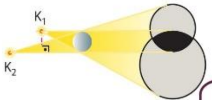
9.Ray Optics and Optical Instruments

Physics Smart Booklet

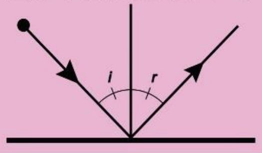
Theory + NCERT MCQs + Topic Wise Practice MCQs + NEET PYQs

Ray Optics



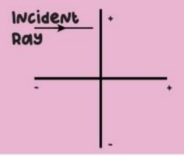
Laws of Reflection

1. The incident ray reflected ray and normal to the reflecting surface all lie in same plane.
2. Angle of reflection is always equal to angle of incidence. i.e., <i = <r



Sign Convention

1. All distances are measured from the pole and is the origin.
2. Distances measured to the right of the pole are taken as positive.
3. Distance above the principal axis are taken as positive.
4. Angle measured from the normal in the anti-clockwise direction are positive.

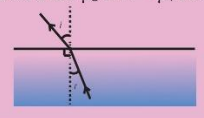


Absolute Refractive Index

It is defined as ratio of speed of light in vacuum to speed of light in medium i.e $n = \frac{c}{v}$

Laws of Refraction

1. The incident ray, refracted ray and normal to the interface of two media all lie on the same plane.
2. Snell's law $\mu_2 \sin r = \mu_1 \sin i$

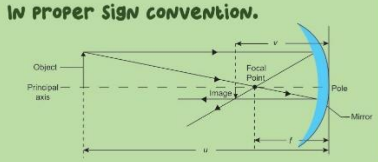


Spherical Mirrors

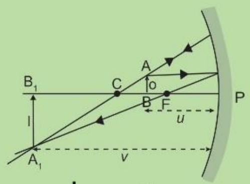
Mirror formula

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

In proper sign convention.



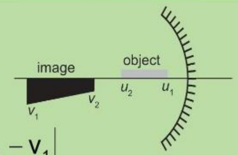
Linear magnification



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

In proper sign convention

Longitudinal magnification



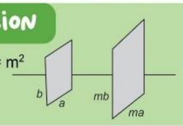
$$m_L = \left|\frac{v_2 - v_1}{u_2 - u_1}\right|$$

For small objects, $m_L = m^2$

Superficial Magnification

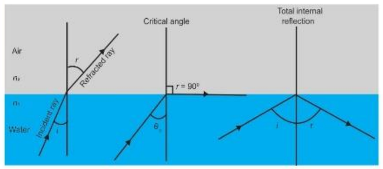
$m_s = \frac{m_a \times m_b}{a \times b}$ For small objects, $m_L = m^2$

$= m^2$



TIR

The balancing back of light ray in the same denser medium after reflection from an interface with a rarer medium is termed as toral internal reflection.



Critical Angle

It is the angle of incidence for which the angle of incidence is 90°.

$$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

Conditions for TIR

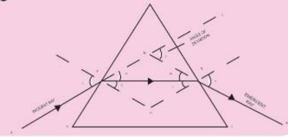
1. The light ray must travel from denser to rarer medium.
2. The angle of incidence must be greater than the critical angle.

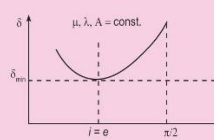
Application of TIR

1. Sparkling of diamond
2. Optical fibre
3. Mirage and optical looming.

Prism

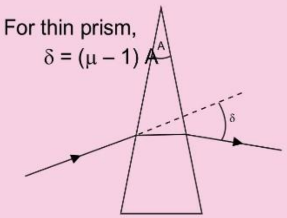
Angle of deviation $\delta = i + e - A$





For minimum deviation
1. $i = e$
2. $r = \frac{A}{2}$
3. $\mu = \frac{\sin\left(\frac{\sin + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

For thin prism,
$\delta = (\mu - 1) A$



Dispersion through Prism

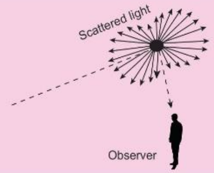
When white light passes through the prism, then it splits into its seven constituent colours. This phenomena of splitting of white light is known as dispersion of light.

Scattering

The deflection of light ray by the fine particles of matter is known as scattering of light. From Ray Leigh scattering.

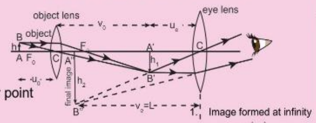
$$I \propto \frac{1}{\lambda^4}$$

where λ is wavelength of light and I is intensity of light.



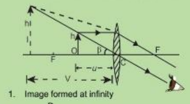
Optical Instrument

Compound Microscope



1. Image formed at infinity $MP = \frac{-v}{u}\left(\frac{D}{f_0}\right)$
2. Image formed at near point $cMP = \frac{-v}{u}\left(1 + \frac{D}{f_0}\right)$

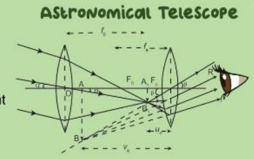
Simple Microscope



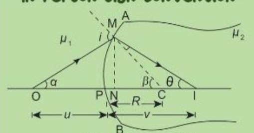
1. Image formed at infinity $MP = \frac{D}{f}$
2. Image formed at near point $MP = 1 + \frac{D}{f}$

Astronomical Telescope

1. Image formed at infinity $MP = \frac{-f_0}{u_0}$
2. Image formed at near point $MP = \frac{-f_0}{f_e}\left[1 + \frac{f_e}{D}\right]$

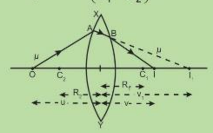


In person sign convention



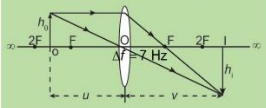
$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

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



In proper sign convention

Lens formula



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

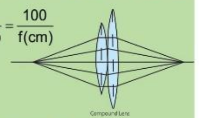
$m = \frac{h'}{h} = \frac{v}{u}$

In person sign convention

Power of lens

It is defined as the reciprocal of focal length of metres, i.e.,

$P = \frac{1}{f(m)} = \frac{100}{f(cm)}$



For combination of lenses,
$P = P_1 + P_2$
$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$
In proper sign convention

Ray Optics and Optical Instruments

Introduction

Light is the agency which helps us to see objects which are very far away e.g., the sun and the stars as well as nearby objects. The science of light is called *optics*.

A beam of light suggests that light travels in straight lines. This is referred to as the *rectilinear propagation* of light. The direction of propagation is shown in a diagram as a *ray*. It is represented by a line and an arrow. The ray is thus a geometrical line and it has no physical existence. In spite of this, the concept of light ray is useful. Geometrical optics, also called as ray optics, is one of the branches of optics which employs the ray concept throughout and is of much practical use. Ray optics does not deal with the physical nature of light and its propagation. The other branch, Physical optics, deals with the nature of light. Physical optics gives us a better understanding of light and furnishes us with more accurate laws than ray optics does. It is found that the laws of ray optics are only approximate.

Reflection of Light

Reflection at a plane surface

A great majority of bodies around us are visible to us due to light reflected by them. Reflection is regular or irregular depending on the nature of reflecting surface.

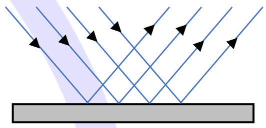


Fig. 1

In the case of smooth surfaces like plane mirrors or a shiny metal surface, a parallel beam of light incident on the surface is reflected only in one particular direction as can be seen from Fig. 1. This is a *regular* reflection.

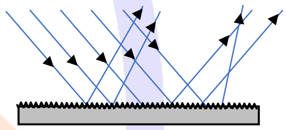


Fig. 2

In the case of a rough reflecting surface like paper, surfaces of wooden plank, or surface of a cloth, light incident in one direction on them will be reflected in various directions or scattered as shown in Fig. 2. This is called *diffused* or *irregular* reflection.

Terminology

Some of the terms commonly used are described below – which are applicable for reflection from any reflecting surface either plane or curved.

Incident ray: Ray striking the mirror from an object or a source of light.

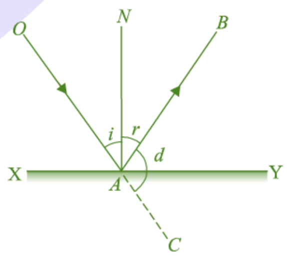
Reflected ray: Ray emerging from the mirror from the point of incidence.

Normal: A perpendicular to the surface of the mirror, usually drawn at the point of incidence.

Angle of incidence (i): Angle between the incident ray and the normal to the mirror at the point of incidence is called angle of incidence.

Angle of reflection (r): Angle between the reflected ray and the normal to the mirror at the point of incidence is called angle of reflection.

Angle of deviation (d): Angle between the direction of the incident ray in the absence of the mirror and the direction of reflected ray is called the angle of deviation.



Reflection from a plane mirror XY

OA – Incident ray

AB – Reflected ray

NA – normal to plane mirror. XY at point of incidence A.

$\angle OAN = i$ = angle of incidence.

$\angle BAN = r$ = angle of reflection.

$\angle BAC = d$ = angle of deviation.

Laws of Reflection

1. Angle of reflection is equal to angle of incidence (r = i).
2. The incident ray, the reflected ray and the normal at the point of incidence lie in the same plane.

These laws are valid at each point on any reflecting surface whether plane or curved.

Important points in the context of reflection from a plane mirror

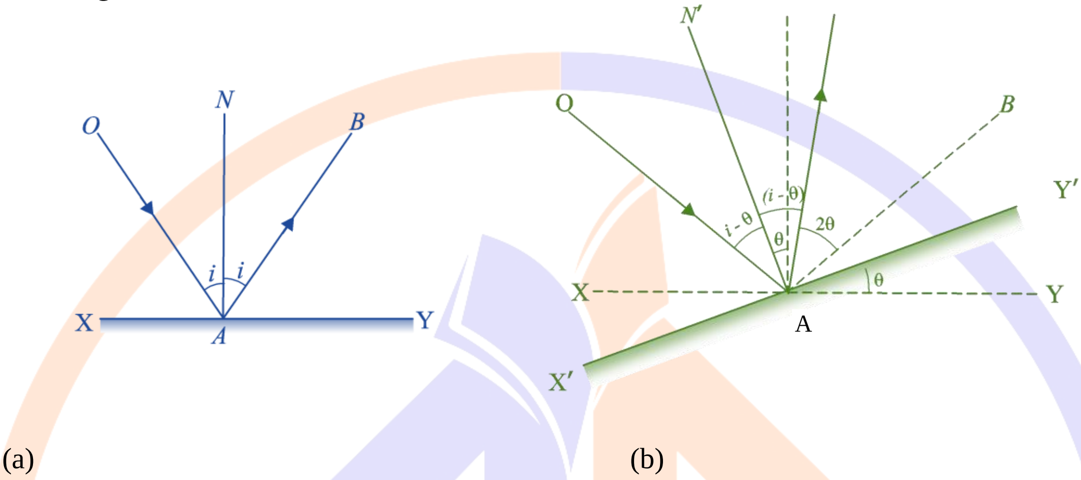
- When the object is real,

(i) the image is virtual , erect and laterally reversed

(ii) the image is of same size as the object

(iii) the image is as far behind the mirror as the object is in front of it.

- If the object is virtual then a real image is formed in front of the mirror which need not be of the same size as the object.
- The angle of deviation between incident and reflected rays is d = (180° – 2i) as r = i
- If a plane mirror is rotated by an angle θ keeping the incident ray direction fixed, then the reflected ray rotates by the angle 2θ along the same sense as that of the rotation of the mirror.

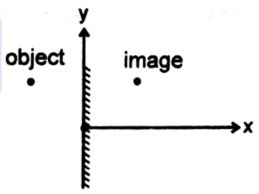


Rotation of a plane mirror and rotation of the reflected ray

Relation between velocity of object and image

From mirror property: $x_{im} = -x_{om}$, $y_{im} = y_{om}$ and $z_{im} = z_{om}$

Here x_{im} means 'x' coordinates of image with respect to mirror. Similarity others have meaning



Differentiating w.r.t time, we get

$v_{(im)x} = -v_{(om)x}$; $v_{(om)y}$; $v_{(im)z} = v_{(om)z}$

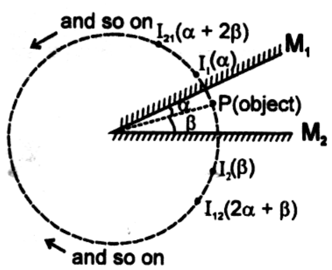
$\Rightarrow$ for x axis $v_{iG} - v_{mG} = -(v_{oG} - v_{mG})$

but for y axis and z axis $v_{iG} - v_{mG} = (v_{oG} - v_{mG})$ or $v_{iG} = v_{oG}$

here v_{iG} = velocity of image with respect to ground

Locating all the images formed by two plane mirrors

Consider two planes mirrors M_1 and M_2 inclined at an angle $\theta = \alpha + \beta$ as shown in figure



Point P is an object kept such that it makes angle that it makes angle α with mirror M_1 and angle β with mirror M_2. Image of object P formed by M_1, denoted by I_1, will be inclined by angle α

on the other side of mirror M_1. This angle is written in bracket in the figure besides I_1. Similarly image of object P formed by M_2, denoted by I_2, will be inclined by angle β on the other side of mirror M_2. This angle is written in bracket in the figure besides I_2.

Now I_2 will act as an object for M_1 which is at an angle $(\alpha + 2\beta)$ from M_1. Its image will formed at an angle $(\alpha + 2\beta)$ on the opposite side of M_1. This image will be denoted as I_{21}, and so on. Think when this process will stop. Hint. The virtual formed by a plane mirror not be in front of the mirror or its extension.

Number of imaged formed by two inclined mirrors

(i) If $\frac{360^\circ}{\theta}$ = even number; number of image $= \frac{360^\circ}{\theta} - 1$

(ii) If $\frac{360^\circ}{\theta}$ = odd number; number of image $= \frac{360^\circ}{\theta} - 1$ if the object is placed on the angle bisector.

(iii) If $\frac{360^\circ}{\theta}$ = odd number; number of image $= \frac{360^\circ}{\theta}$, if the object is not placed on the angle bisector

(iv) $\frac{360^\circ}{\theta} \neq$ integer, then count the number of images as explained above.

Reflection at a spherical surface

Spherical mirror

A spherical mirror is a part of a hollow sphere whose one side is reflecting and the other side is silvered. There are two types of spherical mirrors – concave and convex.

(a) Concave mirror (b) Convex mirror

Concave mirror

It is a spherical mirror whose reflecting surface is concave and the silvered surface is convex.

Convex mirror

It is a spherical mirror whose reflecting surface is convex and the silvered surface is concave.

Terminology

1. **Aperture**: Area of the spherical surface available for reflection is called its aperture.
2. **Pole:** Mid-point of the aperture (or spherical surface) is called pole.
3. **Centre of curvature:** The centre of the sphere of which the given spherical surface forms a part is called centre of curvature.
4. **Radius of curvature:** The radius of the sphere of which the given spherical surface forms a small part of it is called radius of curvature.
   (OR) Distance between the pole and the centre of curvature of a spherical mirror is the radius of curvature.
5. **Principal axis:** A straight line passing through the pole and centre of curvature of a spherical mirror is called its principal axis.

(a) Concave mirror **(b) Convex mirror**

Terminology associated with spherical mirror

AB – aperture of the mirror P – pole of the mirror

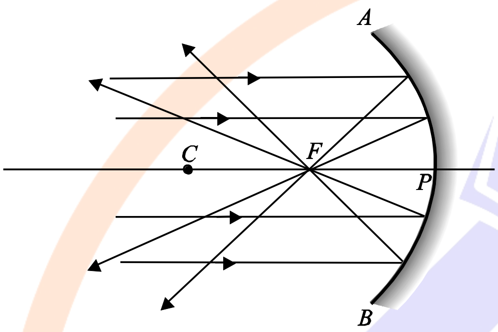
C – Centre of curvature CP – radius of curvature

F – Principal focus

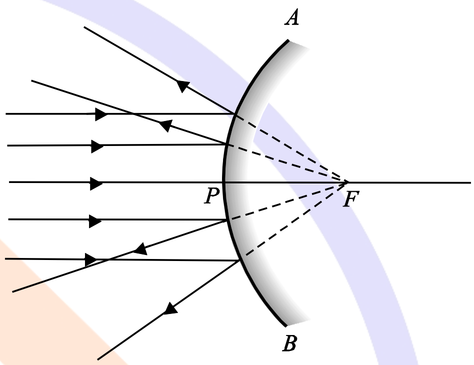
Principal axis – Line passing through points C and P.

6. **Paraxial rays:** Rays which are close to the principal axis and make small angles with it i.e., almost parallel to the principal axis, are called paraxial rays.

7. **Principal focus:** The **principal** focus of a spherical mirror is a fixed point on the principal axis where a narrow beam of light parallel to the principal axis after reflection either actually passes through that point (in the case of a concave mirror) or appears to diverge from that point (in the case of a convex mirror).



(a) Concave mirror



(b) Convex mirror

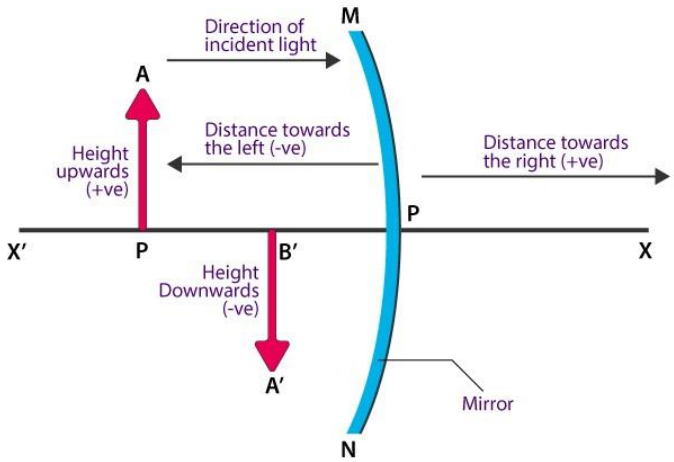
Principal focus of a spherical mirror

8. **Focal length (f):** The distance of the principal focus from the pole of the spherical mirror is called focal length.

9. **Focal plane:** A plane through the principal focus and perpendicular to the principal axis of a spherical mirror is called focal plane.

Sign convention

The sign convention described below is followed for the study of **reflection by a spherical mirror as well as for refraction at a spherical surface.**



The Cartesian Sign Convention

(i) The pole (of a spherical reflecting / a spherical refracting surface or the optical centre of a lens) is taken to be the origin and the principal axis as the X-axis.

(ii) Distances measured along the principal axis (For example: u, v, R, t) are measured from the pole.

- A distance measured in the **same direction** as the incident ray is taken **positive.**
- A distance measured **opposite** to the direction of incident light is taken **negative.**

(In the given diagram, direction of the incident light is taken from **left to right**, so that a distance in the +x direction is positive).

The quantities u, v, R and f respectively denote the x-coordinate of the object, the image, the centre of curvature and the focus.

(iii) ▪ A height measured in the upward direction normal to the principal axis is taken positive.

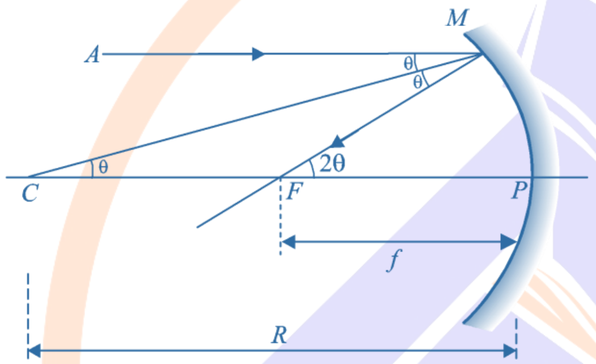
▪ A height measured in the down direction normal to the principal axis is taken negative.

Sign convention for focal length and radius of curvature

(i) Focal length and radius of curvature of a convex mirror is positive, since the principal focus and centre of curvature lie to the right of the pole (is the same direction as that of the incident light).

(ii) Focal length and radius of curvature of a concave mirror is negative, since F and C lie to the left of the pole (is opposite direction to that of incident light).

Relation between focal length and radius of curvature



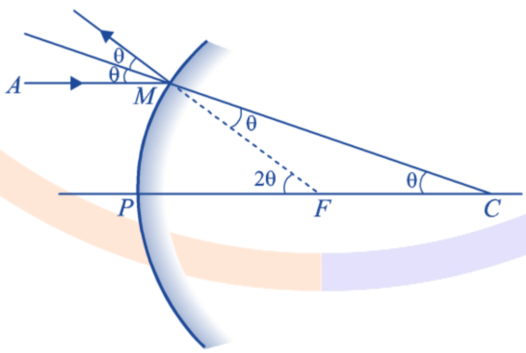
AM – incident ray
MF- reflected ray
C – Centre of curvature
F – Principal focus
P – Pole
MC – Normal to mirror at M.
$\angle AMC = \theta =$ angle of incidence

Reflection from a concave mirror

The principal focus lies midway between the centre of curvature and the pole.

Hence, $f = \frac{R}{2}$

The above relation can be obtained for a convex mirror on the same lines as in the case of a concave mirror. The following diagram shows the ray diagram in the case of a convex mirror.



Reflection from a convex mirror

Mirror equation (or Mirror formula)

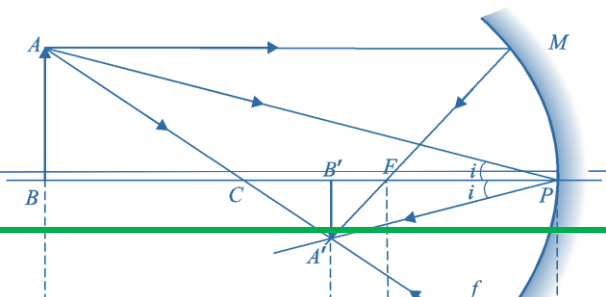
The mirror equation gives the relation between object distance and image distance in case of a spherical mirror. The relationship is given by $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$.

where u is the object distance, v is the image distance and f is the focal length of spherical mirror.

Case 1 : A concave mirror producing a real image

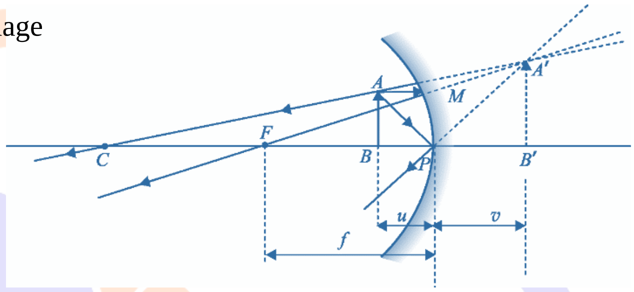
By sign convention:

u = object distance, –ve

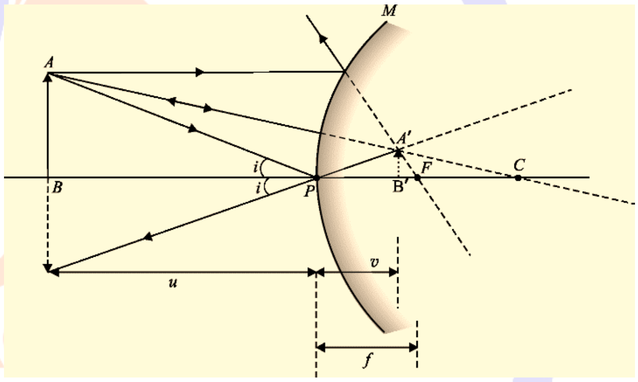


v = image distance, –ve
f = focal length, –ve
R = radius of curvature, –ve

Case 2 : Concave mirror producing a virtual image
By sign convention,
u = object distance, –ve
v = image distance, +ve
f = focal length, –ve
R = radius of curvature, –ve



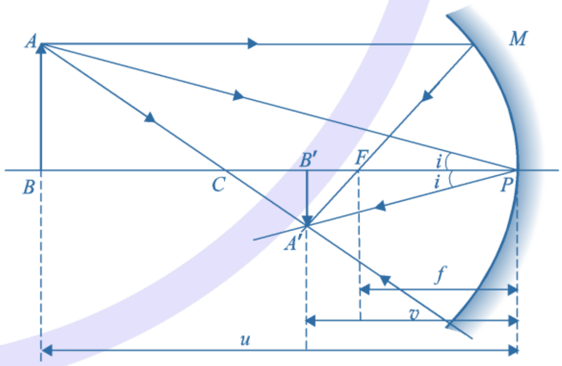
Case 3 : Convex mirror producing virtual image
By sign convention,
u = object distance, –ve,
v = image distance, +ve
f = focal length, +ve,
R = radius of curvature, +ve



Lateral (Linear) magnification (m)

The lateral magnification produced in a spherical mirror is defined as the ratio of height of image (h_I) to the height of the object (h_o) i.e. $m = \frac{h_I}{h_O}$, h_I and h_O will be taken as positive or negative according to the sign convention.

In the case of a concave mirror producing the real image as shown in the figure.



Concave mirror producing a real image

We find that triangles ABP and A′B′P are similar

Hence, $\frac{BA}{B'A'} = \frac{PB}{PB'} \Rightarrow \frac{h_O}{h_I} = \frac{u}{v}$

By sign convention,

u is – ve, v is – ve, h_o is + ve and h_I is – ve $\therefore \frac{h_O}{-h_I} = \frac{-u}{-v}$ or $\frac{h_I}{h_O} = -\frac{v}{u}$

Thus, $m = -\frac{v}{u}$ (Magnification in terms of u and v)

The above equation is also valid for the case of a concave mirror producing a virtual image and for the case of a convex mirror producing a virtual image. Thus, the above equation is valid for all cases of reflection by a spherical mirror.

- **Linear magnification in terms of the focal length of a spherical mirror**

From the mirror equation, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

- Multiplying throughout by –u, $-\frac{u}{v}-1=-\frac{u}{f} \Rightarrow 1-\frac{u}{f}=\frac{1}{m}$ or $\frac{(f-u)}{f}=\frac{1}{m}$

  Thus, $m=\frac{f}{(f-u)}$ (m in terms of object distance and focal length)

- Multiplying the mirror equation by $-v$ throughout, $-\frac{v}{u}-1=-\frac{v}{f} \Rightarrow m=1-\frac{v}{f}$

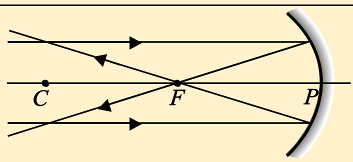
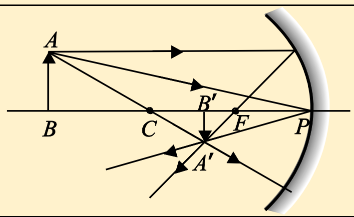
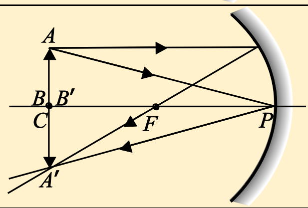
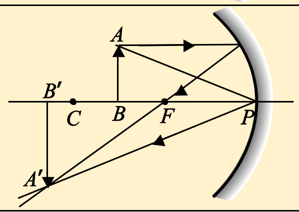
  Thus, $m=\frac{(f-v)}{f}$ (m in terms of image distance and focal length)

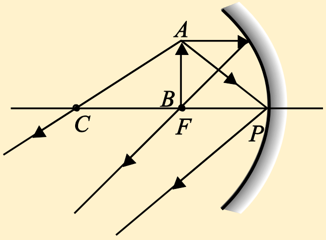
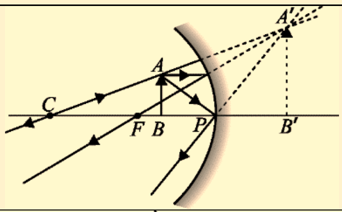
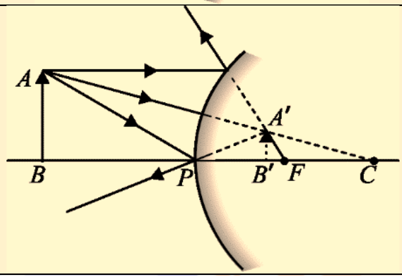
Ray Tracing

Ray tracing is a geometrical method used for locating the image formed due to a spherical mirror. A bundle of rays either converge to form a real image or appear to diverge from a virtual image. If we can draw these rays as they reflect from a mirror, the image can be located. The necessary steps to be followed in locating the image are given below.

1. A ray parallel to the axis after reflection either passes through the focal point (in the case of a concave mirror) or appear to diverge from the focal point (in the case of a convex mirror).
2. A ray passing through the focal point (in case of a concave mirror) or appearing to diverge from focal point (in case of a convex mirror) after reflection passes parallel to the principal axis.
3. A ray passing through the centre of curvature C gets reflected back along the original path (i.e., the ray retraces the path as it is incident normally).
4. A ray striking the pole of the mirror undergoes reflection such that i = r and emerges on the opposite side of the principal axis.

Image formation in a mirror

	Position of the object	Ray diagram	Position of the image	Nature of the image
(i)	At infinity		At F	Real, inverted, highly diminished
(ii)	Beyond the centre of curvature C		Between F and C	Real, inverted, diminished
(iii)	At C		At C	Real, inverted, same size
(iv)	Between F and C		Beyond C	Real, inverted, enlarged

	Position of the object	Ray diagram	Position of the image	Nature of the image
(v)	At F		At infinity	Cannot be ascertained
(vi)	Within F		Behind the mirror	Virtual, erect, enlarged
	Convex mirror (Object anywhere in front of it)		Behind the mirror	Virtual, erect, diminished

Illustrations

1. The image formed by a convex mirror of focal length 30 cm is a quarter of the size of the object. The distance of the object from the mirror is

(A) 30 cm (B) 90 cm (C) 120 cm (D) 60 cm

Ans (B)

$$m = \frac{f}{(f-u)} \Rightarrow \left(+\frac{1}{4}\right) = \frac{(+30)}{(+30)-u} \Rightarrow u = -90 \text{ cm}$$

2. An object is placed 40 cm from a concave mirror of focal length 20 cm. The image formed is

(A) real, inverted and same in size (B) real, inverted and smaller

(C) virtual, erect and larger (D) virtual, erect and smaller

Ans (A)

Real, inverted and same in size because object is at the centre of curvature of the mirror.

3. Radius of curvature of concave mirror is 40 cm and the size of the image is twice as that of object, then the object distance is

(A) 60 cm (B) 20 cm (C) 40 cm (D) 30 cm

Ans (D)

$$f = \frac{R}{2} = 20 \text{ cm}, \ m = 2 \text{ for real image; } m = -2,$$

By using $m = \frac{f}{f-u}, \ -2 = \frac{-20}{-20-u} \Rightarrow u = -30 \text{ cm}$

For virtual image; $m = \pm 2$

So, $+2 = \frac{-20}{-20-u} \Rightarrow u = -10 \text{ cm}$

4. A convex mirror has a focal length f. A real object is placed at a distance f in front of it from the pole produces an image at an

(A) infinity (B) f (C) $\frac{f}{2}$ (D) 2f

Ans (C)

Here focal length f and u = – f

On putting these values in $\frac{1}{f}=\frac{1}{u}+\frac{1}{v} \Rightarrow \frac{1}{f}=-\frac{1}{f}+\frac{1}{v} \Rightarrow v=\frac{f}{2}$

5. A concave mirror gives an image three times as large as the object placed at a distance of 20 cm from it. For the image to be real, the focal length should be

(A) 10 cm (B) –15 cm (C) 20 cm (D) 30 cm

Ans (B)

$$m=\frac{f}{f-u} \Rightarrow -3=\frac{f}{f-(-20)} \Rightarrow f=-15 \text{ cm}$$

6. A concave mirror of focal length f (in air) is immersed in water $\left(\mu=\frac{4}{3}\right)$. The focal length of the mirror in water will be

(A) f (B $\frac{4}{3}$f (C) $\frac{3}{4}$f (D) $\frac{7}{3}$f

Ans (A)

Focal length of the mirror remains unchanged.

7. A convex mirror or focal length ‘f’ forms an image which is $\frac{1}{n}$ times the object. The distance of the object from the mirror is

(A) (n – 1) f (B) $\left(\frac{n-1}{n}\right)$f (C) $\left(\frac{n+1}{n}\right)$f (D) (n + 1) f

Ans (A)

$$m=-\frac{v}{u}=\frac{1}{n} \quad \therefore v=-\frac{u}{n}$$

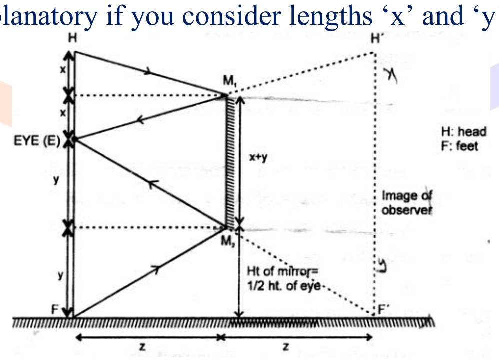
from mirror formula: $\frac{1}{f}=\frac{1}{\left(-\frac{u}{n}\right)}+\frac{1}{u} \quad \therefore u=-(n-1)f$

8. The minimum size of a plane mirror, required to see the full image of an observer is half the size of the size of that observer is

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

Ans (B)

See the following figure. It is explanatory if you consider lengths ‘x’ and ‘y’ as shows in figure



Aliter

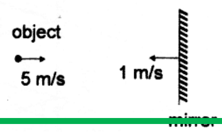
ΔE M_1, M_2 and ΔE H ‘F’ are similar

$$\therefore \frac{M_1M_2}{H'F'}=\frac{z}{2z} \text{ or } M_1M_2=\frac{H'F'}{2}=\frac{HF}{2}$$

9. An object moves with 5 m / s towards right while the mirror moves 1 m / s towards the left as shown. Find velocity of image.

(A) 5 ms^{-1} (B) –7 ms^{-1} (C) 8 ms^{-1} (D) 10 ms^{-1}

Ans (B)



Take → as + direction. $v_i - v_m = v_m - v_0$

$v_i - (-1 = (-1) - 5$

∴ $v_i = -7$ m/s and direction towards left.

10. There is a point object and a plane mirror. If the mirror. If the mirror is moved by 10 cm away from the object find the distance which the image will move.

(A) 20 cm (B) 10 cm (C) 5 cm (D) 30 cm

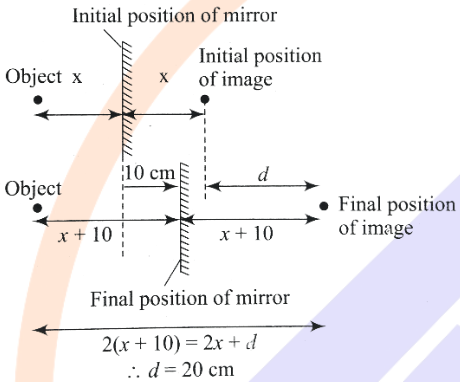
Ans (A)

We know that $x_{im} = -x_{om}$ ort $x_i - x_m = x_m - x_o$

or $\Delta x_i - \Delta x_m = \Delta x_m - \Delta x_o$.

In this Q. $\Delta x_o = 0$; $\Delta x_m = 10\text{cm}$

Therefore $\Delta x_i = 2\Delta x_m - \Delta x_o = 20\text{cm}$



Refraction at a Plane Surface

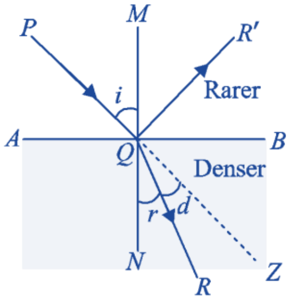
Introduction

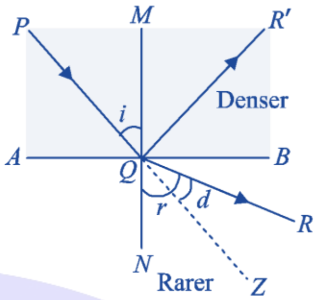
Geometrical optics is the branch of optics that deals with image formation by employing the ray concept of light.

- A medium which allows light through it is called an *optical medium*. Though the word medium is generally perceived as a material medium, vacuum is also an optical medium.
- An optical medium is said to be *homogenous*, if a given physical property (Example: refractive index) has the same value at every point in the medium. Otherwise, it is *inhomogeneous*. An optical medium is said to be *isotropic*, if a given physical property (Example: speed of light) has the same value in all directions. For example, glass, water, benzene etc are isotropic. An optical medium is said to be *anisotropic* if a given physical property has different values in different directions. For example, quartz, calcite, tourmaline etc are anisotropic.
- When light travels from one optical medium to another, its speed and also its wavelength will change. Further, the direction of propagation also changes provided the incident light is not normal to the interface separating the two media. However, the frequency of light remains constant. This is because, frequency is a characteristic of a source, not of medium.

The phenomenon of transmission of light from one homogeneous medium to another associated with a change in its speed is referred to as refraction of light.

Refraction at a Plane Surface





When a ray propagates from a rarer to a denser medium, the reflected ray, bends towards the normal. When a ray of light travels from a denser to a rarer medium the refracted ray bends away from the normal. The cause of refraction is a change in velocity of light.

In the above figures

PQ – incident ray, QR – refracted ray, QR′ – reflected ray

AB – refracting surface, MN – normal to AB at point Q

i – angle of incidence, r – angle of refraction

PQZ – direction of incident ray in the absence of the other medium

The angle of deviation is the angle between the refracted ray and the direction of the incident ray.

When the ray travels from a rarer to a denser medium, the angle of deviation is given by $d = i - r$

When the ray travels from denser to rarer medium the angle of deviation is given by $d = r - i$

Laws of Refraction of Light

I Law

During refraction, the incident ray, the refracted ray and the normal at the point of incidence to the refracting surface lie in the same plane.

II Law (Snell's law)

During refraction, the ratio of sine of the angle of incidence to the sine of the angle of refraction remains a constant for a given pair of media and for a given wavelength of light.

Mathematically, ${}_1n_2 = \frac{\sin i}{\sin r}$

The constant ${}_1n_2$ is called the *refractive index* (*or RI)* of medium 2 with respect to medium 1.

Medium 1 contains the incident ray and the medium 2 contains the refracted ray.

General form of Snell's law: $n_1 \sin i_1 = n_2 \sin i_2$

➢ **Snell's law fails to give the value of RI for normal incidence.**

- Absolute refractive index of a medium = $\frac{\text{speed of light in vacuum}}{\text{speed of light of given wavelength in the medium}} = \frac{c}{v}$

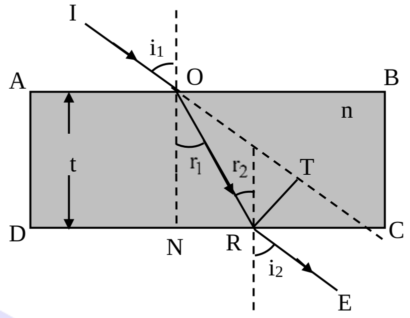
  Since c > v, the absolute RI of a medium is always greater than unity.

- Relative refractive index of medium 2 with respect to medium 1,

$${}_1n_2 = \frac{\text{speed of light in medium 1}}{\text{speed of light in medium 2}} = \frac{v_1}{v_2}$$

$${}_1n_2 = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

Lateral shift (S_L)



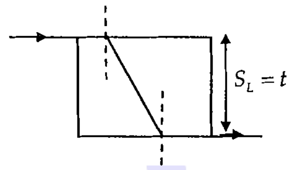
- A ray of light incident obliquely on a parallel sided transparent medium emerges from it parallel to the incident direction provided the medium on both sides of the transparent medium is the same. Lateral shift is given by, $S_L = \frac{t\sin(i-r)}{\cos r}$, where t = thickness of the rectangular slab, i = angle of incidence, r = angle of refraction.
- For small i, r is also small. When i and r in radian,

  $\sin(i-r) \simeq (i-r)$, $\cos r \simeq 1$

  $S_L = \frac{t}{\cos r}\sin(i-r) = t(i-r)$

  By Snell's law, $n = \frac{\sin i}{\sin r} = \frac{i}{r}$ $\therefore r = \frac{i}{n}$

  $S_L = t\left(i - \frac{i}{n}\right) = ti\left(1 - \frac{1}{n}\right)$



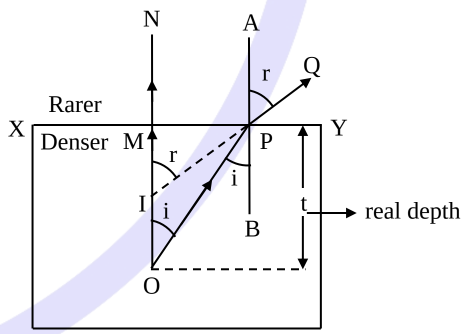
- Lateral shift can also be expressed as $S_L = t\sin(i-r)\sec r$
- For $i = 0$, $r = 0$. $\therefore S_L = 0$.

  Thus, the minimum value of lateral shift is zero. This occurs for normal incidence.
- For grazing incidence, $i = 90°$

  $S_L = \frac{t\sin(90°-r)}{\cos r} = \frac{t\cos r}{\cos r} = t.$

  Thus, the maximum value of lateral shift produced by a glass slab is equal to its thickness.
- When white light is incident on a glass slab, even though the emergent beam consists of composite colours displaced parallel to each other, it is perceived as white light itself.

Normal shift (S_N)



- It is the amount by which an object appears to have been shifted from its real position due to normal refraction at a plane interface separating two optical media.
  - ➢ $n = \frac{\text{real depth}}{\text{apparent depth}}$
  - ➢ $S_N = t\left(1 - \frac{1}{{}_r n_d}\right)$, where ${}_r n_d = {}_{rarer} n_{denser}$

- Normal shift is independent of the position of the object below the bottom of the refracting medium.
- When an **object placed in a rarer medium** of refractive index n_r is viewed along the normal from a **denser medium** of refractive index n_d,

  i. $\frac{\text{real height}}{\text{apparent height}} = \frac{n_r}{n_d}$.

  ii. $S_N = t\left\{\frac{n_d}{n_r} - 1\right\}$ The object appears to be **farther** away, since $\frac{n_r}{n_d} < 1$.

- When an object is viewed through a composite medium having parallel surfaces,

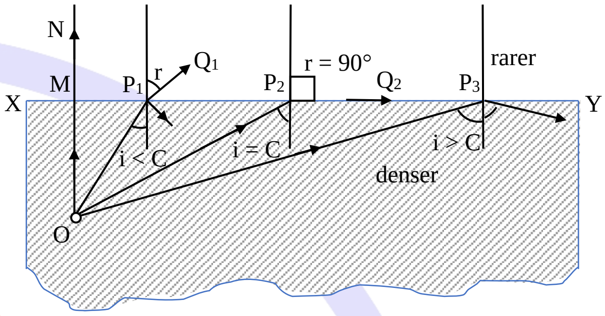
  a. The total normal shift is equal to the sum of the normal shifts produced by individual media.
  $(S_N)_{Total} = S_{N_1} + S_{N_2} + S_{N_3} + ... = \Sigma S_N$

  b. Total apparent depth is equal to sum of individual apparent depths
  $(AD)_{total} = (AD)_1 + (AD)_2 + (AD)_3 + \ldots$

i.e., Total apparent depth $= \frac{(RD)_1}{n_1} + \frac{(RD)_2}{n_2} + \frac{(RD)_3}{n_3} + ... = \sum \frac{RD}{n}$

Total Internal Reflection (TIR)

When a ray of light passes from an optically denser medium (larger n) to an optically rarer medium (smaller n), the angle of refraction r is greater than the corresponding angle of incidence i. $\left(\frac{\sin i}{\sin r} = \frac{n_R}{n_D} < 1\right)$.



As we gradually increase i, the corresponding r will also increase. At a certain value of i = C, known as critical angle (in the denser medium), r will become 90°. If i is increased further, there is no r which can satisfy Snell's law. Thus, the ray will not be refracted. Entire light is then reflected back into the denser medium. This is called *total internal reflection.*

Critical angle for a pair of media and for a given wavelength is the angle of incidence in the denser medium for which the angle of refraction is 90°.

Total internal reflection is the process of reflection at the interface of a pair of media when light passes from a denser medium into a rarer medium and the angle of incidence is greater than the critical angle in the denser medium.

- Relation between refractive index and critical angle $\sin C = \frac{\text{RI of rarer medium } (n_R)}{\text{RI of denser medium} (n_D)}$

If the rarer medium is air or vacuum, $n_R = 1$ and $n_D = n$ absolute refractive index of the medium.

Then, $\sin C = \frac{1}{n}$ or $n = \frac{1}{\sin C}$

- For a given pair of media, $C_{red} > C_{yellow} > C_{violet}$.
- Some consequences of TIR

➢ Brilliance of a diamond is due to TIR, Mirage is due to TIR.

☞

- Consider a light ray going from a denser medium to rarer medium. Deviation of the ray in different cases will be as follows.

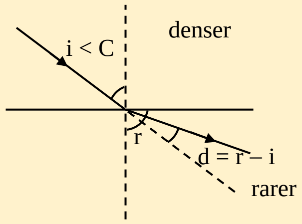


fig. 1

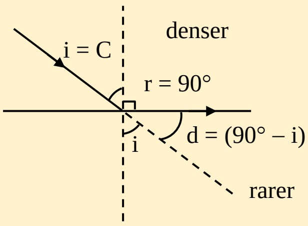


fig. 2

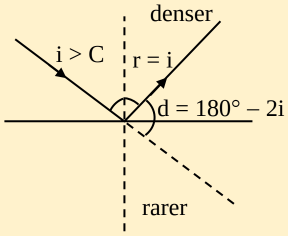


fig. 3

(a) If i < C, d = r – i as shown in the fig (1)
(b) If i = C, d = 90° – C as shown in the fig (2)
(c) If i > C, d = 180° – 2i as shown in the fig (3)
(d) maximum deviation produced for a ray of light traveling from a denser medium to a rarer medium = 180° – 2C

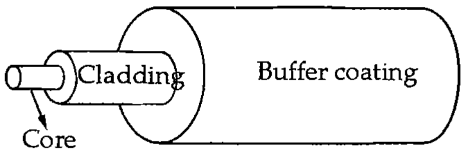
Optical fibre

An optical fibre is a thin, hair like fibre made of extremely pure glass / plastic known as light guiding core. It is coated with a material of lesser refractive index called the cladding.

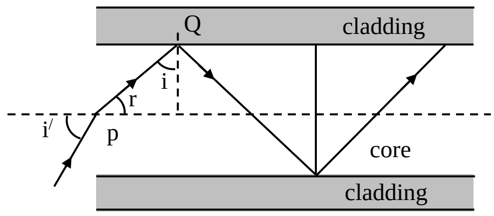
It works on the principle of total internal reflection.

Structure of an optical fibre

Figure shows the structure of an optical fibre and light transmission through it.



(a) Structure of optical fibre



(b) TIR in an optical fibre

1. **Core:** Core is made of extremely pure glass and its diameter is in the range 10 μm to 100 μm (depending on the type).
2. **Cladding:** The core is surrounded by extremely pure glass or plastic material known as cladding whose refractive index is lower than that of the core. The outer diameter is around 125 μm.
3. **Buffer:** For providing safety and strength, the core - cladding system is covered with a plastic coating known as buffer. This also provides optical insulation when hundreds of fibres are packed into a cable. The refractive index of the buffer material is less than that of the cladding.

   When a ray of light entering the fibre from one end is incident on the core-clad interface at an angle greater than the corresponding critical angle it undergoes TIR at that interface. Because of cylindrical symmetry in the fibre structure, this ray will suffer TIR at the lower interface also. So light is guided through the core by repeated TIRs, even in a bent fibre.

Applications

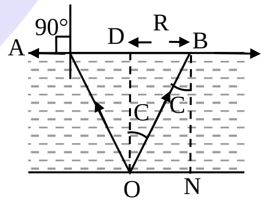
(a) *Gastroscope*: It is a device with which a doctor can visually examine the inside of the stomach of a patient merely by introducing the fibre bundle through the mouth into the stomach.

(b) *Communication*: Optical fibres are already in use as carriers of telephone messages over long distances. The message to be transmitted modulates a laser beam which travels through the optical fibre. The aim of any communication system is to transfer information from one point to another. In optical communication, the optical fibre is used as the carrier of information.

(c) *Stellar spectroscopy*: In the conventional spectroscopy, the image of a star is formed as a disc which is feeble in intensity. To enhance the intensity, a bundle of optical fibres is used. The cross sectional area is made considerably large at the end where light from the star is incident and the cross sectional area is made narrow at the receiving end.

Field of vision of fish (or swimmer)

Rays from the object within a small angled cone fall almost normally and hence come out of the top surface of the slab. Rays incident on the top surface at critical angle graze the surface. Rays incident at angles greater than critical angle experience total internal reflection and hence do not come out of the top surface. Thus, rays which emerge from the top surface fall within a circle of diameter 2R which makes an angle 2C at O. Thus this portion of the slab has to be covered.



A fish (diver) inside the water can see the whole world through a cone with

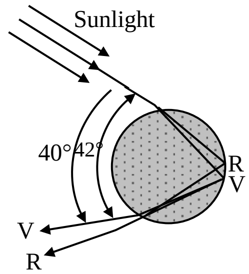
(a) Apex angle = 2C = 98°

(b) Radius of base $r = h\tan C = \frac{h}{\sqrt{n^2-1}}$; for water $r = \frac{3h}{\sqrt{7}}$

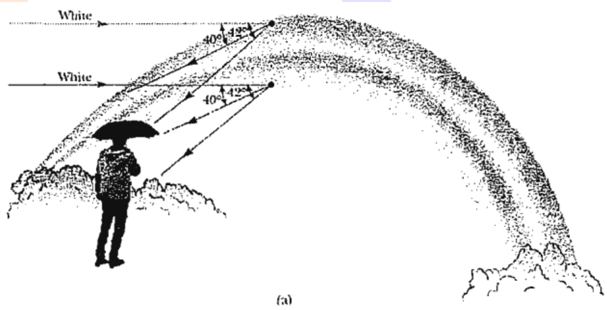
(c) Area of base $A = \frac{\pi h^2}{(n^2-1)}$; for water $A = \frac{9\pi}{7}h^2$

Some natural phenomena due to sunlight

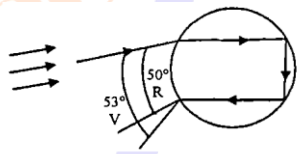
Rainbow



The dispersion of light into a spectrum is demonstrated most vividly in nature through the formation of a rainbow, often seen by an observer positioned between the Sun and a rain shower. To understand how a rainbow is formed, consider figure as shown. A ray of light passing overhead strikes a drop of water in the atmosphere and is refracted and reflected as follows: It is first refracted at the front surface of the drop, with the violet light deviating the most and the red light the least At the back surface of the drop, the light is reflected and returns to the front surface, where it again undergoes refraction as it moves from water into air. The rays leave the drop so that the angle between the incident white light and the returning violet ray is 40° and the angle between the white light and the returning red ray is 42°. This small angular difference between the returning rays causes us to see the coloured rainbow.



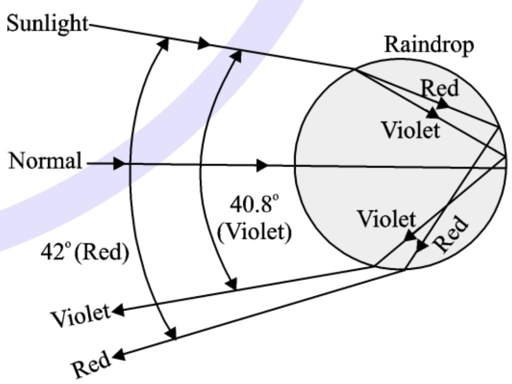
Now consider an observer viewing a rainbow, as in shown in the figure. If a raindrop high in the sky is being observed, the red light returning from the drop can reach the observer because it is deviated the most, but the violet light passes over the observer because it is deviated the least. Hence, the observer sees this drop as being red. Similarly, a drop lower in the sky would direct violet light toward the observer and appear to be violet. (The red light from this drop would strike the ground and not be seen.) The remaining colors of the spectrum would reach the observer from raindrops lying between these two extreme positions.



Rays of some light undergoing two internal reflections inside a raindrops give rise to the secondary rainbow as shown in the figure. The order of sequence of colours violet to red in the secondary is opposite to that in the primary rainbow. Also the secondary rainbow is less bright due to loss of intensity in the second reflection.

The rainbow

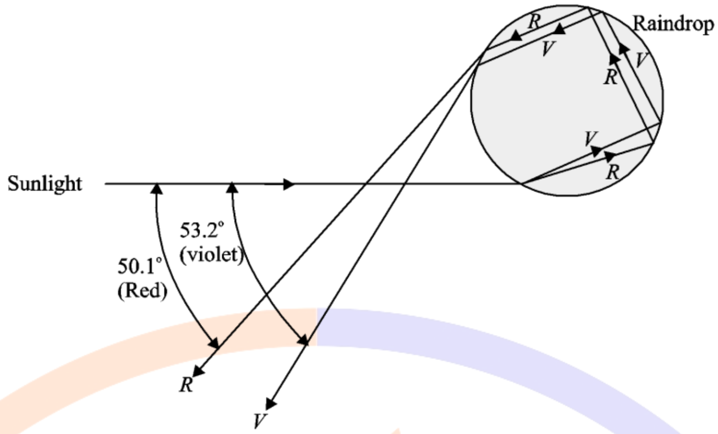
The beauty of a rainbow is due to the combined effect of dispersion, refraction and total internal reflection of sunlight by spherical water droplets of rain. The condition for observing a rainbow is that the sun should be shining in one part of the sky while it is raining in the opposite part of the sky. Sunlight must be from the back of the observer and observer should be facing the rain.



Formation of primary rainbow

Sunlight is a composite beam consisting of several wavelengths and the component colours are VIBGYOR in the order of wavelength. A ray of light entering the rain drop undergoes refraction. As the light enters, it is split into component colours. Longer wavelengths of light are bent the least whereas the shorter wavelengths are bent the most. These component rays strike the inner surface of rain drop at an angle greater than the critical angle. The rays undergo total internal reflection. These rays again strike the front surface of the drop and emerge undergoing refraction once more. It is found that the violet light emerges at angle of 40.8° whereas the red component of light emerges at 42.5°. For other colours, angles lie in between these values. figure explains the formation of primary rainbow.

The formation of secondary rainbow is shown in the figure. The violet component has maximum angle of deviation (53.2°) whereas red component has minimum angle of deviation (50.1°).



Formation of secondary rainbow

Differences between primary and secondary rainbow

Primary rainbow		Secondary rainbow	
1.	Formed due to two refraction and **one** total internal reflection.	1.	Formed due to two refractions and **two** total internal reflections.
2.	Violet color is formed at top and red color at the bottom of rainbow. Angle of deviation for violet is 40.8° while that for red is 42°.	2.	Violet color is formed at the bottom and red color at the top of rainbow. Angle of deviation for violet is 53.2° while that for red is 50.1°.
3.	Intensity of colors is large due to one total internal reflection.	3.	Intensity of colors is small as two reflections occur.

Scattering of light

Scattering of light is the absorption and re-emission of light by atoms, molecules and molecular clusters, when it passed through a material medium.

Scattering of light can be either coherent or incoherent.

Coherent Scattering

In this kind of scattering, only those wavelengths present in the incident beam are present in the scattered radiation. Example: Rayleigh scattering, Mie scattering etc.

Incoherent Scattering

In this kind of scattering, wavelengths other than those present in the incident beam are present in the scattered radiation. Example: Raman effect, Compton effect and fluorescence etc.

Rayleigh Scattering

It is an example of coherent scattering. The intensity of light at right angles to the direction of incident light is proportional to $\left(\frac{1}{\lambda^4}\right)$, where λ is the wavelength of the radiation. $I \propto \frac{1}{\lambda^4}$.

Blue colour of the sky: As sun light passes through the earth's atmosphere, blue colour is scattered most because of shorter wavelength (intensity of violet is negligible). Hence, when seen from a point on the earth, the sky appears blue. In the absence of atmosphere, sky would appear black.

The intensity of scattered light compared to the intensity of incident radiation is always very small. Thus, for study of scattered radiation, laser lights are preferred, as they are very intense.

Blue colour of ocean: Sir C.V. Raman explained the blue colour of the ocean also as due to Rayleigh scattering by the water molecules. To perceive this, enough thickness of the water layer is required. This is the reason for blue colour being observed only in deep waters.

Red colour of setting (or raising) sun: When setting sun is observed from a point on the earth, the path length is longest and density of atmosphere (scattering particle density) is highest. The lower wavelengths (blue etc) are scattered away from line of sight. Hence, in that direction light consists of predominantly longer wavelengths. In fact the colour of the horizon gradually changes from yellow to red.

In Rayleigh scattering, the wavelength in the scattered radiation has no relation to the nature of the scattering particles.

The scattered light in Rayleigh scattering is partially polarised.

Illustrations

1. The refractive index of glass is 1.5 for light whose wavelength in vacuum is 6000 Å. The wavelength of this light when it passes through glass is,

(A) 4000Å (B) 6000Å (C) 9000Å (D) 15000Å

Ans (A)

We know that, $u = \frac{\lambda}{\lambda_1}$

$\lambda = 6000Å$, $\mu = 1.5$

$\therefore \lambda_1 = \frac{6000}{1.5} = 4000$ Å

2. A vessel of depth 2d cm is half filled with a liquid of RI 'μ', and upper half with a liquid of RI μ_2. The apparent depth of the vessel seen perpendicularly from above is

(A) $d\left(\frac{\mu_1\mu_2}{\mu_1+\mu_2}\right)$ (B) $d\left(\frac{1}{\mu_1}+\frac{1}{\mu_2}\right)$ (C) $2d\left(\frac{1}{\mu_1}+\frac{1}{\mu_2}\right)$ (D) $2d\left(\frac{1}{\mu_1\mu_2}\right)$

Ans (B)

Apparent depth, $h' = \frac{d_1}{\mu_1} + \frac{d_2}{\mu_2}$

$$\therefore h' = \frac{d}{\mu_1} + \frac{d}{\mu_2} = d\left(\frac{1}{\mu_1}+\frac{1}{\mu_2}\right)$$

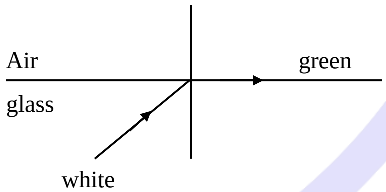
3. White light is incident on the interface of glass and air as shown in the figure. If green light is just totally internally reflected, then the emerging ray in air contains.

(A) yellow, orange, red

(B) violet, indigo, blue

(C) all colours

(D) all colours except green



Ans (A)

We know that; $\sin c = \frac{1}{\mu}$

or $c = \sin^{-1}\left(\frac{1}{\mu}\right)$

$\therefore$ as μ decreases with increase in λ.

Yellow, orange and red have higher wavelength's than green, thus μ is less for these rays.

If μ is less, then critical angle for these rays will be high.

Thus if green is totally internally reflected just, then yellow, orange and red emerge out.

4. *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 of n from the following.

(A) 1.2 (B) $\frac{4}{3}$ (C) 1.4 (D) 1.5

Ans (D)

$\sin I > \sin \theta_c$

$\therefore \sin 45° > \frac{1}{n}$ $\quad [\because \mu = n]$

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

$n > \sqrt{2}$

or $n > 1.414$

5. When light passes from water to air

(A) speed of light in both media is the same
(B) the frequency of light decreases
(C) wavelength increases
(D) wavelength decreases

***Ans** (C)*

When light from a denser medium (water) enters a rarer medium (air) the speed increases and the wavelength also increases. The frequency does not change, since it depends on the source emitting light and is independent of the intervening medium.

6. A body which allows light to pass through it partially is

(A) transparent (B) translucent (C) opaque (D) dichroic

Ans (B)

By definition, a medium which allows light to pass through it partially is a translucent medium.

7. For rectilinear propagation of light, a medium should be necessarily

(A) homogeneous (B) isotropic (C) inhomogeneous (D) anisotropic

Ans (A)

A ray of light passes along a straight line (rectilinear propagation) only, when the medium is homogeneous and this is the necessary condition.

8. A glass slab of thickness 40 mm contains the same number of wavelengths of a light wave as a layer of water of thickness t. If $n_g = \frac{3}{2}$ and $n_w = \frac{4}{3}$, the value of t in mm is

(A) 40 (B) 45 (C) 60 (D) 90

Ans (B)

Let the number of waves be N. The wavelength of the light wave in glass $\lambda_g = \frac{40}{N}$ mm and the wavelength in water is

$\lambda_w = \frac{t}{N}$

Since ${}_w n_g = \frac{n_g}{n_w}$ and ${}_g n_w = \frac{\lambda_w}{\lambda_g}$

We can write $\frac{n_g}{n_w} = \frac{\lambda_w}{\lambda_g} = \frac{t/N}{40/N} = \frac{t}{40}$

i.e., $\frac{3/2}{4/3} = t/40$ or $\frac{9}{8} = \frac{t}{40}$ $\therefore$ $t = 40\left(\frac{9}{8}\right) = 45$ mm

9. Lateral shift produced by a parallel sided glass slab

(A) varies directly as its thickness
(B) varies inversely as its thickness
(C) is independent of the thickness
(D) varies directly as the square of its thickness

Ans (A)

With usual notation, the lateral shift is given by $S_L = \frac{t \sin(i-r)}{\cos r}$

and for a given angle of incidence, $S_L \propto t$

10. A person under water in a swimming pool looks at the diving board. The board

(A) appears at the same position (B) appears nearer
(C) appears farther (D) is not seen.

Ans (C)

This is a case of object in the rarer medium (air) and the observer in the denser medium (water) and therefore the object appears farther.

11. An air bubble in a glass slab of thickness 15 cm is 6 cm on one side and 4 cm on other side. Refractive index of glass is

(A) 1.25 (B) 1.33 (C) 1.50 (D) 1

Ans (C)

Refractive index n = $\frac{\text{real depth}}{\text{apparent depth}}$

Real depth = 15 cm

Apparent depth = 6 + 4 = 10 cm

$\therefore$ Refractive index n = $\frac{15}{10} = 1.5$

12. The critical angle and the refractive index are related by

(A) n = cosec C (B) n = sec C (C) n = sin C (D) $\frac{1}{n}$ = cosec C

Ans (A)

The critical angle and n are related by $n = \frac{1}{\sin C} \Rightarrow n = \text{cosec } C$

13. Total internal reflection is possible when light tends to pass from

(A) air to water (B) water to glass (C) glass to water (D) air to glass

Ans (C)

One of the important conditions for total internal reflection is that a ray of light must pass from a denser medium to a rarer medium. From the given choices we see that if light passes from glass (denser) to water (rarer) the condition is satisfied.

14. A ray of light is passing from medium $1(n_1 = 2)$ to medium $2(n_2 = \sqrt{2})$. The critical angle is

(A) 30° (B) 45° (C) 60° (D) 90°

Ans (B)

We know that, $\sin C = \frac{n_{\text{rarer medium}}}{n_{\text{denser medium}}}$

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

$$\therefore C = \sin^{-1}\left(\frac{1}{\sqrt{2}}\right) = 45^\circ$$

15. Optical fibres work on the principle of

(A) rectilinear propagation of light (B) reflection
(C) refraction (D) total internal reflection.

Ans (D)

Optical fibres can take light along curved paths because the light inside an optical fibre experiences total internal reflection due to a coating of a material of lower refractive index on the surface. So the principle involved in the process of transmission of light through an optical fibre is total internal reflection.

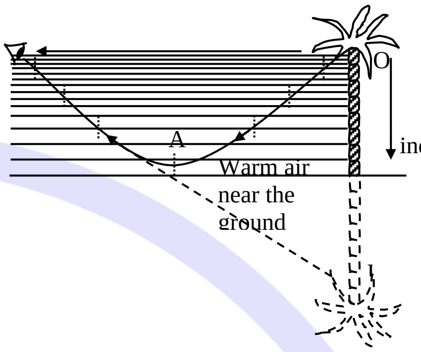
16. Mirage is an optical illusion due to

(A) refraction (B) reflection

(C) total internal reflection (D) refraction and total internal reflection.

Ans (D)

A quivering image of an object is seen just below the object during hot sunny days particularly in deserts. This is because of unequally heated layers of air above the ground. A ray from the top of an object inclined towards ground passes through layers of air which are more and more hotter towards ground. As the temperature increases air becomes less dense and its n decreases. Hence a ray passes from a medium of higher n (denser) to a medium of lower n (rarer). The ray bends away from the normal and finally undergoes total internal reflection and passes upwards. If these rays are received by an observer, one sees an inverted image of the object below it. The formation of mirage is due to both refraction and total internal reflection.



17. The refractive index of a certain glass is 1.5 for light whose wavelength in vacuum is 6000 Å. The wavelength of this light when it passes through glass is

(A) 4000 Å (B) 6000 Å (C) 9000 Å (D) 15000 Å

Ans (A)

$$\lambda_{medium} = \frac{\lambda_{air}}{\mu} = \frac{6000}{1.5} = 4000\ \text{Å}$$

18. When light travels from one medium to the other of which 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

Ans (D)

Velocity and wavelength change but frequency remains same.

19. A light wave has a frequency of 4×10^{14} Hz and a wavelength of 5×10^{-7} metres in a medium. The refractive index of the medium is

(A) 1.5 (B) 1.33 (C) 1.0 (D) 0.66

Ans (A)

$$\mu = \frac{v}{c} = \frac{c}{v\lambda} = \frac{3\times10^8}{4\times10^{14}\times5\times10^{-7}} = 1.5$$

20. The time taken (in seconds) to cross glass of thickness 4 mm and n = 3 by light is

(A) 4×10^{-11} (B) 2×10^{-11} (C) 16×10^{-11} (D) 8×10^{-10}

Ans (A)

$$t = \frac{nx}{c}$$

21. Monochromatic light is refracted from air into the glass of refractive index μ. The ratio of the wavelength of incident and refracted waves is

(A) 1 : μ (B) 1 : μ^2 (C) μ : 1 (D) 1 : 1

Ans (C)

$$\lambda \propto \frac{1}{\mu} \Rightarrow \frac{\lambda_1}{\lambda_2} = \frac{\mu_2}{\mu_1} = \frac{\mu}{1}$$

22. The index of refraction of diamond is 2.0, velocity of light in diamond in cm/second is approximately

(A) 6×10^{10} (B) 3.0×10^{10} (C) 2×10^{10} (D) 1.5×10^{10}

Ans (D)

$$v = \frac{c}{\mu} = \frac{3\times10^8}{2} = 1.5\times10^8 \text{ m/s} = 1.5 \times 10^{10} \text{ cm/s}$$

23. A rectangular tank of depth 8 meter is full of water $\left(\mu = \frac{4}{3}\right)$, the bottom is seen at the depth

(A) 6 m (B) $\frac{8}{3}$ m (C) 8 cm (D) 10 cm

Ans (A)

$$\mu = \frac{h}{h'} \Rightarrow h' = \frac{8}{\frac{4}{3}} = 6 \text{ m}$$

24. A vessel of depth 2d cm is half filled with a liquid of refractive index μ_1 and the upper half with a liquid of refractive index μ_2. The apparent depth of the vessel seen perpendicularly is

(A) $d\left(\frac{\mu_1\mu_2}{\mu+\mu_2}\right)$ (B) $d\left(\frac{1}{\mu_1}+\frac{1}{\mu_2}\right)$ (C) $2d\left(\frac{1}{\mu_1}+\frac{1}{\mu_2}\right)$ (D) $2d\left(\frac{1}{\mu_1\mu_2}\right)$

Ans (B)

$$h' = \frac{d_1}{\mu_1} + \frac{d_2}{\mu_2} = d\left(\frac{1}{\mu_1}+\frac{1}{\mu_2}\right)$$

25. Light travels through a glass plate of thickness t and having refractive index n. If c is the velocity of light tin vacuum, the time taken by the light to travel this thickness of glass is

(A) $\frac{t}{nc}$ (B) tnc (C) $\frac{nt}{c}$ (D) $\frac{tc}{n}$

Ans (C)

$$\text{time} = \frac{\text{distance}}{\text{speed}} = \frac{t}{\frac{c}{n}} = \frac{nt}{c}$$

26. Light takes 8 min 20 s to reach from sun on the earth, if the whole atmosphere is filled with water, the light will take the time $\left({}_a\mu_w = \frac{4}{3}\right)$

(A) 8 min 20 s (B) 8 min (C) 6 min 11 s (D) 11 min 6 s

Ans (D)

$$\mu = \frac{c_a}{c_w} = \frac{t_w}{t_a} \Rightarrow t_w = \frac{25}{3}\times\frac{4}{3} = 11\frac{1}{9} = 11 \text{ min } 6 \text{ s}$$

27. If ${}_1\mu_j$ represents refractive index when a light ray goes from medium i to medium j, then the product ${}_2\mu_1 \times {}_3\mu_2 \times {}_4\mu_3$ is equal to

(A) ${}_3\mu_1$ (B) ${}_3\mu_2$ (C) $\frac{1}{{}_1\mu_4}$ (D) ${}_4\mu_2$

Ans (C)

$${}_2\mu_1 \times {}_3\mu_2 \times {}_4\mu_3 = \frac{\mu_1}{\mu_2}\times\frac{\mu_2}{\mu_3}\times\frac{\mu_3}{\mu_4} = \frac{\mu_1}{\mu_4} \quad {}_4\mu_1 = \frac{1}{{}_1\mu_4}$$

28. Electromagnetic radiation of frequency n, wavelength λ, travelling with velocity v in air, enters a glass slab of refractive index μ. The frequency, wavelength and velocity of light in the glass slab will be respectively

(A) $\frac{n}{\mu}, \frac{\lambda}{\mu}, \frac{v}{\mu}$ (B) $n, \frac{\lambda}{\mu}, \frac{v}{\mu}$ (C) $n, \lambda, \frac{v}{\mu}$ (D) $\frac{n}{\mu}, \frac{\lambda}{\mu}, v$

Ans (B)

Frequency doesnot change with medium but wavelength and velocity decrease with the increase in refractive index.

29. A ray of light is incident on the surface of separation of a medium at an angle 45° and is refracted in the medium at an angle 30°. What will be the velocity of light in the medium?

(A) 1.96×10^8 m/s (B) 2.12×10^8 m/s (C) 3.18×10^8 m/s (D) 3.33×18^8 m/s

Ans (B)

$$\mu = \frac{c}{v} = \frac{\sin i}{\sin r} = \frac{\sin 45°}{\sin 30°} \Rightarrow v = \frac{3\times10^8}{\sqrt{2}} = 2.12\times10^8 \text{ m/s}$$

30. An under water swimmer is at a depth of 12 m below the surface of water. A bird is at a height of 18 m from the surface of water, directly above his eyes. For the swimmer the bird appears to be at a distance from the surface of water equal to (Refractive index of water is $\frac{4}{3}$)

(A) 24 m (B) 12 m (C) 18 m (D) 9 m

Ans (A)

$$\mu = \frac{h'}{h} \Rightarrow h' = \mu h = \frac{4}{3}\times 18 = 24 \text{ cm}$$

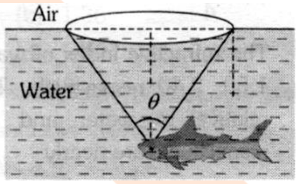
31. A fish is a little away below the surface of a lake. If the critical angle is 49°, then the fish could see things above the water surface within an angular range of θ° where

(A) θ = 49°

(B) θ = 90°

(C) θ = 98°

(D) $\theta = 24\frac{1°}{2}$



Ans (C)

From figure given in question θ = 2c = 98°

32. A point source of light is placed 4 m below the surface of water of refractive index $\frac{5}{3}$. The minimum diameter of a disc which should be placed over the source on the surface of water to cut-off all light coming out of water is

(A) 2 m (B) 6 m (C) 4 m (D) 3 m

Ans (B)

Here $\sin i = \frac{1}{\mu} = \frac{3}{5}$ and hence $\tan i = \frac{3}{4} = \frac{r}{4}$

This gives r = 3 m, hence diameter = 6 m

33. The critical angle for the light going from medium 1 to medium 2 is C. If the speed of light in medium 1 is v_1 the speed of light in medium 2 is

(A) $\frac{v_1}{(1-\cos C)}$ (B) $\frac{v_1}{\sin C}$ (C) $\frac{v_1}{\cos C}$ (D) $v_1 \cos C$

Ans (B)

$$\frac{n_2}{n_1} = \frac{v_1}{v_2} \Rightarrow \sin C = \frac{n_2}{n_1} \Rightarrow v_2 = \frac{v_1}{\sin C}$$

34. Light travelling from a transparent medium to air undergoes total internal reflection at an angle of incidence of 45 degree Then refractive index of the medium may be

(A) 1.5 (B) 1.4 (C) 1.1 (D) $\frac{1}{\sqrt{2}}$

Ans (B)

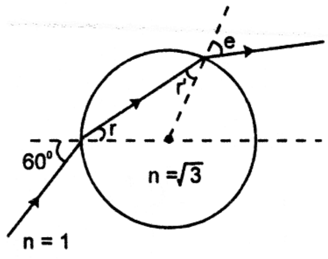
Refractive index of, medium when light travels from medium to air is given by

$\mu = \frac{1}{\sin C}$ where c = critical angle

Here c = 45°

$\Rightarrow \mu = \dfrac{1}{\sin 45°} = \sqrt{2}$ or μ = 1.4

35. A light ray is incident on a glass sphere at an angle of incidence 60° as shown. Find the e and the total deviation after two refractions.



(A) 30° (B) 60°

(C) 90° (D) 45°

Ans (B)

Applying Snell's law 1 sin 60° $= \sqrt{3}\sin r$ $\Rightarrow r = 30°$

From symmetry r′ = r = 30°

Again applying snell's law at second surface 1 sin $e = \sqrt{3}\sin r \Rightarrow e = 60°$

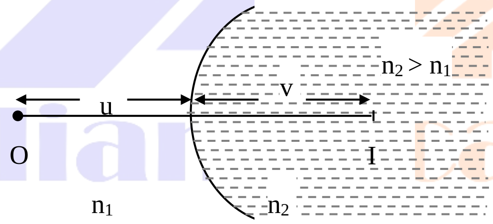
Deviation at first surface = i – r = 60° – 30° = 30°

Deviation at second surface = e – r′ = 60° – 30° = 30°

Therefore total deviation = 60°

Refraction at a Spherical Surface

Consider a spherical surface which separates a rarer medium of refractive index n_1 from a denser medium of refractive index n_2.



Some important terms

Aperture of a spherical surface is the area of the surface available for refraction.

Pole is the mid-point of the spherical surface.

Centre of curvature is the centre of the sphere of which the given surface forms a part.

Radius of curvature (R) is the radius of the spherical surface of which the aperture forms a part.

Principal axis is the straight line passing through the pole and the centre of curvature.

Object space: Region containing incident rays

Image space: Region containing refracted rays

Sign convention

(i) The pole of a spherical refracting surface (or the optical centre of a lens) is taken to be the origin and the principal axis as the X-axis.

(ii) Distances measured along the principal axis (For example: u, v, R, t) are measured from the pole / optical centre.

- A distance measured in the **same direction** as the incident ray is taken **positive.**
- A distance measured **opposite** to the direction of incident light is taken **negative.**

(If the direction of the incident light is taken from **left to right**, a distance in the +x direction is taken positive)

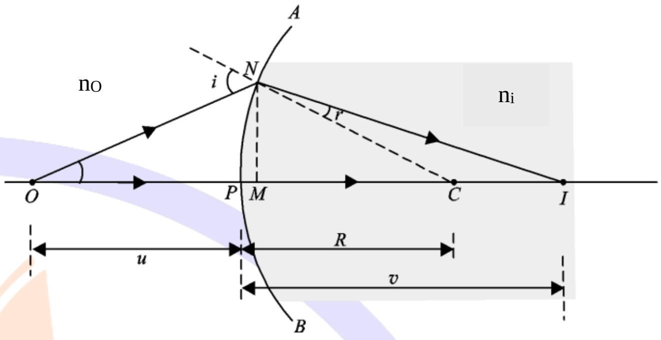
(iii) Sign convention for height

- A height measured in the upward direction normal to the principal axis is taken positive.
- A height measured in the down direction normal to the principal axis is taken negative

Formula for refraction at a spherical surface (Refraction formula)

Case (i): Object is in a rarer medium and the surface is concave towards a denser medium- Real image

O is a point object kept in a rarer medium on the principal axis. P is the pole and C is the centre of curvature. The spherical surface is concave towards a denser medium. n_O is the refractive index of rarer medium where the incident rays are present. n_i is the refractive index of the denser medium where refracted rays are present. The aperture AB is assumed to be small. I is the real image of O formed in the denser medium of refractive index n_i.



Refraction at spherical surface – Formation of real image - object in a

i = angle of incidence,

r = angle of refraction

PO = u = object distance,

PI = v = image distance

PC = R = radius of curvature

By sign convention,

$MO \approx PO = -u$

$MI \approx PI = +v$

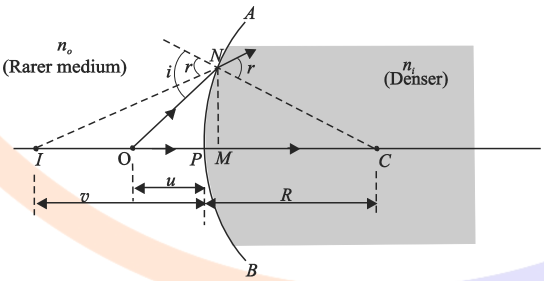
$MC \approx PC = +R$

MC ≈ PC = R = positive

Hence, $\frac{n_i}{v} - \frac{n_o}{u} = \frac{n_i - n_o}{R}$

Case (ii): Object is in a rarer medium and the surface is concave towards a denser medium – virtual image

O is the point object kept in rarer medium on the principal axis. I is the virtual image of O.



i = angle of incidence, r = angle of refraction, PO = u = object distance,

PI = v = image distance, PC = R = radius of curvature.

By sign convention,

$MO \approx PO = -u$

$MI \approx PI = -v$

$MC \approx PC = +R$

$\therefore \frac{n_i}{v} - \frac{n_o}{u} = \frac{n_i - n_o}{R}$ [Formula for refraction at a spherical surface]

Case (iii): Object is in a denser medium and the surface is concave towards the denser medium - real image

O is the point object kept in the denser medium on the principal axis.

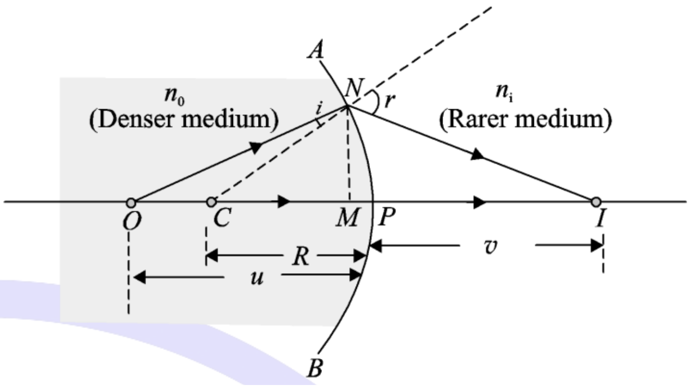
By sign convention,

MO ≈ PO = – u

MI ≈ PI = + v

MC ≈ PC = – R

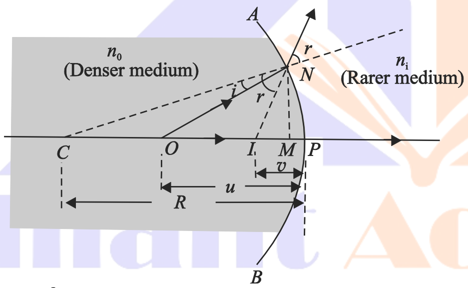
Hence, $-\frac{n_o}{R} + \frac{n_i}{R} = -\frac{n_o}{u} + \frac{n_i}{v}$ or $\frac{n_i}{v} - \frac{n_0}{u} = \frac{n_i - n_o}{R}$



Refraction at a spherical surface – Formation of real image – object in

Case (iv): Object is in a denser medium and the surface is concave towards the denser medium - virtual image

O is the point object kept in the denser medium on the principal axis. I is the virtual image of O.



I is the virtual image of O.

i = angle of incidence, r = angle of refraction,

PO = u = object distance, PI = v = image distance, PC = R = radius of curvature.

Applying Cartesian sign convention,

MO ≈ PO = – u

MI ≈ PI = + v

MC ≈ PC = + R

$-\frac{n_o}{u} + \frac{n_i}{v} = -\frac{n_o}{R} + \frac{n_i}{R}$

Hence, $\frac{n_i}{v} - \frac{n_o}{u} = \frac{(n_i - n_o)}{R}$

Lens

A lens is an optical medium bound by two surfaces of which at least one is either spherical or cylindrical. A parallel beam of light can be made to converge or diverge by passing through a lens.

Aperture (linear aperture) : the diameter of the lens available for refraction.

Principal axis : the straight line passing through centres of curvature of two surfaces.

Principle focus: When a pencil of rays, close and parallel to the principal axis is incident on a lens, after refraction, the rays converge to a fixed point in case of a convex lens and appear to diverge from a fixed point in case of a concave lens. This fixed point on the principal axis is called principal focus of the lens.

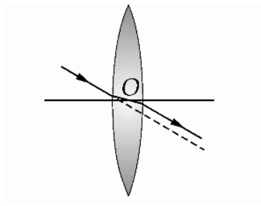
Focal length : the distance between its optic centre and the principal focus.

A lens has a pair of principal foci, one on either side of the lens. The two principal foci are equidistant from the lens.

Thin lens : A lens is considered to be thin when its thickness is negligible compared to the focal length of the lens and the radii of curvature of its two surfaces.

Optic centre

When a ray of light passes through a thin lens, such that the emergent ray is parallel to the incident ray, the refracted ray intersects the principal axis at a unique point called optic centre. A ray passing through the optic centre of a thin lens is undeviated. Further, in case of a thin lens, the lateral shift of the ray is negligible.



Optic centre (O) of a lens

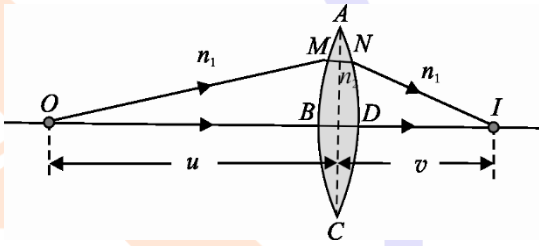
Formula for a thin lens : Lens maker's formula

A lens is considered to be thin when its thickness is negligible compared to the focal length of the lens and the radii of curvature of its two surfaces.

The formula which relates the focal length of a lens to the radii of curvatures of its surfaces and the refractive index of the material of the lens is called the Descartes' formula or Lens maker's formula.

Consider a thin lens of small aperture placed in a medium of refractive index n_1. Let n_2 be the refractive index of the material of the lens. Let f be the focal length of the lens and R_1 and R_2 be the radii of curvature of its two surfaces.

Let O be a point object kept on the principal axis at a distance u from the lens. A ray along the principal axis passes through the lens undeviated. Another ray OM incident on the lens at M undergoes refraction and proceeds along MN. The ray emerges from the lens and intersects the principal axis at I. Therefore, I is the real image of the object O. I is formed at a distance v from the lens.



Formation of real image of a point object by a thin lens

If R_1 and R_2 are the radii of curvature of first and second refracting surfaces of a thin lens of focal length f and refractive index μ(w.r.t. surrounding medium) then the relation between f, μ_1 R_1 and R_2 is know as lens maker's formula.

$$\frac{1}{f}=\left(\frac{n_2}{n_1}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

If the lens is surrounded by air then $n_1 = 1$ and $n_2 = n$ (say). In this case, lens maker's formula is

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

Thin lens equation

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

This equation is called thin lens formula which gives the relation between the image distance, the object distance and the focal length.

Lateral (linear) magnification

Lateral magnification (m) produced by a lens is defined as the ratio of the height of the image (h_I) to the height of the object (h_o). $m=\frac{h_I}{h_O}$

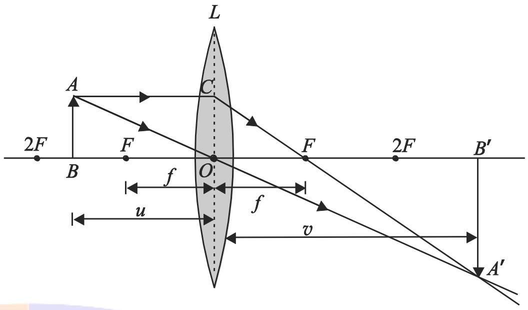
In the figure,

ΔABO and A′B′O are similar.

$$\therefore \frac{B'A'}{BA} = \frac{OB'}{OB} \qquad \dots (1)$$

ΔCOF and A′B′F are similar.

$$\therefore \frac{B'A'}{OC} = \frac{B'F}{OF} \qquad \dots (2)$$



From equations (1) and (2),

$$\frac{h_i}{h_o} = \frac{OB'}{OB} \text{ and } \frac{h_i}{h_o} = \frac{B'F}{OF}$$

$$m = \frac{v}{u} \text{ and } m = \frac{v - f}{f}$$

By sign convention, u is negative, v is positive, f is positive, h_i is negative, h_o is positive

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

Magnification in terms of m, u, f

Consider the lens equation, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Dividing by u throughout, we get

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

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

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

Hence, $m = \frac{f}{u + f}$

Magnification in terms of m, v, f

Consider the lens equation, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Dividing by v throughout, we get

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

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

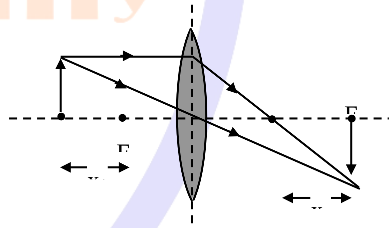
$$m = 1 - \frac{v}{f}$$

Hence, $m = \frac{f - v}{f}$

Newton's Formula

If the distance of object (x_1) and image (x_2) are not measured from optical centre, but from first and second principal foci then Newton's formula states

$f^2 = x_1 x_2$

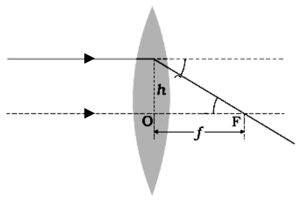


Power of a lens

The ability of a lens to converge (or diverge) light rays is called its power. Thus, the power of a lens is a measure of the convergence or divergence, which a lens introduces in the light falling on it.

The power P of a lens is defined as the tangent of the angle by which it converges (or diverges) a beam of light falling at unit distance from the optical centre.

From the figure, $\tan\theta = \frac{h}{f}$



If $h = 1$ unit and θ (radian) is small, $\tan\theta \approx \theta = \frac{1}{f}$.

Thus, $P = \frac{1}{f}$.

When the focal length of a lens is measured in metre, power of the lens is expressed in dioptre (D). The power of a lens of focal length of 1 metre is one dioptre.

Power of a lens is positive for a converging lens and negative for a diverging lens. For example, when an optician prescribes a corrective spectacle lens of power + 2.0 D, the required lens is a converging lens of focal length (+) 50 cm. A lens of power –2.5 D means the required lens is a diverging lens of focal length (–) 40 cm.

- **A lens surrounded by a liquid**

- When a converging lens is immersed in a liquid whose refractive index is **lower** than that of the lens, $\left(\frac{n_2}{n_1} \sim 1\right)$ decreases. Thus, (1/f) decreases and the focal length of the lens increases.

- When the lens is surrounded by a medium whose refractive index is **equal** to that of the lens, $\left(\frac{n_2}{n_1} \sim 1\right)$ will be zero. The focal length becomes infinity. In other words, a ray passes through the lens undeviated, since a ray of light cannot recognise the existence of the lens.

- When a converging lens is surrounded by a medium whose refractive index is **higher** than that of the lens. Hence a converging lens behaves as a diverging lens. This is why an air bubble inside water behaves like a diverging lens. Conversely, a diverging lens immersed under a liquid of higher refractive index behaves as a converging lens.

Axial magnification

If L and L′ are the lengths of the object along the axis and that of the image which is also along the axis respectively then the axial magnification 'm_a' is given by $m_a = \frac{L'}{L}$

If L is comparable with the object distances u_1 and u_2 of the two ends of the object, then L' is found by taking the difference of v_1 and v_2 which are the image distances corresponding to u_1 and u_2 giving $m_a = \frac{v_2 - v_1}{u_2 - u_1}$

Even if the length L of the object is tiny and cannot be measured with a tolerable accuracy and negligible compared to the object distance at one end or the other of the object then one can write $m_a = \frac{L'}{L} = \frac{\Delta v}{\Delta u} = \frac{dv}{du}$, one can easily see $\Delta u \to 0$

that $\frac{dv}{du} = m_a = -\frac{v^2}{u^2} = -(m_T)^2$, m_T being the transverse magnification. Also $|m_a| = |m_T|^2$

Power of the combination of two thin lenses

Case I: Two thin lenses in contact surrounded by air

Here also, the thickness at the centre of the combination is assumed to be negligible compared to the radii of curvature.

Let f_1 and f_2 be the focal lengths of the two lenses in air.

The focal length of the combination F is given by

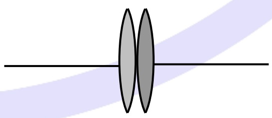


Fig.2

$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$ or $P_c = P_1 + P_2$, where P_1 and P_2 the powers of lenses in air. … (3)

and, $P_c = \frac{1}{F} = \left(\frac{f_1 + f_2}{f_1 f_2}\right)$ is the power of the combination.

Case II: Two thin lenses separated in air co-axially and surrounded by air

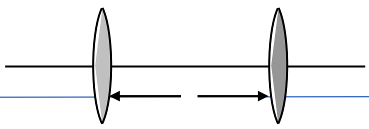


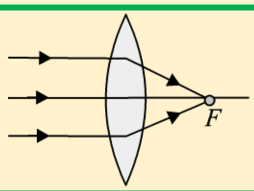
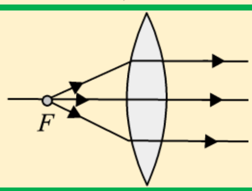
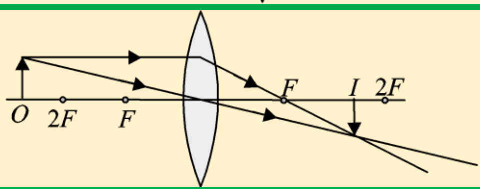
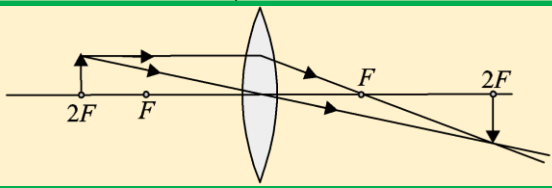
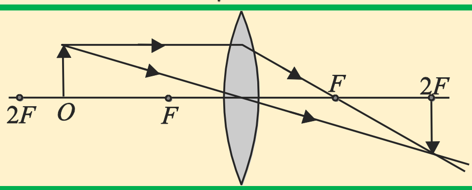
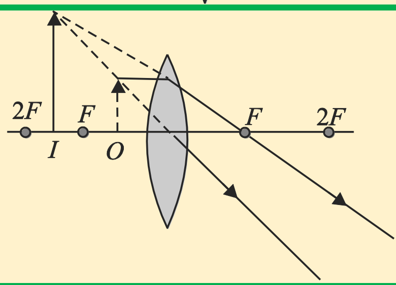
Fig.3

Let x be the separation between the two lenses. The focal length of the combination F in this case is given by $\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}-\frac{x}{f_1 f_2}$, where f_1 and f_2 are the focal lengths of the two lenses in air

or $P_c = P_1 + P_2 - xP_1P_2$ … (4)

where P_c , P_1 and P_2 have usual meaning.

In both the cases if x, f_1 and f_2 are expressed in metres then P_c is expressed in units of 'D'.

	Position of the object	Ray diagram	Position of the image	Nature of the image
1.	At ∞		At F	Real, inverted, diminished.
2.	At F		At ∞	Real, inverted highly enlarged.
3.	Beyond 2F		Between F and 2F	Real, inverted, diminished.
4.	At 2F		At 2F	Real inverted, same size.
5.	Between F and 2F		Beyond 2F	Real, inverted, enlarged.
6.	Within F		Beyond object	Virtual, erect, enlarged.

Sign convention for lenses

		Negative (–)	Positive (+)
(i)	Focal length, f	Concave	Convex

(ii)	Object distance, u	Real object	Virtual object
(iii)	Image distance, v	Virtual image	Real image
(iv)	Magnification, m (= v/u)	Real image	Virtual image

Comparison between sign conventions for a spherical mirror and a lens

(a) Similarities

1. u is negative for real object and +ve for a virtual object in both cases.
2. f is –ve for both concave mirror and concave lens.
3. f is +ve for both convex mirror and convex lens.
4. m is –ve real image and +ve for virtual in both the cases.

(b) Differences

	Spherical mirror	Lens
(i)	$\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$	$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$
(ii)	$m=-\frac{v}{u}$	$m=\frac{v}{u}$
(iii)	v is – ve for a real image and +ve for a virtual image	v is +ve for a real image and –ve for a virtual image

Illustrations

1. A plano-convex lens is made of a material of refractive index 1.5 and radius of curvature of its curved surface is R. Its focal length is equal to

(A) R/2 (B) R (C) 2R (D) 1.5 R

Ans (3)

$$\frac{1}{f}=(1.5-1)\left(\frac{1}{\infty}+\frac{1}{R}\right)=\frac{1}{2R}$$ giving f = 2R

2. The principal focus of an equiconvex lens (n_g = 1.5) is at a distance of 10 cm from the lens immersed in air. When immersed in a liquid of refractive index 1.25, the corresponding distance is

(A) 20 cm (B) 25 cm (C) 15 cm (D) 30 cm

Ans (B)

$$\frac{1}{f_a}=\frac{1}{10}=0.5\times\frac{2}{R} \text{ and } \frac{1}{f_L}=\left(\frac{1.5}{1.25}-1\right)\left(\frac{2}{R}\right)=\frac{0.25}{1.25}\times\frac{1}{5} \text{ as } \frac{2}{R}=\frac{1}{5} \text{ giving}$$

$\therefore$ f_L = 25 cm

3. A camera is fixed with a lens of adjustable focal length at a fixed distance of 5 cm from the screen. An object is brought from ∞ to a point 20 cm from the lens. The change in focal length of the lens is

(A) 2 cm (B) 3 cm (C) 1 cm (D) 4 cm

Ans (3)

When u = ∞, we have f = 5 cm. With u = 20 cm and v = 5 cm, we get $f' = 4$ cm

$\therefore$ Change in focal length = 1 cm.

4. An aeroplane is flying at a height of 1500 m. It has a camera with a lens of focal length 0.45 m and the photographic plate is square and of area 0.09 m^2. How much area on the ground can be photographed at a time?

(A) $10^5\,m^2$ (B) $10^6\,m^2$ (C) $10^4\,m^2$ (D) $10^3\,m^2$

Ans (B)

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

or $h = \frac{h_i}{m} = \frac{0.3}{0.45} \times (1500 - 0.45) \approx 1000 \approx 10^3$ m.

$\therefore$ Area that can be photographed $\approx h^2 = 10^6 m^2$.

5. Given ${}_a n_g = 1.6$ and ${}_a n_w = 1.4$, the ratio of focal length of a convex glass lens surrounded by water to that when it is surrounded by air is found to be equal to

(A) 4.2 (B) 0.42 (C) $\frac{1}{4.2}$ (D) $\frac{1}{0.42}$

Ans (A)

$$\frac{1}{f_a} = 0.6 \times \frac{2}{R} \text{ and } \frac{1}{f_w} = \frac{0.2}{1.4} \times \frac{2}{R} = \frac{2}{7R} \quad \therefore \frac{f_w}{f_a} = \frac{7R}{2} \times \frac{1.2}{R} = 4.2$$

6. One of the surfaces of a glass biconcave lens has twice the radius of curvature of the other. Given the focal length of the lens in air as 0.1 m and $n_g = 1.5$, the radii of curvature of the lenses are

(A) 0.75 m and 1.5 m (B) 0.075 m and 0.15 m

(C) –7.5 m and –1.5 m (D) –7.5 cm and –15 cm

Ans (D)

$$-0.5\left(\frac{1}{R} + \frac{1}{2R}\right) = \frac{-1}{0.1} = -10 \text{ m}^{-1} = \frac{1.5}{2R}$$

$\therefore R = -\frac{1.5}{20}$ m = –0.075 m = –7.5 cm and

2R = – 0.15 m = –15.0 cm.

7. An equiconcave lens ($n_m = 1.5$) has focal length in air as R. Both the surfaces of the lens have same radius of curvature R. On immersion in a transparent medium of refractive index 1.75, the lens will behave as

(A) convergent lens of focal length 3.5 R (B) convergent lens of focal length 3.0 R

(C) divergent lens of focal length 3.5 R (D) divergent lens of focal length 3.0 R

Ans (A)

$$\frac{1}{f_a} = (\mu_g - 1)\left(\frac{-2}{R}\right) \equiv \frac{-1}{R} \text{ giving } (\mu_g - 1) = 0.5 \text{ or } \mu_g = 1.5$$

$$\frac{1}{f'} = \left(1 - \frac{\mu_g}{\mu_1}\right)\left(\frac{1}{R} + \frac{1}{R}\right) = \frac{1}{3.5R}$$ giving f ′ = 3.5 R and hence the lens is convergent.

8. An object O is kept on the axis of a convex lens of focal length 20 cm, at a distance of 30 cm. If the lens is moved upwards by 0.5 cm in its position, the image moves vertically relative to original axis

(A) down by 0.5 cm (B) down by 0.1 cm

(C) up by 1.5 cm (D) up by 0.5 cm

Ans (C)

u = 30 cm and f = 20 cm giving m = 2

The object has a height 0.5 cm after lifting the lens and height is downwardly directed.

As m = 2, the image will have a height 1 cm from the new axis which is 0.5 cm above the old axis. Therefore image moves up by (0.5 cm + 1.0 cm) = 1.5 cm relative to the original axis.

9. A source of light is located at a distance of 90 cm from a screen. A thin converging lens of focal length provides a sharp image of the source when placed between the source and the screen at two positions. The focal length of the lens, given the distance between two positions of the lens $\Delta l = 30$ cm is

(A) 30 cm (B) 25 cm (C) 20 cm (D) 15 cm

Ans (C)

u and v are the object and image distances, say.

Then, it is known that (D – S) = 2u and D = u + v $\therefore$ v – u = s

$u + v = 90$ cm and $v - u = 30$ cm

By solving, $v = 60$ cm and $u = 30$ cm $\quad \therefore f = \frac{uv}{(u+v)} = 20$ cm

10. Sunglass is a combination of two spherical surfaces with radii of curvature $|R_1|$ and $|R_2|$. In this case

(A) R_1 and R_2 are of same magnitude and same sign

(B) R_1 and R_2 are of same magnitude but different sign

(C) R_1 is very large, R_2 is very small.

(D) R_1 is very small, R_2 is very large

Ans (B)

The sunglass has zero power and for this to happen $R_1 = -R_2$ as the expression

$P = \left[\frac{1}{R_1} + \frac{1}{R_2}\right](n-1) = 0$, only if $|R_1| = |R_2|$ and R_1 and R_2 are of opposite sign.

11. A person with a defective eye clearly sees beyond 2.0 metres. Suppose the person wants to read clearly at a distance 30 cm, what is the optical power required for his spectacle lens?

(A) 2D (B) 2.8 D (C) 3.5 D (D) 6D

Ans (B)

For the spectacle lens, it is required that $u = 30$ cm and $v = -200$ cm (this being a virtual image)

giving $\frac{1}{f} = P = \frac{1}{30} - \frac{1}{200} = \frac{17}{600} = \frac{17}{6} D = 2.8\ D$.

12. An equiconvex glass lens ($n_g = 1.5$) with air adjacent to its one surface and a transparent liquid of refractive index 1.8 adjacent to the other surface, has an optical power 2D. If the air is replaced by a transparent medium of refractive index 1.3, the power of the lens is

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

Ans (A)

In the first case,

P_1 the power of surface one $= \frac{1.5-1}{R}$.

Similarly, P_2 the power due to other surface $= \frac{1.8-1.5}{-R}$

Hence $\quad P_1 + P_2 = \frac{0.5}{R} - \frac{0.3}{R} = \frac{0.2}{R} = 2D$. Giving $R = 0.1$m = 10 cm

In the second case $P_1 = \frac{1.5-1.3}{0.1}$ and $P_2 = \frac{1.8-1.5}{-0.1}$ giving $P_1 + P_2 = \frac{0.2}{0.1} - \frac{0.3}{0.1} = (2-3)D = -D$.

13. A convex lens produces a virtual image of magnification 2 of an object placed at 30 cm from the lens. If it is kept in contact with a concave lens, the optical power of the combination is +D. The focal length of the concave lens in meters is

(A) 1.5 m (B) 3 m (C) 5 m (D) 5 m

Ans (A)

$m_T = -2$ and $u = +30$ cm giving

$f_{convex} = \frac{um}{m+1} = \frac{30 \times (-2)}{-2+1} = 60\ cm = 0.6$ m

$\frac{1}{F} = \frac{1}{f} + \frac{1}{f'}$ or $P - \frac{1}{f} = \frac{1}{f'} = 1D$. Hence $f' = \frac{f}{Pf-1} = \frac{0.6}{0.6-1} \Rightarrow f' = -1.5$ m.

14. Two thin convex lenses produce a power of 4.5D when in contact. When they are co-axially separated by 0.2 m, the power reduces to 3.5D. The focal lengths of the two lenses are

(A) 0.5 m, 0.4 m (B) 2 m, 3 m (C) 1 m, infinite (D) infinite, 1

Ans (A)

$\frac{1}{f_1}+\frac{1}{f_2}$ = 4.5 D, f_1 and f_2 being the focal lengths of the lenses when the lenses are in contact … (1)

In the second case we have $\frac{1}{f_1}+\frac{1}{f_2}-\frac{x}{f_1f_2}$ = 3.5 D … (2)

Hence, $\frac{x}{f_1f_2}=\frac{0.2}{f_1f_2}$ = D ⇒ $f_1f_2 = 0.2\ m^2$ from equations (1) and (2)

From equation (1), $f_1 + f_2 = 4.5 \times 0.2 = 0.9$ m. Solving we get, $f_1 = 0.5$ m and $f_2 = 0.4$ m

15. A convex and concave lens of focal lengths f_1 and f_2 are respectively separated by air of thickness $\frac{f_1}{2}$cm . The optical power of the combination is zero, given $|f_2| = nf_1$. The value of n is

(A) 2 (B) $+\frac{1}{2}$ (C) $-\frac{1}{2}$ (D) –2

Ans (B)

$P=\frac{1}{f_1}-\frac{1}{nf_1}+\frac{f_1}{2nf_1^2}=\frac{1}{f_1}\left[1-\frac{1}{n}+\frac{1}{2n}\right]$. We have P = 0 when $n=\frac{1}{2}$.

16. A spherical surface of radius of curvature |R| separates a medium of refractive index 1.5 from air. The centre of curvature is in denser medium. If a point object is kept axially at a distance u in the rarer medium, The condition relating u and R for the image to be real is

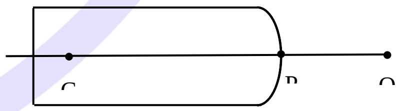
(A) u > 2R (B) u = 2R (C) u < 2R (D) U = 4r

Ans (A)

Here R is positive. We have $\frac{n_1}{u}+\frac{n_2}{v}=\frac{(n_2-n_1)}{R}$ ⇒ $\frac{1}{u}+\frac{1.5}{v}=\frac{1}{2R}$ or $\frac{1.5}{v}=\frac{1}{2R}-\frac{1}{u}$

v is +ve only if u > 2R

17. A point object O is placed in front of a glass rod having spherical end of radius of curvature 30 cm as shown in the figure. The image would be formed at (n_g = 1.5)



(A) 30 cm to the right (B) infinity

(C) 1 cm to the right (D) 30 cm to the left

Ans (A)

Here R = 30 cm, u = 15 cm

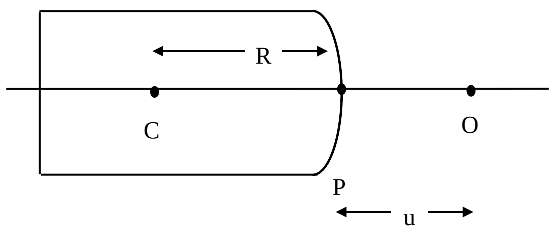
We know that, $\frac{n_0}{u}+\frac{n_i}{v}=\frac{n_0\sim n_i}{R}$

$$\frac{1}{15}+\frac{1.5}{v}=\frac{1.5\sim 1}{30}$$

$$\frac{1.5}{v}=\frac{0.5}{30}-\frac{1}{15}=\frac{0.5-2}{30}$$

$$\frac{1.5}{v}=-\frac{1.5}{30}$$

v = – 30 cm



–ve sign indicates that the image is formed to the right of P.

18. A convex lens of refractive index n_2 is surrounded by a medium of refractive index n_1. The one of least power among (A), (B), (C) and (D) is (R_1 and R_2 are the radii of curvature of the two surfaces)

(A) $R_1 = 2R_2$; $n_2 = 2n_1$ (B) $R_2 = 2R_1$; $n_2 = 3n_1$

(C) $R_1 = R_2$; $n_2 = 1.1n_1$ (D) $R_1 = R_2$; $n_2 = 2n_1$

Ans (C)

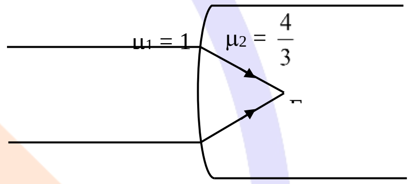
Using $P = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$,

the values of P are $\left(\frac{3}{2R}\right)$, $\left(\frac{6}{R_2}\right)$, $\left(\frac{0.2}{R_2}\right)$ and $\left(\frac{2}{R_2}\right)$ the least is (C).

19. A spherical convex surface separates object and image space of refractive index 1.0 and $\frac{4}{3}$. If radius of curvature of the surface is 10cm, what is the focal length and power of the convex surface?

(A) 0.2 m, 0.2 D (B) 0.4 m, 2.5 D (C) 0.12 m, 2.5 D (D) 0.5 m, 5 D

Ans (B)



We can see, that parallel beam of rays/converge at a point on the principal axis. This is called as principal focus and the distance is called focal length

we will use $\frac{\mu_2}{0} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$ where $\mu_2 = \frac{4}{3}$, $\mu_1 = 1$. $v = f, u = \infty$ $R = +10\text{cm}$

We get, f = 40 cm

or f = 0.4m

Power is defined as the reciprocal of focal length expressed is m.

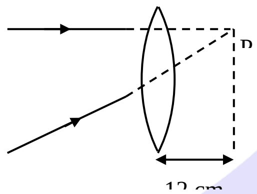
Since the rays are converging, power should be positive.

Hence P (in dioptre) = $\frac{+1}{f\,(\text{metre})} = \frac{1}{0.4} = 2.5\text{D}$

20. A beam of light converges to a point P. Now a lens is placed on the path of the convergent beam 12cm from P. At what point the beam converges if the lens introduced is a convex lens of focal length 20cm?

(A) 7.5 cm (B) 8.5 cm (C) 10 cm (D) None

Ans (A)



7.5 cm towards the right of the lens as v is + it is real

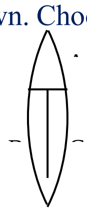
We know that $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{v} = \frac{1}{f} + \frac{1}{u}$

u = 12 cm f = 20 cm

$\therefore \frac{1}{v} = \frac{8}{60} \Rightarrow v = 7.5\text{ cm},$

A real image is formed on the right side of the lens as show at a distance = 7.5 from the lens

21. A thin symmetric double convex lens of power 'P' is cut into three parts A B C as shown. Choose the correct answer.



(A) power of C is P (B) power of A is 2P

(C) power of B is $\frac{P}{2}$ (D) power of B is $\frac{3}{2}$P

Ans (C)

22. An object is immersed in a fluid. In order that the object becomes invisible, it should

(A) behave as a perfect reflector

(B) absorb all light falling on it

(C) have refractive index one

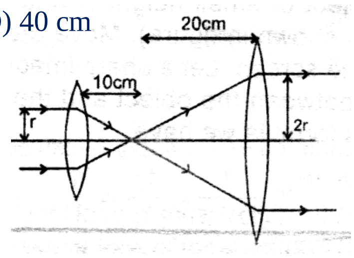
(D) have refractive index exactly matching with that of the surrounding fluid.

Ans (D)

Knowledge based question.

23. Figure shows two converging lenses. Incident rays are parallel to principle axis. What should be the value of d so that final rays are also parallel shall be

(A) 10 cm (B) 20 cm (C) 30 cm (D) 40 cm



Ans (C)

Final rays should be parallel. For this the II focus of L_1 must coincide with I focus of L_2

d = 10 + 20 = 30 cm. Here the diameter of ray beam becomes wider

Refraction through a Prism

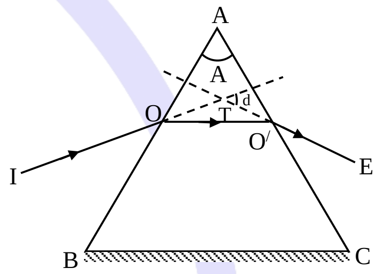
Some important terms

A prism is an optical medium with at least two non-parallel faces. ABC is the principal section of a triangular prism.

Refracting surfaces (AB and AC) are the two rectangular faces which are highly polished.

Base of the prism (BC) is an unpolished surface.

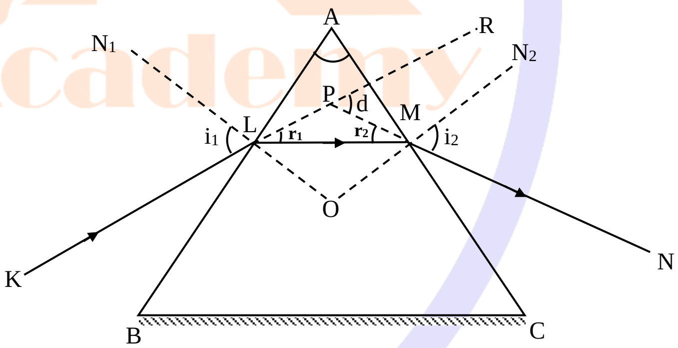
Angle of the prism or refracting angle $(\hat{A} = \angle BAC)$ is the angle between the two refracting surfaces AB and AC.



Angle of deviation (d) is the angle between the incident ray IO (extended) and the emergent ray O/E (extended).

Prism Formula

- A ray of light suffers two refractions on passing through a prism and emerges on the other side. The deviation d of the ray due to the two refractions is given by
  $d = i_1 + i_2 - A$, where A = angle of prism, given by $A = r_1 + r_2$.
- When the deviation is minimum (D), $i_1 = i_2$ and $r_1 = r_2$.

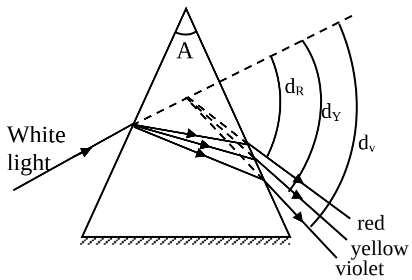


$${}_1n_2 = \frac{\sin(A+D)/2}{\sin(A/2)},$$

where ${}_1n_2 = \frac{n_2}{n_1}$, n_2 = RI of the prism material and n_1 = RI of the surrounding medium

- **Dispersion of light** is the phenomenon of splitting of composite light into its constituent colours on passing through a prism.

According to Cauchy's formula, $n = a + \frac{b}{\lambda^2}$, where a, b are constants for the given material, λ = wavelength of light. Different colours have different wavelengths ($\lambda_r > \lambda_v$). Therefore, n of the material of a prism for different colours will be different ($n_v > n_r$). Hence different colours deviate through different angles on passing through the prism. This is the cause of dispersion. The band of colours displayed on a screen is called a spectrum. A spectrum is called a impure spectrum if one colour blends into the next. Example: Rainbow.



In a pure spectrum, colours are distinctly seen.

Thin prism

A thin prism is one whose refracting angle is about 10°.

Deviation due to a thin prism, d = (n –1) A

where n = refractive index of the material of the prism and A = angle of the prism.

Angular dispersion

Angular dispersion is a measure of the angular separation between the different colours. Suppose d_v and d_R are the deviations of violet and red colours respectively, then angular dispersion between violet and red is given by

$$(d_v - d_R) = (n_v - n_R)A$$

n_v and n_R are the refractive indices of the prism material for violet and red respectively.

Dispersive power (ω)

Dispersive power of a material for two given colours is defined as the ratio of the angular dispersion to the mean deviation for the two colours. If the two colours are violet and red, then

$$\omega = \frac{d_V - d_R}{d} = \frac{n_V - n_R}{n-1}, \text{ where } d = \frac{d_V + d_R}{2}, \; n = \frac{n_v + n_R}{2}$$

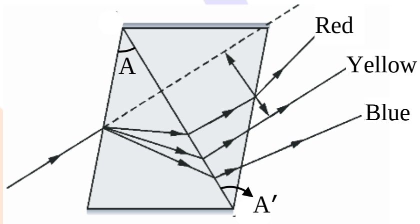
Dispersion without deviation

When a beam of white light is passed through a prism, it undergoes both dispersion and deviation. Two thin prisms can be combined to produce dispersion without deviation.

This is achieved by making net deviation to be zero.

The condition is $A' = -\left(\frac{n-1}{n'-1}\right)A$

A, A′ are the angles of the two prisms. n and n′ are the refractive indices of the prism material for the mean ray.



Dispersion without deviation

Dispersion without deviation (Direct Vision Combination)

The condition for direct vision combination is

$$[n_y - 1]\; A = [n'_y - 1]A' \Leftrightarrow \left[\frac{n_v + n_r}{2}\right]A = \left[\frac{n'_v + n'_r}{2} - 1\right]A'$$

Two or more prisms can be combined in various ways to get different combination of angle dispersion and deviation.

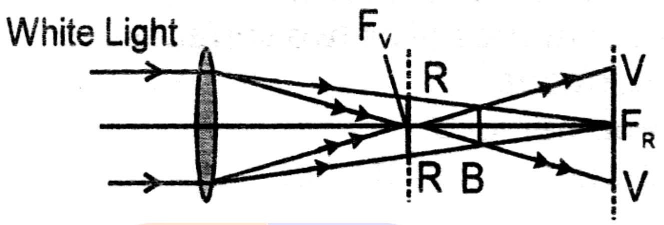
Deviation without dispersion (Achromatic Combination)

Condition for achromatic combination is $(n_v - n_r)A = (n'_v - n'_r)A'$

Chromatic Aberration

The image of a white object in white formed by a lens is usually coloured and blurred. This defect of image is called chromatic aberration and arises due to the fact that focal length of a lens is different for different colours. As R. I. μ of lens is maximum for violet while minimum for red, violet is focused nearest to the lens while red farthest from it as shown in figure.

As a result of this, in case of convergent lens if a screen is placed at F_v centre of the image will be violet and focused while sides are red and blurred. While at F_R, reverse is the case, i. e., centre will be red and focused while sides violet and blurred. The difference between f_v and f_R is a measure of the longitudinal chromatic aberration (L.C.A). i.e., L.C.A. = $f_R - f_V = -$ df with df = $f_V - f_R$ … (1)



However, as for a single lens,

$$\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad …. (2)$$

$$\Rightarrow -\frac{df}{f^2} = d\mu\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad … (3)$$

Dividing equation (3) by (2);

$$-\frac{df}{f} = \frac{d\mu}{(\mu - 1)} = \omega \qquad \left[\omega - \frac{d\mu}{(\mu - 1)}\right] = \text{dispersive power} \quad …. (4)$$

And hence, from Equations (1) and (4), L.C.A. = $-df = \omega f$

Now, as for a single lens neither f nor ω can be zero, we cannot have a single lens free from chromatic aberration.

Condition of Achromatism

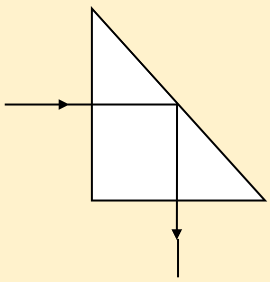
In case of two thin lenses in contact

$$\frac{1}{F} - \frac{1}{f_1} + \frac{1}{f_2} \qquad \text{i.e., } \frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} = 0.......(5)$$

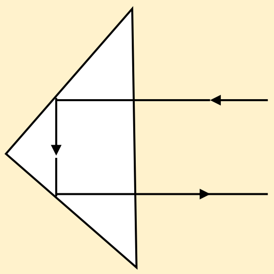
This condition is called of achromatism (for which lenses in contact and the lens combination which satisfies this condition is called is called achromatic lens, from this condition, i.e., from equation (5) it is clear that in case of achromatic doublet.

☞ **Reflecting prism**

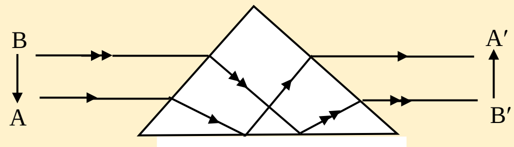
It is an isosceles, right - angled prism. It is generally used to turn an incident beam of light through 90°, 180° or to invert an image.



(i) Turning by 90°

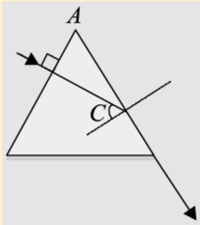


(ii) Turning by 180°



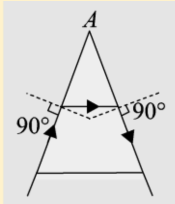
(iii) to upright an inverted image

- **For normal incidence**: $i_1 = r_1 = 0$ and $r_2 = A$ $(\because A = r_1 + r_2)$. Therefore, the angle of emergence depends on the angle of prism.



  - If A = C (the critical angle of incidence), $i_2 = 90°$ and the emergent ray grazes the refracting surface of the prism.
  - If A > C, then $r_2 > C$. Thus, light undergoes total internal reflection at the second surface and there will be no emergent ray at this face.
  - If A < C, then $r_2 < C$. Thus, light emerges from the second face.
- **For grazing incidence** : If $i_1 = 90°$ then $(r_1)_{max} = (r_2)_{max} = C$

  Hence, $A = r_1 + r_2 \Rightarrow A_{max} = (r_1)_{max} + (r_2)_{max} \Rightarrow A_{max} = 2C$

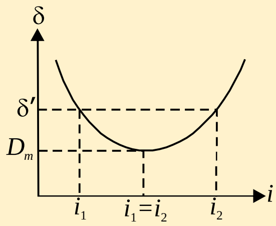


  - If A = 2C, the emergent ray grazes the surface.
  - If A > 2C, the ray undergoes total internal reflection at the second surface and there will be no emergent ray.
  - If A < 2C, the light ray can always emerge.

☞

1. **Maximum deviation in a prism**

   Deviation is given by $\delta = i_1 + i_2 - A$. A is a constant for a given prism. Hence, δ is maximum if i_1 & i_2 are maximum. Maximum possible values of i_1 & i_2 are 90° each. As i_1 and i_2 are interdependent, if i_1 or i_2 is 90° then deviation is maximum.



Graph of δ versus *i*

2. **Prism surrounded by an optical medium**

   If the surrounding medium is rarer than the material of the prism, the refracted ray bends towards the base. If the surrounding medium is denser than the material of the prism, the refracted ray bends away from the base.

   Relative refractive index of a prism of absolute refractive index n_g immersed in water of absolute refractive index n_w is given by ${}_w n_g = \dfrac{n_g}{n_w} = \dfrac{\sin\left(\dfrac{A+D}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$.

3. When the prism is in the minimum deviation position, the refracted ray is parallel to the base. Angle of minimum deviation is maximum for violet & minimum for red.
4. For a small angled prism (Thin prism: refracting angle ~ 5° - 10°), D_m is also very small. Using the condition sin θ ≈ θ, when θ (in radian) is very small, ${}_1n_2 = n_{21} = \dfrac{(A + D_m)/2}{(A/2)} = (n_{21} - 1)A$. Thin prisms do not produce large deviation.

Illustrations

1. A ray of light is incident at 50° on one of the refracting faces of an equilateral prism. The angle between the emergent ray and the incident ray is 40°. The angle between the emergent ray and the face from which it emerges, is

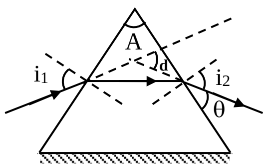
   (A) 60° (B) 50° (C) 40° (D) 30°

Ans (C)

The angle between the emergent ray and the incident ray = deviation (d) = 40°

$i_1 + i_2 - A = d \Rightarrow i_2 = A + d - i_1$

$= 60° + 40° - 50° = 50°$



Angle made by the emergent ray with the face of the prism θ = 90° – i_2 = 40°

2. The refractive indices of the material of a prism for violet and red are 1.65 and 1.62 respectively. The angle of the prism is 10°. The angular dispersion is

   (A) 16.35° (B) 1.635° (C) 0.03° (D) 0.3°

Ans (D)

$d_v - d_r = (n_v - n_r) A = (1.65 - 1.62) \times 10° = 0.03 \times 10 = 0.3°$

3. The difference between the angles of minimum deviation for violet and red rays in a spectrum of a source produced by a prism is 0.3°. If the angle of deviation for the mean ray is 5.4°, the dispersive power of the material of the prism is

(A) 1.62 (B) 18 (C) 5.7 (D) 0.055

Ans (D)

$$\omega = \frac{\text{angular dispersion}}{\text{mean deviation}} = \frac{0.3°}{5.4°} = 0.055$$

4. A thin prism P_1 with angle 5° made from glass of refractive index 1.52 is combined with another thin prism P_2 with angle 4° to produce zero deviation. The refractive index of the material of the prism P_2 is

(A) 1.25 (B) 1.65 (C) 1.584 (D) 1.625

Ans (B)

This being a case of no net deviation, $A(n_y - 1) = A'(n'_y - 1)$

Here $A = 5°$ and $n_y = 1.52$ and $A' = 4°$

$\therefore n'_y = 1.65$.

5. A ray of light is incident normally on the face of a prism of refracting angle 30°. The angle of deviation is 15°. The refractive index of the prism is

(A) 2 (B) $\sqrt{2}$ (C) 1.5 (D) $\sqrt{3}$.

Ans (B)

From the data $\hat{i}_1 = 0$ giving $\hat{r}_1 = 0$ and hence $\hat{r}_2 = 30°$ $(\because \hat{r}_1 + \hat{r}_2 = 30°)$

As $\delta = 15°$, and $(\hat{i}_1 + \hat{i}_2) = (A + \hat{\delta})$ we have $\hat{i}_2 = 45°$

$$\therefore \frac{\sin \hat{i}_2}{\sin \hat{r}_2} = \frac{\sin 45°}{\sin 30°} = \sqrt{2}.$$

6. For a prism of glass ($n_g = 1.6$), the angle of minimum deviation is equal to the angle of the prism. The angle of the prism is equal to

(A) 60° (B) 45° (C) 36.82° (D) 73.7°

Ans (D)

Given $A = \delta_m$ $\therefore$ we have $\dfrac{\sin\left(\dfrac{A + \delta_m}{2}\right)}{\sin \dfrac{A}{2}} = 2\cos\dfrac{A}{2} = 1.6$ giving $\hat{A} = 73.7°$

7. A glass prism ($n_g = 1.4$) has a refracting angle of 40°. The deviation of a monochromatic ray, incident normally on its face, is

(A) 17.7° (B) 34.14° (C) 64.14° (D) 24.14°

Ans (D)

As $\hat{i}_1 = 0$, we have $\hat{r}_1 = 0$ and $\hat{r}_2 = 40°$

$\therefore \dfrac{\sin 40°}{\sin \hat{i}_2} = \dfrac{1}{1.4}$, $\hat{i}_2 = 64.14°$ giving $\delta = 64.14° - 40 = 24.14°$.

8. The angle of minimum deviation is the same as the angle of the prism for a given wavelength. If both the angle of minimum deviation and the angle of the prism are increased by 10 %, the refractive index of the prism

(A) decreases

(B) increases

(C) remains the same

(D) decreases or increases depending on the angle of the prism

Ans (A)

$$\frac{\sin\frac{(A+A)}{2}}{\sin\frac{A}{2}} = 2\cos\frac{A}{2} = n_1$$

As A is increased the refractive index has to decrease $\therefore$ $n_2 < n_1$.

9. Solar radiation, radiation from a mercury lamp and radiation from carbon dioxide (arc), respectively, give

(A) line, band and continuous spectra

(B) line, continuous and band spectra

(C) band, line and continuous spectra

(D) continuous, line and band spectra

Ans (D)

Solar radiation being white light, gives continuous spectrum, mercury lamp gives line spectrum (atomic) and carbon dioxide gives band spectrum (molecular).

10. A thin prism P_1 with angle 5° made from glass of refractive index 1.5 is combined with another thin prism P_2 with angle 4° to produce no net deviation. The refractive index of the prism P_2 is

(A) 1.25 (B) 1.6 (C) 1.625 (D) 1.8

Ans (C)

This being a case of no net deviation, $A(n_y - 1) = A'(n'_y - 1)$

Here A = 5 and n_y = 1.5 and A' = 4 $\therefore$ n'_y = 1.625.

11. Two prisms A and B having angles 4° and 3°, respectively, are combined to produce dispersion without deviation. Prism A has a refractive index 1.54 for the yellow radiation. If the prism B is set for minimum deviation for the yellow radiation, the angle of minimum deviation is

(A) 1.54° (B) 2.16° (C) 1.72° (D) 3.16°

Ans (B)

$(n-1)A - (n'-1)A' = 0$

A = 4°, A' = 3° and n = 1.54. Hence n' = 1.72

Angle of minimum deviation in the case of prism B

$\delta'_m = 0.72 \times 3 = 2.16°$.

12. In minimum deviation conditions, a light ray passing through an equilateral prism travels

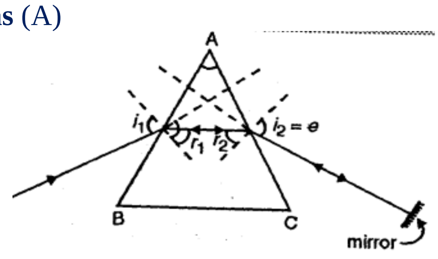
(A) parallel to the base (non-refracting side) of the prism

(B) perpendicular to the base

(C) perpendicular to the first refracting surface.

(D) perpendicular to the second refracting surface.

Ans (A)



As the angle of minimum deviation, $\angle i_1 = \angle e$ and $\angle r_1 = \angle r_2$.

13. In the case of an equilateral prism, it is seen that when a ray strikes grazing at one face, it emerges grazingly at the other. Refractive index of material of the prism is

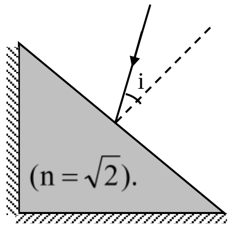
(A) $\frac{\sqrt{3}}{2}$ (B) $\frac{2}{\sqrt{3}}$ (C) 2 (D) data not sufficient

Ans (C)

$\hat{i}_1 = \hat{i}_2 = 90°, \ \hat{r}_1 = \hat{r}_2 = \frac{A}{2} = 30°$

$n = \frac{\sin\ \hat{i}_1}{\sin\ \hat{r}_1} = 2$

14. The sides of an isosceles right prism are coated with a reflecting coating. A ray of light falls on the hypotenuse at an arbitrary angle i. For what value of i, the ray leaving the prism after two reflections is parallel to the incident ray?



(A) 30° (B) 60°

(C) $\tan^{-1}$ (20) (D) any arbitrary angle

Ans (D)

The emergent ray becomes parallel to the incident ray after two reflections from two mirrors placed at right angles.

15. Information of a rainbow light from the sun, on water the droplets undergoes.

(A) dispersion only

(B) only total internal reflection

(C) dispersion and total internal reflection

(D) None of the above

Ans (C)

A rainbow is a consequence of both dispersion and total internal reflection.

16. A narrow beam of light (white colour) passes through a glass slab having parallel faces. Choose the right answer.

(A) The light never splits in different colours

(B) the emergent beam is white

(C) The light inside the slab is split into different colours

(D) The light inside the slab is white

Ans (C)

A slab having parallel faces can be through as two prisms placed with their angle opposite to each other. Where dispassion/split produced by one is cancelled by the other.

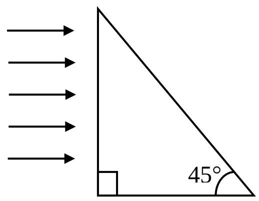
17. A beam of light consisting of real, green and blue colours is incident on a right angled prism. The RI of the material of the prism for red, green and blue are 1.39, 1.44 and 1. 47 respectively. The prism will do this? Which of these is true?

(A) separates part of the red color from the green and blue

(B) separates part of the blue color from the red and green colours

(C) separates all the three colours from one another

(D) not separate even partially any colour from the rest to two colours.



Ans (A)

$\sin i = \frac{1}{\sqrt{2}}$ for only red colour Li is critical angle, ie. Green and blue colours get totally internally reflected.

18. The dispersive powers of glasses and lenses used is an achromatic pair are in the ratio 5 : 3 If the focal length of the lens is 15 cm, then the nature of the other, lens would be

(A) convex, 9 cm (B) concave 9 cm

(C) convex, 25 cm (D) concave, 25 cm

Ans (A)

From the condition of achromatisim,

We know $\frac{\omega_1}{f_1}+\frac{\omega_2}{f_2}=0$

$\therefore \frac{5}{3}=\frac{-(-15)}{f_2} \Rightarrow f_2=+9$ cm

19. The focal length of a think convex lens for red and blue colour is 100.5 cm and 99.5 cm. The dispersive power of the lens is

(A) 0.01 (B) 0.02 (C) 1.005 (D) 0.995

Ans (A)

$\frac{\omega_1}{f_1}+\frac{\omega_2}{f_2}=0$

20. The RI of prism for a monochromatic wave is $\sqrt{2}$ and its refracting angle is 60°. For minimum deviation, the angle of incidence will be

(A) 30° (B) 45° (C) 60° (D) 75°

Ans (B)

We know that $\mu=\frac{\sin i}{\sin\frac{A}{2}}$ $\therefore \sqrt{2}=\frac{\sin i}{\sin 60}$

$\therefore \sin i=\sqrt{2}\times\frac{1}{2}$ $\therefore$ i = 45°

21. Which of the following statements is true?

(A) Velocity of light is constant in all media.

(B) Velocity of light in vacuum is maximum.

(C) Velocity of light is same in all reference frames.

(D) Laws of nature have identical form in all reference frames.

Ans (B)

Velocity of light in vacuum is maximum.

22. A ray PQ incident on the retracting face BA is refracted in the prism BAC as shown in the figure and emerges from the other refracting face AC as RS such that AQ = AR. If the angle of prism A = 60° and the refractive index of the material of prism is $\sqrt{3}$, then the angle of deviation of a is

(A) 60° (B) 30° (C) 45° (D) none of these

Ans (D)

In prism, angle of deviation is given by

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

Where μ = refractive index

A = Angle of prism

Here $\mu=\sqrt{3}$ and A = 60° $\Rightarrow \delta$ = 43.92

23. The refractive index of the material of a prism is $\sqrt{2}$ and its refracting angle is 30°. One of the refracting surfaces of the prism is made a mirror inwards. A beam of monochromatic light entering the prism from the other face will retrace its path after reflection from the mirrored surface if its angle of incidence on the prism is

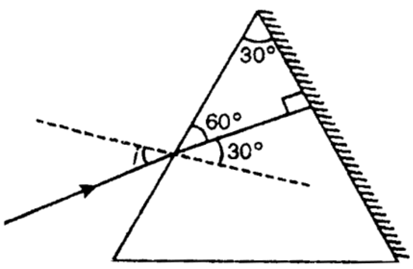
(A) 60° (B) 0° (C) 30° (D) 45°.

Ans (D)

Refractive index is given by $\mu=\frac{\sin i}{\sin r}$

$\Rightarrow \sin i=\mu\sin r$

Substituting $\mu=\sqrt{2}$; r = 30°, we get



$$\sin i = \sqrt{2}\sin 30^\circ = \sqrt{2}\times\frac{1}{2}$$

$$\text{or } \sin i = \frac{1}{\sqrt{2}} \quad \Rightarrow i = \sin^{-1}\left(\frac{1}{\sqrt{2}}\right) \quad \Rightarrow i = 45^\circ$$

Optical instruments

Human eye

The human eye is a natural optical instrument, since it partly resembles photographic camera in principle and construction. The eye lens is shaped like a double convex lens, having mean refractive index 1.437. It is fixed in its place with the help of muscles. It has the ability to change its focal length while seeing near or distinct objects. This unique feature of automatic adjustment and focusing is called *power of accommodation*. The nearest distance upto which eye can see distinctly (by applying maximum power of accommodation) is called *least distance of distinct vision*. For a normal eye, this distance is 25 cm. The angle which an object subtends at our eye is called *visual angle*. The apparent size of an object as seen by our eye depends upon the visual angle. Greater the visual angle, greater is the size of the object.

Some optical instruments are used as an aid to the human eye so as to produce higher magnification and greater resolving power, and to produce the image of close lying objects at the least distance of distinct vision. Microscopes and telescopes are the optical instruments which are so designed to increase the visual angle and hence to increase the apparent size of the image.

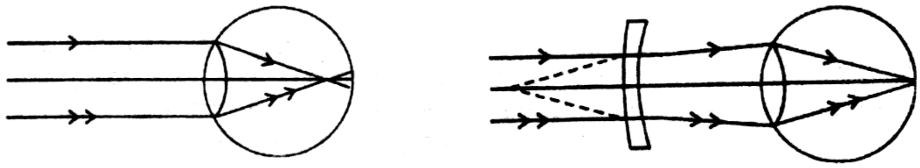
DEFEECTS OF VISION

Regarding eye it is nothing that

(i) In eye convex eye-lens forms real inverted and diminished image at the retina by changing its convexity (the distance between eye lens and retina is fixed)

(ii) The human eye is most sensitive to yellow green light having wavelength 5550 Å and least to violet (4000 Å) and red (7000 Å)

(iii) The size of an object as perceived by eye depends on its visual-angle when object is distant its visual angle θ and hence image I_1 at retina is small (it will appear small) and as it is brought near to the eye its visual angle θ_0 and hence size of image I_2 will increase.

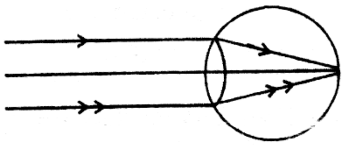


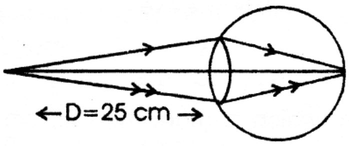
Defective-eye
(A)

Corrected-eye
(B)

(iv) The far and near point for normal eye are usually to be infinity and 25 cm respectively i.e., normal eye see very distant object but near object only it they are at distance greater than 25 cm from the eye. The ability of eye to see objects from infinite distance to 25 cm from it is called Power of accommodation.

(v) If object is at infinity i.e., parallel beam of light enters the eye is least strained and said to be relaxed or unstrained. However if the object is at least distance of distinct vision (L.D.D.V] i.e., D (= 25 cm) eye is under maximum strain and visual angle is maximum.





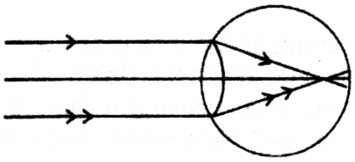
(vi) The limit of resolution of eye is one minute ie., two object will not be visible distantly to the eye if the angle sub tended by them on the eye is lesser than one minute.

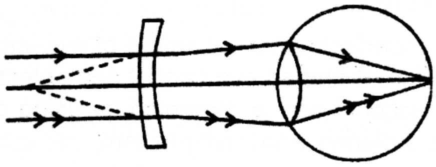
(vii) The persistence of vision is (1 / 10) sec i.e. if time interval between two consecutive light pulses is lesser than 0.1 sec eye cannot distinguish them separately. this fact is taken into account in motion pictures. In case of eye following are the common defects of vision.

MYOPIA

[or short-sightendness or near –sightendness]

In it distant objects are not clearly visible. i.e., For Point is at a distance lesser than Infinity and hence image of distant object is formed before the retina.





This defects is (i.e., negative focal length or power) which forms the image of distant object at the far point of patient-eye [which is lesser than ∞) so that in this case from lens formula we have

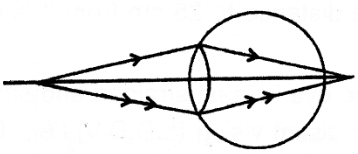
$$\frac{1}{-F.P}-\frac{1}{-(\text{distnace of object})}=\frac{1}{f}=P$$

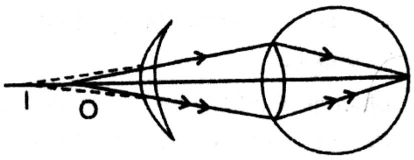
And if the object is at ∞ $P=\frac{1}{f}=\frac{1}{-F.P.}$ … (1)

[Or Long-sightendness of far-sightendness]

In it near object are not clearly visible i.e., Near Point is at a distance greater than 25 cm hence image of near object is formed behind the retina.

This defect is remedied by using spectacles having convergent lens (i.e., positive focal length of power) which the image of near objects at the Near Point of the





Patient-eye (which is more than 25 cm). So that in this case from lens formula we have

$$\frac{1}{-N.P.}-\frac{1}{(\text{distance of object})}=\frac{1}{f}=P$$

If object is placed at D = 25 cm = 0.25 m

$$P = \frac{1}{f} = \left[\frac{1}{0.25} - \frac{1}{N.P.}\right] \qquad \ldots (2)$$

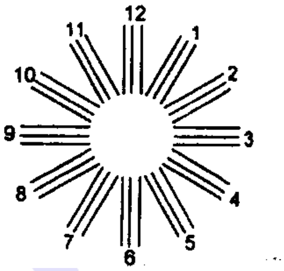
where N.P. is near point of eye

PRESBYOPIA

In this both near and far objects are not clearly visible i.e., far point is lesser than infinity and near point greater than 25 cm. It is an old age disease as at old age ciliary muscles lose their elasticity and so can not change the focal length of eye-lens effectively and hence loses its power of accommodation.

ASTIGMATISM

In it due to imperfect spherical nature of eye-lens, the focal length of eye is two orthogonal direction becomes different and so eye cannot see object in two orthogonal directions clearly simultaneously. This defect is directional and is remedied by using cylindrical lens in particular direction. If in the spectacle of a person suffering from astigmatism, the lens is slightly rotated the arrangement will get spoiled.



Microscope

Microscope is an optical instrument which forms a magnified image of a close and minute object.

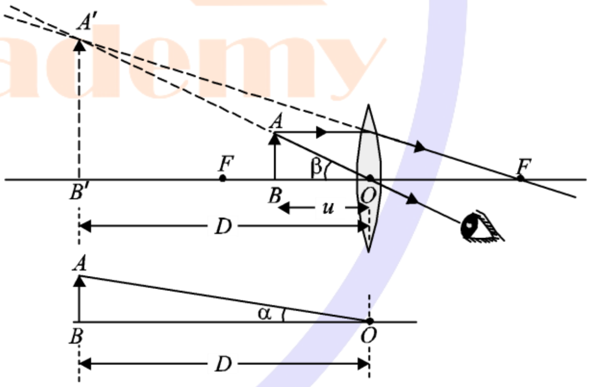
The general formula for the magnifying power of the microscope is

$$M = \frac{\text{Angle subtended by image at the eye } (\beta)}{\text{Angle subtended by object at the eye } (\alpha)\text{, when placed at least distance of distinct vision}}$$

Simple Microscope

A convex lens of small focal length is called a simple microscope or a magnifying glass.

Consider an object AB placed between the principal focus F and the optic centre O of a convex lens L. The formation of the virtual image A′B′ of the object is shown in figure. The position of the object AB is so adjusted that its image A′B′ is formed at the least distance of distinct vision (D) as shown in figure.



The magnifying power of the simple microscope is given by

$$M = \frac{\beta}{\alpha} \qquad \ldots (1)$$

It can be shown that the magnifying power of simple microscope is

$$M = 1 + \frac{D}{f} \qquad \ldots (2)\text{, where f is the focal length of the lens.}$$

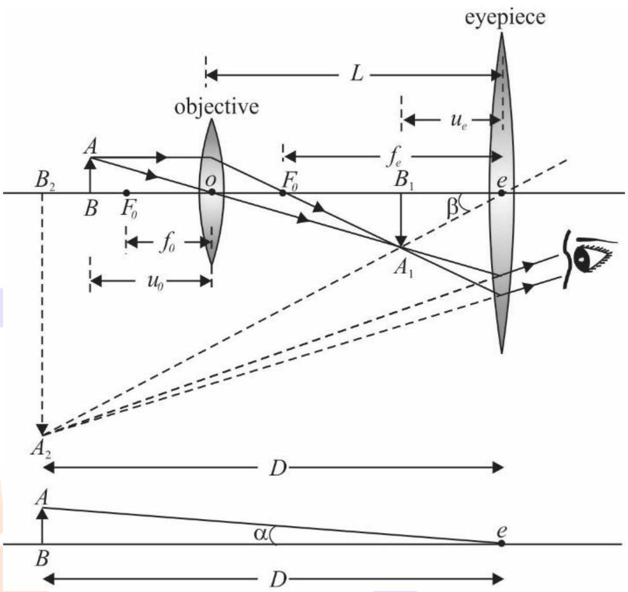
From the equation (2), it follows that lesser the focal length of the convex lens used as simple microscope, larger will be the magnifying power obtained.

When the object lies at the principal focus of the lens, the image is formed at infinity. In this case, the magnifying power of the simple microscope is given by

$$M = \frac{D}{f} \qquad \ldots (3)$$

☞ It should be noted that the magnification produced by a lens is equal to $\frac{v}{u}$. The magnifying power of a simple microscope and the magnification produced by the lens are different from each other. The two become equal, only when the image is formed at the least distance of distinct vision.

Compound Microscope



A compound microscope is used to see extremely small objects. It consists of two convex lenses placed co-axially at the two ends of a long cylindrical metallic tube. The lens of short aperture and short focal length facing the object is called the object lens. The second lens of short focal length but large aperture is called the eye lens. Cross-wires are mounted on the focus of the eye lens.

The object under observation, AB is kept slightly beyond the principal focus (F_o) of the objective. The image A_1B_1 of the object formed by the objective is inverted, real and magnified. The eyepiece is so adjusted that the image A_1B_1 lies within the principal focus (F_e) of the eyepiece. This serves as the real object for eyepiece. The position of the eyepiece is further adjusted so that the final image formed A_2B_2 is at the least distance of distinct vision (D). The eyepiece behaves as a simple microscope.

The eyepiece behaves as a simple microscope. The magnifying power when image is formed at D is

$M_e = 1 + \frac{D}{f_e}$ where f_e is the focal length of eyepiece.

The linear magnification produced by the objective is $M_o = \frac{v_o}{u_o}$

The magnification produced by the compound microscope is the product of magnifications produced by eyepiece and the objective.

$M = M_o M_e$

where, M_o – magnifying power of objective and M_e – magnifying power of eyepiece.

The magnifying power of the compound microscope is

$$M = \frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right)$$

The object is placed very close to the principal focus of the objective. Hence, u_o is very nearly equal to f_o. The image is formed very close to the eyepiece. Therefore, v_o is very nearly equal to the length L of the microscope (distance between the tow lenses). Thus, we get

$$M = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right) \text{ (Final image formed at D)}$$

Hence, smaller the focal lengths of objective and eyepiece, larger is the magnification.

If the final image is formed at ∞, then

$$M_e = \frac{D}{f_e}$$

Magnifying power in this case is

$$M = \frac{L}{f_o} \cdot \frac{D}{f_e} \qquad \text{(Final image at } \infty \text{ - Normal adjustment)}$$

In this case, $L = f_o + f_e$.

In this case, the compound microscope is said to be in **normal adjustment**.

Since D, f_0 and f_e are constants, the magnifying power increases with the increase with the increase in the tube length.

To increase the magnifying power of the microscope:

(1) focal length of the object lens should be small.

(2) object should be placed very near to the first focus of the objective.

(3) focal length of eye-lens should be small.

ASTRONOMICAL TELESCOPE

It is an optical instrument used to increase the visual angle of distant large objects such as a star a planet or a cliff etc. Astronomical telescope consists of two converging lens. The one facing the object is called objective or field-lens and has large focal length and aperture. The distance between the two lenses is adjustable.

As telescope is used to see distant objects, in it object is between ∞ and 2F of objective and hence image formed by objective is real, inverted, and diminished and is between F and 2F on the other side of it. This image is (called intermediate image) acts as object for eye-piece and shifting the position of eye-piece is brought with in its focus. So final image I, with respect to intermediate image is erect, virtual, enlarged and at a distance D to ∞ from the eye. This in turns implies that final image with respect to object is inverted, enlarged and at a distance D to ∞ from the eye.

magnifying Power of a telescope is defined as

$$MP = \frac{\text{Visual angle with instrument}}{\text{Visual angle for unaddedeye}} = \frac{\theta}{\theta_0}$$

$$\theta_0 = \left(\frac{y}{f_0}\right) \text{ nad } \theta = \left(\frac{y}{-u_e}\right)$$

$$\text{So } MP = \frac{\theta}{\theta_0} = -\left[\frac{f_0}{u_0}\right] \text{ with length of tube}$$

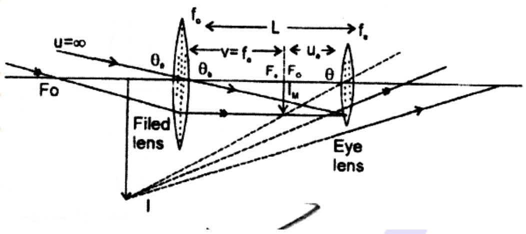
$L=(f_0 + u_e)$ …. (1)

Now there are two possibilities

(d_1) if the final image is at infinity (far point)

This situation is called normal adjustment as in this situation eye is least strained or relaxed. In this situation as for eye-piece v = ∞

$$\frac{1}{-\infty} - \frac{1}{u_e} = \frac{1}{f_e} \quad \text{i.e., } u_e = f_e$$



αSo, substituting this value of u_e in equation (1) we have

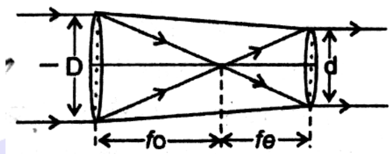
$$MP = -\left(\frac{f_0}{f_e}\right) \text{ and } L = (f_0 + f_0)$$

Usually telescope operates in this mode unless stated other wise. In this mode as u_e is maximum for a given telescope MP is minimum while length of tube maximum.

(d_2) If the final image is at D (near point)

In this situation as for eye-piece v = D

$$\frac{1}{-D} - \frac{1}{-u_e} = \frac{1}{f_e} \qquad \text{i.e., } \frac{1}{-u_e} = \frac{1}{f_e}\left[1 + \frac{f_e}{D}\right]$$



So substituting this value of u_e in Equation (1) we, have

$$MP = \frac{f_0}{f_e}\left[1 + \frac{f_e}{D}\right] \text{ with } L = f_0 + \frac{f_e D}{f_e + D} \quad \ldots (3)$$

In this situation u_e is minimum so for a given telescope MP is maximum while length of tube minimum and eye is most strained. In case of a telescope if object and final image are at infinity and total light entering the telescope leaves it parallel to its axis as shown in figure.

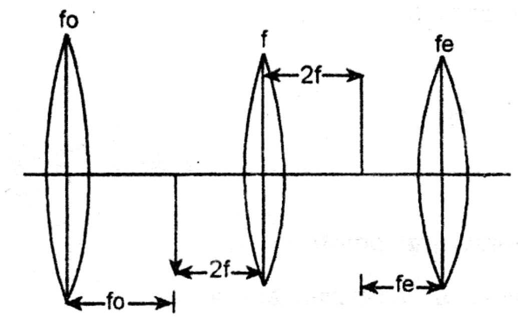
$$\frac{f_0}{f_e} = \frac{\text{Aperture of object}}{\text{Aperture of eye piece}}$$

$$\text{i.e., } MP = \frac{f_0}{f_e} = \frac{D}{d} \quad \ldots (4)$$

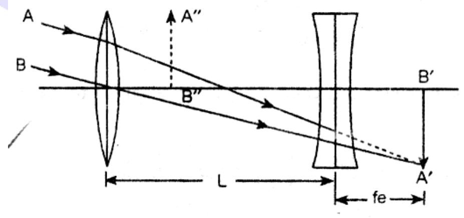
TERRESTRIAL TELESCOPE

Uses a thrd lens in between objective and eyepieces so as to form final image erect. This lens simply invert the imaged formed by objective without affecting the magnification.

Length of tube L = $f_0 + f_e + 4f$



GALILEO'S TELESCOPE



Convex lens are objective. Concave lens are eyepiece Field of view is much smaller

∵ eyepiece lens in concave.

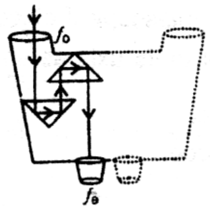
(i) $M = \frac{f_0}{f_e}\left[1 - \frac{f_e}{v_e}\right]$

(ii) $M = \frac{f_0}{f_e}$

Final image is at α $L = f_0 - f_e$

(iii) $M = \frac{f_0}{f_e}\left[1 - \frac{f_e}{D}\right]$. Final image is at D. $L = f_0 - u_e$

BINOCULAR



Binocular

In this telescope as intermediate image is outside the tube, the telescope cannot be used for making measurements. If two telescope are mounted parallel to each other so that an object can be seen by both the eyes simultaneously, the arrangement is called 'binocular'. In a binocular, the length of each tube is reduced by using a set of totally reflecting prisms. which provide intense, erect image free from lateral inversion. Through a binocular we get two imaged of the same object from different angles at same time. Their superposition givens the perception of depth also with length and breadth. i.e., binocular vision given proper three-dimensional (3.d) image.

Illustrations

1. In a compound microscope, the intermediate image is

(A) virtual, erect and magnified (B) real, erect and magnified

(C) real, inverted and magnified (D) virtual, inverted and reduced

Ans (C)

Intermediate image is formed by the objective. It is real inverted and magnified.

2. The magnifying power of telescope is 9. When it is adjusted for parallel rays, the distance between the objective and the eyepiece is found to be 20 cm. The focal lengths of the converging lenses used are

(A) 18 cm, 2 cm (B) 11 cm, 9 cm (C) 22.5 cm, 2.5 cm (D) 16 cm, 4 cm

Ans (A)

$M = \frac{f_0}{f_e} = 9$

$f_0 + f_e = 20 \Rightarrow f_0 = 18$ cm, $f_e = 2$ cm

3. Magnification of a compound microscope is 3.0. Focal length of the eye piece is 5 cm and the image is formed at the distance of distinct vision 25 cm. The magnification of the objective lens is

(A) 5 (B) 7.5 (C) 10 (D) 15

Ans (A)

Magnification of eye lens $M = 1 + \frac{d}{f_e} = 1 + \frac{25}{5} = 6$

$M = M_0 \times M_e = 30 \Rightarrow M_0 = \frac{30}{6} = 5$

4. In a compound microscope the intermediate image is

(A) virtual, erect and magnified
(B) Real, erect and magnified
(C) real, inverted and magnified
(D) virtual, inverted and reduced

Ans (C)

Hint : Intermediate image is formed by the objectives it is real inverted and magnified.

5. A card sheet divided into squares each of size 1 mm^2 is being viewed at a distance of 9 cm through a magnifying glass (converging lens of focal length 9 cm) held close to the eye. The magnification produced is

(A) 10
(B) 20
(C) 5
(D) 1

Ans (A)

Area = 1 mm^2, u = –9 cm, f = 10 cm $\therefore$ v = –90 cm

from Lens formula $\left[\frac{1}{v} - \frac{1}{u} = \frac{1}{f}\right]$

$\therefore$ magnification $m = \frac{v}{u} = \frac{-90}{-9} = 10$

6. A myopic person has been using a spectacles of power 1.00 D for distant vision. During old age he also needs to use separate reading glass of power +2.0 D. What is his new near point?

(A) 60 cm
(B) 20 cm
(C) 100 cm
(D) 50 cm

Ans (D)

P = –1 D, f = –1 m = –100 cm

Normal vision, u = –∞ $\therefore \frac{1}{v} = -\frac{1}{100}$ $\therefore$ v = –100 cm

To focus new objects at distance 25 cm to 100 cm, persons accommodation is lost in old age, so he needs another spectacles.

$\therefore$ P + 2D

$f = \frac{1}{2} = 50$ cm and $v = 25$ cm $\therefore$ u = 50 cm

Near point shifts to 50 cm

NCERT LINE BY LINE QUESTIONS

1. Which of the following statements is wrong for an image formation of a real object? [NCERT Pg. 315]
   (1) The magnification produced by convex mirror is always less than one
   (2) A virtual, inverted, same size image can be obtained using plane mirror
   (3) A virtual, erect, magnified image can be formed using a concave mirror
   (4) A real, inverted, same sized image can be formed using a convex mirror
2. Advanced sunset and delayed sunset is due to [NCERT Pg. 318]
   (1) Atmospheric reflection (2) Atmospheric refraction
   (3) Atmospheric scattering (4) Atmospheric dispersion
3. If μ_a, μ_b and μ_c are refractive indices of media A,B and C respectively such that $\mu_a > \mu_b > \mu_c$, total internal reflection can take place when a ray of light travels from [NCERT Pg. 320]
   (1)C to A (2) C to B (3) B to A (4) B to C
4. Which of the following concept is used in optical fibre? [NCERT Pg. 322]
   (1) Refraction of light (2) Scattering of light
   (3) Dispersion of light (4) Total internal reflection
5. In the position of minimum deviation when a ray of yellow light passes through the prism, then its [NCERT Pg. 331]
   (1) Angle of incidence is less than angle of emergence
   (2) Angle of incidence is greater than emergent angle
   (3) Sum of angle of incidence and emergent angle is equal to 90°
   (4) Angle of incidence is equal to angle of emergence
6. The focal length of a lens depends upon (NCERT Pg.S27]
   (1) Nature of material of lens (2) Colour of light
   (3) Medium in which lens is placed (4) All of these
7. A screen is placed at a distance of 40 cm away from an illuminated object. A converging lens is placed between the source and screen and it is attempted to form the image of the source on the screen. If no lens position could be found, the focal length of the lens [NCERT Pg. 347]
   (1) Should be greater than 10 cm (2) May be 6 cm

(3) May be infinity (4) Must be less than 10 cm

8. In a compound microscope, the intermediate image is [NCERT Pg. 340]

(1) Virtual, erect and magnified (2) Real, erect and magnified

(3) Real, inverted and magnified (4) Virtual, erect and reduced

9. Mark the correct option among following statements. [NCERT Pg. 337]

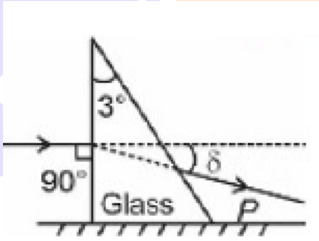
(1) If far point come closer to eye, the defect is farsightedness.

(2) If near point goes ahead (away from eye), the defect is called myopia.

(3) If defective far point is 1 m away from eye, divergent lens should be used

(4) If near point is 1 m away from eye, divergent lens should be used

10. P is a small angled prism of angle 3° made from material of refractive index 1.2. A ray of light is incident on it as shown in figure. The angle of deviation for the rays refracted from prism is [NCERT Pg. 331]



(1) 2° (2) 3° (3) 0.8° (4) 0.6°

11. When white light enters a prism, it gets split into its constituent colours. This is due to [NCERT Pg. 333]

(1) Scattering of light (2) Dispersion of light

(3) Reflection of light (4) Diffraction of light

12. A compound microscope consists of an objective lens of focal length 1 cm and an eye piece with focal length of 2.0 cm and tube has length 20 cm. What is its magnification? [NCERT Pg. 341]

(1) 100 (2) 200 (3) 220 (4) 250

13. With regards to a telescope, which statement is incorrect. [NCERT Pg. 340]

(1) Telescope is used to provide angular magnification of distant objects

(2) Telescope has objective lens of large power

(3) Final image of refracting telescope is inverted

(4) With larger diameter of objective fainter objects can be observed

14. Match the elements of List-I with List-II [NCERT Pg. 339]

List - I	List-II
(A)Simple microscope	(E) Image magnified, inverted and virtual
(B)Compound microscope	(F) Image virtual, erect and high resolution
(C)Astronomical telescope	(G) Virtual, inverted and high resolution

(D)Terrestrial telescope (H) Image virtual, erect and enlarged

(1) A-H, B-F, C-E, D-G (2) A-H, B-E, C-G, D-F

(3) A-H, B-E, C-F, D-G (4) A-F, B-G, C-E, D-G

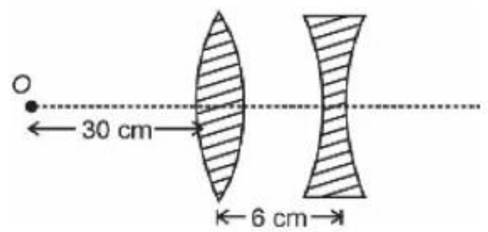
15. A simple magnifier has converging lens of focal length 2.5 cm. What is its linear magnification for the image formed at near point? [NCERT Pg. 341]

(1) 6 (2) 9 (3) 11 (4) 16

16. A prism has prism angle of 60° and its absolute refractive index is 1.76. The prism is dipped in a transparent liquid of refractive index x. If the angle of minimum deviation is found to 46° in liquid, what is x? [NCERT Pg. 331]

(1) 1.1 (2) 1.3 (3) 1.4 (4) 1.5

17. Find the position of the image formed by lens combination with convex lens of focal length 10 cm and concave lens of focal length 12 cm. The object is kept at 30 cm from the convex lens as shown [NCERT Pg. 330]



(1) 36 cm to right of convex lens (2) 36 cm to right of concave lens
(3) 16 cm to left of concave lens (4) 20 cm to right of convex lens

18. A small pin fixed on table top is viewed from above from a distance of 40 cm. By what distance would pin appear to be raised if viewed from the same point through a 12 cm thick glass slab held parallel to the table? Refractive index of glass is 1.5 [NCERT Pg. 345]
(1) 4 cm (2) 5 cm (3) 6 cm (4) 8 cm

19. Biconvex lenses are to be manufactured from glass of refractive index 1.5 with both faces of same radii of curvature. The radius of curvature required if focal length is 15 cm will be [NCERT Pg. 344]
1) 10 cm 2) 15 cm 3) 20 cm 4) 25 cm

20. A light pipe is made of glass fibre of refractive index 1.57. The outer covering of the pipe is made of a material of refractive index 1.36. The range of angles of incident rays with the axis of the pipe for which total internal reflection inside the pipe take place is nearly [NCERT Pg. 344]
1) $0° < i < 38°$ 2) $0° < i < 90°$ 3) $0° < i < 60°$ 4) $0° < i < 53°$

NCERT BASED PRACTICE QUESTIONS

1. The phenomenon of scattering obey Rayleigh's law i.e. $I \propto \frac{1}{\lambda^4}$. Therefore, then the traffic signals are of red colour. In this case the scattering particle (air molecules) should have size
(1) greater than the wave length (2) smaller than the wave length
(3) of the order of wavelength (4) None

2. Paraxial rays in geometrical optics are those rays which are
(1) parallel to principal axis making large angle of incidence
(2) non-parallel to principal axis
(3) parallel to principal axis making small angle of incidence
(4) None

3. If an object is placed in front of a concave mirror and the lower half of the mirror is covered with opaque material then what happens
(1) lower half of the object will be seen as image
(2) upper half of the object will be seen as image
(3) No change in the image will taken place
(4) image will be completely formed with less intensity

4. Optical fibre consists of core and cladding whose refractive index are related as
(1) $\mu_{core} = \mu_{clading}$ (2) $\mu_{core} > \mu_{clading}$ (3) $\mu_{core} < \mu_{clading}$ (4) No relation between them

5. Dispersion occurs due to
(1) Refractive index of medium for different frequencies is same
(2) Refractive index of medium for different frequencies is different
(3) Refractive index is different for same frequency
(4) It does not depends on frequency

6. Sun is visible a little before sunrise and until a little after the actual sunset due to
(1) Reflection (2) Refraction
(3) Scattering (4) Total internal reflection

7. While moving in a bus or a car during a hot summer day, a distant patch on road appears to be wet. It is due to
(1) Reflection (2) Total internal reflection
(3) Scattering (4) Dispersion

8. Clouds which have droplets of water appear to white. This happens because of
(1) Dispersion (2) Scattering
(3) Chromatic aberration (4) Total internal reflection

9. In modern microscopes, multi component lenses are used for both objective and eye lens to improve image quality by minimising.
(1) Reflection (2) Optical aberration
(3) Magnifying power (4) Scattering

10. Thick lenses shows chromatic aberration due to
(1) Refraction (2) Total internal reflection
(3) Dispersion (4) Scattering

11. Rainbow formation is due to
(a) Refraction (b) Dispersion
(c) Total internal reflection (d) Scattering
(1) a and b (2) a, b and c
(3) b and c (4) b, c and d

12. The condition for observing a rainbow are that sun should be shining in one part of the sky while it would be raining in
(1) same part of sky (2) opposite part of sky
(3) rain is not required (4) it can rain anywhere

13. In secondary rainbow there are

(1) 1 total internal reflection (2) 2 total internal reflection
(3) No internal reflection (4) Depends on the size of water droplet

14. Modern telescopes are designed in such a way that there is no chromatic aberration present. It is used by having
(1) Convex lens (2) Concave mirror
(3) Both concave mirror and convex lens (4) Prism

15. Laws of reflection are strictly valid for
(1) Plane surfaces (2) Rough surfaces
(3) All types of surfaces (4) None of these

16. A short pulse of white light is incident from air to a glass slab at normal incidence. After travelling through the slab, the first colour to emerge is
(1) Blue (2) Green (3) Violet (4) Red

17. A passenger in an aeroplane shall
(1) Never see a rainbow
(2) may see a primary and a secondary rainbow as concentric circles
(3) may see a primary and a secondary rainbow as concentric arcs.
(4) shall never see a secondary rainbow

18. In telescope, which mirror is used as objective instead of convex lens
(1) Parabolic concave mirror (2) Plane mirror
(3) Convex mirror (4) Mirror can't be used

19. Objective lens of telescope has large aperature
(1) to increase intensity and resolving power (2) to reduce resolving power
(3) to obtain small magnifying power (4) to reduce intensity

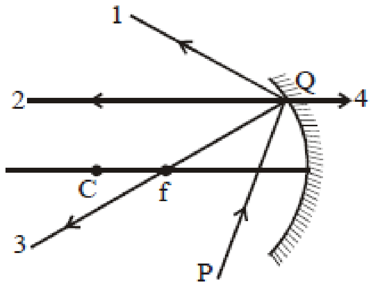
20. In vacuum, all colours
(1) have same speed (2) have different-different speed
(3) do not move (4) absorb all colours

21. A person can see his inverted image in a concave mirror when he is
(1) between focus and center of curvature (C) (2) beyond C
(3) between focus & pole (4) at focus

22. Which of the following colours of white light deviated most when passes through a prism.
(1) Red light (2) Violet light (3) Yellow light (4) Both (1) & (2)

23. An under-water swimmer cannot see very clearly even in absolutely clear water because of
(1) absorption of light in water
(2) scattering of light in water
(3) reduction of speed of light in water
(4) change in the focal length of eye lens

24. The direction of ray of light incident on a concave mirror is shown by PQ while direction in which the would travel after reflection is shown by four rays, marked 1,2,3 and 4 which of the four rays correctly shown the direction of reflected ray ?



(1) 1 (2) 2 (3) 3 (4) 4

25. Optical densness of a medium is measured in terms of _____.

(1) refractive index (2) mass density (3) (1) & (2) both (4) can't measure

26. Virtual image formed by convex mirror has magnification ___

(1) Positive (2) Negative

(3) convex mirror can't form virtual image

(4) None of these

27. An air bubble is formed inside water. It act as a :-

(1) convex mirror (2) converging lens (3) diverging lens (4) plane mirror

28. An object is first seen in red light and then in violet light through a simple microscope. In which case is the magnifying power longer.

(1) violet light (2) red light

(3) same in both light (4) can't see magnified image

29. A convergent lens of 6 diopters is combined with a diverging lens of –2 diopters. Find the power of combination?

(1) 4 diopter (2) 6 diopter (3) 8 diopter (4) 10 diopter

30. A prism is made up of flint glass whose dispersive power is 0.053. Find the angle of dispersion if the mean refractive index of flint glass is 1.68 and the refracting angle of prism is 3^o .

(1) 20.08^o (2) 10.08^o (3) 0.208^o (4) 0.108^o

31. If x and y be the distances of the object and image formed by a concave mirror from its focus and f be the focal length then

(1) $xf = y^2$ (2) $xy = f^2$ (3) $x/y = f$ (4) $x/y = f^2$

32. How does refractive index (μ) of a material vary with respect to wavelength (λ)? A and B are constants

(1) $\mu = A + B\lambda^2$ (2) $\mu = A + \frac{B}{\lambda^2}$ (3) $\mu = A + B\lambda$ (4) $\mu = A + \frac{B}{\lambda}$

33. A convex mirror is used to form the image of an object. Then which of the following statements is/are true?

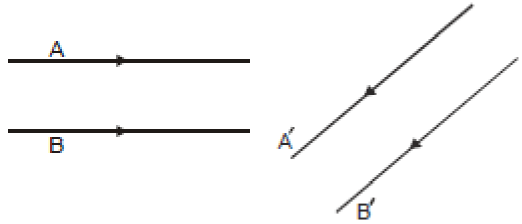
I. The image lies between the pole and the focus

II. The image is diminished in size

III. The image is real

(1) I only (2) II only (3) I and III (4) I and II

34. Figure shows two rays A and B being reflected by a mirror and going as A' and B'. The mirror

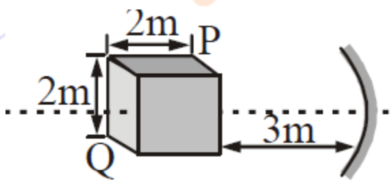


(1) is plane (2) is convex (3) is concave (4) may be any spherical mirror

35. **Assertion :** The focal length of the convex mirror will increase, if the mirror is placed in water.
Reason : The focal length of a convex mirror of radius R is equal to , $f = R/2$.
(1) Assertion is correct, reason is correct; reason is a correct explanation for assertion.
(2) Assertion is correct, reason is correct; reason is not a correct explanation for assertion
(3) Assertion is correct, reason is incorrect
(4) Assertion is incorrect, reason is correct.

36. Which of the following is incorrect statement?
(1) the magnification produced by a convex mirror is always less than one
(2) a virtual, erect, same-sized image can be obtained using a plane mirror
(3) a virtual, erect, magnified image can be formed using a concave mirror
(4) a real, inverted, same-sized image can be formed using a convex mirror.

37. A cube of side 2 m is placed in front of a concave mirror of focal length 1m with its face P at a distance of 3 m and face Q at a distance of 5 m from the mirror. The distance between the image of face P and Q is

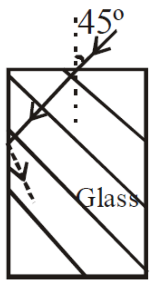


(1) 1 m (2) 0.5 m (3) 0.5 m (4) 0.25 m

38. A light ray falls on a rectangular glass slab as shown. The index of refraction of the glass, if total internal reflection is to occur at the vertical face, is

(a) $\sqrt{3/2}$ (b) $\frac{(\sqrt{3}+1)}{2}$

(c) $\frac{(\sqrt{2}+1)}{2}$ (d) $\sqrt{5}/2$



1) a 2) b 3) c 4)d

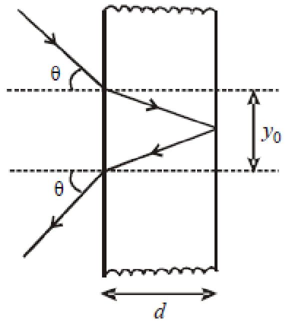
39. A ray of light incident from air on a glass plate of refractive index n is partly reflected and partly refracted at the two surfaces of the glass. The displacement $y0$ in the figure is

(a) $\dfrac{2d\sin\theta}{\sqrt{n^2-\sin^2\theta}}$

(b) $\dfrac{2d\sin\theta}{\sqrt{\sin^2\theta-\dfrac{1}{n^2}}}$

(c) $\dfrac{2d\sqrt{n^2-\sin^2\theta}}{\sin\theta}$

(d) None of these



1) a   2) b   3) c   4)d

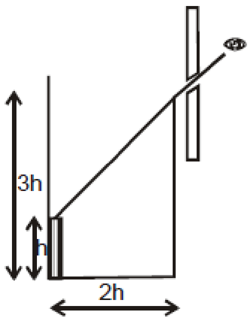
40. An observer can see through a pin-hole the top end of a thin rod of height *h*, placed as shown in the figure. The beaker height is 3h and its radius *h*. When the beaker is filled with a liquid up to a height 2*h*, he can see the lower end of the rod. Then the refractive index of the liquid is

(a) $\frac{5}{2}$

(b) $\sqrt{\frac{5}{2}}$

(c) $\sqrt{\frac{3}{2}}$

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



1) a   2) b   3) c   4)d

41. **Assertion :** When a convex lens (μ_g= 3/2) of focal length *f* is dipped in water, its focal length becomes $4/3f$.

Reason : The focal length of convex lens in water becomes 4*f*.

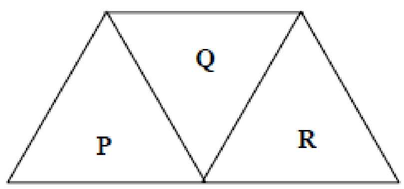
(1) Assertion is correct, reason is correct; reason is a correct explanation for assertion.

(2) Assertion is correct, reason is correct; reason is not a correct explanation for assertion

(3) Assertion is correct, reason is incorrect

(4) Assertion is incorrect, reason is correct.

42. A given ray of light suffers minimum deviation in an equilateral prism *P*. Additional prism *Q* and *R* of identical shape and of the same material as *P* are now added as shown in the figure. The ray will now suffer



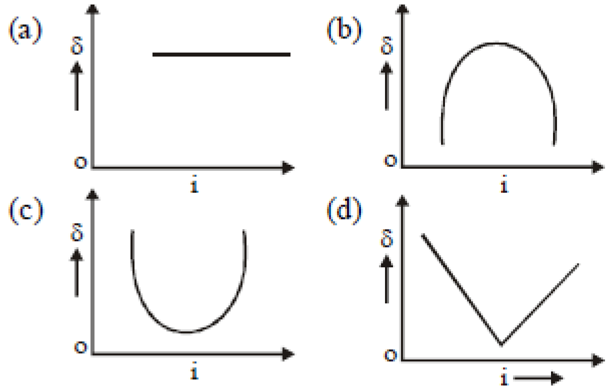
(1) greater deviation

(2) no deviation

(3) same deviation as before

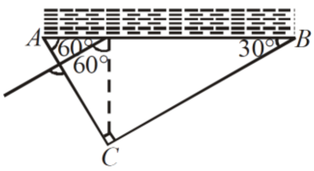
(4) total internal reflection

43. The graph between angle of deviation (4) and angle of incidence (i) for a triangular prism is represented by



1) a 2) b 3) c 4)d

44. ACB is right - angle prism with other angles as 60° and 30°. Refractive index of the prism is 1.5. AB has thin layer of liquid on it as shown. Light falls normally on the face AC. For total internal reflections, maximum refractive index of the liquid is



(1) 1.4 (2) 1.3 (3) 1.2 (4) 1.6

45. To increase the angular magnification of a simple microscope, one should increase
(1) the focal length of the lens
(2) the power of the lens
(3) the aperture of the lens
(4) the object size

46. A student look at distant tree of height 15m with a telescope of magnifying power 25. To the student, the tree appears.
(1) 20 times taller (2) 15 times taller (3) 15 times nearer (4) 25 times nearer

47. Resolving power of a telescope increases with
(1) increase in focal length of eye-piece
(2) increase in focal length of objective
(3) increase in aperture of eye piece
(4) increase in aperture of objective

48. A normal eye has retina 2cm behind the eye lens. What is the power of the eye-lens when the eye is fully relaxed?
(1) 50 D (2) 54 D (3) 40 D (4) 45 D

49. In a compound microscope, the focal length of objective lens is 1.2 cm and focal length of eye piece is 3.0 cm. When object is kept at 1.25 cm in front of objective, final image is formed at infinity. Magnifying power of the compound microscope should be:
(1) 200 (2) 100 (3) 400 (4) 150

50. The magnifying power of a telescope is 9. When it is adjusted for parallel rays, the distance between the objective and the eye piece is found to be 20 cm. The focal length of lenses are
(1) 18 cm, 2 cm (2) 11 cm, 9 cm (3) 10 cm, 10 cm (4) 15 cm, 5 cm

51. The focal lengths of objective lens and eye lens of a Galilean telescope are respectively 30 cm and 3.0 cm. telescope produces virtual, erect image of an object situated far away from it at least distance of distinct vision from the eye lens. In this condition, the magnifying power of the Galilean telescope should be:

(1) + 11.2 (2) – 11.2 (3) – 8.8 (4) + 8.8

TOPIC WISE PRACTICE QUESTIONS

Topic 1: Plane Mirror, Spherical Mirror and Reflection of Light

1. A concave mirror forms the image of an object on a screen. If the lower half of the mirror is covered with an opaque card, the effect would be to make the

(1) image less bright.

(2) lower half of the image disappear.

(3) upper half of the image disappear.

(4) image blurred.

2. Which of the following is incorrect statement?

(1) the magnification produced by a convex mirror is always less than one

(2) a virtual, erect, same-sized image can be obtained using a plane mirror

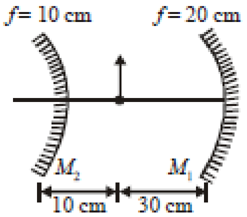
(3) a virtual, erect, magnified image can be formed using a concave mirror

(4) a real, inverted, same-sized image can be formed using a convex mirror.

3. A man 160 cm high stands in front of a plane mirror. His eyes are at a height of 150 cm from the floor. Then the minimum length of the plane mirror for him to see his full length image is

(1) 85 cm (2) 170 cm (3) 80 cm (4) 340 cm

4. In Fig. find the total magnification after two successive reflections first on M_1 and on M_2.



(1) + 1 (2) –2 (3) +2 (4) –1

5. In image formation from spherical mirrors, only paraxial rays are considered because they

(1) are easy to handle geometrically

(2) contain most of the intensity of the incident light

(3) form nearly a point image of a point source

(4) show minimum dispersion effect

6. Two mirrors are placed at right angles to each other. A man is standing between them combing his hair. How many image will he see?

(1) 2 (2) 3 (3) 1 (4) zero

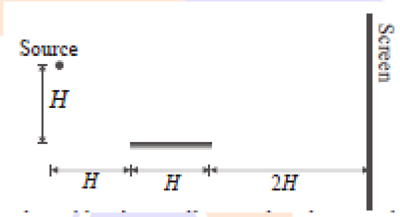
7. The light reflected by a plane mirror may form a real image

(1) if the rays incident on the mirror are diverging

(2) if the rays incident on the mirror are converging
(3) if the object is placed very close to the mirror
(4) under no circumstances

8. Two plane mirrors are inclined at 70°. A ray incident on one mirror at angle θ after reflection falls on second mirror and is reflected from there parallel to first mirror. The value of θ is
(1) 50° (2) 45° (3) 30° (4) 55°

9. A point source has been placed as shown in the figure. What is the length on the screen that will receive reflected light from the mirror?



(1) 2*H* (2) 3*H* (3) *H* (4) None of these

10. When a plane mirror is placed horizontally on a level ground at a distance of 60 *m* from the foot of a tower, the top of the tower and its image in the mirror subtend an angle of 90° at the eye. The height of the tower will be
(1) 30 *m* (2) 60 *m* (3) 90 *m* (4) 120 *m*

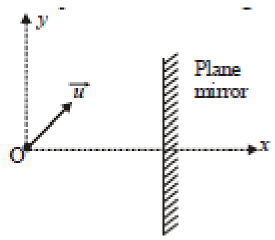
11. In a concave mirror, an object is placed at a distance x_1 from focus, and image is formed at a distance x_2 from focus. Then focal length of mirror is
(1) $\sqrt{x_1x_2}$ (2) $\frac{x_1-x_2}{2}$ (3) $\frac{x_1+x_2}{2}$ (4) $\sqrt{\frac{x_1}{x_2}}$

12. A ray of light is incident at 50° on the middle of one of the two mirrors arranged at an angle of 60° between them. The ray then touches the second mirror, get reflected back to the first mirror, making an angle of incidence of
(1) 50° (2) 60° (3) 70° (4) 80°

13. Two plane mirrors are inclined to each other at a certain angle. A ray of light first incident on one of them at an inclination of 10° with the mirror retraces its path after five reflections. The angle between the mirrors is :
(1) 12° (2) 22° (3) 30° (4) 20°

14. A rod of length 2 m is placed in front of a concave mirror of focal length 1m laying horizontally with its one end at a distance of 3 m and other end at a distance of 5 m from the mirror. The length of the image is
(1) 2 m (2) 2.5 m (3) 3.5 m (4) 0.25 m

15. A plane mirror is kept parallel to *y*-axis. A point object is approaching the mirror with velocity $\bar{u}=\left(10\hat{i}+10\hat{j}\right)$ m/s. The magnitude of relative velocity of objective w.r.t image is equal to



(1) $20\sqrt{2}$ m/s (2) 20 m/s (3) $10\sqrt{2}$ m/ s (4) 10 m/s

16. A car is fitted with a convex side-view mirror of focal length 20 cm. A second car 2.8 m behind the first car is overtaking the first car at a relative speed of 15 m/s. The speed of the image of the second car as seen in the mirror of the first one is :

(1) $\frac{1}{15}$ m/s (2) 10 m/s (3) 15 m/s (4) $\frac{1}{10}$ m/s

17. A point object is kept in front of a plane mirror. The plane mirror is doing SHM of amplitude 2 cm. The plane mirror moves along the x - axis which is normal to the mirror. The amplitude of the mirror is such that the object is always in front of the mirror. The amplitude of SHM of the image is

(1) 0 (2) 2 cm (3) 4 cm (4) 1 cm

18. A point source of light is placed in front of a plane mirror. Then

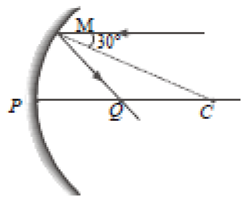
(1) all the reflected rays meet at a point when produced backward

(2) only the reflected rays close to the normal meet at a point when produced backward.

(3) only the reflected rays making a small angle with the mirror, meet at a point when produced backward.

(4) light of different colours make different images.

19. A ray parallel to principal axis is incident at 30° from normal on concave mirror having radius of curvature



R. The point on principal axis where rays are focussed is *Q* such that *PQ* is

(1) $\frac{R}{2}$ (2) $\frac{R}{\sqrt{3}}$ (3) $\frac{2\sqrt{R}-R}{\sqrt{2}}$ (4) $R\left(1-\frac{1}{\sqrt{3}}\right)$

20. Two mirrors, one concave and the other convex, are placed 60 cm apart with their reflecting surfaces facing each other. An object is placed 30 cm from the pole of either of them on their axis. If the focal lengths of both the mirrors are 15 cm, the position of the image formed by reflection, first at the convex and then at the concave mirror, is :

(1) 19.09 cm from the pole of the concave mirror

(2) 19.09 cm from the pole of the convex mirror

(3) 11.09 cm from the pole of the concave mirror

(4) 11.09 cm from the pole of the convex mirror

Topic 2: Refraction of Light at Plane Surface and Total Internal Reflection

21. A green light is incident from the water to the air – water interface at the critical angle (θ). Select the correct statement.

(1) The entire spectrum of visible light will come out of the water at an angle of 90º to the normal.

(2) The spectrum of visible light whose frequency is less than that of green light will come out to the air medium.

(3) The spectrum of visible light whose frequency is more than that of green light will come out to the air medium.

(4) The entire spectrum of visible light will come out of the water at various angles to the normal.

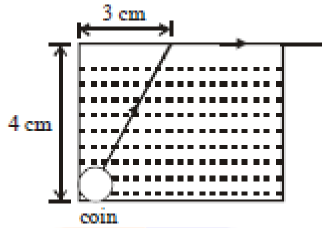
22. The ratio of thickness of plates of two transparent medium A and B is 6 : 4. If light takes equal time in passing through them, then refractive index of A with respect to B will be

(1) 1.33 (2) 1.75 (3) 1.4 (4) 1.5

23. The refractive indices of glass and water with respect to air are $\frac{1}{2}$ and $\frac{1}{\sqrt{3}}$ respectively. Then the refractive index of glass with respect to water is

(1) $\frac{1}{\sqrt{3}}$ (2) $\frac{\sqrt{3}}{2}$ (3) $\frac{2}{\sqrt{3}}$ (4) 2

24. A small coin is resting on the bottom of a beaker filled with liquid. A ray of light from the coin travels upto the surface of the liquid and moves along its surface. How fast is the light travelling in the liquid?

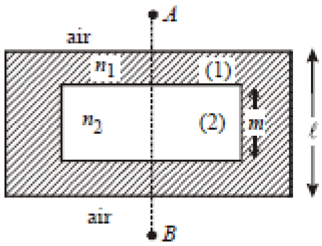


(1) 2.4×10^8 m/s (2) 3.0×10^8 m/s (3) 1.2×10^8 m/s (4) 1.8×10^8 m/s

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

(1) 5/3 (2) 5/4 (3) 16/15 (4) 1.5

26. In a thick glass slab of thickness ℓ and refractive index n_1 a cuboidal cavity of thickness m is carved as shown in the figure and is filled with liquid of *R.I.* n_2 ($n_1 > n_2$). The ratio of ℓ/m, so that shift produced by this slab is zero when an observer *A* observes an object *B* with paraxial rays is



(1) $\dfrac{n_1 - n_2}{n_2 - 1}$ (2) $\dfrac{n_1 - n_2}{n_2(n_1 - 1)}$ (3) $\dfrac{n_1 - n_2}{n_1 - 1}$ (4) $\dfrac{n_1 - n_2}{n_1(n_2 - 1)}$

27. When light falls on a given plate at angle of incidence of 60º, the reflected and refracted rays are found to be normal to each other. The refractive index of the material of the plate is then

(1) 0.866 (2) 1.5 (3) 1.732 (4) 2

28. Total internal reflection can take place only if

(1) light goes from optically rarer medium (smaller refractive index) to optically denser medium

(2) light goes from optically denser medium to rarer medium

(3) the refractive indices of the two media are close to different

(4) the refractive indices of the two media are widely different

29. An electromagnetic radiation of frequency n, wavelength λ, travelling with velocity v in air, enters a glass slab of refractive index μ. The frequency, wavelength and velocity of light in the glass slab will be respectively

(1) $\frac{n}{\mu}, \frac{\lambda}{\mu}$ and $\frac{v}{\mu}$ (2) $n, \frac{\lambda}{\mu}$ and $\frac{v}{\mu}$ (3) $n, 2\lambda$ and $\frac{v}{\mu}$ (4) $\frac{2n}{\mu}, \frac{\lambda}{\mu}$ and v

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

(1) emerge into the air without any deviation

(2) be reflected back into the glass

(3) be absorbed

(4) emerge into the air with an angle of refraction equal to 90º

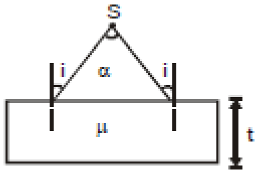
31. A narrow beam of white light goes through a slab having parallel faces

(1) the light never splits in different colours

(2) the emergent beam is white

(3) the light inside the slab is split into different colours
(4) the light inside the slab is white

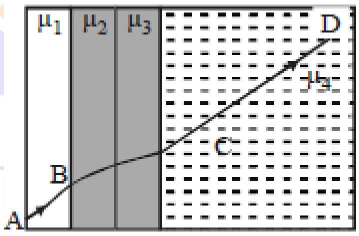
32. A diverging beam of light from a point source *S* having divergence angle α, falls symmetrically on a glass slab as shown. The angles of incidence of the two extreme rays are equal. If the thickness of the glass slab is *t* and the refractive index *n*, then the divergence angle of the emergent beam is



(1) zero (2) α (3) $\sin^{-1}\left(\frac{1}{n}\right)$ (4) $2\sin^{-1}\left(\frac{1}{n}\right)$

33. A fish looking up through the water sees the outside world contained in a circular horizon. If the refractive index of water is 4/3 and the fish is 12 cm below the surface, the radius of this circle in cm is
(1) $36\sqrt{5}$ (2) $4\sqrt{5}$ (3) $36\sqrt{7}$ (4) $36/\sqrt{7}$

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



(1) $\mu_1 = \mu_2$ (2) $\mu_2 = \mu_3$ (3) $\mu_3 = \mu_4$ (4) $\mu_4 = \mu_1$

35. A ray of light passes from vacuum into a medium of refractive index μ, the angle of incidence is found to be twice the angle of refraction. Then the angle of incidence is
(1) $2\cos^{-1}\left(\frac{\mu}{2}\right)$ (2) $\sin^{-1}(\mu)$ (3) $\sin^{-1}\left(\frac{\mu}{2}\right)$ (4) $\cos^{-1}\left(\frac{\mu}{2}\right)$

36. The wavelength of a monochromatic light in vacuum is λ. It travels from vacuum to a medium of absolute refractive index μ. The ratio of wavelength of the incident and refracted wave is
(1) $\mu^2 : 1$ (2) $1 : 1$ (3) $\mu : 1$ (4) $1 : \mu$

37. Let the *x-z* plane be the boundary between two transparent media. Medium 1 in $z \geq 0$ has a refractive index of $\sqrt{2}$ and medium 2 with $z < 0$ has a refractive index of $\sqrt{3}$. A ray of light in medium 1 given by the vector $\vec{A} = 6\sqrt{3}\hat{i} + 8\sqrt{3}\hat{j} - 10\hat{k}$ is incident on the plane of separation. The angle of refraction in medium 2 is:
(1) 45° (2) 60° (3) 75° (4) 30°

38. A vessel of depth *x* is half filled with oil of refractive index μ_1 and the other half is filled with water of refractive index μ_2. The apparent depth of the vessel when viewed from above is
(1) $\frac{x(\mu_1+\mu_2)}{2\mu_1\mu_2}$ (2) $\frac{x\mu_1\mu_2}{2(\mu_1+\mu_2)}$ (3) $\frac{x\mu_1\mu_2}{(\mu_1+\mu_2)}$ (4) $\frac{2x(\mu_1+\mu_2)}{\mu_1\mu_2}$

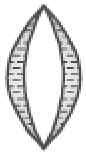
39. The index of refraction of diamond is 2.0 velocity of light in diamond in cm per second is approximately
(1) 3×10^{11} (2) 1.5×10^{10} (3) 2.8×10^{11} (4) 3.1×10^{12}

Topic 3: Refraction of light at Spherical Surface and Power of Lens

40. A convex lens is immersed in a liquid of refractive index greater than that of glass. It will behave as a
(1) convergent lens

(2) divergent lens
(3) plane glass
(4) homogeneous liquid

41. A convex lens is made of 3 layers of glass of 3 different materials as in the figure. A point object is placed on its axis. The number of images of the object are

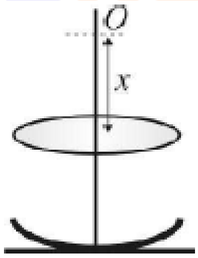


(1) 3 (2) 4 (3) 1 (4) 2

42. A lens made of glass whose index of refraction is 1.60 has a focal length of + 20 cm in air. Its focal length in water, whose refractive index is 1.33, will be
(1) three times longer than in air
(2) two times longer than in air
(3) same as in air
(4) None of these

43. A convex lens is in contact with concave lens. The magnitude of the ratio of their powers is 2/3. Their equivalent focal length is 30 cm. What are their individual focal lengths (in cm)?
(1) –15, 10 (2) –10, 15 (3) 75, 50 (4) –75, 50

44. A convex lens of focal length 40 cm is held co-axially 12 cm above a mirror of focal length 18 cm. An object held x cm above the lens gives rise to an image coincident with it. Then x is equal to:

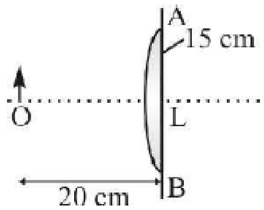


(1) 12 cm (2) 15 cm (3) 18 cm (4) 30 cm

45. A converging beam of rays is incident on a diverging lens. Having passed through the lens the rays intersect at a point 15 cm from the lens on the opposite side. If the lens is removed the point where the rays meet will move 5 cm closer to the lens. The focal length of the lens is
(1) – 10 cm (2) 20 cm (3) –30 cm (4) 5 cm

46. A body is located on a wall. Its image of equal size is to be obtained on a parallel wall with the help of a convex lens. The lens is placed at a distance '*d*' ahead of second wall, then the required focal length will be
(1) only $\frac{d}{4}$
(2) only $\frac{d}{2}$
(3) more than $\frac{d}{4}$ but less than $\frac{d}{2}$
(4) less than $\frac{d}{4}$

47. A point object is placed at a distance of 20 cm from a thin plano-convex lens of focal length 15 cm. If the plane surface is silvered, the image will form at :

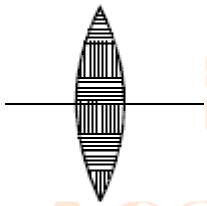


(1) 60 cm left of AB
(2) 30 cm left of AB
(3) 12 cm left of AB
(4) 60 cm right of AB

48. A plano convex lens fits exactly into a plano concave lens. Their plane surfaces are parallel to each other. If lenses are made of different materials of refractive indices μ_1 and μ_2, R is the radius of curvature of the curved surface of the lenses, then the focal length of the combination is

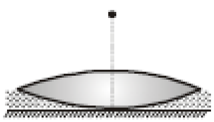
(1) $\frac{R}{2(\mu_1-\mu_2)}$ (2) $\frac{R}{(\mu_1-\mu_2)}$ (3) $\frac{2R}{(\mu_2-\mu_1)}$ (4) $\frac{R}{2(\mu_1+\mu_2)}$

49. The layered lens as shown is made of two types of transparent materials one indicated by horizontal lines and the other by vertical lines. The number of images formed of an object will be



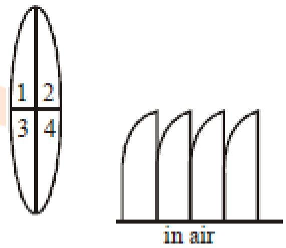
(1) 1 (2) 2 (3) 3 (4) 6

50. A drop of water is placed on a glass plate. A double convex lens having radius of curvature of each surface is 20 cm is placed on it. The focal length of water is ($\mu_w = 4/3$)



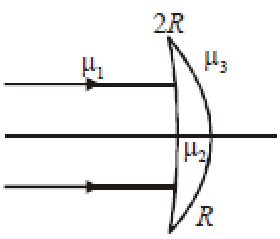
(1) – 20 cm (2) 60 cm (3) 20 cm (4) – 60 cm

51. The given lens is broken into four parts rearranged as shown. If the initial focal length is *f*, then after rearrangement the equivalent focal length is



(1) *f* (2) *f* / 2 (3) *f* / 4 (4) 4 *f*

52. Figure shows a concavo - convex lens μ_2. What is the condition on the reflective indices so that the lens is diverging?



(1) $2\mu_3 < \mu_1 + \mu_2$
(2) $2\mu_3 > \mu_1 + \mu_2$
(3) $\mu_3 > 2(\mu_1 - \mu_2)$
(4) none of these

53. A spherical surface of radius of curvature R separates air (refractive index 1.0) from glass (refractive index 1.5). The centre of curvature is in the glass. A point object *P* placed in air is found to have a real image *Q* in the glass. The line *PQ* cuts the surface at a point *O*, and *PO* = *OQ*. The distance *PO* is equal to

(1) 5 *R* (2) 3 *R* (3) 2 *R* (4) 1.5 *R*

54. A parallel beam of light is incident on a converging lens parallel to its principal axis. As one moves away from the lens on the other side on its principal axis, the intensity of light

(1) remains constant
(2) continuously increases
(3) continuously decreases
(4) first increases then decreases

55. A luminous object is placed at a distance of 30 cm from the convex lens of focal length 20 cm. On the other side of the lens, at what distance from the lens a convex mirror of radius of curvature 10 cm be placed in order to have an upright image of the object coincident with it?

(1) 12 cm (2) 30 cm (3) 50 cm (4) 60 cm

Topic 4: Prism and Dispersion of Light

56. If a glass prism is dipped in water, its dispersive power

(1) increases
(2) decreases
(3) does not change
(4) may increase or decrease depending on whether the angle of the prism is less than or greater than 60°

57. A prism of refracting angle 60^0 has minimum angle of deviation of 30o what must be the angle of incidence for this case?

(1) 90^0 (2) 45^0 (3) 30^0 (4) 15^0

58. A ray is incident at an angle of incidence *i* on one surface of a prism of small angle A and emerges normally from the opposite surface. If the refractive index of the material of prism is μ, the angle of incidence *i* is nearly equal to

(1) $\frac{A}{\mu}$ (2) $\frac{A}{2\mu}$ (3) μA (4) $\frac{\mu A}{2}$

59. Light of wavelength 4000 Å is incident at small angle on a prism of apex angle 4°. The prism has $n_v = 1.5$ and $n_r = 1.48$. The angle of dispersion produced by the prism in this light is

(1) 0.2° (2) 0.08° (3) 0.192° (4) None of these

60. A black spot is present just inside one of the face of an equilateral prism. A man places his eye directly at the opposite corner. He sees two images of the spot at an angular separation of 60°. Then the minimum value of refractive index of the prism is:

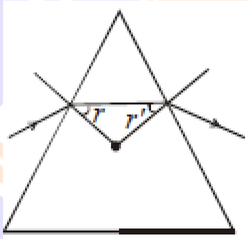
(1) $\mu = \frac{\sqrt{3}}{2}$ (2) $\mu = 2$ (3) $\mu = \frac{3}{2}$ (4) $\mu = \frac{2}{\sqrt{3}}$

61. A thin prism P_1 with angle 4° and made from glass of refractive index 1.54 is combined with another prism P_2 made of glass of refractive index 1.72 to produce dispersion without deviation. The angle of prism P_2 is
(1) 5.33° (2) 4° (3) 2.6° (4) 3°

62. There is a prism with refractive index equal to $\sqrt{2}$ and the refracting angle equal to 60°. One of the refracting surfaces of the prism is polished. A beam of monochromatic light will retrace its path if its angle of incidence over the refracting surface of the prism is
(1) $\sin^{-1}\left(\sqrt{2}\right)$ (2) $\sin^{-1}\left(2/\sqrt{3}\right)$ (3) $\sin^{-1}\left(\frac{\sqrt{3}}{\sqrt{2}}\right)$ (4) $\sin^{-1}\left(\frac{1}{\sqrt{2}}\right)$

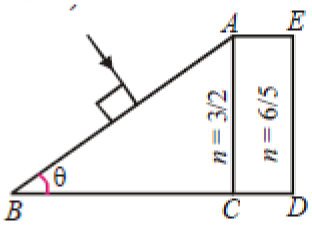
63. Angle of minimum deviation for a prism of refractive index 1.5, is equal to the angle of prism. Then the angle of prism is
(1) 42° (2) 52° (3) 62° (4) 82°

64. r and r' denote the angles inside an equilateral prism, as usual, in degrees.
Consider that during some time interval from $t = 0$ to $t = t$, r' varies with time as $r' = 10 + t^2$.
During this time r will vary as (assume that r and r' are in degree)



(1) $50 - t^2$ (2) $50 + t^2$ (3) $60 - t^2$ (4) $60 + t^2$

65. In Fig. ABC is the cross section of a right - angled prism and ACDE is the cross section of a glass slab. The value of θ so that incident normally on the face AB does not cross the face AC is (given $\sin^{-1}$ (3/5) = 37°).



(1) $\theta \le 37^0$ (2) $\theta < 37°$ (3) q $\le 53°$ (4) $\theta < 53°$

Topic 5: Optical Instruments

66. The image formed by an objective of a compound microscope is
(1) real and diminished
(2) real and enlarged
(3) virtual and enlarged
(4) virtual and diminished

67. An astronomical telescope has a large aperture to
(1) reduce spherical aberration
(2) have high resolution
(3) increases span of observation
(4) have low dispersion

68. The diameter of the objective lens of microscope makes an angle β at the focus of the microscope. Further, the medium between the object and the lens is an oil of refractive index n. Then the resolving power of the microscope
(1) increases with decreasing value of n
(2) increases with decreasing value of β

(3) increases with increasing value of $n \sin 2\beta$

(4) increases with increasing value of $\frac{1}{n \sin 2\beta}$

69. The focal length of the objective and the eyepiece of a telescope are 50 cm and 5 cm respectively. If the telescope is focussed for distinct vision on a scale distant 2 m from its objective, then its magnifying power will be :

(1) – 4 (2) – 8 (3) + 8 (4) – 2

70. A telescope has an objective lens of focal length 150 cm and an eyepiece of focal length 5 cm. If a 50 m tall tower at a distance of 1 km is observed through this telescope in normal setting, the angle formed by the image of the tower is θ, then θ is close to :

(1) 6.1 rad (2) 3.2 rad (3) 1.5 rad (4) 0.2 rad

NEET PREVIOUS YEARS QUESTIONS

1. An object is placed at a distance of 40 cm from a concave mirror of focal length 15 cm. If the object is displaced through a distance of 20 cm towards the mirror, the displacement of the image will be **[2018]**

(1) 30 cm away from the mirror

(2) 36 cm away from the mirror

(3) 36 cm towards the mirror

(4) 30 cm towards the mirror

2. The refractive index of the material of a prism is $\sqrt{2}$ and the angle of the prism is 30°.One of the two refracting surfaces of the prism is made a mirror inwards, by silver coating. A beam of monochromatic light entering the prism from the other face will retrace its path (after reflection from the silvered surface) if its angle of incidence on the prism is **[2018]**

(1) 60° (2) 45° (3) Zero (4) 30°

3. An astronomical refracting telescope will have large angular magnification and high angular resolution, when it has an objective lens of **[2018]**

(1) small focal length and large diameter

(2) large focal length and small diameter

(3) small focal length and small diameter

(4) large focal length and large diameter

4. A thin prism having refracting angle 10° is made of glass of refractive index 1.42. This prism is combined with another thin prism of glass of refractive index 1.7. This combination produces dispersion without deviation. The refracting angle of second prism should be **[2017]**

(1) 6° (2) 8° (3) 10° (4) 4°

5. A beam of light from a source L is incident normally on a plane mirror fixed at a certain distance x from the source. The beam is reflected back as a spot on a scale placed just above the source I. When the mirror is rotated through a small angle θ, the spot of the light is found to move through a distance y on the scale. The angle q is given by **[2017]**

(1) $\frac{y}{x}$ (2) $\frac{x}{2y}$ (3) $\frac{x}{y}$ (4) $\frac{y}{2x}$

6. A astronomical telescope has objective and eyepiece of focal lengths 40 cm and 4 cm respectively. To view an object 200 cm away from the objective, the lenses must be separated by a distance : **[2016]**

(1) 37.3 cm (2) 46.0 cm (3) 50.0 cm (4) 54.0 cm

7. The angle of incidence for a ray of light at a refracting surface of a prism is 45°. The angle of prism is 60°. If the ray suffers minimum deviation through the prism, the angle of minimum deviation and refractive index of the material of the prism respectively, are : **[2016]**

(1) $45^0, \frac{1}{\sqrt{2}}$ (2) $30^0, \sqrt{2}$ (3) $45^0, \sqrt{2}$ (4) $30^0, \frac{1}{\sqrt{2}}$

8. Two identical thin plano-convex glass lenses (refractive index 1.5) each having radius of curvature of 20 cm are placed with their convex surfaces in contact at the centre. The intervening space is filled with oil of refractive index 1.7. The focal length of the combination is **[2015]**

(1) –25 cm (2) –50 cm (3) 50 cm (4) –20 cm

9. The refracting angle of a prism is 'A', and refractive index of the material of the prism is cot(A/2). The angle of minimum deviation is : **[2015]**

(1) 180° – 2A (2) 90° – A (3) 180° + 2A (4) 180° – 3A

10. In an astronomical telescope in normal adjustment a straight black line of length L is drawn on inside part of objective lens. The eye-piece forms a real image of this line. The length of this image is *l*. The magnification of the telescope is : **[2015]**

(1) $\frac{L}{I}-1$ (2) $\frac{L+I}{L-I}$ (3) $\frac{L}{I}$ (4) $\frac{L}{I}+1$

11. The angle of a prism is 'A'. One of its refracting surfaces is silvered. Light rays falling at an angle of incidence 2A on the first surface returns back through the same path after suffering reflection at the silvered surface. The refractive index μ, of the prism is : **[2014]**

(1) 2 sin A (2) 2 cos A (3) $\frac{1}{2}$ cos A (4) tan A

12. If the focal length of objective lens is increased then magnifying power of : **[2014]**

(1) microscope will increase but that of telescope decrease.

(2) microscope and telescope both will increase.

(3) microscope and telescope both will decrease

(4) microscope will decrease but that of telescope increase

13. Which colour of the light has the longest wavelength? **[NEET – 2019]**

(1) red (2) blue (3) green (4) violet

14. Pick the wrong answer in the context with rainbow **[NEET – 2019]**

(1) When the light rays undergo two internal reflections in a water drop, a secondary rainbow is formed.

(2) The order of colours is reversed in the secondary rainbow.

(3) An observer can see a rainbow when his front is towards the sun.

(4) Rainbow is a combined effect of dispersion refraction and reflection sunlight.

15. Two similar thin equi-convex lenses, of focal length *f* each, are kept coaxially in contact with each other such that the focal length of the combination is F_1. When the space between the two lenses is filled with glycerine (which has the same refractive index (μ = 1.5) as that of glass) then the equivalent focal length is F_2. The ratio $F_1 : F_2$ will be : **[NEET – 2019]**

(1) 2 : 1 (2) 1 : 2 (3) 2 : 3 (4) 3 : 4

16. In total internal reflection when the angle of incidence is equal to the critical angle for the pair of media in contact, what will be angle of refraction? **[NEET– 2019]**

(1) 180° (2) 0°

(3) equal to angle of incidence (4) 90°

17. An equiconvex lens has power P. It is cut into two symmetrical halves by a plane containing the principal axis. The power of one part will be : **[NEET – 2019 (ODISSA)]**

(1) 0 (2) $\frac{P}{2}$ (3) $\frac{P}{4}$ (4) P

18. A double convex lens has focal length 25 cm. The radius of curvature of one of the surfaces is double of the other. Find the radii if the refractive index of the material of the lens is 1.5 : **[NEET – 2019 (ODISSA)]**

(1) 100 cm, 50 cm (2) 25 cm, 50 cm
(3) 18.75 cm, 37.5 cm (4) 50 cm, 100 cm

19. A plano-convex lens of unknown material and unknown focal length is given. With the help of a spherometer we can measure the **[NEET – 2020 (Covid-19)]**

(1) focal length of the lens
(2) radius of curvature of the curved surface
(3) aperture of the lens
(4) refractive index of the material

20. An object is placed on the principal axis of a concave mirror at a distance of 1.5 f (f is the focal length). The image will be at **[NEET – 2020 (Covid-19)]**

(1) .3 f (2) 1.5 f (3) .1.5 f (4) 3 f

21. If the critical angle for total internal reflection from a medium to vacuum is 45°, then velocity of light in the medium is, **[NEET – 2020 (Covid-19)]**

(1) 1.5×10^8 m/s (2) $\frac{3}{\sqrt{2}} \times 10^8$ (3) $\sqrt{2} \times 10^8$ m/s (4) 3×10^8 m/s

22. The power of a biconvex lens is 10 dioptre and the radius of curvature of each surface is 10 cm. Then the refractive index of the material of the lens is, **[NEET – 2020 (Covid-19)]**

(1) $\frac{4}{3}$ (2) $\frac{9}{8}$ (3) $\frac{5}{3}$ (4) $\frac{3}{2}$

23. A ray is incident at an angle of incidence i on one surface of a small angled prism (with angle of prism A) and emerges normally from the opposite surface. If the refractive index of the material of the prism is μ, then the angle of incidence is nearly equal to **[NEET – 2020]**

1) $\frac{\mu A}{2}$ 2) $\frac{A}{2\mu}$ 3) $\frac{2A}{\mu}$ 3) μA

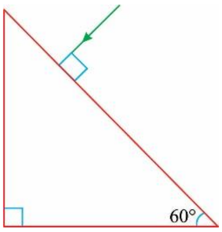
24. A lens of large focal length and large aperture is best suited as an objective of an astronomical telescope since **[NEET-2021]**

1) a large aperture contributes to the quality and visibility of the images
2) a large area of the objective ensures better light gathering power
3) a large aperture provides a better resolution
4) all of the above.

25. A convex lens 'A' of focal length 20 cm and a concave lens 'B' of focal length 5 cm are kept along the same axis with a distance 'd' between them. If a parallel beam of light falling on 'A' leaves 'B' as a parallel beam, then the distance 'd' in cm will be **[NEET-2021]**

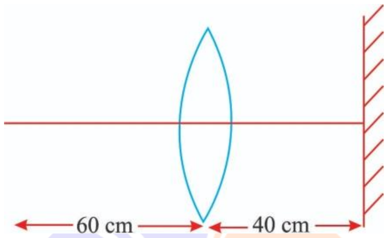
1) 15 2) 50 3) 30 4) 25

26. Find the value of angle of emergence from the prism. Refractive index of the glass is $\sqrt{3}$. **[NEET-2021]**



1)30° 2) 45° 3) 90° 4) 60°

27. A point object is placed at a distance of 60 cm from a convex lens of focal length 30 cm. If a plane mirror were put perpendicular to the principal axis of the lens and at a distance of 40 cm from it, the final image would be formed at a distance of **[NEET-2021]**



1) 30 cm from the lens, it would be a real image
2) 30 cm from the plane mirror, it would be a virtual image
3) 20 cm from the plane mirror, it would be a virtual image
4) 20 cm from the lens, it would be a real image

28. A biconvex lens has radii of curvature, 20 cm each. If the refractive index of the material of the lens is 1.5, the power of the lens is: **[NEET-2022]**

1) +2D 2) +20 D 3) +5D 4) Infinity

29. A light ray falls on a glass surface of refractive index $\sqrt{3}$, at an angle 60^0. The angle between the refracted and reflected rays would be: **[NEET-2022]**

1) 30^0 2) 60^0 3) 90^0 4) 120^0

30. Two transparent media A and B are separated by a plane boundary. The speed of light in those media are 1.5×10^8 m/s and 2.0×10^8 m/s, respectively. The critical angle for a ray of light for these two media is **[NEET-2022]**

1) $\sin^{-1}(0.500)$ 2) $\sin^{-1}(0.750)$ 3) $\tan^{-1}(0.500)$ 4) $\tan^{-1}(0.750)$

NCERT LINE BY LINE QUESTIONS – ANSWERS

1) d	2) b	3) d	4) d	5) d	6) d	7) a	8) c	9) c	10) d
11) b	12) d	13) b	14) b	15)c	16) a	17) b	18) a	19) b	20) a

NCERT BASED PRACTICE QUESTONS - ANSWERS

1) 2	2) 3	3) 4	4) 2	5) 2	6) 2	7) 2	8) 2	9) 2	10) 3
11) 2	12) 2	13) 2	14) 2	15) 3	16) 4	17) 2	18) 1	19) 1	20) 1
21) 2	22) 2	23) 4	24) 1	25) 1	26) 2	27) 3	28) 1	29) 1	30) 4
31) 2	32) 2	33) 4	34) 1	35) 4	36) 4	37) 4	38) 1	39) 1	40) 2

41) 4	**42)** 3	**43)** 3	**44)** 1	**45)** 2	**46)** 4	**47)** 4	**48)** 1	**49)** 1	**50)** 1
51) 4									

TOPIC WISE PRACTICE QUESTIONS - ANSWERS

1)	1	2)	4	3)	3	4)	3	5)	3	6)	2	7)	2	8)	1	9)	1	10)	2
11)	1	12)	3	13)	3	14)	4	15)	2	16)	1	17)	3	18)	1	19)	4	20)	1
21)	2	22)	4	23)	2	24)	4	25)	1	26)	2	27)	3	28)	2	29)	2	30)	4
31)	2	32)	2	33)	4	34)	4	35)	1	36)	3	37)	1	38)	1	39)	2	40)	2
41)	3	42)	1	43)	1	44)	2	45)	3	46)	2	47)	3	48)	2	49)	1	50)	4
51)	2	52)	1	53)	1	54)	4	55)	3	56)	2	57)	2	58)	3	59)	4	60)	4
61)	4	62)	3	63)	4	64)	1	65)	2	66)	2	67)	2	68)	3	69)	4	70)	3

NEET PREVIOUS YEARS QUESTIONS-ANSWERS

1)	2	2)	2	3)	4	4)	1	5)	4	6)	4	7)	2	8)	2	9)	1	10)	3
11)	2	12)	4	13)	1	14)	3	15)	2	16)	4	17)	4	18)	3	19)	2	20)	1
21)	2	22)	4	23)	4	24)	4	25)	1	26)	4	27)	4	28)	3	29)	3	30)	2

TOPIC WISE PRACTICE QUESTIONS - SOLUTIONS

1. **(1)** Due to covering the reflection from lower part is not there so it makes the image less bright.

2. **(4)** Convex mirror always forms, virtual, erect and smaller image.

3. **(3)** The minimum length of the mirror is half the length of the man. This can be proved from the fact that $\angle i = \angle r$.

4. **(3)** For M_1 : $V = -60$, $m_1 = -2$

For M_1 : $u = +20$, $F = 10$

$$\frac{1}{V} = \frac{1}{20} = \frac{1}{10} \Rightarrow V = 20$$

$$\therefore M_2 = -\frac{20}{20} = -1$$

$$\therefore M = m_1 \times m_2 = +2$$

5. **(3)** Because they form nearly point image of point source.

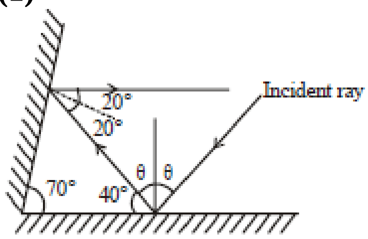
6. **(2)** When two plane mirrors are inclined at an angle θ, the number of image obtained is

$$n = \frac{360^0}{\theta} = \frac{360^0}{90^0} \Rightarrow n = 4\,(\text{even})$$

so $(n-1) = 3$ image will be formed.

7. **(2)** A plane mirror may form a real image when the rays incident on it are converging.

8. **(1)**



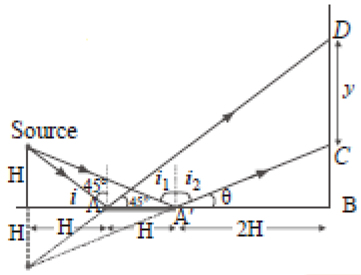
From fig. $40^0 + \theta = 90^0 \quad \therefore \theta = 90^0 - 40^0 = 50^0$

9. **(1)** In $\Delta ABD, \frac{BD}{3H} = \tan 45^0$ or $BD = 3H$

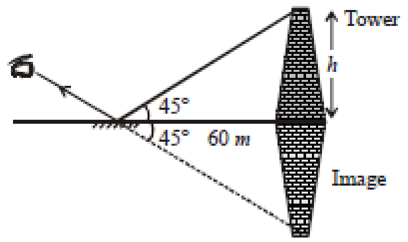
And in $\Delta A^{|}BC$

$\frac{BC}{2H} = \tan\theta = \frac{1}{2}$ or $BC = H$

Now, $y = BD - BC = 3H - H = 2H$



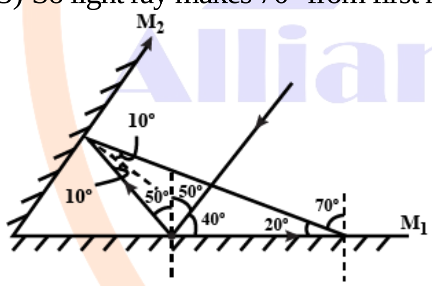
10. **(2)** $\tan 45^0 = \frac{h}{60} \Rightarrow h = 60m$



11. **(1)** Here, $u = f + x_1$, $v = f + x_2$

use $f = \frac{uv}{u+v}$ and solve to get $f = \sqrt{x_1 x_2}$

12. (3) So light ray makes 70° from first mirror.



13. (3) On second mirror ray of light retraces its path

$\Rightarrow$ ray of light falls normally on the second mirror

i.e., b=90

$a = 90 - r_1 = 60$

$\theta = 180 - (b+a) = 30^0$

14. **(4)** Using the mirror equation, $\frac{1}{f} = \frac{1}{u} + \frac{v}{f}$

For point A, $\frac{1}{v_A} = -1 + \frac{1}{3} = -\frac{2}{3}$

So, $v_A = -\frac{3}{2} = -1.5$

Similarly for point B,

$\frac{1}{v_B} = -1 + \frac{1}{5} = -\frac{4}{5}$

So, $v_A = -\frac{5}{4} = -1.25$

the distance between two points is then $1.5 - 1.25 = 0.25$ m

15. **(2)** Velocity of image in mirror

$\vec{v} = -10\hat{i} + 10\hat{j} \quad \vec{v}_{rel} = \vec{u} - \vec{v} = 20\hat{i}$

16. **(1)** From mirror formula

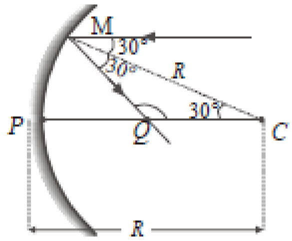
$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \text{ so, } \frac{dv}{dt} = -\frac{v^2}{u^2}\left(\frac{du}{dt}\right)$$

$$\Rightarrow \frac{dv}{dt} = -\left(\frac{f}{u-f}\right)^2 \frac{du}{dt} \Rightarrow \frac{dv}{dt} = \frac{1}{15} m/s$$

17. (3) Assume the mirror is at the origin and it is moving about the origin along x direction between x = -2 and x = +2 as its extreme positions.
Assume that the object is placed at co=ordinate of x = - (2+x)
So, when mirror is at position x = -2, the object's image will be formed at x co-ordinate X = - 2+x
And when the mirror is at position x = +2, the image is formed at X = 6+x
So, the net difference in the position of image between these 2 co-ordinates is (6 + x) - (-2 + x) = 8
So, the amplitude will be half of this distance. So the answer is 8/2 = 4 cm.

18. (1) The image of a point source in plane mirror will be a virtual point image, behind the mirror. So the reflected rays should meet at this point when produced backwards.

19. **(4)** From similar triangles,

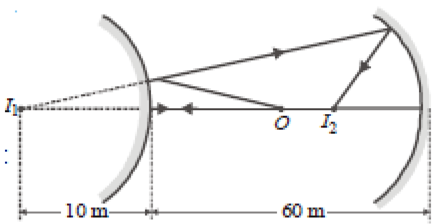


$$\frac{QC}{\sin 30^0} = \frac{R}{\sin 120^0}$$

$$\text{or } QC = R \times \frac{\sin 30^0}{\sin 120^0} = \frac{R}{\sqrt{3}}$$

$$\text{Thus } PQ = PC - QC = R - \frac{R}{\sqrt{3}} = R\left(1 - \frac{1}{\sqrt{3}}\right)$$

20. **(1)** For convex mirror :



$$\frac{1}{v} + \frac{1}{-30} = \frac{1}{+15}$$

or $v = 10\,cm$

For concave mirror:

$$\frac{1}{v} + \frac{1}{-70} = \frac{-1}{15} \text{ or } v = -19.90\,cm$$

21. **(2)** For critical angle θ_c, $\sin\theta_c = \frac{1}{\mu}$

For greater wavelength or lesser frequency μ is less.
So, critical angle would be more. So, they will not suffer reflection and come out at angles less then 90°.

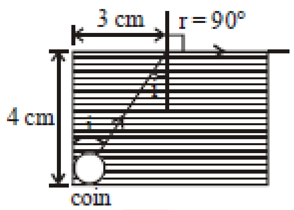
22. (4) Time taken by light to travel distance x through a medium of refractive index μ is

$$t=\frac{\mu x}{c}\Rightarrow\frac{\mu_B}{\mu_A}=\frac{x_A}{x_B}=\frac{6}{4}\Rightarrow\mu_B=\frac{3}{2}=1.5$$

23. **(2)** given ${}^a\mu_g=\frac{1}{2},{}^a\mu_w=\frac{1}{\sqrt{3}}$ $\quad\because {}^a\mu_w\times{}^w\mu_g={}^a\mu_g$

$$\therefore {}^w\mu_g=\frac{{}^a\mu_g}{{}^a\mu_w}=\frac{1/2}{1/\sqrt{3}}=\frac{\sqrt{3}}{2}$$

24. **(4)** Hypotenuse comes out to be 5 cm



$$\frac{1}{\mu}=\frac{\sin i}{\sin 90^0}\ ;\ \mu=\frac{1}{\sin i}=\frac{5}{3}$$

Speed, $v=\frac{c}{\mu}=\frac{3\times10^8}{5/3}=1.8\times10^8\,m/s$

25. **(1)** Given that ${}_w\mu_g=\frac{5}{4}$ and ${}_a\mu_w=\frac{4}{3}$

$$\therefore {}_a\mu_g={}_w\mu_g\times{}_a\mu_w=\frac{5}{4}\times\frac{4}{3}=\frac{5}{3}$$

26. **(2)** Shift $=(\ell-m)\left(1-\frac{1}{n_1}\right)+m\left(1-\frac{1}{n_2}\right)=0$

27. **(3)** Here i = 60°. As the angle between reflected and refracted ray is 90°, then i + r = 90 or r = 30°

Now $\mu=\frac{\sin i}{\sin r}=\frac{\sin 60^0}{\sin 30^0}=\frac{\sqrt{3}/2}{1/2}=\sqrt{3}=1.732$

The angle for which i + r = 90°, called Brewster' Angle.

28. **(2)** According to Snell's Law, $\frac{\sin i}{\sin r}=\frac{\mu_2}{\mu_1}$

where r = 90° for particular incidence angle called critical angle. When the incidence angle is equal to or greater than i_c, then total internal reflection occurs. It takes place when ray of light travels from optically denser medium $(\mu_1>\mu_2)$ to optically rarer medium.

29. **(2)** We know that frequency of electromagnetic radiation remains the same when it changes the medium.

Further, $\mu=\frac{\text{velocity of light in vacuum}}{\text{velocity of light in medium}}=\frac{\lambda_v}{\lambda_m}$

$$\lambda_m=\frac{\lambda_v}{\mu}=\frac{\lambda}{\mu}$$

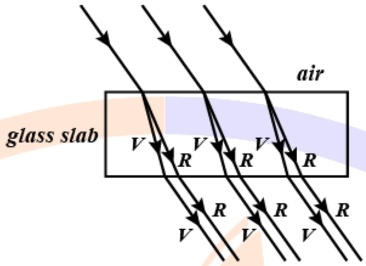
Similarly, $\mu=\frac{\text{velocity of light in vacuum}}{\text{velocity of light in medium}}$

30. **(4)** $\sin C=\frac{1}{\mu}=\frac{1}{\sqrt{2}}$ $\qquad\therefore C=\sin^{-1}\left(\frac{1}{\sqrt{2}}\right)=45^0$

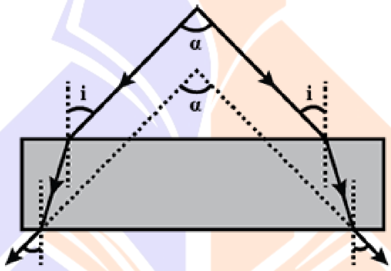
Now, $\frac{\sin C}{\sin r}=\frac{1}{\mu}$ or $\frac{\sin 45^0}{\sin r}=\frac{1}{\sqrt{2}}$

$\sin r=1$ or $r=90^0$

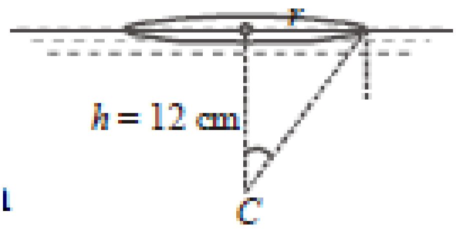
31. (2) Refraction of light of different wavelength is shown in the figure. The light inside slab clearly splits up into different colors. The emergent ray from a single white ray is a beam of different colors, parallel to the incident ray. However the emergent beam is white, because the white rays adjacent to the incident white ray above also split into different colors that add up to these wavelengths to produce a white beam of light parallel to the incident white beam.



32. (2) Since rays after passing through the glass slab just suffer lateral displacement hence we have angle between the emergent rays as α.



33. **(4)** $\sin C = \frac{1}{\mu} = \frac{1}{4/3} = \frac{3}{4}$

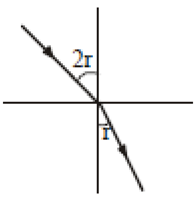


Now, $r = h \tan C = 12 \times \frac{3}{\sqrt{7}} = \frac{36}{\sqrt{7}}$ cm

34. (4) The emergent ray CD can become parallel to incident ray AB after traveling through different media, only when both of them travel in same medium of same refractive index.

$\therefore \mu_4 = \mu_1$

35. **(1)** $\mu = \frac{\sin i}{\sin r} \quad \because i = 2r$



$\Rightarrow \mu = \frac{\sin 2r}{\sin r} = \frac{2\sin r.\cos r}{\sin r}$

$r = \cos^{-1}\left(\frac{\mu}{2}\right), \quad \therefore i = 2\cos^{-1}\left(\frac{\mu}{2}\right)$

36. **(3)** $\{\mu\lambda\}_{vacuum} = \{\mu\lambda\}_{medium}$

$\Rightarrow \frac{\lambda_i}{\lambda_r} = \frac{\mu}{1}$

$\therefore$ Ratio is $\mu : 1$

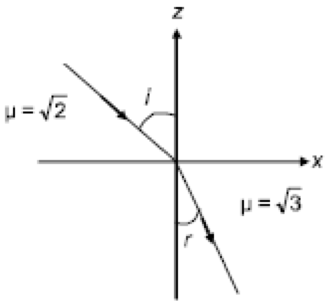
37. **(1)** Angle of incidence is given by

$$\cos(\pi - i) = \frac{\left(6\sqrt{3}\hat{i} + 8\sqrt{3}\hat{j} - 10\hat{k}\right)\hat{k}}{20}$$

$$-\cos i = -\frac{1}{2}; \ \angle i = 60^0$$

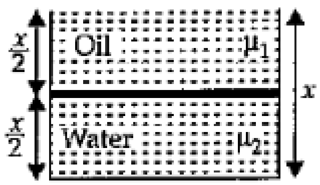
From Snell's law,

$$\sqrt{2}\sin i = \sqrt{3}\sin r \ ; \ \angle r = 45^0$$



38. (1) As refractive index, $\mu = \frac{\text{Real depth}}{\text{Apparent depth}}$

$\therefore$ Apparent depth of the vessel when viewed from above is



$$d_{apparent} = \frac{x}{2\mu_1} + \frac{x}{2\mu_2}$$

$$= \frac{x}{2}\left(\frac{1}{\mu_1} + \frac{1}{\mu_2}\right)$$

$$= \frac{x}{2}\left(\frac{\mu_2 + \mu_1}{\mu_1\mu_2}\right) = \frac{x(\mu_1 + \mu_2)}{2\mu_1\mu_2}$$

39. **(2)** $v = \frac{C}{\mu} = \frac{3\times10^{10}}{2} = 1.5\times10^{10}\,m/s$

40. **(2)** $\frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ As $\frac{\mu_2}{\mu_1} < 1$

$\therefore$ f is negative. It acts as divergent lens.

41. (3) A lens made of three different materials as shown have only one focal length. Thus , for a given object there is only one image.

42. **(1)** Given that,

the refractive index of the lens wr..t air, ${}_a\mu_g = 1.60$

and the refractive index of water w.r.t air

${}_a\mu_w = 1.33$

the focal length of the lens in air, *f*=20*cm*.

We know that for a lens

$$\frac{1}{f}=(\mu-1)\frac{1}{R_1}-\frac{1}{R_2}$$

When the lens is in the air

$$\frac{1}{20}=\left({}_a\mu_g-1\right)\frac{1}{R_1}-\frac{1}{R_2}$$

or $\frac{1}{20}=(1.60-1)\frac{1}{R_1}-\frac{1}{R_2}$

or $\frac{1}{20}=0.60\times\frac{1}{R_1}-\frac{1}{R_2}$ -----(i)

When the lens is in the water

$$\frac{1}{f^|}=\left({}_w\mu_g-1\right)\frac{1}{R_1}-\frac{1}{R_2}$$

or $\frac{1}{f^|}=\frac{{}_a\mu_g}{{}_a\mu_w}-1\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

or $\frac{1}{f^|}=\frac{{}_a\mu_g-{}_a\mu_w}{{}_a\mu_w}\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

$\therefore \frac{1}{f^|}=\frac{1.60-1.33}{1.33}\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

$\frac{1}{f^|}=\frac{27}{133}\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ ...(*ii*)

On dividing Eq. (*i*) by Eq. (*ii*), we get

$$\frac{f^|}{20}=\frac{0.60\times133}{27}$$

or $f^|=20\times2.95\,\text{cm}\approx60\,\text{cm}$

Hence, its focal length is three times longer than in air

43. **(1)** $\frac{|P_1|}{|P_2|}=\frac{2}{3}\Rightarrow\frac{f_2}{f_1}=\frac{2}{3}$ --------(i)

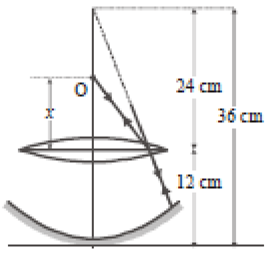
Focal length of their combination

$\frac{1}{f}=\frac{1}{f_1}-\frac{1}{f_2}\Rightarrow\frac{1}{30}=\frac{1}{f_1}-\frac{1\times3}{2f_1}$ from (i)

$\Rightarrow\frac{1}{30}=\frac{1}{f_1}\left[1-\frac{3}{2}\right]=\frac{1}{f_1}\times\left(-\frac{1}{2}\right)$

$\therefore f_1=-15\text{cm}\quad \therefore f_2=\frac{2}{3}\times f_1=\frac{2}{3}\times15=10\text{cm}$

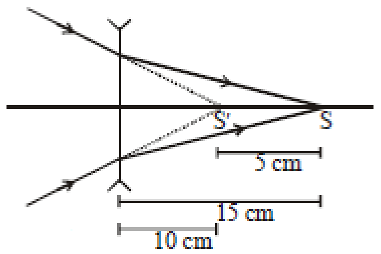
44. **(2)** u = 24 cm, $v = x$



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

or $\frac{1}{x}-\frac{1}{24}=\frac{1}{40}$; $\therefore x=15\text{cm}$

45. **(3)** By lens formula,



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

u = 10 cm, v = 15 cm, f = ?

Putting the values, we get

$\frac{1}{15}-\frac{1}{10}=\frac{1}{f}$

$\frac{10-15}{150}=\frac{1}{f}$

$\therefore f=-\frac{150}{3}=-30\,\text{cm}$

46. **(2)** Using the lens formula $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$

Given $v = d$, for equal size image $v = u = d$

By sign convention $u = -d$

$\therefore \frac{1}{f}=\frac{1}{d}+\frac{1}{d}$ or $f=\frac{d}{2}$

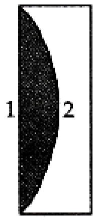
47. **(3)** If f_e be the focal length of the lens, then

$\frac{1}{f_e}=\frac{2}{15}+\frac{1}{\infty}\Rightarrow f_e=7.5\text{cm}$

Now using mirror formula, we have

$\frac{1}{v}+\frac{1}{-20}=\frac{1}{-7.5}\Rightarrow v=-12\text{cm}$

48. **(2)** The combination of two lenses 1 and 2 is as shown in figure.



$\therefore \frac{\ }{f}=\frac{1}{f_1}+\frac{1}{f_2}$

According to lens maker's formula

$\frac{1}{f_1}=(\mu_1-1)\left(\frac{1}{\infty}-\frac{1}{-R}\right)=\frac{(\mu_1-1)}{R}$

$$\frac{1}{f_2} = (\mu_2 - 1)\left(\frac{1}{-R} - \frac{1}{\infty}\right)$$

$$= (\mu_2 - 1)\left(-\frac{1}{R}\right) = -\frac{(\mu_2 - 1)}{R}$$

$$\therefore \frac{1}{f} = \frac{(\mu_1 - 1)}{R} - \frac{(\mu_2 - 1)}{R}$$

$$\frac{1}{f} = \frac{(\mu_1 - \mu_2)}{R};\ f = \frac{R}{(\mu_1 - \mu_2)}$$

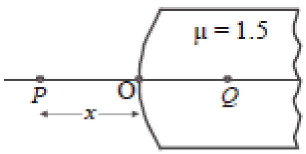
49. **(1)** Considering refraction at the curved surface,
$u = -20$, $\mu_2 = 1$
$\mu_1 = 3/2$, $R = +20$
Applying $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R} \Rightarrow \frac{1}{v} - \frac{3/2}{-20} = \frac{1 - 3/2}{20} \Rightarrow v = -10$
i.e., 10 cm below the curved surface or 10 cm above the actual position of flower

50. **(4)** $\frac{1}{f} = (\mu_w - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \left(\frac{4}{3} - 1\right)\left(\frac{1}{-20} - \frac{1}{\infty}\right)$
$\therefore f = -60\,\text{cm}$

51. (2) focal length of each part is 2f
effective focal length be F
$\frac{1}{F} = \frac{1}{2f} + \frac{1}{2f} + \frac{1}{2f} + \frac{1}{2f} = \frac{2}{f}$
F=2f

52. **(1)** Using, $\frac{\mu}{v} - \frac{1}{u} = \frac{\mu - 1}{R}$ or $\frac{1.5}{v} - \frac{1}{-15} = \frac{1.5 - 1}{+30}$
$\therefore v = -30\,\text{cm}$

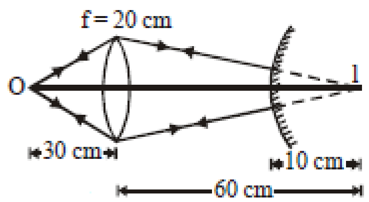
53. **(1)** Using, $\frac{\mu}{v} - \frac{1}{u} = \frac{\mu - 1}{R}$



or $\frac{1.5}{x} - \frac{1}{-x} = \frac{(1.5 - 1)}{R}$; $\therefore x = 5R$

54. **(4)** The parallel beam of light converges at the focus on the other side and then diverges. Hence till the person moves to the focus the intensity will increase. Beyond the focus, it will decrease

55. **(3)** For the lens,
$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$



$\frac{1}{v} - \frac{1}{-30} = \frac{1}{20} \Rightarrow v = 60\,\text{cm}$

Coincidence is possible when the image is formed at the centre of curvature of the mirror. Only then the rays refracting through the lens will fall normally on the convex mirror and retrace their path to form the image at O. So, the distance between lens and mirror = 60 – 10 = 50 cm.

56. **(2)** Dispersive power of a prism $\omega = \frac{\mu_V + \mu_R}{\mu_y - 1} = \frac{d\mu}{\mu - 1}$

where $\mu = \mu_y = \frac{\mu_V + \mu_R}{2}$

57. (2) Given: A prism of refractive index $\sqrt{2}$ has refracting angle 60^0.

To find the angle of incidence in order that a ray suffers minimum deviation

Solution:

As per the given criteria,

refractive index of the prism, $\mu = \sqrt{2}$

Angle of the prism, $A = 60^0$

For minimum angle of deviation we have angle of incidence is equal to angle of emergence, i.e., i=e

Hence, $i = \frac{A + \delta_m}{2}$, where δ_m is the minimum deviation angle.

We know,

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}} \Rightarrow \sqrt{2} = \frac{\sin i}{\sin\frac{60}{2}}$$

$$\Rightarrow \sin i = \sqrt{2} \times \sin(30)$$

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

Multiply and divide by $\sqrt{2}$, we get

$$\sin i = \frac{1}{\sqrt{2}} \Rightarrow i = 45^0$$

58. **(3)** As refracted ray emerges normally from opposite surface, $r_2 = 0$

As $A = r_1 + r_2 \quad \therefore r_1 = A$

Now, $\mu = \frac{\sin i_1}{\sin r_1} = \frac{i_1}{r_1} = \frac{i}{A}; \ i = \mu A$

59. **(4)** Dispersion will not occur for a light of single wavelength $\lambda = 4000$ Å

60. **(4)** $\frac{\sin 60^0}{\sin 90^0} = \frac{1}{\mu} \Rightarrow \mu = \frac{2}{\sqrt{3}}$

61. **(4)** The deviation produced as light passes through a thin prism of angle A and refractive index μ is $\delta = A(\mu - 1)$.We want deviation produced by both prism to be zero.

$$\delta = \delta' \Rightarrow A(\mu - 1) = A'(\mu' - 1) \Rightarrow A' = \frac{4 \times (1.54 - 1)}{(1.72 - 1)}$$

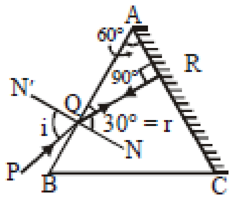
$$= 4 \times 0.75 = 3^0$$

62. **(3)** It is clear from the figure that the ray will retrace the path when the refracted ray QR is incident normally on the polished surface *AC*. Thus, angle of refraction $r = 60°$

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

$\therefore \sin i = \mu \times \sin r = \sqrt{2} \times \sin 60^0$

$= \sqrt{2} \times \frac{\sqrt{3}}{2}$ or $i = \sin^{-1}\sqrt{\frac{3}{2}}$



63. (4) Let δ_m be the angle of minimum deviation $A=\delta_m$

$A = \delta_m$

$$\mu = \frac{\sin\frac{(A+\delta_m)}{2}}{\sin\left(\frac{A}{2}\right)}$$

$$1.5 = \frac{\sin\left(\frac{A+A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$$1.5 = \frac{\sin\left(\frac{A}{2}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{2\sin\frac{A}{2}\cos\frac{A}{2}}{\sin\left(\frac{A}{2}\right)}$$

$$1.5 = 2\cos\frac{A}{2} \Rightarrow 0.75 = \cos\frac{A}{2}$$

$$\frac{A}{2} = \cos^{-1}(0.75) \Rightarrow \frac{A}{2} = 41^0 \Rightarrow A = 82^0$$

64. **(1)** In a prism: $r + r' = A \Rightarrow r = A - r'$

$\therefore r = 60^0 - (10 + t^2) = 50 - t^2$

65. **(2)** $A = 90^0 - \theta \Rightarrow r_2 = A = 90^0 - \theta > \theta$

$\cos\theta > \sin\theta_c = \frac{6/5}{2/3} = \frac{4}{5}$

(θ_c is critical angle)

$\theta < \cos^{-1}\frac{4}{5} = 37^0$

66. **(2)** The image formed by objective lens of compound microscope is real and enlarged, while final image formed by compound microscope is inverted, virtual, enlarged and at a distance D to infinite or from an eye, on same side of eye piece.

67. **(2)** The aperture of objective lens of Astronomical telescope is large to get better resolution. Since resolution of telescope power is $R = \frac{D}{1.22\lambda}$, where D is the diameter of the objective lens of Telescope.

68. **(3)** Resolving power of microscope,

$$R.P. = \frac{2n\sin\theta}{\lambda}$$

$\lambda =$ Wavelength of light used to illuminate the object

n = Refractive index of the medium between object and objective

$\theta =$ Angle

69. **(4)** Given : $f_0 = 50$ cm, $f_e = 5$cm, d = 25 cm, $u_0 = -200$ cm

Magnification M =?

As $\frac{1}{v_0}-\frac{1}{u_0}=\frac{1}{f_0}$

$$\Rightarrow \frac{1}{v_0}=\frac{1}{f_0}+\frac{1}{u_0}=\frac{1}{50}-\frac{1}{200}=\frac{4-1}{200}=\frac{3}{200} \text{ or } v_0=\frac{200}{3}\text{cm}$$

Now $v_e=d=-25\,\text{cm}$

From, $\frac{1}{v_e}-\frac{1}{u_e}=\frac{1}{f_e}$

$$-\frac{1}{u_e}=\frac{1}{f_e}-\frac{1}{v_e}=\frac{1}{5}+\frac{1}{25}=\frac{6}{25} \text{ or, } v_e=\frac{-25}{6}\text{cm}$$

Magnification $M=M_0\times M_e$

$$=\frac{v_0}{u_0}\times\frac{v_e}{u_e}=\frac{-200/3}{200}\times\frac{-25}{-25/6}=-\frac{1}{3}\times 6=-2$$

70. **(3)** Magnifying power of telescope,

$$MP=\frac{\beta(\text{angle subtended by image at eye piece})}{\alpha(\text{angle subtended by object on piece})}$$

Also, $MP=\frac{f_0}{f_e}=\frac{150}{5}=30$

$$\alpha=\frac{50}{1000}=\frac{1}{20}\text{rad}$$

$$\therefore \beta=\theta=MP\times\alpha=30\times\frac{1}{20}=\frac{3}{2}=1.5\,\text{rad}$$

NEET PREVIOUS YEARS QUESTIONS-EXPLANATIONS

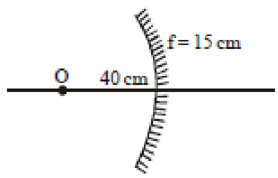
1. **(2)** using mirror formula, $\frac{1}{f}=\frac{1}{v_1}+\frac{1}{u}$

$$-\frac{1}{15}=\frac{1}{v_1}+\frac{1}{u}\Rightarrow\frac{1}{v_1}=\frac{1}{-15}+\frac{1}{40}$$

$\therefore v_1=-24\text{cm}$

When object is displaced by 20 cm towards mirror

Now, $u_2=-20$



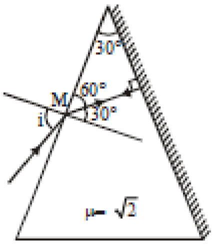
So, $\frac{1}{f}=\frac{1}{v_2}+\frac{1}{u_2}$

$$\frac{1}{-15}=\frac{1}{v_2}-\frac{1}{20}\Rightarrow\frac{1}{v_2}=\frac{1}{20}-\frac{1}{15}$$

$\therefore v_2=-60\text{cm}$

Therefore image shifts away from mirror by = 60 – 24 = 36 cm

2. **(2)** For retracing the path, light ray should be normally incident on silvered face.
$A = r + O \Rightarrow r = 30°$



Applying Snell's law at point M,

$$\frac{\sin i}{\sin 30^0} = \frac{\sqrt{2}}{1} \Rightarrow \sin i = \sqrt{2} \times \frac{1}{2}$$

or $\sin i = \frac{1}{\sqrt{2}}$ i.e., $i = 45^0$

3. **(4)** For telescope, angular magnification $= \frac{f_0}{f_E}$

So, focal length of objective lens should be large.

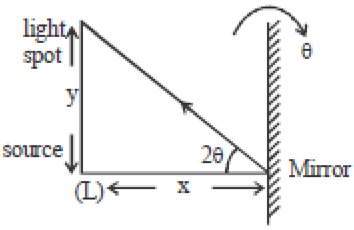
Angular resolution $= \frac{D}{1.22\lambda}$. So, D should be large.

So, objective lens of refracting telescope should have large focal length (f_0) and large diameter D for larger angular magnification.

4. **(1)** For dispersion without deviation
$(\mu - 1)A1 + (\mu' - 1)A_2 = 0$
$(\mu - 1)A1 = (\mu' - 1)A_2$
$(1.42 – 1) \times 10° = (1.7 – 1)A_2$
$4.2 = 0.7A_2 \Rightarrow A_2 = 6°$

5. **(4)** When mirror is rotated by angle q reflected ray will be rotated by 2θ.

$$\frac{y}{x} = 2\theta \Rightarrow \theta = \frac{y}{2x}$$



6. **(4) Given:** Focal length of objective, $f_0 = 40$cm
Focal length of eye – piece $f_e = 4$ cm
image distance, $v_0 = 200$ cm
Using lens formula for objective lens

$$\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0} \Rightarrow \frac{1}{v_0} = \frac{1}{f_0} + \frac{1}{u_0}$$

$$\Rightarrow \frac{1}{v_0} = \frac{1}{40} + \frac{1}{-200} = \frac{+5-1}{200} \Rightarrow v_0 = 50\,\text{cm}$$

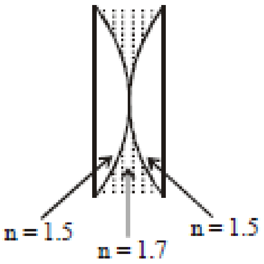
Tube length $\ell = |v_0| + f_e = 50 + 4 = 54$cm

7. **(2)** $i = 45°; A = 60°$;
Angle of minimum deviation, $\delta_m = 2i – A = 30°$
Refractive index of material of prism

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin A/2} = \frac{\sin 45^0}{\sin 30^0} = \frac{1}{\sqrt{2}} = \frac{2}{1} = \sqrt{2}$$

8. **(2)** Using lens maker's formula,

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



$$\frac{1}{f_1} = \left(\frac{1.5}{1} - 1\right)\left(\frac{1}{\infty} - \frac{1}{-20}\right)$$

$$\Rightarrow f_1 = 40\text{cm}$$

$$\frac{1}{f_2} = \left(\frac{1.7}{1} - 1\right)\left(\frac{1}{-20} - \frac{1}{+20}\right) \Rightarrow f_2 = -\frac{100}{7}\text{ cm}$$

and $\frac{1}{f_3} = \left(\frac{1.5}{1} - 1\right)\left(\frac{1}{\infty} - \frac{1}{-20}\right) \Rightarrow f_3 = 40\text{ cm}$

$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} \Rightarrow \frac{1}{f_{eq}} = \frac{1}{40} + \frac{1}{-100/7} + \frac{1}{40}$$

$$\therefore f_{eq} = -50\text{cm}$$

Therefore, the focal length of the combination is – 50 cm.

9. **(1)** As we know, the refractive index of the material of the Prism

$$\mu = \frac{\sin\left(\frac{\delta_m + A}{2}\right)}{\sin(A/2)}$$

$$\cot A/2 = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin A/2} = \frac{\cos(A/2)}{\sin(A/2)} \quad [\because \mu = \cot(A/2)]$$

$$\Rightarrow \sin\left(\frac{\delta_m + A}{2}\right) = \sin(90^0 + A/2)\delta_{min} = 180^0 - 2A$$

10. **(3)**

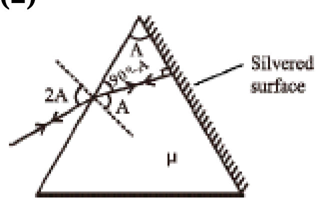
Magnification by eye piece

$$m = \frac{f}{f+u}$$

$$-\frac{1}{L} = \frac{f_e}{f_e + [-(f_0 + f_e)]} = -\frac{f_e}{f_0} \text{ or } \frac{1}{L} = \frac{f_e}{f_0}$$

Magnification, $M = \frac{f_0}{f_e} = \frac{L}{1}$

11. **(2)**



According to Snell's law $\mu = \frac{\sin i}{\sin r}$

$$\Rightarrow (1)\sin 2A = (\mu)\sin A \Rightarrow \mu = 2\cos A$$

12. **(4)** Magnifying power of microscope $=\frac{LD}{f_0 f_e}\propto\frac{1}{f_0}$

Hence with increase f_0 magnifying power of microscope decreases

Magnifying power of telescope $=\frac{f_0}{f_e}\propto f_0$

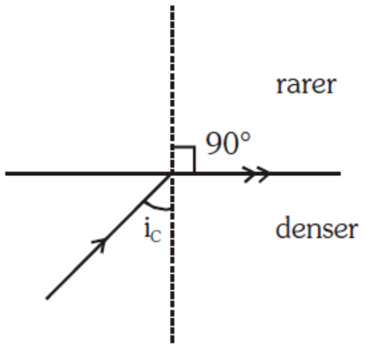
Hence with increase f_0 magnifying power of telescope increases

13. Longest wavelength is of red colour

14. An observer can see a rainbow when his back is towards the Sun

15. $\frac{1}{F_1}=\frac{1}{f}+\frac{1}{f}\Rightarrow F_1=f/2$ and $F_2=f\Rightarrow\frac{F_1}{F_2}=\frac{1}{2}$

16. At critical angle



angle of refraction = 90°

17. Focal length do not change → Power do not change

18. For the double convex lens

$f=25cm$, $R_1=R$ and $R_2=-2R$ (sign convention)

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

$$\Rightarrow\frac{1}{25}=(15-1)\left(\frac{1}{R}-\frac{1}{-2R}\right)=0.5\left(\frac{3R}{2}\right)$$

$$\Rightarrow\frac{1}{25}=\frac{3}{4}\frac{1}{R}\Rightarrow R=18.75cm$$

$$R_1=18.75m,\ R_2=2R=37.5\text{ cm}$$

19. Sphere meter is used to measure radius of curvature of the curved surface.

20. By using mirror formula $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$

We have $\frac{1}{-1.5f}+\frac{1}{v}=\frac{1}{-f}\Rightarrow\frac{1}{v}=-\frac{1}{f}+\frac{1}{1.5f}$

$$\Rightarrow\frac{1}{v}=\frac{-1.5+1}{1.5f}=\frac{-0.5}{1.5f}\Rightarrow v=-3f$$

21. $\sin\theta_C=\frac{1}{\mu}$

$$\mu=\frac{1}{\sin\theta_C}=\frac{1}{\sin 45^0}=\frac{1}{\left(1/\sqrt{2}\right)}=\sqrt{2}$$

$$\mu=\frac{c}{v}\Rightarrow v=\frac{c}{\mu}=\frac{3\times10^8}{\sqrt{2}}m/s$$

22. $P=\frac{100}{f}\Rightarrow f=\frac{100}{p}=\frac{100}{10}=10cm$

$$f = \frac{R}{2(\mu - 1)} \text{ (for equi-convex lens)}$$

$$\Rightarrow 10 = \frac{10}{2(\mu - 1)}$$

$$\Rightarrow (\mu - 1) = \frac{1}{2} \Rightarrow \mu = \frac{1}{2} + 1 = \frac{3}{2}$$

23. Normal emergence

$i_2 = r_2 = 0$

$\therefore A = r_1 + r_2 = r_1$

For small angle

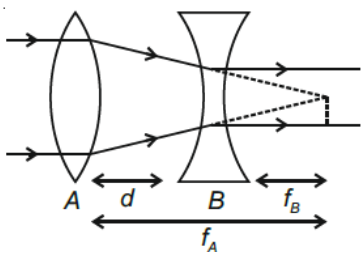
$$\mu = \frac{\sin i_1}{\sin r_1} = \frac{i_1}{r_1}$$

$$i_1 = \mu A$$

24. $MP = \frac{f_0}{f_e}$; $R.P. = \frac{a}{1.22\lambda}$

Large aperture(1) of the objective lens provides better resolution $\therefore$ Good quality of image is formed and also it gathers more light.

25.



$d = f_A - f_B = 20 - 5 = 15$ cm

26.

$i_1 = 0$

$r_1 = 0$

$\mu = \sqrt{3}$

$r_2 = 30^0$

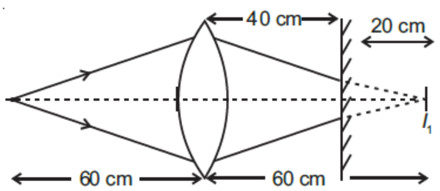
Snell's law $1 \times \sin i_2 = \sqrt{3} \times \sin 30^0$; $\sin i_2 = \frac{\sqrt{3}}{2} = i_2 = 60^0$

27. Using lens formula for first refraction from convex lens

$$\frac{1}{v_1} - \frac{1}{u} = \frac{1}{f}$$

$v_1 = ?$, $u = -60$ cm, $f = 30$ cm

$$\Rightarrow \frac{1}{v_1} + \frac{1}{60} = \frac{1}{30} \Rightarrow v_1 = 60 \text{ cm}$$



I_1 here is first image by lens

The plane mirror will produce an image at distance 20 cm to left of it.

For second refraction from convex lens, u = –20 cm, v = ? , f = 30 cm

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}\Rightarrow\frac{1}{v}+\frac{1}{20}=\frac{1}{30}$$

$$\Rightarrow\frac{1}{v}=\frac{1}{30}-\frac{1}{20}\Rightarrow v=-60\text{ cm}$$

Thus the final image is virtual and at a distance,
60 – 40 = 20 cm from plane mirror.

28. $P=(\mu-1)\frac{2}{R}$

$$=(1.5-1)\times\frac{2}{2\times10^{-2}}=5D$$

29. Here $\mu=\tan i$

$\therefore$ Reflected and refracted rays are perpendicular

$\theta=90^0$

30. Let 'θ_c' be critical angle ; C_r = speed of light in rarer medium ; C_d = speed of light in denser medium

$$\frac{1}{\sin\theta_c}=\frac{C_r}{C_d}\Rightarrow\frac{1}{\sin\theta_c}=\frac{2\times10^8}{1.5\times10^8}$$

$$\sin\theta_c=\frac{3}{4}\Rightarrow\theta_c=\sin^{-1}\left(\frac{3}{4}\right)$$