (D) 9/4.

2. The refractive index of glass and water w.r.t air are 3/2 and 4/3. The refractive index of glass w.r.t water is
   (A) 3/2 (B) 2/3
   (C) 3/4 (D) 9/8

3. When light travels from rarer medium to denser medium
   (A) Refracted ray bends towards normal (B) Refracted ray bends away from normal
   (C) Ray undeviated from path (D) We cannot identified the ray.

4. When light ray travels from denser medium to rarer medium
   (A) Refracted ray bends towards normal (B) Refracted ray bends away from normal
   (C) Ray undeviated from path (D) We cannot identified the ray.

5. An object in a denser medium appears nearer as seen from rarer medium. Then the refractive index of denser medium is

(A) $\frac{\sin r}{\sin i}$ (B) $\frac{\tan r}{\tan i}$

(C) $\frac{\text{real depth}}{\text{apparent depth}}$ (D) $\frac{\text{apparent depth}}{\text{real depth}}$.

6. Let a ray of light be incident on a parallel glass plate of thickness 8cm at an angle 60º. The refracted angle is o 30º. The emergent ray does not under go deviation and dispersion but shifts laterally and travel parallel to the direction of incident ray. The normal distance between incident and emergent rays is lateral shift. The speed of light is $2 \times 10\ ms^{-1}$ in the glass then the distance AB is

(A) $\frac{8}{\sqrt{3}}$cm (B) $\frac{16}{\sqrt{3}}$cm

(C) $\frac{24}{\sqrt{3}}$cm (D) $\frac{32}{\sqrt{3}}$cm.

7. In question no. 6 above, the lateral shift is

(A) $\frac{8}{\sqrt{3}}$cm (B) $\frac{16}{\sqrt{3}}$cm

(C) $\frac{24}{\sqrt{3}}$cm (D) $\frac{32}{\sqrt{3}}$cm.

8. In question no. 6 above, the time taken to cover the distance AB inside the slab is ______ $\times 10^{-8}$ s.

(A) $\frac{8}{\sqrt{3}}$cm (B) $\frac{16}{\sqrt{3}}$cm

(C) $\frac{24}{\sqrt{3}}$cm (D) $\frac{32}{\sqrt{3}}$cm.

9. A beaker of depth 10cm is filled with a liquid of refractive index 4/3 upto a depth of 6cm and remaining depth is filled with a liquid of refractive index 6/5. The apparent depth of the beaker when observed normally is

(A) 9.8 cm (B) 8.8cm

(C) 7.8cm (D) 6.8 cm

10. A travelling microscope is focussed on to a point on the bottom of a vessel. A liquid whose refractive index is $\frac{6}{5}$ is poured in it. The microscope is lifted to 6cm to focus it again. The depth of the liquid in the vessel is

(A) 18cm (B) 36cm

(C) 9cm (D) 24cm

Week 21 : Worksheet

1. If the temperature of the medium increases, then the critical angle is
(A) Increases (B) Decreases
(C) Remains same (D) First increases then decreases

2. The critical angle for a ray of light suffering total internal reflection will be smallest for light travelling from
(A) water to air (B) glass to air
(C) glass to water (D) water to glass

3. The phenomenon of total internal reflection does play the role in the
(A) formation of rainbow (B) sparkling of diamond
(C) phenomenon of mirage (D) all the above

4. Total Internal reflection is the reason of
(A) Brilliancy of a diamond (B) Shining of small air bubble in water
(C) Formation of looming in cold countries (D) all of the above.

5. Ratio of wavelengths of light passing from one medium to another is 4 : 5. Then the ratio of the speeds of the light in two media is:
(A) 4 : 5 (B) 5 : 4
(C) $\sqrt{5}$: 2 (D) 2 : $\sqrt{5}$

6. When light travels from one medium to other the refractive index is different then which of the following will change ?
(A) frequency, wavelength and velocity (B) frequency and wavelength
(C) frequency and velocity (D) wavelength and velocity.

7. The critical angle of light passing from glass to air is minimum for
(A) red (B) green
(C) yellow (D) violet.

8. Critical angle for a medium is 45º. Its refractive index is
(A) $\sqrt{2}$ (B) $\frac{1}{\sqrt{2}}$
(C) $\sqrt{3}$ (D) $\frac{1}{\sqrt{3}}$.

9. Refractive index of a medium is 2. Its critical angle is
(A) 60º (B) 30º
(C) 40º (D) 50º.

10. Refractive index of a medium is $\frac{2}{\sqrt{3}}$. Its critical angle will be
(A) 45º (B) 60º
(C) 30º (D) 90º.

Week 22 : Worksheet

1. In the case of equilateral glass prism, refractive index of the material of the prism is $\sqrt{2}$. The angle of minimum deviation is
   (A) 60º (B) 30º
   (C) 45º (D) ( ) $\sin^{-1}(\sqrt{2})$

2. A ray of light passes through an equilateral glass prism, such that the angle of incidence is equal to the angle of emergence. If the angle of emergence is $\frac{3}{4}$ times the angle of the prism. The refractive index of the glass prism is
   (A) 1.71 (B) 1.61
   (C) 1.41 (D) 1.21

3. The maximum value of index of refraction of a material of prism which allows the passage of light through it when the refracting angle of prism A is
   (A) $\sqrt{1+\tan^2\frac{A}{2}}$ (B) $\sqrt{1+\cot^2\frac{A}{2}}$
   (C) $\sqrt{1+\cos^2\frac{A}{2}}$ (D) $\sqrt{1+\sin^2\frac{A}{2}}$.

4. A prism with less than ____________ degrees is called small angled prism.
   (A) 10º (B) 20º
   (C) 15º (D) 30º.

5. In the case of equilateral glass prism, refractive index of the material of the prism is $\sqrt{2}$. The angle of minimum deviation is
   (A) 60º (B) 30º
   (C) 45º (D) $\sin^{-1}\left(\sqrt{2}\right)$.

6. A ray of light is incident on one of the refracting surfaces of an equilateral prism, at an angle of incidence 48º in the minimum deviation position, deviation produced by the prism is
   (A) 48º (B) 36º
   (C) 24º (D) 18º

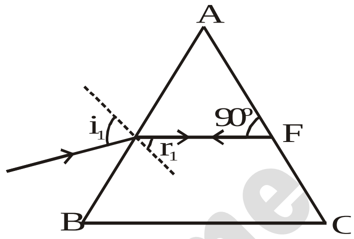
7. A ray is incident at an angle of incidence i on one surface of prism of small angle A. The refractive index of the material of the prism is ?. The angle of incidence is nearly equal to
   (A) $\frac{A}{2\mu_0}$ (B) $\frac{\mu A}{2}$
   (C) $\frac{A}{\mu}$ (D) μA.

8. The deviation of a ray through a prism is related to the angle of prism as

(A) $\delta = (\mu - 1)\,A$ (B) $\delta = (A - 1)\,\mu$

(C) $\delta = (1 - \mu)\,A$ (A) $A = (\mu - 1)\,\delta$.

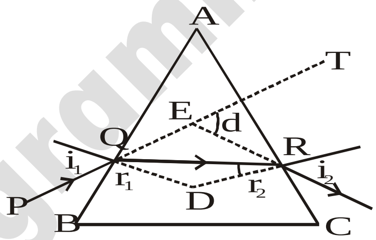
9. The side AC of a glass prism of refractive index 1.5 is silvered. A ray of light falls on the face AB such that it retraces its path. What is the angle of incidence, if the angle of the prism is 35º. (sin 35º = 0.574) $\sin^{-1}(0.86) = 59.4^\circ$



(A) 59.4º (B) 64.6º

(C) 35º (D) 72º.

10. When the prism is in the minimum deviation position (Figure). Choose the correct one.



(A) $i_1 = i_2 = I$ and $r_1 = r = r$

(B) Angle of minimum deviation is. Dm=2 (i-A)

(C) Angle of incident $i = \frac{A + D_m}{4}$

(D) Angle of refraction r = A/4

Week 23 : Worksheet

1. A double convex air bubble in water would behave as a

(A) convergent lens (B) circle

(C) divergent lens (D) plane mirror.

2. The distance between the optical centre and the principal focus is

(A) focal length (B) object distance

(C) image distance (D) foci

3. The graph drawn with object distance along x-coordinate and image (real) distance as y-coordinate for a convex is a

(A) straight line (B) circle

(C) parabola (D) rectangular hyperbola

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

(A) equal to unity (B) equal to 1.33

(C) between unit and 1.33 (D) greater than 1.33

5. When the lens is thin and radii of cunvature of two refracting surface are equal then the geometric centre of the lens becomes.

(A) principal focus (B) optical center

(C) front vertex (D) back vertex

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

(A) 1.5f (B) 2f

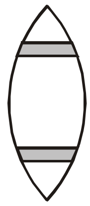
(C) 2.5f (D) 4f

7. The maximum image distance in the case of a concave lens is
(A) f (B) 4f
(C) infinity (D) 2f

8. A thin lens produces an image of the same size as the object. Then from the optical centre of the lens, the distance of the object is
(A) zero (B) 4f
(C) 2f (D) f/2

9. The focal length of a convex lens is maximum for
(A) ultraviolet rays (B) violet
(C) yellow (D) red rays

10. A layered lens as shown in the figure is made of two materials indicated by different shades. A point object is placed on its axis. The lens will form.



(A) one image (B) two images
(C) five images (D) three images

Week 24 : Worksheet

1. Lens makers formula is valid only for
(A) Paraxial rays & thin lens (B) Paraxial rays & thick lens
(C) marginal rays & thin lens (D) marginal rays & thick lens

2. A biconvex lens has radii of curvature 20cm each. If the refractive index of the material of the lens is 1.5. Its focal length is
(A) 20cm (B) 10cm
(C) 30cm (D) 15cm

3. A convex lens of focal length 24cm (μ =1.5) is totally immerged in water (μ =1.33) then its focal length in water.
(A) 100cm (B) 96cm
(C) 92cm (D) 120cm

4. Decreasing the radii of the two surfaces of a double convex or double concave lens
(A) increases its focal length
(B) decreases its focal length
(C) neither increases nor decreases the focal length
(D) increases or decreases

5. A diverging meniscus lens of radii of curvatures 25cm and 50cm has a refractive index 1.5. It focal length is (in cm)
(A) –50 (B) -100
(C) 100 (D) 50

6. Two thin lenses of focal lengths 1 f and 2 f are in contact and coaxial. The combination is equivalent to a single lens of power

(A) $\frac{f_1 f_2}{f_1 + f_2}$
(B) $\frac{1}{2}(f_1 + f_2)$
(C) $\frac{f_1 + f_2}{f_1 f_2}$
(D) $\sqrt{f_1 f_2}$.

7. Two thin convex lenses of focal length f_1 and f_2 are placed with a distance d between them for the power of the combination to be zero, the separation d is.

(A) $f_1 - f_2$
(B) $f_1 + f_2$
(C) f_1 / f_2
(D) $\sqrt{f_1 f_2}$

8. The focal power of a convergent lens of focal length 12.5cm is

(A) +8D
(B) +6D
(C) +7D
(D) +12.5D

9. Two lenses of power +8 and -3 dioptres are placed in contact, then the power of the combination is

(A) +2D
(B) +5D
(C) +4D
(D) +6D

10. A convex lens of glass is immersed in water compared to its power in air, its power in water will

(A) increases
(B) decrease
(C) not change
(D) decrease for red light increase for a violet light and power P

Week 25 : Worksheet

1. When light ray passes rarer medium (μ_1) into denser medium (μ_2), the object distance (u) and image distance (v) then the radius of curvature (R) of the concave refracting surface

(A) $\frac{(\mu_2 - \mu_1)uv}{\mu_2 u - v\mu_1}$
(B) $\frac{\mu_2 u - v\mu_1}{(\mu_2 - \mu_1)uv}$
(C) $\frac{(\mu_1 - \mu_2)uv}{v\mu_1 - u\mu_2}$
(D) $\frac{vu_1 - u\mu_2}{(\mu_1 - \mu_2)uv}$.

2. A denser medium of refractive index 1.5 has a concave surface of radius of curvature 12 cm. An object is situated in the denser medium at a distance of 9 cm from the pole. Locate the image due to refraction in air.

(A) A real image at 8 cm
(B) A virtual image at 8 cm
(C) A real image at 4.8 cm
(D) A virtual image at 4.8 cm

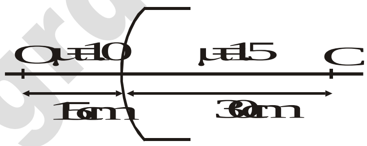
3. In a medium of refractive index 1.6 and having a convex surface has a point object in it at a distance of 12 cm from the pole. The radius of curvature is 6 cm. Locate the image as seen from air.

(A) A real image at 30 cm (B) A virtual image at 30 cm
(C) A real image at 4.28 cm (D) A virtual image at 4.28 cm

4. A sunshine recorder globe of 20 cm diameter is made of glass of μ = 1.5. A ray enters the globe parallel to the axis. Find the position from the centre of the sphere where the ray crosses the axis.
(A) 15 cm (B) 17 cm
(C) 16 cm (D) 10 cm.

5. A convex refracting surface of radius of curvature 20 cm separates two media of refractive indices 4/3 and 1.60. An object is placed in the first medium (μ = 4/3) at a distance of 200 cm from the refracting surface. Calculate the position of image formed.
(A) at 234.15 cm in rarer media (B) at 234.15 cm in denser media
(C) at 238.15 cm in rarer media (D) at 238.20 cm in rarer media.

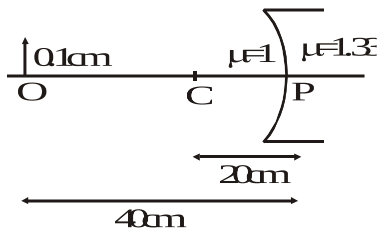
6. Locate the image of the point object O in the situation shown in figure. The point C denotes the centre of curvature of the separating surface.



(A) –30 cm (B) –20 cm
(C) ∞ (D) –40 cm.

7. One end of a horizontal cylindrical glass rod (μ = 1.5) of radius 5 cm is rounded in the shape of a hemisphere. An object 0.5 mm high is placed perpendicular to the axis of the rod at a distance of 20 cm from the rounded edge. Locate the image of the object and find its height.
(A) 20 cm; 10 mm (B) 30 cm; 0.5 mm
(C) 20 cm; 5 mm (D) 30 cm; 1 mm.

8. Find the size of image formed in the situation shown in figure.



(A) 0.5 cm (B) 0.4 cm
(C) 0.8 cm (D) 0.6 cm.

9. A sphere of glass (μ = 1.5) is of 20 cm diameter. A parallel beam enters it from one side. Where will it get focused on the other side ?
(A) 6 cm (B) 4 cm
(C) 8 cm (D) 5 cm.

10. A glass sphere of 15 cm radius has a small bubble 6 cm from the centre. The bubble is seen along a diameter of the sphere from the side on which it lies. How far from the surface will it appear to be, if refractive index of glass is 1.5 ?
(A) –7.2 cm (B) –7.4 cm
(C) –7.5 cm (D) –7.7 cm.

Week 26 : Worksheet

1. Far sighted people who have lost their spectacles can still read a book by looking through a small hole in a street of paper, this is because
(A) in doing so the focal length of the eye is effectively increased
(B) in doing so the focal length of the eye effectively increased
(C) in doing so the distance of the object increased
(D) the pin hole produces an image of letters at a longer distance

2. A myopic person cannot see objects lying beyond 2m. The focal length and power of the lens required to remove this defect will be
(A) 1m and 0.5D (B) −2m and −0.5D
(C) 0.5m and 0.5D (D) −0.5 and 0.5D

3. The power of the lens, a short sighted person uses is 2 dioptre. The maximum distance of an object which he can see without spectacle is
(A) 25 cm (B) 50 cm
(C) 100 cm (D) 10 cm

4. For a person suffering from a combination of astigmatism and myopia the type of glasses, that must be used to correct vision is
(A) Plano convex (B) Plano concave
(C) Plano spherical (D) Sphero cylindrical

5. Colour blindness can be cured by using
(A) cancave lesn (B) canvex lens
(C) spherical lens (D) not curable at all

6. The near point and the far point of a child are at 10 cm and 100 cm respectively. If the retina is 2 cm behind the eye lens,
The lower range of the power of the eye lens is
(A) 40D (B) 51D
(C) 60D (D) 55D

7. The upper range of the power of the eye lens in the above question no. 6 is
(A) 60D (B) 55D
(C) 40D (D) 31D

8. Range of the power of the eye lens in the above question no. 6 is
(A) 40D −51D (B) 51D −60D
(C) 55D −60D (D) 31D−40D.

9. A person cannot see beyond 100 cm. He should use a glass of power,
(A) –1 D (B) +1 D
(C) –2 D (D) +2 D.

10. The near point of a person is 100 cm. The power of the lens that can be prescribed for him is
(A) 3D (B) 4D
(C) –2D (D) 2D.

Week 27 : Worksheet

1. To obtain maximum magnification with a simple microscope where should the eye be placed.
(A) close to lens
(B) half way between focus and optical centre
(C) close to the focus
(D) away from lens

2. To obtain a magnified image at distance of distinct vision with a simple microscope where should the object be placed
(A) away from focus (B) at focus
(C) between focus and optical centre (D) Both (A) and (B)

3. In simple microscope the magnifying power (MP) is
(A) MP=0
(B) $MP = \frac{\text{visual angle with instrument}}{\text{maximum visual angle for unaided eye}}$
(C) $MP = \frac{\text{maximum visual angle for unaided eye}}{\text{visual angle with instrument}}$
(D) Both (A) and (C)

4. The focal length of a converging lens is 8 cm. Then its magnifying power when it is used as a reading lens to form the image at near point
(A) 4.125 (B) 3.125
(C) 2.125 (D) 5.125

5. The focal length of a magnifier is 5 cm then the magnifying power of a lens relaxed eye (far point) is
(A) 20 (B) 25
(C) 5 (D) 10

6. Magnifying power of a simple microscope increases by
(A) increase in focal length (B) decrease in focal length
(C) increase the size of object (D) Both (B) and (C)

7. For which of the following colour, the magnifying power of a microscope will be maximum
(A) green (B) red
(C) violet (D) yellow

8. When the length of a microscope tube increases, its magnifying power
(A) decreases (B) increases
(C) does not change (D) may decrease or increase

9. A compound microscope is of magnifying power 100. The magnifying power of its eyepiece is 4. Find the magnification of its objective ?
(A) 4 (B) –25
(C) 0.04 (D) –50

10. The objective of a compound microscope is essentially
(A) concave lens of large focal length and small aperture
(B) convex lens of small focal length and large aperture
(C) convex lens of large focal length and large aperture
(D) convex lens of small focal length and small aperture

Week 28 : Worksheet

1. Atmospheric refraction is due to
(A) changing pressure in the atmosphere (B) varying density of atmosphere
(C) varying temperature of the atmosphere (D) both (B) and (C).

2. The sun appears red during set and rise due to
(A) scattering of light (B) atmospheric refraction
(C) dispersion (D) total internal reflection.

3. The sun is seen before it comes to our horizon because
(A) scattering of light (B) atmospheric refraction
(C) dispersion (D) total internal reflection.

4. When sunrays enter through window in the early morning the path of the light ray becomes visible when dust or smoke come on its way. This is known as
(A) scattering of light (B) tyndall effect
(C) dispersion (D) refaction of light.

5. The rainbow is formed due to
(A) dispersion and refraction
(B) scattering and refraction
(C) dispersion and scattering
(D) reflection total internal reflection and dispersion of light

6. Twinkling of stars occurs due to
(A) scattering of light (B) atmospheric refraction
(C) dispersion (D) total internal reflection.

7. The sky is blue because of,
(A) scattering of light (B) atmospheric refraction
(C) dispersion (D) total internal reflection.

8. Sea appears blue because of
(A) scattering of light (B) atmospheric refraction
(C) dispersion (D) total internal reflection.

9. The sun appears bigger during rise and set
   (A) scattering of light
   (B) atmospheric refraction
   (C) dispersion
   (D) total internal reflection.

10. The scattering of components of light is directly proportional to its
    (A) frequency
    (B) amplitude
    (C) velocity
    (D) colour.

KEY

Ray Optics

ASSIGNMENT

Week 17; Worksheet

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

Week 18; Worksheet

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

Week 19; Worksheet

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

Week 20; Worksheet

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

Week 21; Worksheet

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

Week 22; Worksheet

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

Week 23; Worksheet

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

Week 24; Worksheet

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

Week 25; Worksheet

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

Week 26; Worksheet

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

Week 27; Worksheet

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

Week 28; Worksheet

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

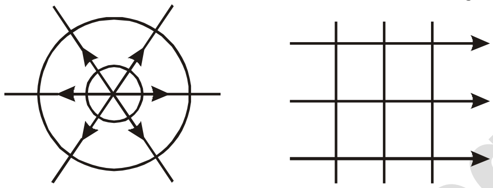
WAVE OPTICS

➢ HUYGEN'S PRINCIPLE

• Wavefronts and Rays

A wavefront is defined as a surface joining the points of same phase. The speed with which the wavefront moves outwards from the source is called the phase velocity or wave velocity. The energy of the wave moves in a direction perpendicular to the wavefront.

Figure shows light waves emitting out from a point source forming a spherical wavefront in three dimensional space. The energy travels outwards along straight lines emerging from the source, along radii of the spherical wavefront These lines are called the rays.



(a) (b)

Important

- ❖ Rays are perpendicular to wavefronts
- ❖ The time taken by light to travel from one wavefront to another is the same along any line.

Huygen's Principle

- ❖ Every point on a wavefront vibrates in same phase and with same frequency
- ❖ Every point on a wavefront acts like a secondary source and sends out a spherical wave, called a secondary wavelet.
- ❖ Wavefronts move in space with the velocity of wave in that medium.

• SUPERPOSITION PRINCIPLE

The phenomena of interference is based on the principle of superposition. It states that the instantaneous optical disturbance at a point, where two or more light waves overlap, is the sum of the optical disturbances that would be produced by each of the waves separately.

• COHERENT SOURCES

Two source are said to be coherent if they have the same frequency and the phase relationship remains constant and independent of time. In this case, the total intensity I is not just the sum of individual intensities I_1 and I_2 due to two sources but also includes an interference term whose magnitude depends on the phase difference at a given point.

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

where ϕ is the phase difference between the two sources and $2\sqrt{I_1 I_2}\cos\phi$ is called as interference term.

- **INCOHERENT SOURCES**

Two sources are said to be incoherent if they have different frequency and phase different is not constant with respect to time. In this case the $2\sqrt{I_1 I_2}\cos\phi$ averaged over a cycle is zero.

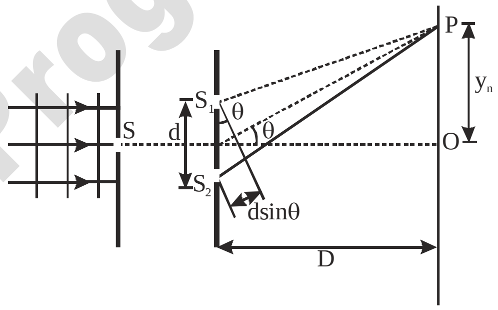
For such incoherent sources $I = I_1 + I_2$.

➢ **INTERFERENCE . YOUNG'S DOUBLE SLIT EXPERIMENT**

It was carried out in 1802 by the English scientist Thomas Young to prove the wave nature of light.

Two slits S_1 and S_2 are made in an opaque screen, parallel and very close to each other. These two are illuminated by another narrow slits S and light fall on both S_1 and S_2 which behave like coherent sources. Note that the coherent sources are derived from the same source. In this way, any phase change which occurs in S will occur in both S_1 and S_2. The phase difference $(\phi_1 - \phi_2)$ between S_1 and S_2 is unaffected and remains constant.

Light now spreads out from both S_1 and S_2 and falls on a screen. It is essential that the waves from the two sources overlap on the same part of the screen. If one slit is covered up, the other produces a wide smoothly illuminated patch on the screen. But when both slits are open, the patch is seen to be crossed by dark and bright bands called interference fringes. This redistribution of intensity, pattern is called interference pattern.



Schematic arrangement of YDSE

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

where is the phase difference and I is the resultant intensity.

Condition for bright fringes or maxima,

$$\phi = 2n\pi$$

or path difference, $p = n\lambda$ where n = 0, 1, 2, …….

$$I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$$

Condition for dark fringes or minima,

$$\phi = (2n-1)\pi$$

or path difference $p = \left(n - \frac{1}{2}\right)\lambda$, where n = 1, 2, 3, …….

$$I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$$

[The relation between phase difference (ϕ) and path difference (p) is given by

$$\phi = \frac{2\pi}{\lambda} p$$]

How to find the Position of the nth Maxima or Minima on the Screen ?

Let P be the position of the nth maxima on the screen. The two waves arriving at P follow the path S_1P and S_2P, thus the path difference between the two waves is

$$p = S_1P - S_2P = d\sin\theta$$

From experimental conditions, we know that D >> d, therefore, the angle is small,

Thus $\sin\theta \approx \tan\theta = \frac{y_n}{D}$

$\therefore \quad p = d\sin\theta = d\tan\theta = d\left(\frac{y_n}{D}\right) \Rightarrow \quad y_n = pD/d$

For nth maxima

$p = n\lambda$

$\therefore \quad y_n = n\lambda\frac{D}{d}$ **where n = 0, 1, 2, ……….**

For nth minima $p = \left(n - \frac{1}{2}\right)\lambda$

$\therefore \quad y_n = \left(n - \frac{1}{2}\right)\frac{\lambda D}{d}$ **where n = 1, 2, 3, ……..**

Note that the nth minima comes before the nth maxima.

- **Fringe Width**

It is defined as the distance between two successive maxima or minima.

$\therefore \quad \omega = y_{n+1} - y_n = (n+1)\frac{\lambda D}{d} - \frac{n\lambda D}{d}$ or $\omega = \frac{\lambda D}{d}$

[If λ changes to λ' then the fringe width $\omega' = \frac{\lambda' D}{d}$]

- **Optical Path**

It is defined as distance travelled by light in vacuum taking the same time in which it travels a given path length in a medium. If light travels a path length d in a medium at speed v, the tame taken by it will be (d/c). So optical path length

$L = c \times \left[\frac{d}{v}\right] = \mu d$ (because $\mu = \frac{c}{v}$)

Since for all media optical path length is always greater then geometrical path length. When two light waves arrive at a point by travelling different distances in different media, the phase difference between the two is related by their optical path difference instead of simply path difference.

- **Fringe Shift**

When a transparent film of thickness t and refractive index μ is introduced infront of one of the slits, the fringe pattern shifts in the direction where the film is placed.

Illustration 19

In a YDSE, if D = 2 m; d = 6 mm and l = 6000 A, then

(a) find the fringe width

(b) find the position of the 3rd maxima

(c) find the position of the 2nd minima

Solution (a) Fringe width,

$$\omega = \frac{\lambda D}{d} = \frac{(6000 \times 10^{-10})(2)}{6 \times 10^{-3}} = 0.2\,\text{mm}$$

(b) Position of 3rd maxima

$$y_3 = \frac{3\lambda D}{d} = 3\omega = 3(0.2) = 0.6\,\text{mm}$$

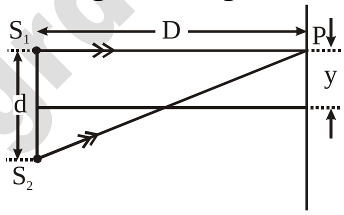
(c) Position of 2nd minima

$$y_2 = \left(2 - \frac{1}{2}\right)\frac{\lambda D}{d} = \frac{3}{2}\omega = \frac{3}{2}(0.2) = 0.3\,\text{mm}$$

Illustration 20

White light is used to illuminate the two slits in a Young's double slit experiment. The separation between the slits is d and the screen is at a distance D >> d from the slits. At a point on the screen directly in front of one of the slits find the missing wavelengths.

Solution According to theory of interference, position y of a point on the screen is given by



$$y = \frac{D}{d}(\Delta x)$$

and as for missing wavelengths intensity will be min.

(=0) if $\Delta x = (2n - 1)\lambda / 2$

So, $y = D\dfrac{(2n-1)\lambda}{2d}$

However, here d = b and y = (b/2).

So, $\lambda = \dfrac{b^2}{(2n-1)D}$ with n = 1, 2, 3, ….

i.e., wavelengths (b^2/D), (b^2/3D), (b^2/5D), etc., will be absent (or missing) at point P.

Illustration 21:

How to find fringe shift ?

Solution :

Consider the YDSE arrangement shown in the figure.

A film of thickness t and refractive index m is placed in front of the lower slit.

The optical path difference is given by

$p = [(S_2P - t) + \mu t] - S_1P$

or $p = (S_2P - S_1P) + t(\mu - 1)$

Since $S_2P - S_1P = d\sin\theta$

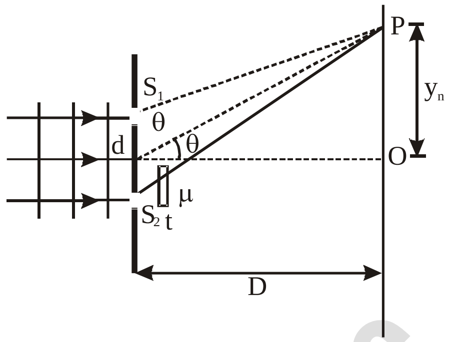
$\therefore$ $p = d\sin\theta + t(\mu - 1)$

As $\sin\theta \approx \tan\theta = \frac{y'_n}{D}$

$\therefore \quad p = \frac{d.y'_n}{D} + t(\mu - 1)$

or $y'_n = \frac{n\lambda D}{d} - (\mu - 1)\frac{tD}{d}$

In the absence of film the position of the nth maxima is given by equation



$y_n = \frac{n\lambda D}{d}$

Therefore, the fringe shift is given by

$FS = y_n - y'_n = (\mu - 1)\frac{tD}{d}$

Note the shift is in the direction where the film is introduced.

Illustration 22

In a YDSE =6000A D = 2 m, d = 6 mm. When a film of refractive index 1.5 is introduced in front of the lower slit, the third maxima shifts to the origin.

(a) find the thickness of the film

(b) find the positions of the fourth maxima

Solution

(a) Since 3rd minima shifts to the origin, therefore, the fringe shift is given by

$FS = y_3 = \frac{3\lambda D}{d}$

From equation (xvii), we know

$FS = (\mu - 1)\frac{tD}{d} \quad \therefore \ (\mu - 1)\frac{tD}{d} = 3\frac{\lambda D}{d}$ or $t = \frac{2\lambda}{\mu - 1}$

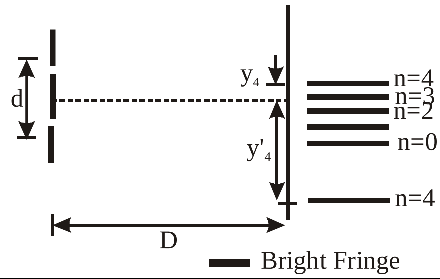
Here $\lambda = 0.6 \times 10^{-6}$ m; μ 1.5

$\therefore \quad t = \frac{(3)(0.6 \times 10^{-6})}{1.5 - 1} = 3.6\mu m$

(b) There are two positions of 4th maxima; one above and the other below the origin.

$y_4 = 1\omega = \frac{\lambda D}{d} = 0.2$ mm

$y'_4 = -7\omega = \frac{\lambda D}{d} = -1.4$ mm



❖❖❖

KEY POINTS

- In case of superposition of two waves,
  $I_R = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$ or $I_R \propto \left(A_1^2 + A_2^2 + 2A_1A_2\cos\phi\right)$
- Condition for constructive interference

  $\phi = \pm 2\pi n$, n = 1, 2, 3, ….
  $(\Delta x) = \pm n\lambda$, n = 1, 2, 3, ….
- Condition for destructive interference

  $\phi = \pm(2n-1)\pi$, n = 1, 2, 3, ….
  $(\Delta x) = \pm(2n-1)\lambda/2$ n = 1, 2, 3, …
- Distance of nth bright fringe from C.B.F. is

  $(y_n)_B = \pm n\lambda\frac{D}{d}$, n = 0, 1, 2, 3, ….

  Distance of nth dark fringe from C.B.F. is

  $(y_n)_D = \pm(2n+1)\frac{\lambda D}{2d}$, n = 0, 1, 2, 3, ….
- Fringe width (w) = lD/d, Angular fringe width = w/D = l/d
- Equivalent optical path of a medium of R.I, m and distance d is md.
- Displacement of fringe pattern due to introduction of a transparent sheet of R.I. m and thickness t in YDSE = y_0 = (m – 1) t (D/d), in the same side in which the transparent sheet is introduced.

ASSIGNMENT

Week 29 : Worksheet

1. Newton has postulated his corpuscular theory on the basis of:
(A) Newton's ring (B) colour due to thin film
(C) dispersing of light (D) rectilinear propagation of light.

2. The wavefront is a surface in which:
(A) all points are in the same phase
(B) there are pairs of points in opposite phase.
(C) there are pairs of points with phase difference ($\pi/2$)
(D) there is no relation between the phases.

3. The concept of secondary wavelets from all points on a wavefront was first proposed by:
(A) Newton (B) Huygen
(C) Faraday (D) Raman.

4. Interference proves:
(A) transverse nature of waves (B) longitudinal nature of waves
(C) wave nature (D) particle nature.

5. Two waves of equal amplitude and wavelength but differing in phase are superimposed. Amplitude of resultant wave is maximum when phase difference is:
(A) zero (B) $\pi/12$
(C) π (D) $3\pi/2$.

6. The phenomenon of interference of light was first studied and explained by:
(A) Newton (B) Fresnel
(C) Huygens (D) Young.

7. The path difference equivalent to a phase difference of 270º (given wavelength of wave $=\lambda$) is:
(A) zero (B) $\lambda/2$
(C) $3\lambda/4$ (D) λ.

8. The light waves from two independent monochromatic light sources are given by:
$y_1 = 2 \sin \omega t$ and $y_2 = 3 \cos \omega t$.
then the correct statement is
(A) Both the waves are coherent
(B) Both the waves are incoherent
(C) Both the waves have different time periods
(D) None of the above.

9. According to modern theory for nature of light, the light has:
(A) wave nature only (B) particle nature only
(C) both particle and wave (dual) nature (D) neither particle nature nor wave nature.

10. When path difference between two points in a wave is λ then their phase difference will be
(A) π (B) 2π
(C) 1.5π (D) 3π.

Week 30 : Worksheet

1. In Young's double slit interference experiment if the distance between the slits is made 3-fold, the fringe width becomes.
(A) (1/3) fold (B) 3 fold
(C) (1/9) fold (D) 9 fold.

2. In Young's double slit experiment the separation between the slits is halved and the distance between the slits and screen is doubled. The fringe width is:
(A) unchanged (B) halved
(C) doubled (D) quadrupled.

3. In a certain double slit experimental arrangement, interference fringes of width 1.0 mm each are observed when light of wavelength 5000 Å is used. Keeping the setup unaltered if the source is replaced by another of wavelength 6000 Å, the fringe width will be:
(A) 0.5 mm (B) 1.0 mm
(C) 1.2 mm (D) 1.5 mm.

4. The Young's double slit experiment is performed with blue and with green light of wavelengths 4360 Å and 5460 Å respectively. If x is the distance of 4th maximum from the central one, then:
(A) x(blue) = x(green) (B) x(blue) > x (green)
(C) x(blue) < x (green) (D) $\frac{x(\text{blue})}{x(\text{green})} = \frac{5460}{4360}$

5. In Young's double slit experiment carried out with light of wavelength λ= 5000 Å, the distance between the slits is 0.2 mm and the screen is at 200 cm from the plane of slits. The central maximum is at x = 0. The third maximum will be at x equal to
(A) 1.67 cm (B) 1.5 cm
(C) 0.5 cm (D) 5.0 cm.

6. The fringe width in Young's double slit experiment on a screen which is placed at a distance of 1 m from the slits 10^{-3} m apart when the light used has wavelength 6×10^{-7} m, is equal to:
(A) 3×10^{-10} m (B) 3×10^{-4} m
(C) 6×10^{-10} m (D) 6×10^{-4} m.

7. Monochromatic green light of wavelength 5×10^{-7} m illuminates a pair of slits 1 mm apart. The separation of bright lines in the interference pattern formed on a screen 2m away is:
(A) 0.25 mm (B) 0.1 mm
(C) 1.0 mm (D) 0.01 mm.

8. In Young's double slit experiment, the intensity of a bright fringe is:
(A) equal to the intensity of light wave from any one slit
(B) twice the intensity of light wave from any slit
(C) three times the intensity of wave from any slit
(D) four times the intensity of wave from any slit.

9. In Young's double slit experiment. If width (aperture) of the slit S is increased keeping other parameters constant, then the interference fringes will :
(A) remain unchanged (B) form closer
(C) form further away (D) gradually disappear.

10. In a Young's double slit experiment, fringe width equal to 1 mm is observed. Then the distance of the nearest bright fringe from the central fringe will be:
(A) 1 mm
(B) 0.5 mm
(C) 2 mm
(D) insufficient data, cannot be determined.

KEY

Wave Optics

ASSIGNMENT

Week 29; Worksheet

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

Week 30; Worksheet 2

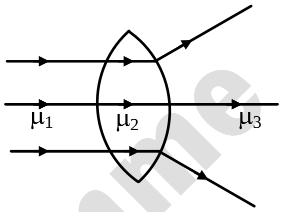
1.	(A)	2.	(D)
3.	(C)	4.	(C)
5.	(B)	6.	(D)
7.	(C)	8.	(D)
9.	(D)	10.	(A)

COMPETITIVE CORNER

Straight Objective Type

This section contains multiple choice questions. Each question has 4 choices (A), (B), (C), (D), out of which ***ONLY ONE*** *is correct. Choose the correct option.*

1. A parallel beam of light falls on a convex lens. The path of the rays is shown in the figure. It follows that **(IIT - 1979)**



(A) $\mu_1 > \mu_2 > \mu_2$ (B) $\mu_1 < \mu_2 < \mu_2$

(C) $\mu_1 = \mu_2 < \mu_2$ (D) $\mu_1 = \mu_2 > \mu_2$

2. When a ray of light enters a glass slab from air : **(IIT - 1980)**

(A) its wavelength decreases

(B) its wavelength increases

(C) its frequency increases

(D) neither its wavelength nor its frequency changes

3. In Young's double slit experiment, the separation between the slits is halved and the distance between the slits and the screen is doubled. The fringe width is : **(IIT - 1981)**

(A) unchanged (B) halved

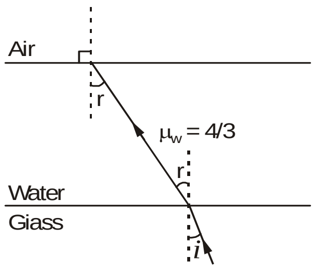
(C) doubled (D) quadrupled

4. A hollow double concave lens is made of very thin transparent material. It can be filled with air or either of two liquids L_1 or L_2 having refracting indices n_1 and n_2 respectively ($n_2 > n_1 > 1$). The lens will diverge a parallel beam of light if it is filled with :**(IIT - 2000)**

(A) air and placed in air (B) air and immersed in L_1

(C) L_1 and immersed in L_2 (D) L_2 and immersed in L_1

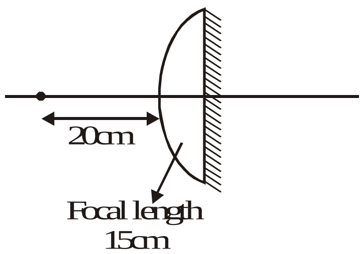
5. A ray of light is incident at the glass-water interface at an angle I, it emerges finally parallel to the surface of water, then the value of μ_g would be: **(2003; 2M)**



(A) $\left(\frac{4}{3}\right)\sin i$ (B) $\frac{1}{\sin i}$

(C) $\frac{4}{3}$ (D) l

6. An object is placed 20 cm in front of a plano–convex lens of focal length 15 cm. The plane surface of the lens is silvered. The image will be formed at a distance **(IIT - 2006)**



(A) 60 cm to the left of the lens

(B) 12 cm to the right of the lens

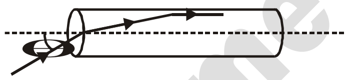
(C) 60 cm to the right of the lens

(D) 12 cm to the left of the lens

7. A ray of light traveling in water is incident on its surface open to air. The angle of incidence is θ, which is less than the critical angle. Then there will be **(IIT – 2007)**

(A) Only a reflected ray and no refracted ray.
(B) Only a refracted ray and no reflected ray.
(C) A reflected ray and a refracted ray and the angle between them would be less than $180^o - 2\theta$.
(D) A reflected ray and a refracted ray and the angle between them would be greater than $180^o - 2\theta$.

8. A transparent solid cylindrical rod has a refractive index of $\frac{2}{\sqrt{3}}$. It is surrounded by air. A light ray is incident at the mid–point of one end of the rod as shown in the figure.



[AIEEE – 2009]

The incident angle θ for which the light ray grazes along the wall of the rod is :

(A) $\sin^{-1}\left(\frac{1}{2}\right)$ (B) $\sin^{-1}\left(\frac{\sqrt{3}}{2}\right)$
(C) $\sin^{-1}\left(\frac{2}{\sqrt{3}}\right)$ (D) $\sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$.

9. Two lenses of power – 15D and +5D are in contact with each other. The focal length of the combination is

[AIEEE – 2007]

(A) - 20 cm (B) - 10 cm
(C) + 20 cm (D) + 10 cm

10. The refractive index of glass is 1.520 for red light and 1.525 for blue light. Let D_1 and D_2 be the angles of minimum deviation for the red and blue light respectively in a prism of this glass. Then **[AIEEE – 2006]**

(A) $D_1 < D_2$
(B) $D_1 = D_2$
(C) D_1 can be less than or greater than D_2 depending upon the angle of prism
(D) $D_1 > D_2$

$D = (n – 1)A$

For blue light n is greater than that for red light, so $D_2 > D_1$.

Multiple Correct Answer Type

This section contains multiple choice questions. Each question has 4 choices (A), (B), (C), (D), out of which ***ONE or MORE*** *is correct. Choose the correct options.*

1. The radius of curvature of the convex face of a plano-convex lens is 12 cm and its refractive index is 1.5. Its focal length is f. When the plane surface of the lens is silvered, it behaves like a concave mirror of focal length F. Then **(IIT – 1979)**

(A) f = 24 cm (B) f = 6 cm
(C) F = 12 cm (D) F = 24 cm

2. A converging lens is used to form an image on a screen. When the upper half of the lens is covered by an opaque screen : **(IIT – 1986)**
(A) half of the image will disappear (B) complete image will be formed
(C) intensity of the image will increase (D) intensity of the image will decrease

3. An astronomical telescope has an angular magnification of magnitude 5 for distance objects. The separation between the objective and the eye piece is 36 cm and the final image is formed at infinity. The focal length f_o of the objective and the focal length f_e of the eyepiece are : **(IIT – 1989)**
(A) f_o = 45 cm and f_e = –9 cm (B) f_a = 50 cm and f_e = 10 cm
(C) f_o = 7.2 cm and f_e = 5 cm (D) f_o = 30 cm and f_e = 6 cm

4. Which of the following form(s) a virtual and erect image for all positions of the object? **(IIT – 1996)**
(A) Convex lens (B) Concave lens
(C) Convex mirror (D) Concave mirror

5. A converging lens is used to form an image on a screen. When the upper half of the lens is covered by an opaque screen **[IIT JEE 1986]**
(A) half the image will disappear (B) complete image will increase
(C) intensity of image will increase (D) intensity of image will decrease

6. A ray of light travelling in a transparent medium falls on a surface separating the medium from air at an angle of incidence of 45°. The ray undergoes total internal reflection. If n is the refractive index of the medium with respect to air, select the possible value(s) of n from the following **[IIT JEE 1998]**
(A) 1.3 (B) 1.4
(C) 1.5 (D) 1.6

7. A diminished image of an object is to be obtained on a screen 1.0 m from it. This can be achieved by appropriately placing **[IIT JEE 1995]**
(A) a convex mirror of suitable focal length
(B) a concave mirror of suitable focal length
(C) a convex lens of focal length less than 0.25 m
(D) a concave lens of suitable focal length

8. White light is used to illuminate the two slits in Young's double slit experiment. The separation between the slits is b and the screen is at a distance d (>b) from the slits. At a point on the screen directly in front of one of the slits, certain wavelengths are missing. Some of these missing wavelengths are **[IIT JEE 1984]**
(A) $\lambda = \frac{b^2}{d}$ (B) $\lambda = \frac{2b^2}{d}$
(C) $\lambda = \frac{b^2}{3d}$ (D) $\lambda = \frac{2b^2}{3d}$

9. If Young's double slit experiment is performed by white light, then
(A) the central fringe will be dark
(B) the central fringe will be white
(C) the bright fringe next to central fringe is used
(D) the bright fringe next to central fringe is violet

10. The following phenomena give evidence about wave nature of light
(A) interference (B) diffraction
(C) polarisation (D) photoelectric effect

Linked Comprehension Type

*This section contains paragraphs. Based upon each paragraph multiple choice questions have to be answered. Each question has 4 choices (A), (B), (C) and (D), out of which **ONLY ONE** is correct. Choose the correct option.*

COMPREHENSION – I

The figure is a scaled diagram of an object and a converging lens surrounded by air. F is the focal point of lens as shown

1. At which of the labeled points can the images be formed?
(A) A (B) B
(C) C (D) D

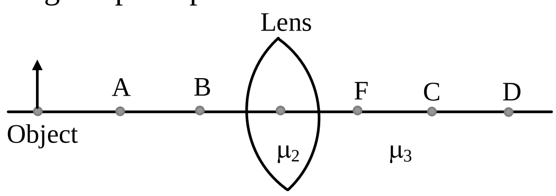
2. Which option describes the image most accurately?
(A) Real erect (B) Real, inverted
(C) Virtual, erect (D) Virtual, inverted

3. If a parallel beam of blue light is focused at F, then the parallel beam of red light is focused at
(A) F (B) D
(C) to the left of and close to F (D) to the right of and close to F

4. The whole system is immersed in a liquid having the refractive index greater than the refractive index of the lens material. Then mark the correct option for this new situation
(A) The image will be real
(B) The image will be inverted
(C) The image will be formed on the same side of the lens as the object is
(D) The image will be enlarged relative to the object

COMPREHENSION – II

The radius of curvature of the curved face of a thin planoconvex lens is 10 cm and it is made of glass of refractive index 1.5. A small object is approaching the lens with a speed of 1 cms^{-1} moving along the principal axis



5. The focal length of the lens is
(A) 5 cm (B) 10 cm
(C) 15 cm (D) 20 cm

6. The focal length of the lens is
(A) 1 cms^{-1} (B) 2 cms^{-1}
(C) 3 cms^{-1} (D) 4 cms^{-1}

7. When the object is at a distance of 30 cm from the lens, the magnitude of the rate of change of the lateral magnification is
(A) 0.1 per second (B) 0.2 per second
(C) 0.3 per second (D) 0.4 per second

COMPREHENSION – III

A telescope is an optical instrument that is used to examine distant objects. Two types of telescopes are in us-refracting and reflecting telescopes. A refracting astronomical telescope consists of two converging lenses called the objective and the eyepiece. The objective faces the distant object. The image of the object is formed at the focal plane of the objective. The position of the eyepiece is adjusted till this image is within the first focus of the eyepiece. A highly magnified final image is formed which is seen by the eye held close to the eyepiece. If both the object and the final image are at infinity, the telescope is said to be in normal adjustment.

8. In a refracting astronomical telescope, the final image is
(A) real, inverted and magnified (B) real, erect and magnified
(C) virtual, erect and magnified (D) virtual, inverted and magnified

9. The magnifying power of a telescope is high if
(A) Both the objective and eyepiece have long focal lengths
(B) Both the objective and the eyepiece have long focal lengths
(C) The objective has a short focal length and the eyepiece has a long focal length
(D) The objective has a long focal length and the eyepiece has a short focal length

10. The resolving power of a telescope is increased. If
(A) The objective of a bigger diameter is used
(B) The objective of a smaller diameter is used
(C) The objective of a higher focal length is used
(D) The eyepiece of a shorter focal length is used

Matrix Match Type

This section contains Matrix-Match Type questions. Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in ***Column–I*** *have to be matched with statements (p, q, r, s) in* ***Column–II****. The answers to these questions have to be appropriately bubbled as illustrated in the following example.*

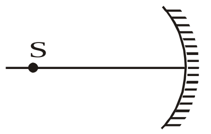
If the correct matches are A-p, A-s, B-q, B-r, C-p, C-q and D-s, then the correctly bubbled 4 $\times$ 4 matrix should be as follows:

1. An optical component and an object S placed along its optic axis are given in Column I. The distance between the object and the component can be varied. The properties of images are given in Column II. Match all the properties of images from Column II with the appropriate components given in Column I. Indicate your answer by darkening the appropriate bubbles of the 4 × 4 matrix given in the ORS.

(IIT – 2008)

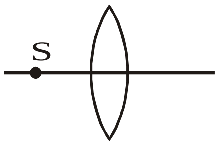
Column I

(A)

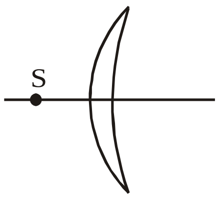


(B)

(C)



(D)



Column II

(p) Real image

(q) Virtual image

(r) Magnified image

(s) Image at infinity

2. Two transparent media of refractive indices μ_1 and μ_3 have a solid lens shaped transparent material of refractive index μ_2 between them as shown in figures in Column II. A ray traversing these media is also shown in the figures. In Column I different relationship between μ_1, μ_2 and μ_3 are given. Match them to the ray diagrams shown in Column II.

(IIT – 2010)

Column I

(A) $\mu_1 < \mu_2$

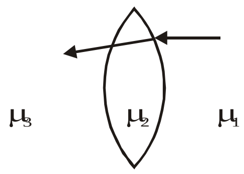
(B) $\mu_1 > \mu_2$

(C) $\mu_2 = \mu_3$

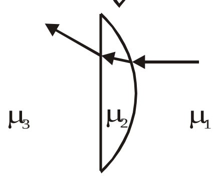
(D) $\mu_2 > \mu_3$

Column II

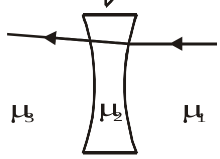
(p)



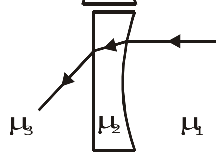
(q)



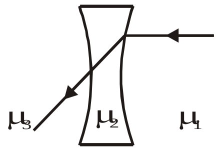
(r)



(s)



(t)



Integer Answer Type

1. The focal length of a thin biconvex lens is 20 cm. When an object is moved from a distance of 25 cm in front of it to 50 cm, the magnification of its image changes from m_{25} to m_{50}. The ratio $\frac{m_{25}}{m_{50}}$ is

(IIT – 2010)

2. A large glass slab ($\mu = 5/3$) of thickness 8 cm is placed over a point source of light on a plane surface. It is seen that light emerges out of the top surface of the slab from a circular area of radius R cm. What is the value of R ?

(IIT – 2010)

3. The image of an object approaching a convex mirror of radius of curvature 20 m along its optical axis is observed to move from $\frac{25}{3}$m to $\frac{50}{7}$m in 30 seconds. What is the speed of the object in km per hour ?

(IIT – 2010)

*4. Two sources of intensities I and 4I are used in an interference experiment. The intensities at points where the waves from two sources superpose with a phase difference of   is aI. Find a ?

[ROORKEE 1991]

*5. How long (in μ sec) will light take in travelling a distance of 450 metre in water? Given that μ for water is 4/3 and the velocity of light in vacuum is 3×10^{10} cm/sec.

❖❖❖

KEY
Ray Optics & Wave Optics

COMPETITIVE CORNER

SINGLE CHOICE

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

MULTIPLE CORRECT ANSWER TYPE

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

COMPREHENSION TYPE

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

MATCHING COLUMN TYPE

1. (A) – (p), (q), (r), (s), (B) – (q), (C) – (p), (q), (r), (s), (D) – (p), (q), (r), (s)
2. (A) – (p), (r); (B) – (q), (s), (t); (C) – (p), (r), (t); (D) – (q), (s)

INTEGER ANSWER TYPE

1. 6.
2. 6.
3. 3.
4. 1.
5. 2.

HINTS AND SOLUTIONS

SINGLE CHOICE

1. Since the ray does not bend at the first face of the lens, that is, it is not refracted, $\mu_1 = \mu$. When this ray meets the second face, it bends toward the normal to that face. Hence $\mu_2 > \mu$.

2. $\lambda = \frac{v}{f}$

In moving from air to glass, *f* remains unchanged while *v* decreases. Hence, λ should decrease.

3. $\omega = \frac{\lambda D}{d}$

d is halved and *D* is doubled

$\therefore$ Fringe width ω will become four times.

$\therefore$ correct option is (D)

4. The lens makers' formula is :

$$\frac{1}{f} = \left(\frac{n_1}{n_m} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Where n_L = Refractive index of lens and

n_m = Refractive index of medium.

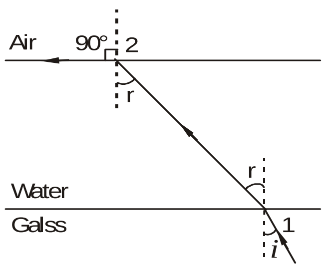
In case of double concave lens, R_1 is negative and R_2 is positive. Therefore $\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ will be negative.

For the lens to be diverging in nature, focal length '*f* ' should be negative or $\left(\frac{n_L}{n_m} - 1\right)$ should be positive or $n_L > n_m$ but since $n_2 > n_1$(given), therefore the lens should be filled with L_2 and immersed in L_1.

5. Applying

Snell's law (μ sin *I* = constant)

at 1 and 2, we have



$\mu_1 \sin i_1 = \mu_2 \sin i_2$

Here, $\mu_1 = \mu_{glass}$, $i_1 = I$

$\mu_2 = \mu_{air} = 1$ and $i_2 = 90°$

$\therefore \quad \mu_g \sin I = (1)(\sin 90°)$

or $\quad \mu_g = \frac{1}{\sin i}$

6. Focal length F of equivalent mirror is given by

$$\frac{1}{F}=\frac{2}{f_e}+\frac{1}{f_m}=\frac{2}{15}+\frac{1}{\infty} \text{ or } F=\frac{15}{2} \text{ cm}$$

The equivalent mirror will concave mirror of focal length $\frac{15}{2}$ cm.

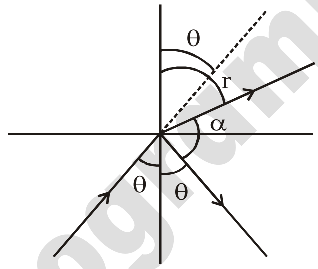
Now for a spherical mirror,

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{F} \Rightarrow \frac{1}{v}+\frac{1}{-20}=\frac{-2}{15}$$

$$\Rightarrow \frac{1}{v}=\frac{-2}{15}+\frac{1}{20}=\frac{-8+3}{60}=-\frac{5}{60}=-\frac{1}{12}$$

v = –12 cm

7. In the figure,



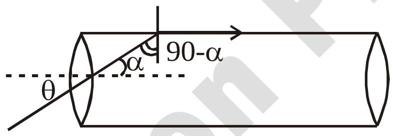
$\alpha = \pi - (r + \theta)$

as $r > \theta$

$\Rightarrow r + \theta > 2\theta$

$\Rightarrow \pi - (r + \theta) < \pi - 2\theta.$

8. $$1\times\sin 90=\frac{2}{\sqrt{3}}\sin(90-\alpha)$$



$$\Rightarrow \cos\alpha=\frac{\sqrt{3}}{2}$$

So $\sin\alpha=\sqrt{1-\frac{3}{4}}=\frac{1}{2}$

Now, $1\times\sin\theta=\frac{2}{\sqrt{3}}\sin\alpha$

$$=\frac{2}{\sqrt{3}}\times\frac{1}{2}=\frac{1}{\sqrt{3}}$$

$$\Rightarrow \theta=\sin^{-1}\frac{1}{\sqrt{3}}$$

MULTIPLE CORRECT ANSWER TYPE

1. $$\frac{1}{f}=(1.5-1)\left(\frac{1}{12}+\frac{1}{\infty}\right)=\frac{0.5}{12}$$

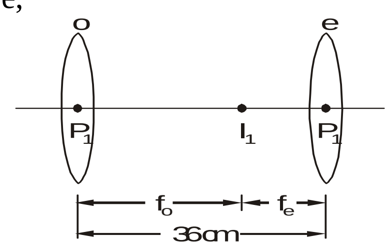
$\Rightarrow$ f = 24 cm

When the lane face is silvered,

$$F=\frac{f}{2}=\frac{24}{2}=12\text{cm}$$

2. When upper half of the lens is covered, image is formed by the rays coming from lower half of the lens. Or image will be formed by less number of rays. Therefore, intensity of image will decrease. But complete image will be formed.

3. Image formed by objective (I_1) is at second focus of it because objective is focused for distance objects. Therefore,



$P_1I_1 = F_o$

Further I_1 should lie at first focus of eye piece because final image is formed at infinity.

$\therefore \quad P_2I_1 = f_e$

Given P_1P_2 = 36 cm

$\therefore \quad f_o + f_e = 36$ …(1)

Further angular magnification is given as 5. Therefore,

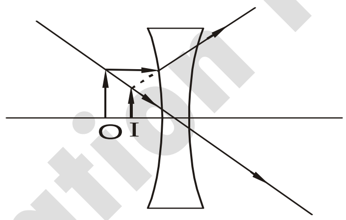
$\frac{f_o}{f_e} = 5$ …(2)

Solving Eqs. (1) and (2), we get

f_o = 30 cm and f_e = 6 cm

$\therefore$ correct option is (D)

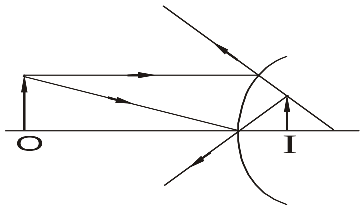
4. For a lens : $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$



i.e., $\frac{1}{v} = \frac{1}{f} + \frac{1}{u}$

For a concave lens, *f* and *u* are negative, *i.e.*, *v* will always be negative and image will always be virtual.

For a mirror :



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

Here, *f* is positive and *u* is negative for a convex mirror. Therefore, *v* is always positive and image is always virtual.

6. For total internal reflection to take place :

Angle of incidence, $I >$ critical angle, θ_c

or $\sin I > \sin \theta_c$

or $\sin 45° > \frac{1}{n}$

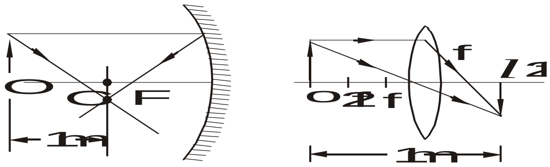
or $\quad \frac{1}{\sqrt{2}} > \frac{1}{n}$

or $\quad n > \sqrt{2}$

or $\quad n > 1.414$

Therefore, possible values of n can be 1.5 or 1.6 in the given options.

7. Image can be formed on the screen if it is real. Real image of reduced size scan be formed by a concave mirror or a convex lens as shown in figure.



A diminished real image is formed by a convex lens when the object is placed beyond $2f$ and the image of such object is formed beyond $2f$ on other side.

Thus, $d > (2f + 2f)$

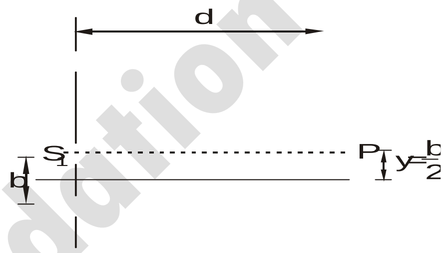
Or $\quad 4f < 0.1$ m

Or $\quad f < 0.25$ m

8. At P (directly in front of S_1)

$$y = \frac{b}{2}$$

$\therefore$ Path difference,



$$\Delta X = S_2P - S_1P = \frac{y.(b)}{d} = \frac{\left(\frac{b}{2}\right)(b)}{d} = \frac{b^2}{2d}$$

Those wavelengths will be missing for which

$$\Delta X = \frac{\lambda_1}{2}, \frac{3\lambda_2}{2}, \frac{5\lambda_3}{2} \ \ldots$$

$$\therefore \quad \lambda_1 = 2\Delta x = \frac{b^2}{d}$$

$$\lambda_2 = \frac{2\Delta x}{3} = \frac{b^2}{3d}$$

$$\lambda_3 = \frac{2\Delta x}{5} = \frac{b^2}{5d}$$

$\therefore \quad$ correct options are (a) and (c)

COMPREHENSION TYPE

1. As object is between infinity and 2F, image will be between F and 2F and the point C is lying in this region.
2. Real, inverted, diminished.
3. Wavelength of blue light is smaller than wavelength of red light
$\lambda_B < \lambda_R$
So, $f_B < f_R$
(But f_B and F_R differ by very small value)
So, image for red light would be on the right side of and very close to F.

4. Now, lens behaves as a diverging lens, so lens will form virtual, erect and diminished image on the same side of lens as the object.
5. $\frac{1}{f} = (n-1)\times\frac{1}{R} = (1.5-1)\times\frac{1}{10}$ gives f = 20 cm.
6. Lens formula is
$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \text{. . . (i)}$$
(here u = - 30 cm and f = +20 cm)
Differentiating equation (i) with respect to time t, we get
$$-\frac{1}{v^2}\frac{dv}{dt} + \frac{1}{u^2}\frac{du}{dt} = 0 \text{ or } \frac{dv}{dt} = \left(\frac{v^2}{u^2}\right)\frac{du}{dt}$$
Speed of image = $\left(\frac{v^2}{u^2}\right)\times$ speed of object
$= \left(\frac{60}{30}\right)^2 \times 1 = 4 \text{ cms}^{-1}$.
7. Linear magnification is given by
$$m = \frac{v}{u} \quad \text{. . . (ii)}$$
Differentiating equation (ii) with respect to time, we have
$$\frac{dm}{dt} = -\frac{v}{u^2}\frac{du}{dt} + \frac{1}{u}\frac{dv}{dt} = \frac{1}{u^2}\left(-v\frac{du}{dt} + u\frac{dv}{dt}\right)$$
$$= \frac{1}{(30)^2}(-60\times1 - 30\times4) = -0.2 \text{ per second}$$
$\therefore$ Magnitude of $\frac{dm}{dt} = 0.2$ per second.
9. The magnifying power of a telescope (if the object is at infinity) is given by
$$M = \frac{f_0}{f_e}.\frac{D+f_0}{D}$$
Where D = least distance of distinct vision, where the final image is formed.

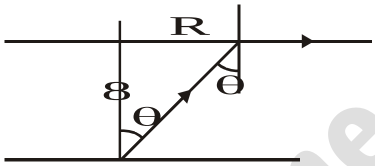
10. The resolving power of a telescope is given by
$$RP = \frac{d}{1.22\lambda}$$
The resolving power is independent of f_0 or f_e.

INTEGER ANSWER TYPE

1. $m = \frac{|f|}{|f - u|}$

$\frac{m_{25}}{m_{50}} = 6$.

2.



$\sin\theta = \frac{3}{5} \Rightarrow \tan\theta = \frac{3}{4}$

$\frac{R}{8} = \frac{3}{4} \Rightarrow R = 6 \text{ cm}$.

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

$\frac{3}{25} + \frac{1}{u_1} = +\frac{2}{20}$

$\frac{1}{u_1} = \frac{+10 - 12}{100}$

$u_1 = -50 \text{ m}$

$\frac{7}{50} + \frac{1}{u_2} = \frac{2}{20}$

$\frac{1}{u_2} = \frac{10 - 14}{100} = -\frac{1}{25}$

$u_2 = -25 \text{ m}$

$v = \frac{25}{30} \times \frac{18}{5} = \frac{5 \times 18}{30} = 3 \text{ km/hr}$.

4. The intensity at point at which phase difference between two coherent waves is

$I_\delta = a_1^2 + a_2^2 + 2a_1a_2\cos\delta = I_1 + I_2 + 2\sqrt{(I_1I_2)}\cos\delta$

where $I_1 = a_1^2$ and $I_2 = a_2^2$ are the intensities due to individual waves respectively.

Here $I_1 = I, I_2 = 4I$ and $\delta = \pi$

Therefore, $I_\delta = I + 4I + 2\sqrt{(I \times 4I)}\cos\pi = 5I - 4I = I$ i.e., a = 1

5. We know that

$\mu = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in water}}$

$\frac{4}{3} = \frac{3 \times 10^{10}}{\text{velocity of light in water}}$

or velocity of light in water = $2.25 \times 10^{10} \text{ cm/sec}$

Time taken = $\frac{450 \times 100}{2.25 \times 10^{10}} = 2 \times 10^{-6}$ sec.

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