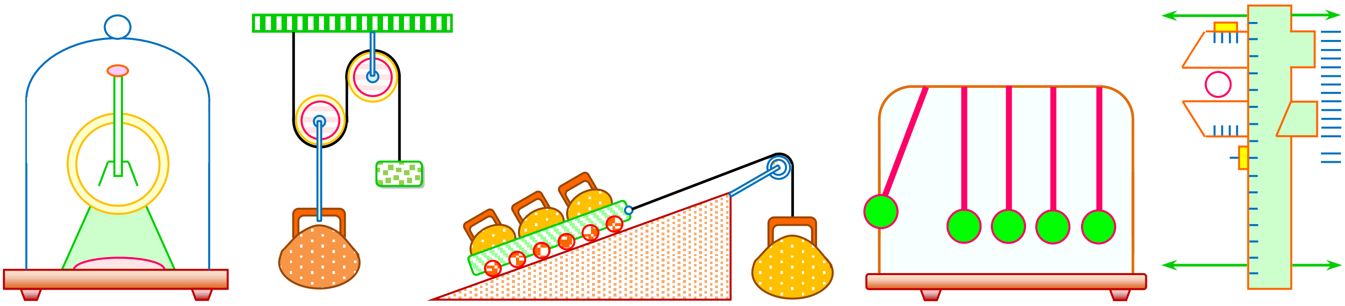
INDIA'S FIRST COLOUR SMART BOOK

PHYSICS XII

OPTICS

Key Features

- All-in-one Study Material (for Boards/IIT/Medical/Olympiads)
- Multiple Choice Solved Questions for Boards and Entrance Examinations
- Concise, Conceptual & Trick-based Theory
- Magic Trick Cards for Quick Revision and Understanding
- NCERT & Advanced Level Solved Examples



PHYSICS BOOKLET FOR JEE NEET & BOARDS

India's First Colour Smart Book

OPTICS

1 RAY OPTICS

Ray optics treats propagation of light in terms of rays and is valid only if the size of the obstacle is much greater than the wavelength of light. It concerns with the image formation and deals with the study of the simple facts such as rectilinear propagation, laws of reflection and refraction by geometrical methods.

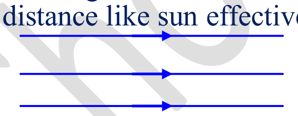
1.1 RAY

A ray can be defined as an imaginary line drawn in the direction in which light is travelling. Light behaves as a stream of energy propagated along the direction of rays. The rays are directed outward from the source of light in straight lines.

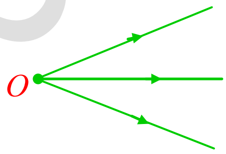
1.2 BEAM OF LIGHT

A beam of light is a collection of these rays. There are mainly three types of beams.

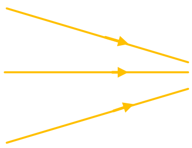
(i) Parallel beam of light: A search light and the headlight of a vehicle emit a parallel beam of light. The source of light at a very large distance like sun effectively gives a parallel beam.



(ii) Divergent beam of light: The rays going out from a point source generally form a divergent beam.



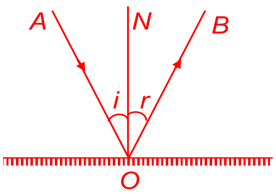
(iii) Convergent beam of light: A beam of light that is going to meet (or converge) at a point is known as a convergent beam. A parallel beam of light after passing through a convex lens becomes a convergent beam.



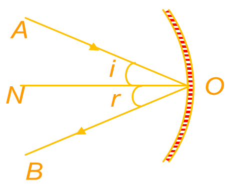
2 REFLECTION

When a ray of light is incident at a point on the surface, the surface throws partly or wholly the incident energy back into the medium of incidence. This phenomenon is called reflection.

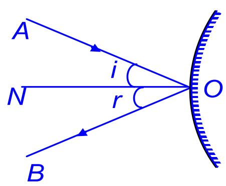
Surfaces that cause reflection are known as mirrors or reflectors. Mirrors can be plane or curved.



Plane mirror



Concave mirror



Convex mirror

In the above figures,

O is the point of incidence

AO is the incident ray

OB is the reflected ray

ON is the normal at the incidence

Angle of incidence: The angle which the incident ray makes with the normal at the point of incidence is called the angle of incidence. It is generally denoted by 'i'.

Angle of reflection: The angle which the reflected ray makes with the normal at the point of incidence is called the angle of reflection. It is generally denoted by 'r'.

Glancing angle: The angle which the incident ray makes with the plane reflecting surface is called glancing angle. It is generally denoted by 'g'.

$g = 90° - i$ … (1)

2.1 LAWS OF REFLECTION

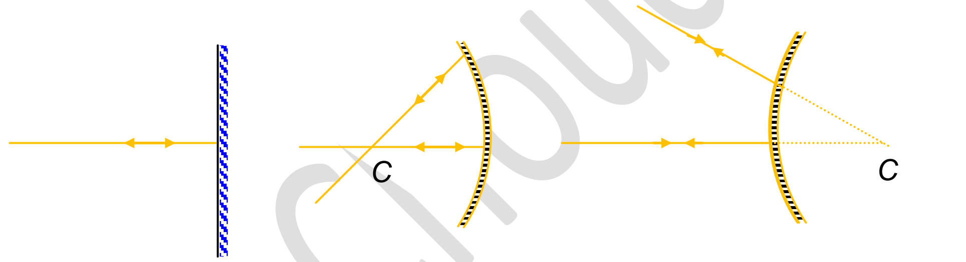
(i) The incident ray, the reflected ray and the normal to the reflecting surface at the point of incidence, all lie in the same plane.

(ii) The angle of incidence is equal to the angle of reflection, i.e., $\angle i = \angle r$

These laws hold good for all reflecting surfaces either plane or curved.

Some important points

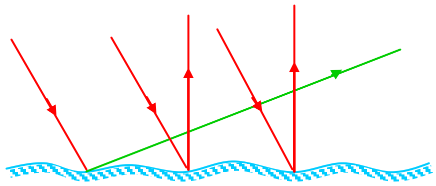
(i) If $\angle i = 0$, $\angle r = 0$, i.e., if a ray is incident normally on a boundary, after reflection it retraces its path.



Plane mirror | Concave mirror | Convex mirror

(ii) None of frequency, wavelength and speed changes due to reflection. However, intensity and hence amplitude ($I \propto A^2$) usually decreases.

(iii) If the surface is irregular, the reflected rays of an incident beam of parallel light rays will be in random directions. Such an irregular reflection is called diffused reflection.

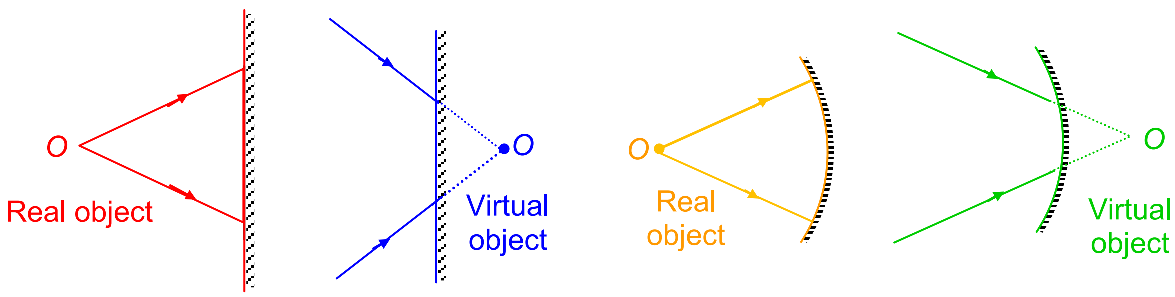


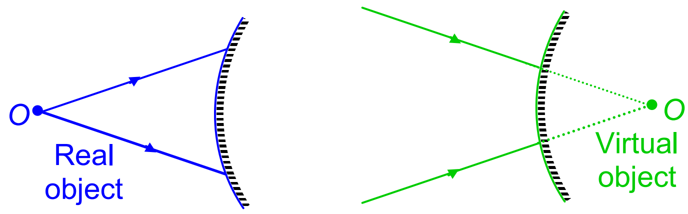
Diffused reflection

2.2 REAL AND VIRTUAL OBJECTS

If the rays from a point on an object actually diverge from it, then the object is said to be real.

If the rays incident on the mirror do not start from a point but appear to converge at a point, then that point is the virtual object for the mirror.



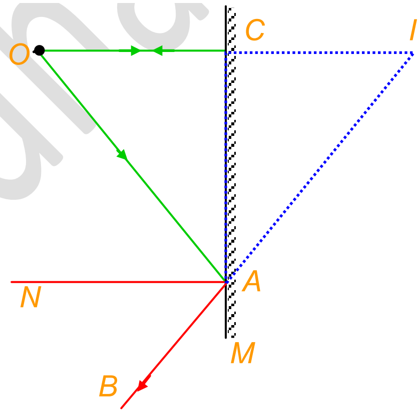


2.3 REAL AND VIRTUAL IMAGES

If the rays from a point object after reflection (or refraction) actually meet at or appear to diverge from a point *I*, then *I* is said to be the image of the object *O*.

Images can be real or virtual. If the reflected or refracted rays actually meet at the point *I*, then *I* is said to be a real image of the object *O*. But if the reflected or a refracted ray do not actually meet but only appear to diverge from the point *I*, then *I* is said to be the virtual image of the object *O*.

3 IMAGE FORMATION BY A PLANE MIRROR



Let us consider a point object *O* placed in front of a mirror *M*. A ray of light *OA* from *O* incident on *M* at *A*, is reflected along *AB* so that $\angle OAN = \angle NAB$. A ray *OC* incident on the mirror at *C*, is reflected back along *CO*. Thus, the ray reflected by the plane mirror *M* appears to come from a point *I* behind the mirror where *I* is the point of intersection of *BA* and *OC* produced. Thus, *I* is the image of the point *O*.

Now,

$$\angle AOC = \angle OAN$$

$$\angle NAB = \angle CIA$$

Also, $\angle OAN = \angle NAB$ ($\because \angle i = \angle r$)

$\therefore$ $\angle AOC = \angle CIA$

$\therefore$ $\Delta OCA \cong \Delta ACI$

$\Rightarrow$ $OC = CI$

3.1 CHARACTERISTICS OF THE IMAGE FORMED BY A PLANE MIRROR

(i) The image formed is at the same distance behind the reflecting surface as the object is in front of it.

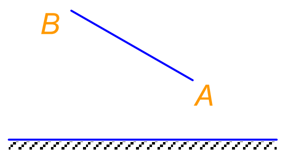
(ii) The size of the image is the same as that of the object.

(iii) The image is virtual and erect which means no light actually passes through it

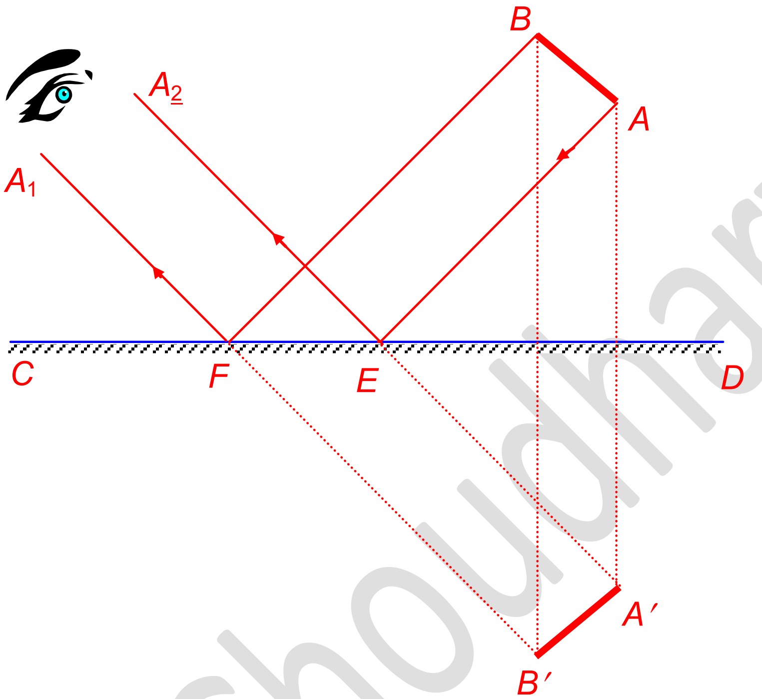
(iv) The image is laterally inverted i.e., side-wise inverted. Example:- If a right handed batsman observes his stance in a plane mirror. He appears left handed. The left hand side of the image thus corresponds to the right hand side of the object and vice-versa. Thus, the image is said to be laterally inverted with respected to the object.

Illustration 1

Question: **Find graphically the position of the observer's eye, which will allow him to see in a plane mirror of finite dimensions, the image of the straight line arranged as shown.**



Solution:

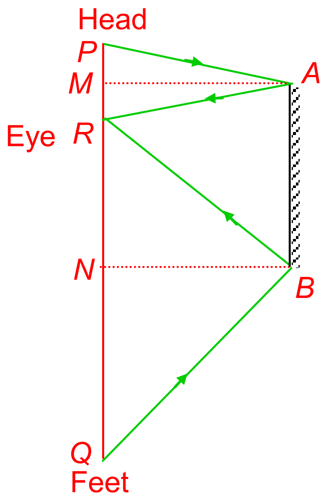


$A'B'$ is the reflected image of AB by CD. The reflected rays EA_2 and FA_1 must reach the eye so that the whole image can be seen.

Illustration 2

Question: **What is the minimum length of a plane mirror required for a person of height 2m to see his full image? Is there any restriction on the position of the top edge of the mirror?**

Solution: The man can view his entire image if the light rays from the top of his head and from his feet reach his eye.



Let AB be the mirror. PQ represents the man of height h and R is the position of his eyes. Light rays from P gets reflected at A and reach his eyes. Light from Q gets reflected at B and reaches his eyes. AM and BN are normals to the mirror AB.

Now, $AB = MN = MR + RN$

$$= \frac{1}{2}(PR + RQ) \ (\because \Delta APM \cong \Delta ARM;$$

$\Delta BQN \cong \Delta BRN)$

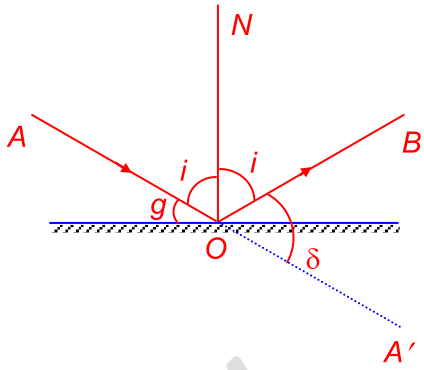
$$= \frac{PQ}{2} = \frac{h}{2}$$

Hence the length of the mirror $= \frac{h}{2}$ = **1 m**

It is clear from the ray diagram that the top edge of the plane mirror (A) must be at a horizontal level half-way between the eyes (R) and the top of his head (P).

3.2 DEVIATION PRODUCED BY A PLANE MIRROR

Deviation is defined as the angle between directions of the incident ray and the reflected ray (or, the emergent ray). It is generally denoted by δ.



Here, $\angle A'OB = \delta = \angle AOA' - \angle AOB = 180° - 2\,i$

Or, $\quad \boldsymbol{\delta = 180° - 2i}$ **... (2)**

We know, $g = 90° - i$

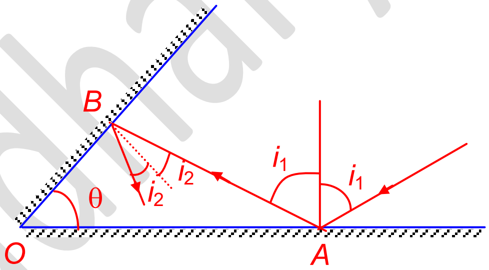
$\therefore \quad \delta = 180° - 2\,(90° - g)$

or $\quad \boldsymbol{\delta = 2g}$ **... (3)**

Illustration 3

Question: **Two plane mirrors are inclined at angle $\theta = 60^0$ with each-other. A ray of light strikes one of them. Find its deviation after it has been reflected twice-one from each mirror.**

Solution: **Case I :**



δ_1 = clockwise deviation at $A = 180° - 2i_1$

δ_2 = anticlockwise deviation at $B = 180° - 2i_2$

Now, from $\Delta\, OAB$, we have

angle O + angle A + angle $B = 180°$

$\Rightarrow \quad i_1 - i_2 = \theta$

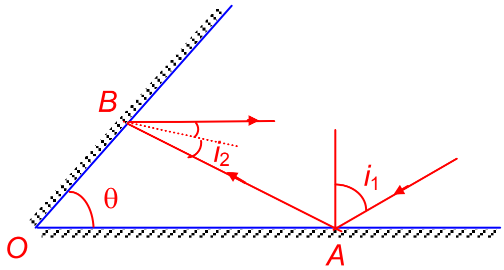
As $\quad i_1 > i_2,\ \delta_1 < \delta_2$

Hence, the net angle clockwise deviation $= \delta_2 - \delta_1$

$= (180° - 2i_2) - (180° - 2i_1)$

$= 2(i_1 - i_2) = 2\theta\ = \mathbf{120^0}$

Case II :



δ_1 = clockwise deviation at $A = 180° - 2i_1$

δ_2 = clockwise deviation at $B = 180° - 2i_2$

Now, from ΔOAB, we have

Angle O + angle A + angle $B = 180°$

or, $\quad \theta + (90° - i_1) + (90° - i_2) = 180°$

$\Rightarrow \quad i_1 + i_2 = \theta$

Hence, net clockwise deviation $= \delta_2 + \delta_1$

$= (180° - 2i_2) + (180° - 2i_1)$

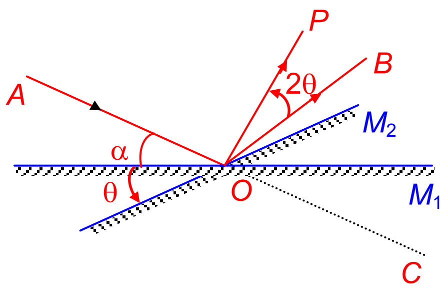
$= 360° - 2\,(i_1 + i_2)$

$= 360° - 2\theta$

$\Rightarrow \quad$ Net anti-clockwise deviation $= 360° - (360° - 2\theta) = 2\theta = \mathbf{120^0}$

3.3 ROTATION OF THE REFLECTED RAY BY A PLANE MIRROR

Let a ray AO be incident at O on a plane mirror M_1. Let α be the glancing angle with M_1. If OB is the reflected ray, then the angle of deviation $(\angle COB) = 2\alpha$. Let the mirror be rotated through an angle θ to a position M_2, keeping the direction of the incident ray constant. The ray is now reflected from M_2 along OP.



The glancing angle with $M_2 = (\alpha + \theta)$.

Hence, the new angle of deviation (i.e., $\angle COP$)

$= 2(\alpha + \theta)$

The reflected ray has thus been rotated through $\angle BOP$ when the mirror is rotated through an angle θ and since

$$\angle BOP = \angle COP - \angle COB$$

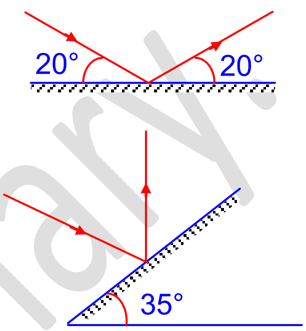
or, $$\angle BOP = 2(\alpha + \theta) - 2\alpha = 2\theta$$

Thus, keeping the incident ray fixed, if the plane mirror is rotated through an angle θ about an axis in the plane of mirror, then the reflected ray is rotated through an angle 2θ.

Illustration 4

Question: **A ray of light is travelling at an angle of 20° above the horizontal. At what angle with the horizontal must a plane mirror be placed in its path so that it becomes vertically upward after reflection.**

Solution: Let us first place the mirror horizontally. The reflected ray now goes at an angle of 20° above the horizontal as shown below.



To make the reflected ray vertical, it has to be rotated anticlockwise by 70°. Hence the mirror must be rotated by

$$\frac{70°}{2} = 35°$$

$\Rightarrow$ the angle of the mirror with the horizontal = **35°.**

3.4 IMAGES OF AN OBJECT FORMED BY MIRRORS INCLINED TO EACH OTHER

If two plane mirrors are kept inclined to each-other at angle θ with their reflecting surfaces facing each-other, then multiple reflections take place and more than one images are formed.

NUMBER OF IMAGES FORMED

(i) if $\left(\frac{360}{\theta}\right)$ is an even integer, the number of images formed

$$n = \frac{360°}{\theta} - 1 \qquad \ldots (4)$$

(ii) If $\left(\frac{360°}{\theta}\right)$ is an odd integer, the number of images formed

$n = \frac{360°}{\theta}$ **when the object is placed unsymmetrical to the mirrors… (5 A)**

$n = \frac{360°}{\theta}$ **-1 when the object is placed symmetrical to the mirrors… (5 B)**

Illustration 5

Question: **Rays of light are incident on a plane mirror at 40°. At what angle with the first should a second mirror be placed such that the rays emerge from the second mirror parallel to the first mirror.**

Solution: In triangle BOC, we have

$2\theta + 50° = 180°$

or, $\theta = \frac{130°}{2} = $ **65°**

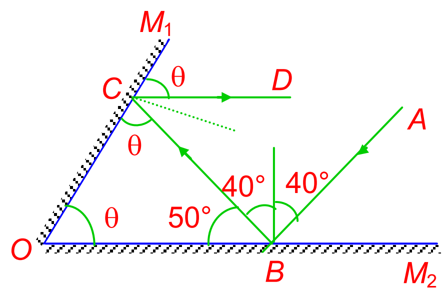


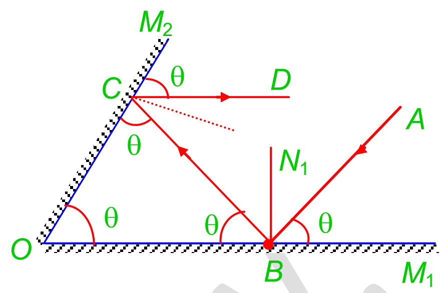
Illustration 6

Question: **Find the angle between two plane mirrors such that a ray of light incident on the first mirror and parallel to the second mirror is reflected from the second mirror, parallel to the first mirror.**

Solution: In triangle *BOC*, we have

$3\theta = 180°$

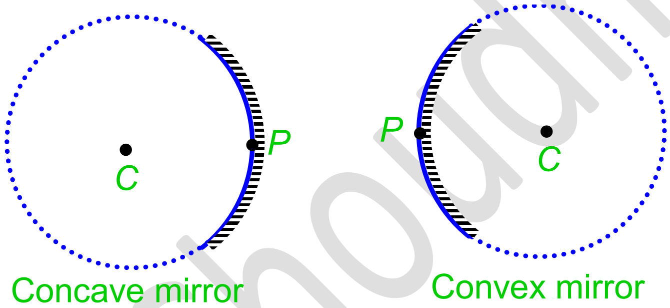
$\theta =$ **60°**



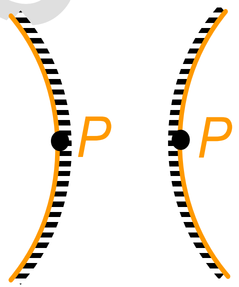
4 REFLECTION AT SPHERICAL MIRROR

4.1 SOME IMPORTANT DEFINITIONS

(i) Spherical Mirrors: A spherical mirror is a part of a hollow sphere or a spherical surface. They are classified as concave or convex according to the reflecting surface being concave or convex respectively.



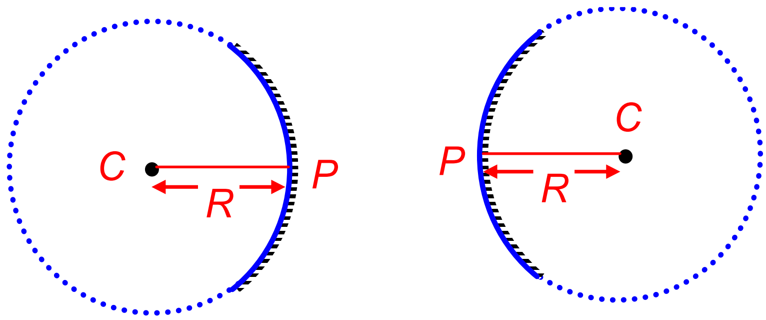
(ii) Pole or Vertex: The geometrical centre of the spherical mirror is called the pole or vertex of the mirror.



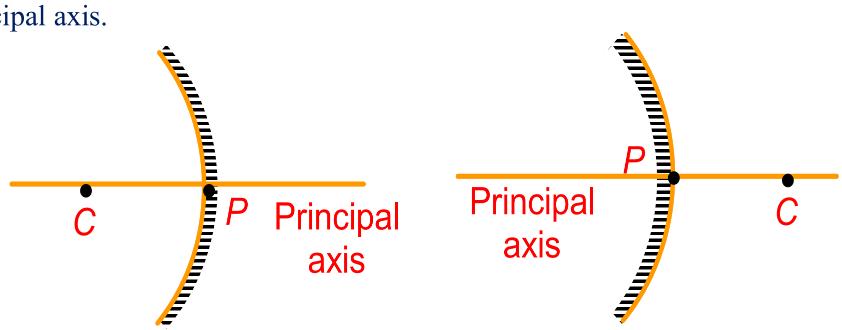
In the above figures, the point *P* is the pole.

(iii) Centre of curvature: The centre *C* of the sphere of which the spherical mirror is a part, is the centre of curvature of the mirror.

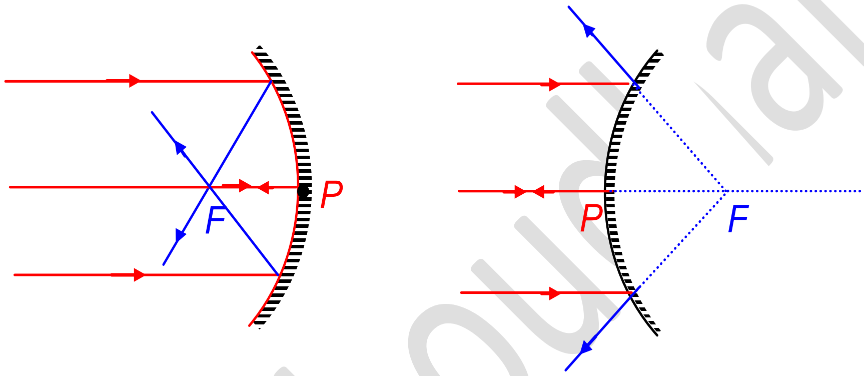
(iv) Radius of curvature (R): Radius of curvature is the radius *R* of the sphere of which the mirror forms a part.



(v) Principal axis: The line *CP* joining the pole and the centre of curvature of the spherical mirror is called the principal axis.



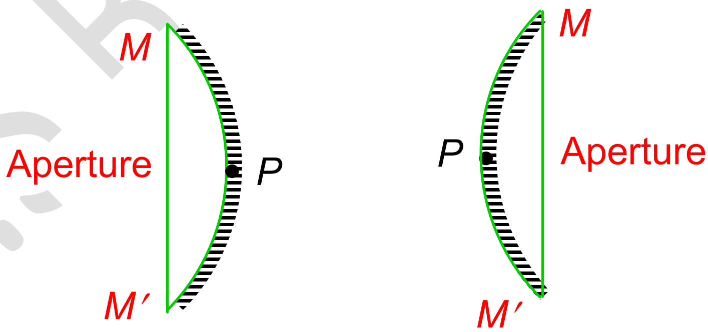
(v) Focus (F): If a parallel beam of rays, parallel to the principal axis and close to it, is incident on a spherical mirror; the reflected rays converge to a point *F* (in case of a concave mirror) or appear to diverge from a point *F* (in case of a convex mirror) on the principal axis. The point *F* is called the focus of the spherical mirror.



Concave mirror   Convex mirror

(vi) Focal Length (f): Focal length is the distance *PF* between the pole *P* and focus *F* along the principle axis.

(vii) Aperture: The line joining the end points of a spherical mirror is called the aperture or linear aperture.



4.2 RELATION BETWEEN f AND R

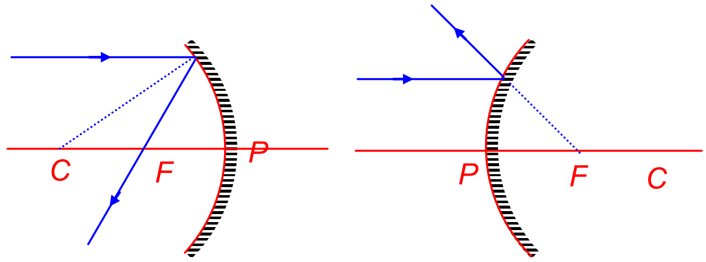
The magnitude of focal length in spherical mirrors is half the radius of curvature, i.e.,

$$f = \frac{R}{2} \quad \dots (6)$$

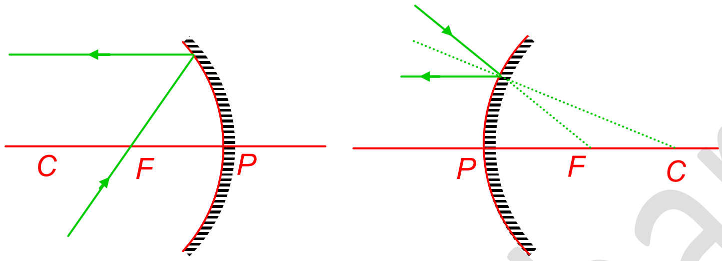
4.3 RULES FOR IMAGE FORMATION

The reflection of light rays and formation of images are shown with the help of ray diagrams. Some typical incident rays and the corresponding reflected rays are shown below.

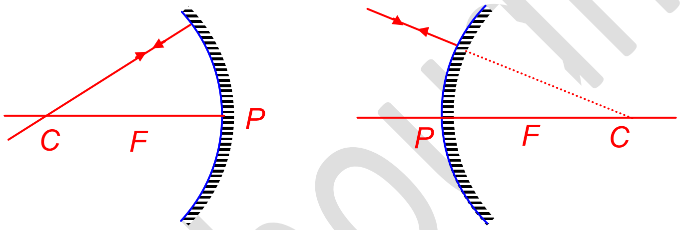
(i) A ray passing parallel to the principal axis after reflection from the spherical mirror passes or appears to pass through its focus (by the definition of focus)



(ii) A ray passing through or directed towards focus after reflection from the spherical mirror becomes parallel to the principal axis (by the principle of reversibility of light).

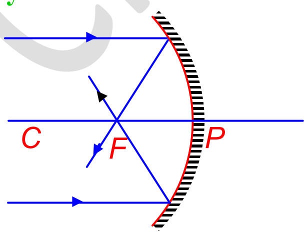


(iii) A ray passing through or directed towards the centre of curvature, after reflection from the spherical mirror, retraces its path (as for it $\angle i = 0$ and so $\angle r = 0$)



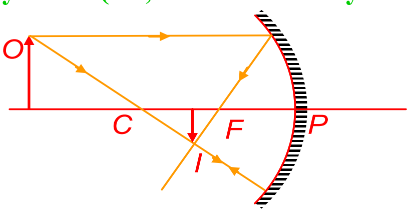
4.4 IMAGE FORMATION BY A CONCAVE MIRROR FOR A REAL LINEAR OBJECT

(i) When the object is at infinity:



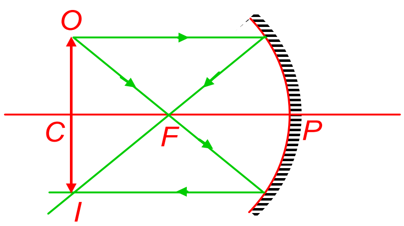
The image is formed at *F*. It is real, inverted and highly diminished.

(ii) When the object lies beyond *C* (i.e., between infinity and *C*):



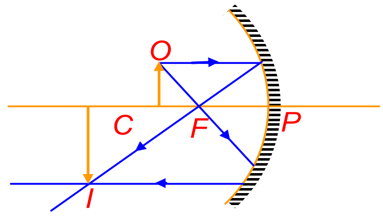
The image is formed between *F* and *C*. It is real, inverted and diminished.

(iii) When the object lies at *C*:



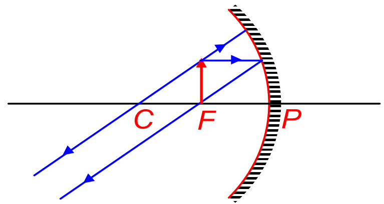
The image is formed at *C* itself. It is real, inverted and of the same size as the object is.

(iv) When the object lies between *F* and *C*:



The image is formed beyond *C* (i.e., between *C* and infinity). It is real, inverted and enlarged.

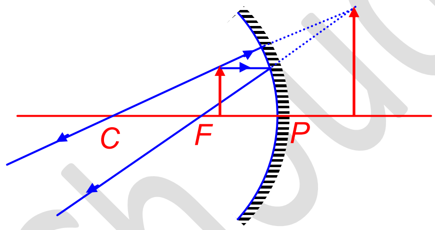
(v) When the object is at *F*:



The image is formed at infinity. It is real, inverted and highly enlarged.

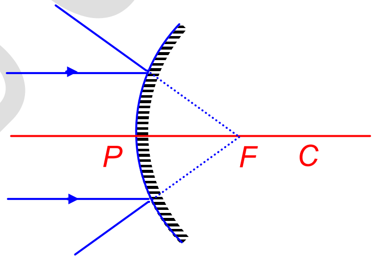
(vi) When the object lies between *P* and *F*:

The image is formed behind the concave mirror. It is virtual, erect and enlarged.



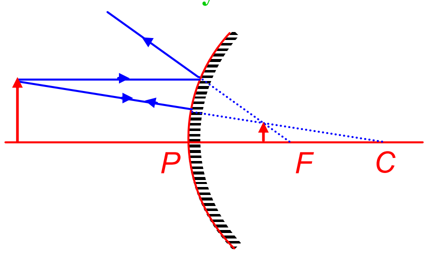
4.5 IMAGE FORMATION BY A CONVEX MIRROR FOR A REAL LINEAR OBJECT

(i) When the object is at infinity:



The image is formed at *F*. It is virtual, erect and highly diminished.

(ii) When the object lies in between infinity and *P* :

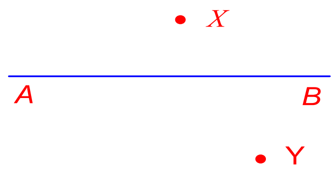


The image is formed between *P* and *F*. It is virtual, erect and diminished.

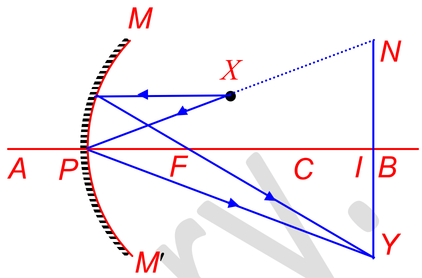
In case of image formation unless stated otherwise, object is taken to be real and we consider only rays that are close to the principal axis and that make small angles with it. Such rays are called paraxial rays. In practice this condition may be achieved by using a mirror whose size is much smaller than the radius of curvature of the surface. Otherwise the image will be distorted.

Illustration 7

Question: **An image Y is formed of a point object X by a mirror whose principal axis is AB as shown. Draw a ray diagram to locate the mirror and its focus. Write down the steps of construction of the ray diagram.**



Solution: (i) From Y, we drop a perpendicular on the principal AB such that $YI = IN$.



(ii) We draw a line joining points N and X so that it meets the principal axis at P. The point P will be the pole of the mirror as a ray reflected from the pole is always symmetrical about principal axis.

(iii) As the image Y of real object X is real, inverted and enlarged, the mirror must be concave and as principal section of the mirror passes through pole and is perpendicular to the principal axis. MM' will be the mirror.

(iv) From X, we draw a line parallel to the principal axis AB towards the mirror so that it meets the mirror at M. We join M & Y, so that it intersects the principal axis at F. F will be the focus of the mirror as any ray parallel to the principal axis after reflection from the mirror intersects the principal axis at the focus.

4.6 NOTATION USED

u **:** Distance of the object from the pole of spherical mirror.

v **:** Distance of the image from the pole of the spherical mirror.

f **:** Focal length of the spherical mirror.

R **:** Radius of curvature of the spherical mirror.

4.7 SIGN CONVENTION

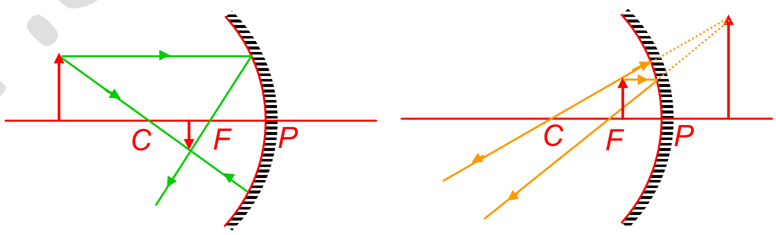
(i) Whenever and wherever possible, the ray of light is taken to travel from left to right.

(ii) All distances are measured from the pole of the spherical mirror along the principal axis.

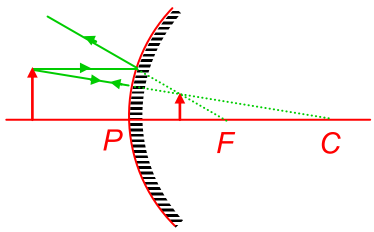
(iii) Distances measured along the principal axis in the direction of the incident ray are taken to be positive while the distances measured along the principal axis against the direction of the incident rays are taken to be negative.

(iv) Distances measured above the principal axis are taken to be positive while distances measured below the principal axis are taken to be negative.

Example:



(a) (b)



(c)

Figure	*U*	*v*	*R*	*f*
(a)	– ve	– ve	– ve	– ve
(b)	– ve	+ ve	– ve	– ve
(c)	– ve	+ ve	+ ve	+ ve

Important Points Regarding Sign Convection:

(i) If the point (i) is valid, our convention coincides with right hand co-ordinate (or new Cartesian co-ordinate system). If the point (i) is not valid, convention is still valid but does not remain co-ordinate convention.

(ii) In this sign convention, focal length of a concave mirror is always negative while the focal length of a convex mirror is always positive.

4.8 MIRROR FORMULA

Object distance, image distance and focal length in spherical mirrors are related by the equation:

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}=\frac{2}{R} \quad \dots (7)$$

Illustration 8

Question: **An object is placed in front of a concave mirror at a distance of 7.5 cm from it. If the real image is formed at a distance of 30 cm from the mirror, find the focal length of the mirror. What would be the focal length if the image is virtual.**

Solution: **Case I:** When the image is real.

We have

$u = -7.5$ cm; $v = -30$ cm ; $f = ?$

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

or, $f=\frac{uv}{u+v}=\frac{(-7.5)\times(-30)}{-7.5-30}$

$= -6$ **cm**

Case II: When the image is virtual:

In this case,

$u = -7.5$ cm

$v = +30$ cm

We know

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

or, $f=\frac{uv}{u+v}=\frac{(-7.5)\,(30)}{-7.5+30}=$ **– 10 cm**

4.9 LINEAR MAGNIFICATION

For linear object, the ratio of the image size (*I*) to the object size (O) is called linear magnification or transverse magnification or lateral magnification. It is generally denoted by *m*.

$$m=\frac{\text{Height of the image}}{\text{Height of the object}}=\frac{I}{O} \quad \dots (8)$$

$$m=-\frac{v}{u}=\frac{f-v}{f}=\frac{f}{f-u} \quad \dots (9)$$

Illustration 9

Question: **An object 5 mm high is placed 30 cm from a convex mirror whose focal length is 20 cm. Find the position (in cm), size (in mm) and nature of the image.**

Solution: We have,

$u = -30$ cm ; $v = ?$ $f = +20$ cm

We know

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

or, $$v=\frac{uf}{u-f}=\frac{(-30)\,(+20)}{-30-20}=+12 \text{ cm}$$

The image is formed 12 cm behind the mirror, it is virtual.

Now, $$m=\frac{I}{O}=-\frac{v}{u}=-\frac{12}{-30}$$

or, $$I=\frac{2}{5}\times O=\frac{2}{5}\times 5=+2 \text{ mm}$$

Hence the height of the image = **2mm**

The positive sign indicates that the image is erect.

Illustration 10

Question: **An object 2 mm high is placed 150 mm from a concave mirror of focal length 5 cm. Find the position (in mm) and size (in mm) of the image.**

Solution: We have

$u = -15$ cm; $v = ?$ $f = -5$ cm

We know that

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f} \quad \text{or,} \quad v=\frac{uf}{u-f}=\frac{(-15)(-5)}{-15+5}=-7.5 \text{ cm}=\mathbf{-75 \text{ mm}}$$

The image is formed at a distance of 75 mm in front of mirror.

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

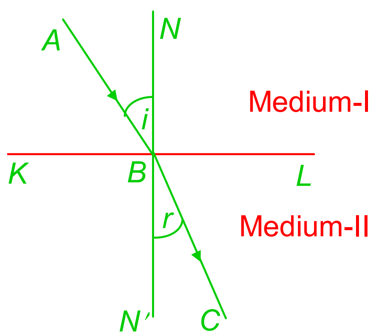
or, $$\frac{I}{O}=-\frac{(-7.5)}{(-15)} \quad \text{or,} \quad I=\mathbf{-1 \text{ mm}}$$

The negative sign indicates that image is inverted.

5 REFRACTION OF LIGHT AT PLANE SURFACE

5.1 REFRACTION

In a homogeneous medium, light rays travel in a straight line. Whenever a ray of light passes from one transparent medium to another, it gets deviated from its original path while crossing the interface of the two media (except in case of normal incidence). This phenomenon of deviation or bending of light rays from their original path while passing from one medium to another is called refraction.



$AB \rightarrow$ **Incident ray.**

$BC \rightarrow$ **Refracted ray**

$NBN' \rightarrow$ **The normal to the refracting surface at the point of incident**

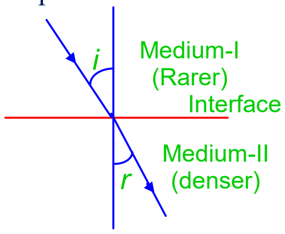
$\angle i \rightarrow$ **The angle of incidence.**

$\angle r \rightarrow$ **The angle of refraction.**

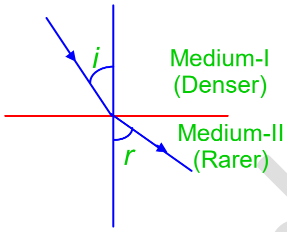
$KL \rightarrow$ **Interface.**

In the second medium, the ray either bends towards the normal or away from the normal with respect to its path in the first medium.

If the refracted ray bends towards the normal with respect to the incident ray, then the second medium is said to be optically denser as compared to the first medium.



If the refracted ray bends away from the normal, then the second medium is said to be (optically) rarer as compared to the first medium.



5.2 LAWS OF REFRACTION

The phenomenon of refraction takes place according to the following two laws:

(i) The incident ray, the refracted ray and the normal to the refracting surface at the point of incidence, all lie in the same plane.

(ii) The ratio of sine of the angle of incidence to the sine of the angle of refraction is a constant for any two given media and for light of given colour.

If the angle of incidence and the angle of refraction be *i* and *r* respectively, then

$$\frac{\sin i}{\sin r} = \text{constant} . \qquad \ldots (10)$$

This law is called Snell's law

Some Important Points

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

This constant is known as refractive index (R. I.). of the second medium with respect to the first medium. It is denoted by ${}_1\mu_2$ (or ${}_1n_2$).

(ii) Refractive index is the relative property of the two media. If the first medium carrying the incident ray is air (strictly vacuum), then the ratio $\frac{\sin i}{\sin r}$ is called the absolute refractive index of the second medium. It is dented by μ or *n*.

(iii) According to the **wave theory of light**.

$${}_1\mu_2 = \frac{\sin i}{\sin r} = \frac{\text{velocity of light in medium 1}}{\text{velocity of light in medium 2}} = \frac{v_1}{v_2}$$

Hence, the absolute refractive index of the medium is given by

$$\mu = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in medium}} = \frac{C}{V}$$

(iv) If the absolute refractive indices of the media 1 and 2 are μ_1 and μ_2 respectively, then

$${}_1\mu_2 = \frac{V_1}{V_2} = \frac{C/V_1}{C/V_2} = \frac{\mu_2}{\mu_1}$$

(v) We know ${}_1\mu_2 = \frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$

or, $\mu_1 \sin i = \mu_2 \sin r$ … (11)

This is the most general formula for the refraction at a surface.

(vi) We have

$$\frac{\mu_2}{\mu_1} = \frac{C/V_2}{C/V_1} = \frac{V_1}{V_2}$$

or, $$V \propto \frac{1}{\mu}$$

This shows that the higher is the refractive index of a medium, lesser is the velocity of light in that medium. Thus, a medium having higher absolute refractive index is called optically denser; while the one having smaller absolute refractive index is called to be optically rarer.

(vii) The frequency of light remains unchanged while passing from one medium to another. Hence

$$\frac{\mu_2}{\mu_1} = \frac{V_1}{V_2} = \frac{\nu\lambda_1}{\nu\lambda_2} = \frac{\lambda_1}{\lambda_2}$$

(viii) If the ray of light is incident normally on a boundary, i.e., $\angle i = 0$, then from Snell's law

$$\mu_1 \sin\theta = \mu_2 \sin r$$

or, $\sin r = 0$

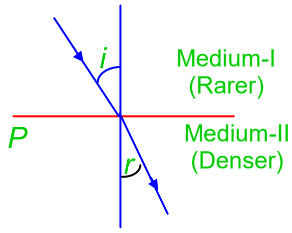
$\Rightarrow \angle r = 0$

Thus, light in the second medium will pass undeviated.

5.3 PRINCIPLE OF REVERSIBILITY OF LIGHT RAYS

A ray travelling along the path of the refracted ray is reflected along the path of the incident ray.

In the same way, a refracted ray reversed to travel back along its path will get refracted along the path of the incident ray. Thus, the incident ray and the refracted ray are mutually reversible. This is called the principle of reversibility of light.



When a ray of light travels from first medium to the second medium, we have

$${}_1\mu_2 = \frac{\sin i}{\sin r} \quad \text{… (i)}$$

When the path of the ray is reversed, it travels from medium-II to medium-I.

Using Snell's Law. We have

$${}_2\mu_1 = \frac{\sin r}{\sin i} \quad \text{… (ii)}$$

Multiplying (i) and (ii), we get,

$${}_1\mu_2 \times {}_2\mu_1 = 1$$

or, $${}_1\mu_2 = \frac{1}{{}_2\mu_1} \quad \text{… (12)}$$

Illustration 11

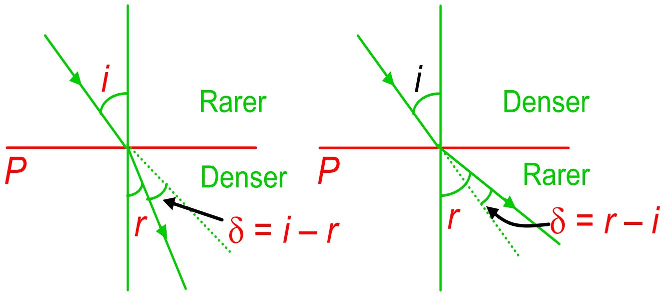
Question: **If wavelength of light in glass is 7200 Å, then find the wavelength of same light (in Å) in water ($\mu_w = 4/3$, $\mu_g = 3/2$)**

Solution:

$$\frac{\lambda_{water}}{\lambda_{glass}} = \frac{\mu_{glass}}{\mu_{water}}$$

$$\lambda = \frac{3/2}{4/3} \times 7200\,\text{Å} = \mathbf{8100\ Å}$$

5.4 DEVIATION OF A RAY DUE TO REFRACTION

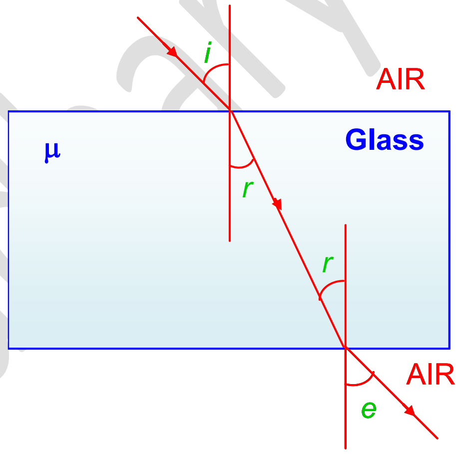


When a light ray goes from the rarer medium to the denser medium. It bends towards the normal. If a light ray goes from the denser medium to the rarer medium, it bends away from the normal.

In both cases, the magnitude of the angle of the deviation for the light ray is $= |i - r|$.

5.5 REFRACTION THROUGH A GLASS SLAB

When a light ray passes through a glass slab having parallel faces, it gets refracted twice before finally emerging out of it.



First refraction takes place from air to glass.

So, $\mu = \dfrac{\sin i}{\sin r}$ … (i)

The second refraction takes place from glass to air.

So, $\dfrac{1}{\mu} = \dfrac{\sin r}{\sin e}$ … (ii)

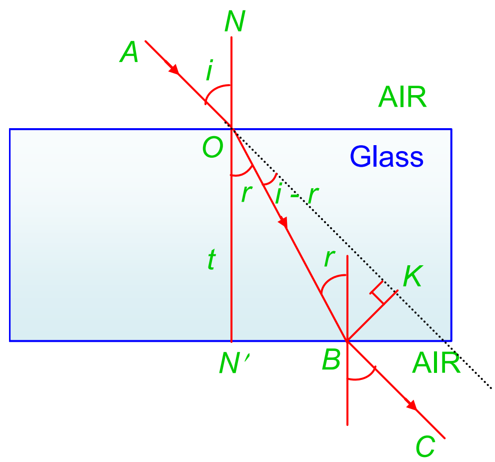
From equation (i) and equation (ii), we get

$$\frac{\sin i}{\sin r} = \frac{\sin e}{\sin r} \quad \Rightarrow i = e$$

Thus, the emergent ray is parallel to the incident ray.

5.6 LATERAL SHIFT

The perpendicular distance between the incident ray and the emergent ray, when the light is incident obliquely on a parallel sided refracting glass slab is called 'lateral shift'.



In right-angled triangle OBK, we have

$\angle BOK = i - r$

$\therefore \quad \sin(i - r) = \dfrac{d}{OB}$

or, $\quad d = OB \sin(i - r)$ … (i)

In right angled triangle $ON'B$, we have

$$\cos r = \frac{ON'}{OB} \quad \text{or,} \quad OB = \frac{t}{\cos r}$$

Substituting the above value of OB in equation (i), we get

$$d = \frac{t}{\cos r} \sin(i - r) \quad \ldots (13)$$

Illustration 12

Question: A ray of light is incident at an angle of 60° on one face of a rectangular glass slab of thickness $2\sqrt{3}$ mm and refractive index $\sqrt{3}$. Calculate the lateral shift produced in mm.

Solution: Here

$i = 60°$; $\mu = \sqrt{3}$ and $t = 2\sqrt{3}$ m

Now, $\mu = \frac{\sin i}{\sin r}$ or, $\sin r = \frac{\sin i}{\mu} = \frac{\sin 60°}{\sqrt{3}} = \frac{1}{2}$

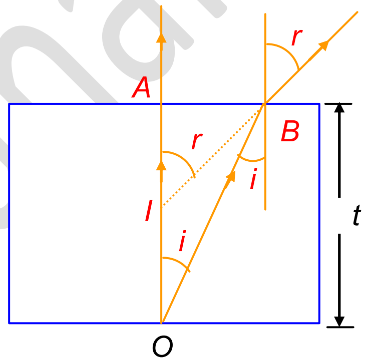
$\Rightarrow r = 30^0$

Now, lateral shift, $d = \frac{t}{\cos r}\sin(i - r) = \frac{2\sqrt{3}}{\sqrt{3}}$ = **2mm**

5.7 APPARENT DEPTH AND NORMAL SHIFT

Case I: When the object is in denser medium and the observer is in rarer medium (near normal incidence)

When an object O is in denser medium of depth 't' and absolute refractive index μ and is viewed almost normally to the surface from the outside rarer medium (say air), its image is seen at I. AO is the real depth of the object. AI is the apparent depth of the object. OI is called apparent shift.



According to Snell's law. $\frac{1}{\mu} = \frac{\sin i}{\sin r}$

or, $\frac{1}{\mu} = \frac{\tan i}{\tan r}$ ($\because$ i and r are small angles)

or, $\mu = \frac{\tan r}{\tan i}$ or, $\mu = \frac{AB}{AI} \times \frac{AO}{AB}$

or, $\mu = \frac{AO}{AI}$

$$\Rightarrow \mu = \frac{\text{Real depth}}{\text{Apparent depth}} \quad \ldots (14)$$

Also,

Apparent depth = $\frac{\text{Real depth}}{\mu} = \frac{t}{\mu}$ and, apparent shift $(OI) = t - t/\mu = t\,[1 - \frac{1}{\mu}]$

Illustration 13

Question: A tank filled with a liquid to a height of 12.5 cm. The apparent depth of a needle lying at the bottom of the tank is measured by a microscope to be 10 cm. If water is replaced by water of refractive index 1.66 up to the same height, by what distance (in mm) would the microscope have to be moved to focus on the needle again?

Solution: When the tank is filled with water:

Real depth = 12.5 cm; Apparent depth = 10 cm

When the tank is filled with the water

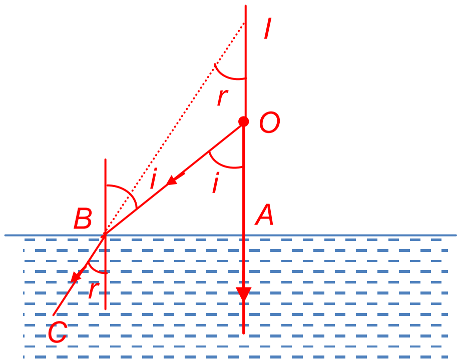
Real depth = 12.5 cm; μ = 1.66

$\therefore$ Apparent depth = $\frac{\text{Real depth}}{\mu} = \frac{12.5}{1.66}$ = 7.5 cm

Therefore, the distance through which the microscope to be moved

= 10 cm – 7.5 cm = 2.5 cm = **25 mm**

Case II: When the object is in rarer medium and the observer is in denser medium (Near normal incidence).



When an object O is in rarer medium (say air) is seen from within a denser medium (say water), the image of O appears to be raised up to I.

The real height = $AO = h$

The apparent height = AI ; and the

Apparent shift = OI

The refraction is taking place from the rarer medium to the denser medium. So, according to Snell's law $\mu = \dfrac{\sin i}{\sin r}$

or, $\mu = \dfrac{\tan i}{\tan r}$ ($\because$ i and r are small angles)

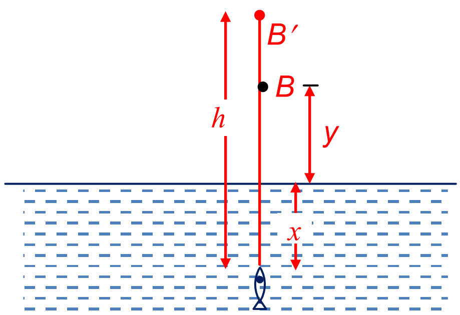
or, $\mu = \dfrac{AB}{AO} \times \dfrac{AI}{AB}$ or, $\mu = \dfrac{AI}{AO}$

$\Rightarrow$ $\mu = \dfrac{\text{Apparent height}}{\text{Real height}} \Rightarrow AI = \mu\, AO$ … (15)

$\therefore$ Apparent shift $(OI) = AI - AO = (\mu - 1)h$

Illustration 14

Question: **A fish rising vertically to the surface of water in a lake uniformly at the rate of 3m/s observes a king fisher bird diving vertically towards water at the rate 9 m/s vertically above it. If the refractive index of water is 4/3, find the actual velocity of the dive of the bird in cm/sec.**



Solution: If at any instant, the fish is at a depth 'x' below water surface while the bird at a height y above the surface, then the apparent height of the bird from the surface as seen by the fish will be given by

$\mu = \dfrac{\text{Apparent height}}{\text{Real height}}$

or, Apparent height = μy

So, the total apparent distance of the bird as seen by the fish in water will be

$h = x + \mu y$

or, $\dfrac{dh}{dt} = \dfrac{dx}{dt} + \mu \dfrac{dy}{dt}$

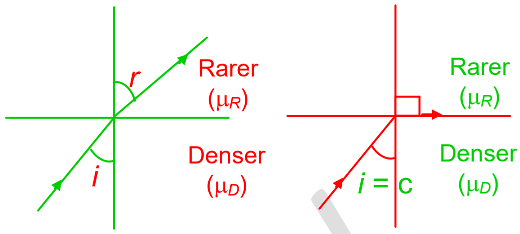
or, $9 = 3 + \mu\left(\frac{dy}{dt}\right)$

or, $\frac{dy}{dt} = \frac{6}{(4/3)} = 4.5 \text{ m/s} = \mathbf{450 \text{ cm/s.}}$

5.8 CRITICAL ANGLE

When a ray of light goes from a denser medium to a rarer medium, the angle of refraction is greater than the angle of incidence. If the angle of incidence is increased, the angle of refraction may eventually become 90°.

The angle of incidence for which the angle of refraction is 90° is called the critical angle for that interface. It is generally denoted by *C*.



5.9 EXPRESSION FOR CRITICAL ANGLE

Let μ_R be the refractive index of the rarer medium and μ_D be the refractive index of the denser medium. Obviously, $\mu_r < \mu_D$

From Snell's law

$$\frac{\sin C}{\sin 90°} = \frac{\mu_R}{\mu_D}$$

or, $\frac{\sin C}{1} = \frac{\mu_R}{\mu_D}$

or, $\sin C = \frac{1}{\mu}$. **… (16)**

where $\mu = \frac{\mu_D}{\mu_R}$ is refractive index of the denser medium w.r. t the rarer medium.

5.10 TOTAL INTERNAL REFLECTION

If a ray of light travelling in a denser medium strikes a rarer medium at an angle of incidence *i* which is greater than the critical angle *C*, it gets totally reflected back into the same medium. This phenomenon is called as 'total internal reflection'.

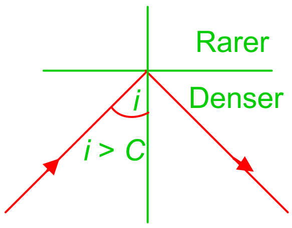
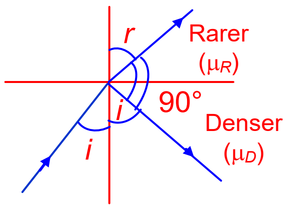


Illustration 15

Question: **A ray of light from a denser medium strikes a rarer medium at an angle of incidence $i = \tan^{-1}$ (1/2). If the reflected and the refracted rays are mutually perpendicular to each-other, what is the value of the critical angle in degree?**



Solution: From Snell's law, we have

$$\frac{\sin i}{\sin r} = \frac{\mu_R}{\mu_D}$$

or, $\mu = \frac{\mu_D}{\mu_R} = \frac{\sin r}{\sin i}$ … (i)

According to the given problem.

$$i + r + 90° = 180°$$

or, $r = 90° - i$

Substituting the above value of r in equation (i), we get

$$\mu = \frac{\sin(90 - i)}{\sin i}$$

or, $\mu = \cot i$ … (ii)

By definition $C = \sin^{-1}\left(\frac{1}{\mu}\right)$

or, $C = \sin^{-1}\left(\frac{1}{\cot i}\right)$ (using equation (ii)

or, $C = \sin^{-1}(\tan i) = \sin^{-1}(1/2)$

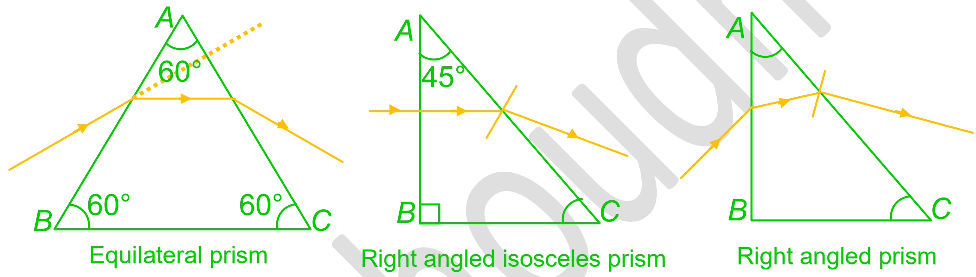
$\Rightarrow$ $C = \pi/6 = \mathbf{30^0}$

6 REFRACTION THROUGH A PRISM

6.1 PRISM

Prism is a transparent medium bounded by any number of surfaces in such a way that the surface on which light is incident and the surface from which light emerges are plane and non-parallel.

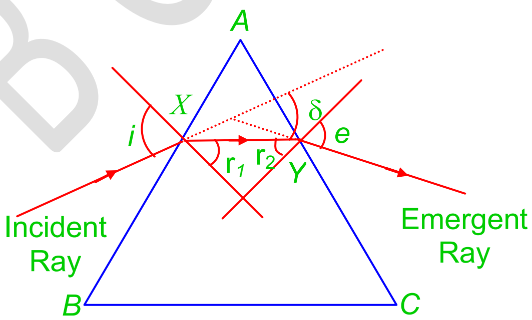
Generally equilateral, right-angled isosceles or right-angled prism are used.



6.2 ANGLE OF THE PRISM OR REFRACTING ANGLE OF THE PRISM

The angle between the two refracting faces involved is called the refracting angle or the angle (A) of the prism.

6.3 DEVIATION PRODUCED BY A PRISM:



A ray of light striking at one face of a triangular glass prism gets refracted twice and emerges out from the other face as shown above.

The angle between the emergent and the incident rays is called the angle of deviation (δ).

From ΔAXY, we have

$$A + (90° - r_1) + (90° - r_2) = 180°$$

$\Rightarrow$ $\mathbf{r_1 + r_2 = A}$ **… (17)**

Now, deviation $\delta = (i - r_1) + (e - r_2)$

$= (i + e) - (r_1 + r_2)$

$\Rightarrow$ $\mathbf{\delta = (i + e) - A}$ **…(18)**

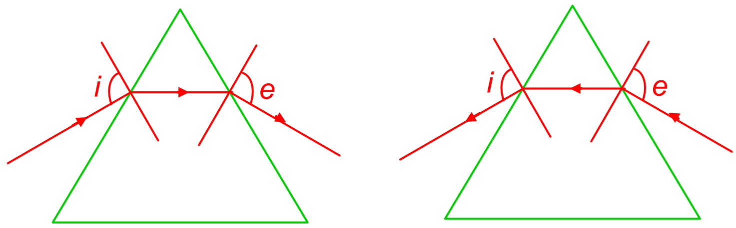
or, $\delta + A = i + e$

Important Points

(i) We have two equations from Snell's law at X and Y

$$\frac{\sin i}{\sin r_1} = \mu \text{ and } \frac{\sin r_2}{\sin e} = \frac{1}{\mu}$$

(ii) It can be easily seen that if we reverse the emergent ray, it goes back along the same path. The angles of incidence and emergence get interchanged but the angle of deviation remains the same.



Angle of incidence = i
Angle of emergence = e
$\therefore$ $(i + e) = A + \delta$

Angle of incidence = e
Angle of emergence = i
$\therefore$ $(e + i) = A + \delta$

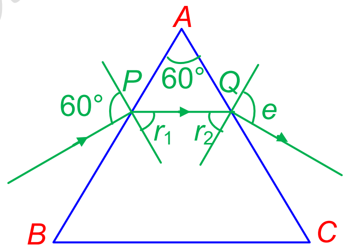
Thus the same angle of deviation δ is possible for two different angles of incidence: i and e such that

$$i + e = A + \delta$$

Illustration 16

Question: **A ray of light is incident on one face of a prism ($\mu = \sqrt{3}$) at an angle of 60°. The refracting angle of the prism is also 60°. Find the angle of emergence and the angle of deviation.**

Solution: Angle of incidence = $i = 60°$



At point P, $\frac{\sin 60°}{\sin r_1} = \frac{\sqrt{3}}{1}$

$\Rightarrow$ $\sin r_1 = 30^0$

Using $r_1 + r_2 = A$, we get
$r_2 = A - r_1 = 60° - 30° = 30^0$

At point Q, $\frac{\sin r_2}{\sin e} = \frac{1}{\sqrt{3}}$

$\Rightarrow$ $\sin e = \frac{\sqrt{3}}{2}$

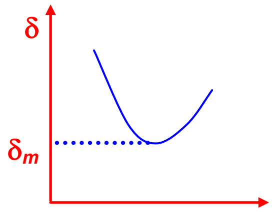
$\Rightarrow$ $e = 60^0$

Illustration 17

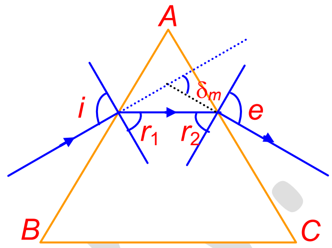
Question: **A ray of light makes an angle of 60° on one of the faces of a prism and suffers a total deviation of 30° on emergence from the other face. If the angle of the prism is 30°, show that the emergent ray is perpendicular to the other face.**

Solution: The angle of deviation $\delta = (i_1 + i_2) - A$
here, $\delta = 30°$, $i_1 = 60°$; $A = 30°$
Hence $30° = 60° + i_2 - 30° = 30° + i_2$
$\Rightarrow$ $i_2 = 0$
The angle of emergence is zero. This means that the emergent ray is perpendicular to the second face.

6.4 MINIMUM DEVIATION AND CONDITION FOR MINIMUM DEVIATION



The angle of deviation depends on the angle of incidence in a peculiar way. When the angle of incidence is small, the deviation is large. As i increase, δ decreases rapidly and attains a minimum value and then increases slowly with increase of i. The minimum value of δ so attained is called the minimum deviation (δ_m).



Theory and experiment shows that δ will be minimum when the path of the light ray through the prism is symmetrical, i.e.,

Angle of incidence = angle of emergence

or, $\angle i = \angle e$

For the refraction at the face AB, we have

$$\frac{\sin i}{\sin r_1} = \mu \text{ (Snell's Law)} \quad \text{or,} \quad \sin i = \mu \sin r_1$$

and, $$\frac{\sin e}{\sin r_2} = \mu$$

or, $\sin e = \mu \sin r_2$

∴ $\mu \sin r_1 = \mu \sin r_2$

or, $r_1 = r_2$

Hence, the condition for **minimum deviation is $i = e$ and $r_1 = r_2$** … (19)

6.5 RELATION BETWEEN REFRACTIVE INDEX AND THE ANGLE OF MINIMUM DEVIATION

When $\delta = \delta_m$, we have

$e = i$ and $r_1 = r_2 = r$ (say)

We know

$$A = r_1 + r_2 = r + r = 2r$$

or, $$r = \frac{A}{2}$$

Also, $A + \delta = i + e$

or, $A + \delta_m = i + i$

or, $$i = \frac{A+\delta_m}{2}$$

The refractive index of the material of the prism is given by

$$\mu = \frac{\sin i}{\sin r} \text{ (Snell's law)}$$

or, $$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$$ … (20)

Illustration 18

Question: **A ray of light incident at an angle 90^0 with the face of an equilateral prism passes symmetrically. Calculate the refractive index of the material of the prism.**

Solution: As the prism is an equilateral one, $A = 60°$. As the ray of light passes symmetrically, the prism is in the position of minimum deviation.

So, $r = \frac{A}{2} = \frac{60°}{2} = 30°$

also, $i = 90^0$

$\therefore \quad \mu = \frac{\sin i}{\sin r} = \frac{\sin 90°}{\sin 30°} = \frac{1}{0.5} = \mathbf{2}$

Illustration 19

Question: **The refracting angle of the prism is 60° and the refractive index of the material of the prism is $\sqrt{3}$. Calculate the angle of minimum deviation in degree.**

Solution: Here , $A = 60°; \mu = \sqrt{3}$

Now, $\mu = \dfrac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

or, $\sqrt{3} = \dfrac{\sin\left(\frac{60°+\delta_m}{2}\right)}{\sin\frac{60°}{2}} = \dfrac{\sin\left(\frac{60+\delta_m}{2}\right)}{\sin 30°}$

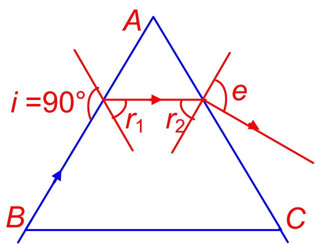
or, $\sin\left(\frac{60°+\delta_m}{2}\right) = \sqrt{3}\sin 30° = \frac{\sqrt{3}}{2}$

or, $\frac{60°+\delta_m}{2} = 60^0$

$\delta_m = \mathbf{60^0}$

6.6 GRAZING INCIDENCE

When $I = 90°$, the incident ray grazes along the surface of the prism and the angle of refraction (r_1) inside the prism becomes equal to the critical angle for glass-air pair. This is known as **grazing incidence**.



6.7 GRAZING EMERGENCE

When $e = 90°$, the emergent ray grazes along the prism surface. This happens when the light ray strikes the second face of the prism at the critical angle for glass-air pair. This is known as **grazing emergence**.

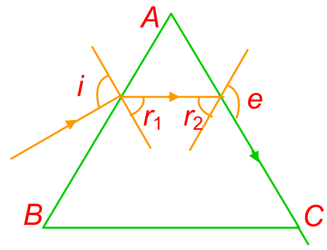
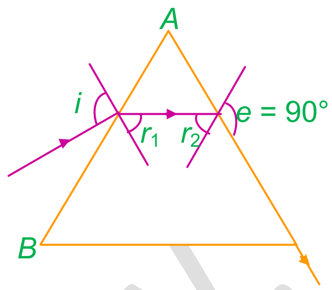


Illustration 20

Question: **A ray of light falls on one side of a prism whose refracting angle is 75°. Find the angle of incidence in order that the emergent ray may just graze the other side. $(\mu = \sqrt{2})$**

Solution: Given: $A = 75°$, $e = 90°$

$\therefore r_2 = C$, the critical angle of the prism.



Now, $\mu = \dfrac{1}{\sin C}$

or, $\sin C = \dfrac{1}{\mu} = \dfrac{1}{\sqrt{2}}$

$\Rightarrow \quad C = 45^0$

Again, $A = r_1 + r_2$

$\Rightarrow \quad r_1 = A - r_2 = 75^0 - 45^0$

$= 30^0$

For the refraction at the surface AB, we have

$\mu = \dfrac{\sin i}{\sin r_1}$ (Snell's Law)

or, $\sin i = \mu \sin r_1$

$= \sqrt{2} \times \sin 30^0 = \dfrac{1}{\sqrt{2}}$

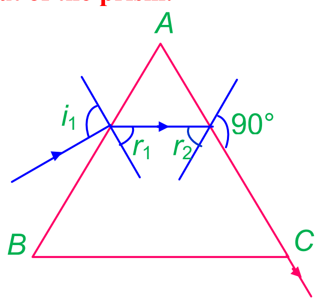
$i = \mathbf{45^0}$

Illustration 21

Question: **The refractive index of the material of a prism of refracting angle 74° is 1.66 for a certain monochromatic ray. What should be the minimum angle of incidence of this ray on the prism so that no total internal reflection takes place as they come out of the prism.**

Solution: Given $A = 74°$, $\mu = 1.66$

we have



$\mu = \dfrac{1}{\sin C}$

or, $\sin C = \dfrac{1}{\mu} = \dfrac{3}{5}$

$\Rightarrow \quad C = 37^0$

For total internal reflection not to take place at the surface AC, we have

$r_2 \le C$

or, $(r_2)_{max} = C$

Now, $r_1 + r_2 = A$

or, $r_1 = (A - r_2)$

or, $(r_1)_{min} = A - (r_2)_{max} = 74° - 37° = 37°$

For the refraction at the first face,

We have, $\mu = \dfrac{\sin i_1}{\sin r_1}$

or, $\sin i_1 = \mu \sin r_1 = 5/3 \times \sin 37^0$

$\Rightarrow \quad i_1 = \mathbf{90°}$

6.8 MAXIMUM DEVIATION

We know $\delta = (i + e) - A$

Deviation will be maximum when the angle of incidence i is maximum, i.e., $i = 90°$. Hence,

$$(\delta)_{max} = (90° + e) - A$$

This is the expression for the maximum deviation.

Illustration 22

Question: **Find the minimum and maximum angle of deviation for a prism with angle A = 60° and μ = 1.5.**

Solution: **Minimum deviation:**

The angle of minimum deviation occurs when $i = e$ and $r_1 = r_2$ and is given by

$$\mu = \frac{\sin\frac{(A+\delta_m)}{2}}{\sin\frac{A}{2}}$$

$\Rightarrow$ $\delta_m = 2\sin^{-1}\left(\mu \sin\frac{A}{2}\right) - A$

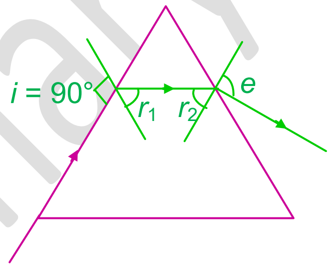
Substituting μ = 1.5 and A = 60°, we get

$\delta_m = 2\sin^{-1}(0.75) - 60° =$ **37°**

Maximum deviation:

The deviation is maximum when i = 90° or e = 90° that is at grazing incidence or grazing emergence.

Let i = 90°



$\Rightarrow$ $r_1 = C = \sin^{-1}\left(\frac{1}{\mu}\right)$

$\Rightarrow$ $r_2 = \sin^{-1}\left(\frac{2}{3}\right) = 42°$

$\Rightarrow$ $r_2 = A - r_1 = 60° - 42° = 18°$

Using $\frac{\sin r_2}{\sin e} = \frac{1}{\mu}$, we have

$\sin e = \mu \sin r_2 = 1.5 \times \sin 18°$

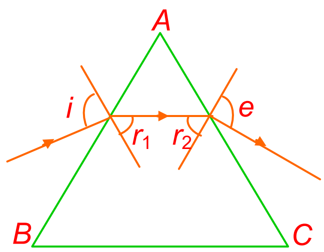
$\Rightarrow$ $\sin e = 4.63$

$\Rightarrow$ $e = 28°$

$\therefore$ Deviation $= \delta_{max} = (i + e) - A = 90° + 28 - 60° =$ **58°**

6.9 DEVIATION THROUGH A PRISM OF SMALL ANGLE

If the angle of the prism A is small, r_1 and r_2 (as $r_1 + r_2 = A$) and i and e will be small.



For the refraction at the face AB, we have $\mu = \frac{\sin i}{\sin r_1}$

or, $\mu = \frac{i}{r_1}$ (since i and r_1 are small angles, $\sin i_1 \approx i_1$ and $\sin r_1 \approx r_1$)

$\Rightarrow$ For refraction at the face AC, we have

$$\mu = \frac{\sin e}{\sin r_2}$$

or, $\mu = \frac{e}{r_2}$ ($\because$ e and r_2 are small angles, so $\sin e \simeq e$ and $\sin r_2 \simeq r_2$)

$\Rightarrow$ $e = \mu r_2$ … (ii)

Now, deviation produced by a prism

$\delta = (i + e) - A$

or, $\delta = (\mu r_1 + \mu r_2) - A$ or, $\delta = \mu(r_1 + r_2) - A$

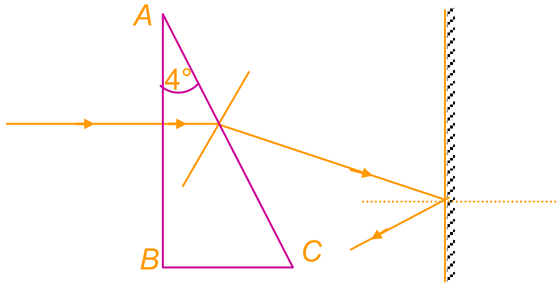
or $\delta = \mu A - A$ [$\because$ $r_1 + r_2 = A$]

or, $\boldsymbol{\delta = (\mu - 1) A}$ **… (21)**

The above formula is valid for all positions of the prism provided the angle of the prism A is small (say ≤ 10°).

Illustration 23

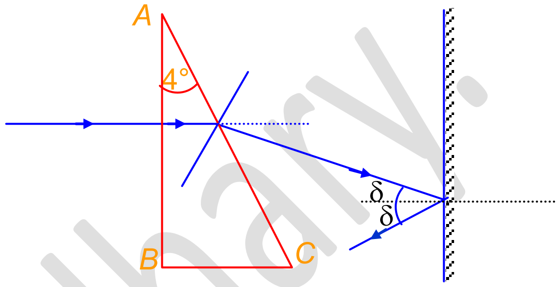
Question: **A prism having a refracting angle 4° and refractive index 1.5 is located in front of a vertical plane mirror as shown. A horizontal ray of light is incident on the prism. What is the angle of incidence at the mirror?**



Solution: The deviation suffered by refraction through the small angled prism is given by

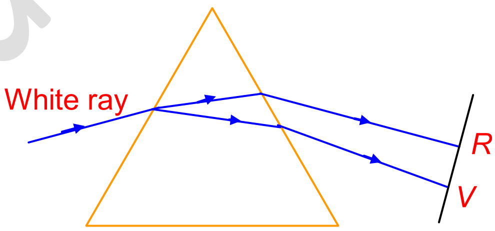
$\delta = (\mu - 1)A = (1.5 - 1) \times 4° = \mathbf{2°}$

This gives the angle of incidence 2° at the mirror.



7 DISPERSION OF LIGHT THROUGH A PRISM

Dispersion: When a ray of white light is passed through a prism, it splits up into its constituent colours. This phenomenon of splitting up of white light into constituent colours is called dispersion. The band of seven colours produced on the screen is called the spectrum of the source emitting the incident white light.



Rainbow the most colourful phenomenon in nature is primarily due to the dispersion of sunlight by raindrops suspended in air.

7.1 CAUSE OF DISPERSION

The different colour of light are due to different wavelengths. The wavelengths of violet colour is smaller than that of the red colour.

Cauchy obtained expression for the refractive index of a material in terms of the wavelength of the light. It is given by

$$\mu = a + \frac{b}{\lambda^2}, \quad \ldots (22)$$

where a & b are constants for the material

Since the wavelength of violet colour is smaller than that of red colour, from the above formula, it follows that the refractive index of the material for violet colour is more than that for red colour.

i.e., $\mu_v > \mu_R$

for a small angled prism, we have

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

since $\mu_V > \mu_R$, we have

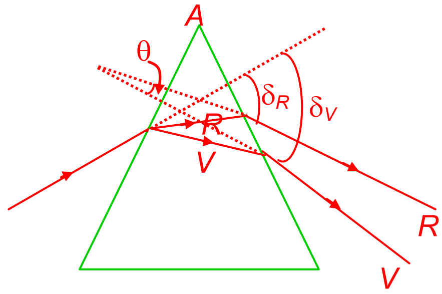
$$\delta_V > \delta_R$$

7.2 ANGULAR DISPERSION

In case of dispersion of light, the angle between the extreme rays (i.e., violet and red) is called angular dispersion or simply dispersion.

Angular dispersion = $\theta = \delta_V - \delta_R$ ... (23)

Let μ_V and μ_R be the refractive indices of the material of the prism for violet and red colours respectively. Let A be the angle of the prism.



We have ,

$\delta_V = (\mu_V - 1) A$;

$\delta_R = (\mu_R - 1) A$

$\therefore \delta_V - \delta_R = (\mu_V - \mu_R)A$

7.3 DISPERSIVE POWER (ω)

The ratio of (angular) dispersion to the deviation of the mean ray (yellow) is called the **dispersive power of the prism**. It is denoted by ω.

$\omega = \dfrac{\theta}{\delta} = \dfrac{\delta_V - \delta_R}{\delta}$, where δ is the deviation of the mean ray; δ_V and δ_R are the deviations of the violet and the red rays respectively.

7.4 DISPERSIVE POWER IN TERMS OF REFRACTIVE INDEX

In a thin prism,

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

$\therefore \quad \delta_V = (\mu_v - 1) A;\ \ \delta_R = (\mu_R - 1) A$

Hence, $\delta_V - \delta_R = (\mu_V - \mu_R) A$

$\therefore \quad \omega = \dfrac{\theta}{\delta} = \dfrac{\delta_V - \delta_R}{\delta} \Rightarrow \omega = \dfrac{\mu_V - \mu_R}{\mu - 1}$ ... (24)

Illustration 24

Question: **Calculate the dispersive power (in multiple of 10^{-3}) of crown glass-prism from the following data for crown glass**

$\mu_V = 1.503$; $\mu_r = 1.497$

Solution: For crown glass

$\mu_V = 1.503$; $\mu_R = 1.497$

$\therefore \quad \mu_Y = \dfrac{\mu_V + \mu_R}{2} = \dfrac{1.503 + 1.497}{2} = 1.500$

Hence, the dispersive power of crown glass

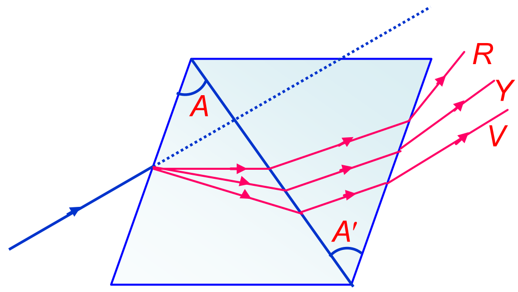
$\omega = \dfrac{\mu_V - \mu_r}{\mu_Y - 1} = \dfrac{0.006}{0.5} = 12 \times 10^{-3}$

$\therefore$ Required value is **12**

7.5 DISPERSION WITHOUT DEVIATION (DIRECT VISION SPECTROSCOPE)

Let two prisms of different material of dispersive powers ω and ω′ be placed in contact, with their bases turned opposite to each-other. Let A and A' be the angles of the first and the second prism respectively.

Let μ_V, μ_R and μ be the refractive indices of the material of the prism for violet, red and yellow colours respectively.



Let μ_V' μ_R', μ′ be the corresponding values of the material of the second prism.

Deviation of the mean ray by the first prism is

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

Deviation of the mean ray by the second prism is

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

Since the combination does not produce any deviation

$\delta + \delta' = 0$ or, $(\mu - 1)A + (\mu' - 1)A' = 0$

or, $$\frac{A'}{A} = -\frac{(\mu - 1)}{\mu' - 1)} \quad \text{... (25)}$$

The negative sign indicates that the two prisms are placed with their bases opposite to each-other.

NET ANGULAR DISPERSION

The angular dispersion produced by the first prism,

$\delta_V - \delta_R = (\mu_V - \mu_R)A$

The angular dispersion produced by the second prism,

$\delta_V' - \delta_R' = (\mu_V' - \mu_R')A'$

∴ Net angular dispersion

$= (\delta_V - \delta_R) + (\delta_V' - \delta_R')$

$= (\mu_V - \mu_R)A + (\mu_V' - \mu_R')A'$

$= A\left[(\mu_V - \mu_R) + (\mu_V' - \mu_R')\frac{A'}{A}\right]$

Substituting $\frac{A'}{A} = -\left(\frac{\mu - 1}{\mu - 1}\right)$ in the above equation,

Net angular dispersion $= A\left[\mu_V - \mu_R) - \frac{(\mu - 1)}{(\mu' - 1)} \times (\mu_V' - \mu_R')\right]$

$= (\mu - 1)A\left[\left(\frac{\mu_V - \mu_R}{\mu - 1}\right) - \left(\frac{\mu_V' - \mu_R'}{\mu' - 1}\right)\right]$

or, net angular dispersion = $(\mu - 1)A[\omega - \omega']$ **... (26)**

Illustration 25

Question: **Find the angle of the flint glass prism which should be combined with a crown glass prism of 6° so as to give dispersion but no deviation.**
For crown glass; $\mu_V = 1.520$; $\mu_R = 1.48$
For flint glass; $\mu_V' = 1.78$; $\mu_R' = 1.72$

Solution: For no deviation,

$$\frac{A'}{A} = -\left(\frac{\mu - 1}{\mu' - 1}\right)$$

or, $$A' = -\left(\frac{\mu - 1}{\mu' - 1}\right)A$$

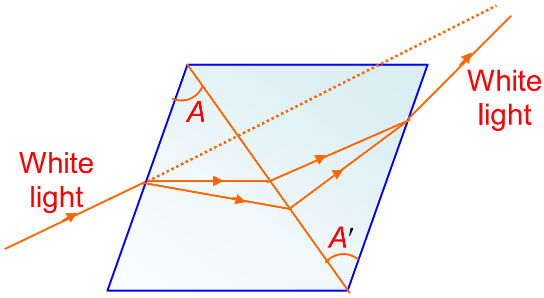
Now, $$\mu = \frac{\mu_V + \mu_R}{2} = \frac{1.520 + 1.48}{2} = 1.5$$

$$\mu' = \frac{\mu_V' + \mu_R'}{2} = \frac{1.78 + 1.72}{2} = 1.75$$

∴ $$A' = -\left(\frac{1.5 - 1}{1.75 - 1}\right) \times 6^0 = 4^0$$

7.6 DEVIATION WITHOUT DISPERSION (ARCHROMATIC COMBINATION OF PRISM)

Let two thin prisms of dispersive powers ω and ω' and angles A and A' placed in contact with their bases turned opposite to each-other.



Let μ_V, μ_R and μ be the refractive indices of the material of the first prism for violet, red and mean light respectively.

Let μ_V' μ_R' and μ' be the corresponding values for the material of the second prism.

Angular dispersion produced by the first prism

$(\delta_V - \delta_R) = (\mu_V - \mu_R) A$

The angular dispersion produced by the second prism.

$(\delta_V' - \delta_R') = (\mu_V' - \mu_R') A'$

Since the combination does not produce any dispersion

$$(\delta_V - \delta_R) + (\delta_V' - \delta_R') = 0$$

or, $A(\mu_V - \mu_R) + A'(\mu_V' - \mu_R') = 0$

or, $$\frac{A'}{A} = -\left(\frac{\mu_V - \mu_R}{\mu_V' - \mu_R'}\right) \quad \dots (27)$$

This is the condition for no dispersion or condition for achromatism.

The negative sign indicates that two prisms should be placed in opposite manner.

Another form:

We have

$$A(\mu_V - \mu_R) + A'(\mu_V' - \mu_R') = 0$$

or, $$\left(\frac{\mu_V - \mu_R}{\mu - 1}\right)(\mu - 1)A + \left(\frac{\mu_V' - \mu_R'}{\mu' - 1}\right) \times (\mu' - 1)A' = 0$$

But $(\mu - 1)A = \delta$ and $(\mu' - 1)A' = \delta'$, the deviations for mean light by the first and the second prism respectively.

Also, $\omega = \dfrac{\mu_V - \mu_R}{\mu - 1}$, the dispersive power of the first prism.

$\omega' = \left(\dfrac{\mu_V' - \mu_R'}{\mu' - 1}\right)$, the dispersive power of the second prism.

$\therefore$ $\delta\omega + \delta'\omega' = 0$

$\Rightarrow$ $$\frac{\omega}{\omega'} = -\frac{\delta'}{\delta} \quad \dots (28)$$

NET DEVIATION

The deviation suffered by the mean light through the first prism.

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

The deviation suffered by the mean light through the second prism

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

Net deviation $= \delta + \delta' = (\mu - 1)A + (\mu' - 1)A' = (\mu - 1)A\left[1 + \dfrac{(\mu' - 1)A'}{(\mu - 1)A}\right]$

$$= (\mu - 1)A\left[1 + \frac{(\mu' - 1)}{(\mu - 1)}\left(\frac{\mu_V - \mu_R}{\mu_V' - \mu_R'}\right)\right]$$

or, **Net deviation** $$= (\mu - 1)A\left[1 - \frac{\omega}{\omega'}\right] \quad \dots (29)$$

Illustration 26

Question: **Find the angle of a prism of dispersive power 0.020 and refractive index 1.60 to form an achromatic combination with the prism of angle 4° and dispersive power 0.040 having refractive index 1.75. Also calculate the resultant deviation.**

Solution: $\omega = 0.020$; $\mu = 1.60$; $\omega' = 0.040$; $\mu' = 1.75$

$A' = 4°$

For no dispersion

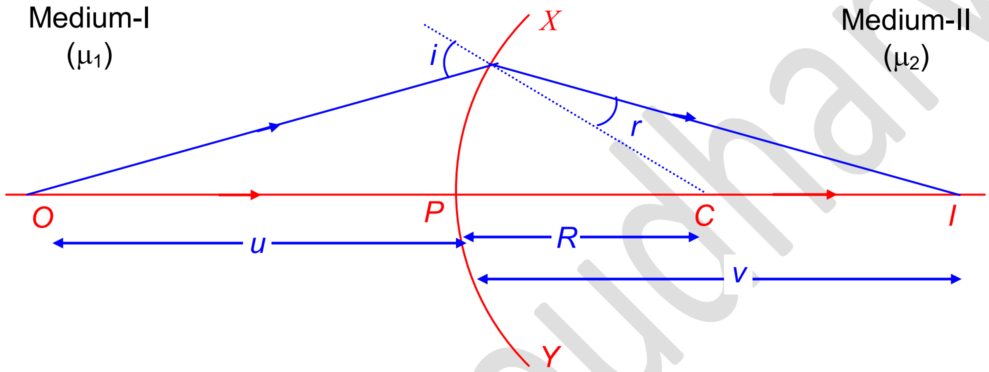
$\omega\delta + \omega'\delta' = 0$

or, $\omega(\mu - 1)A + \omega'(\mu' - 1)A' = 0$

or, $A = -\dfrac{\omega' A'(\mu' - 1)}{\omega(\mu - 1)} = \dfrac{0.040}{0.020} \times 4 \times \dfrac{0.75}{0.60} = -10°$

Net deviation

$= -10(1.60 - 1) + (4(1.75 - 1) = \mathbf{-3^0}$



Consider a spherical surface of radius R separating two media with refractive indices μ_1 and μ_2 ($\mu_2 > \mu_1$).

If u is the object distance and v is the image distance, for light rays going from medium I to the medium II,

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R} \quad \text{... (30)}$$

Also, the transverse magnification in this case is

$$m = \frac{I}{O} = \frac{\mu_1}{\mu_2}\frac{v}{u} \quad \text{... (31)}$$

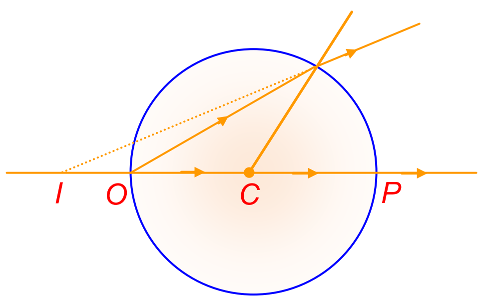
IMPORTANT POINTS

(i) These equations are valid for all refracting surfaces convex, concave or plane. In case of plane refracting surface, $R \to \infty$.

(ii) The rules for signs for a single refracting surface are same as for spherical mirrors.

Illustration 27

Question: **If a mark of size 0.2 cm on the surface of a glass sphere of diameter 10 cm and μ = 1.5 is viewed through the diametrically opposite point, where will the image be seen and of what size? (in mm)**



Solution: As the mark is on one surface, refraction will take place on the other surface (which is curved). Further refraction is taking place from glass to air. So,

$\mu_1 = 1.5$; $\mu_2 = 1$; $R = -5$ cm; $u = -10$ cm; $v = ?$

Using the formula

$$\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}, \text{ we have}$$

$$\frac{1}{v}-\frac{1.5}{(-10)}=\frac{1-1.5}{-5} \quad \text{or,} \quad v=-20 \text{ cm}$$

Hence, the image is at a distance of 20 cm from *P* towards *O*.
In case of refraction at a curved surface, we have

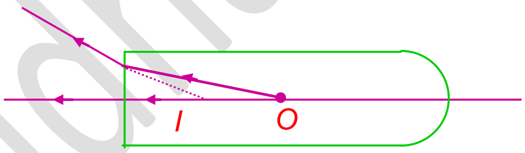
$$m=\frac{I}{O}=\frac{\mu_1}{\mu_2}\frac{v}{u}=\frac{(1.5)\times(-20)}{1\times(-10)}=+3$$

So, the image is virtual, erect and of size $I = m \times O = 3 \times 0.2 = 0.6$ cm = **60 mm**

Illustration 28

Question: **A transparent rod 40 cm long is cut flat at one end and rounded to a hemispherical surface 12 cm radius at the other end. A small object is embedded within the rod along its axis and half way between its ends. When viewed from the flat end of the rod, the object appears 10 cm deep. What is its apparent depth when viewed from the curved end?**

Solution: **Case I:** When the object is viewed from the flat surface:

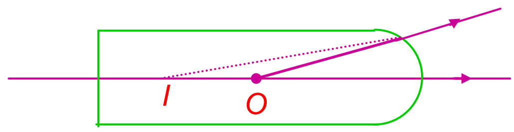


Real depth of the object = 20 cm
Apparent depth = 10 cm

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

we have, $\mu=\frac{20}{10}=2$

Case II: When the object is viewed through the curved surface:



Here the refraction is taking place at the single curved surface. So we will use

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

Here, $\mu_1 = 2$; $\mu_2 = 1$; $u = -20$ cm ; $v = ?$ $R = -12$ cm

$$\frac{1}{v}-\frac{2}{(-20)}=\frac{1-2}{-12}$$

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

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

$$\frac{1}{v}=\frac{10-12}{120}=\frac{-2}{120}$$

$\Rightarrow$ v = **60 cm**

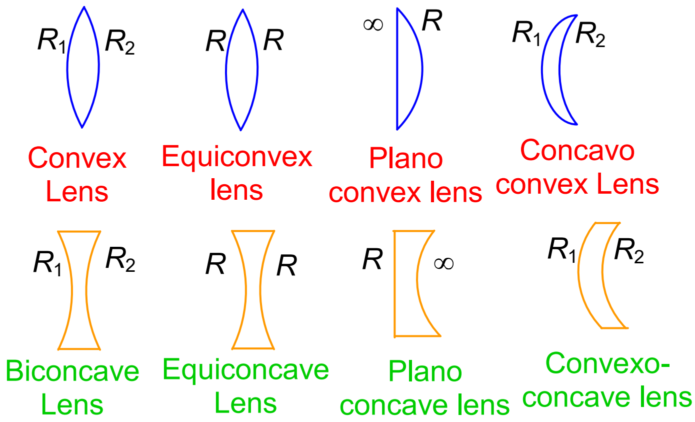
Hence the object appears 60 cm deep from the curve surface.

9 REFRACTION THROUGH THIN LENSES

Lens : A lens is a transparent medium bounded by two refracting surfaces such that at least one of the refracting surfaces is curved.

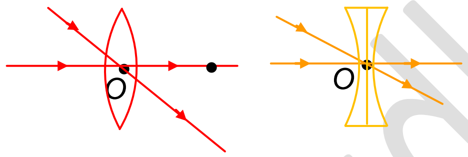
If the thickness of the lens is negligibly small in comparison to the object distance or the image distance, the lens is called thin. Here we shall limit our self to thin lenses.

Types of lenses: Broadly, lenses are of the following types:

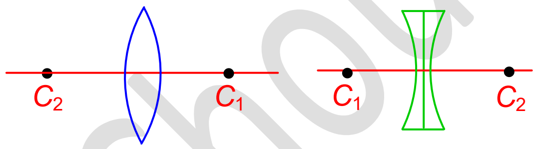


9.1 SOME IMPORTANT DEFINITIONS

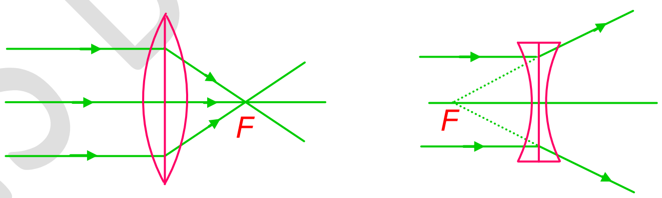
(i) Optical centre: Optical centre is a point for a given lens through which any ray passes undeviated.



(ii) Principal axis: The line joining the centres of curvature of the two bounding surfaces is called the principal axis.



(iii) Focus (F): A parallel beam of light, parallel and close to the principal axis of the lens after refraction passes through a fixed point on the principal axis (in case of convex lens) or appear to diverge from a point on the principal axis (in case of concave lens). This point is called the principal focus or focus of the lens. It is generally denoted by *F*.



Lenses have two foci because light can strike the lens from both the sides.

(iv) Focal length (*f*) : The distance between the optical centre and the focus of a lens is called its focal length. It is denoted by *f*.

9.2 SIGN CONVENTION

(i) Whenever and wherever possible, rays of light are taken to travel from left to right.

(ii) Distances are measured along the principal axis from the optical centre of the lens.

(iii) Distances measured along the principal axis in the direction of the incident rays are taken as positive while those measured against the direction of the incident rays are taken negative.

(iv) Distances measured above the principal axis are taken as positive and those measured below the principal axis are taken as negative.

Example

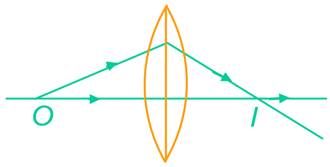


Figure I

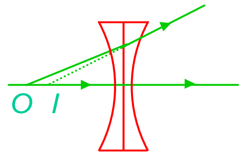


Figure II

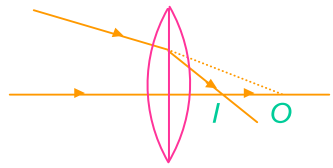
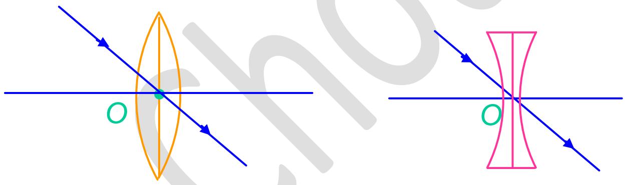


Figure III

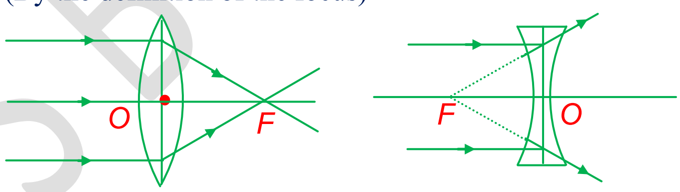
Figure	*u*	*v*	*f*	R_1	R_2
(i)	– ve	+ ve	+ ve	+ ve	– ve
(ii)	– ve	– ve	– ve	– ve	+ ve
(iii)	+ ve	+ ve	+ ve	+ ve	– ve

9.3 RULES FOR IMAGE FORMATION

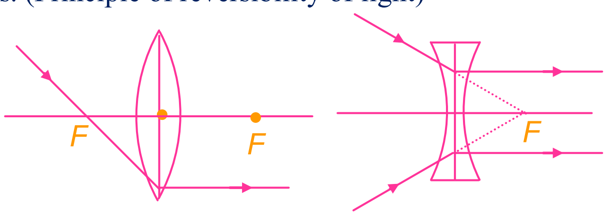
(i) A ray passing through the optical centre of the lens proceeds undeviated through the lens. (By the definition of optical centre)



(ii) A ray passing parallel to the principal axis after refraction through the lens passes or appear to pass through the focus. (By the definition of the focus)



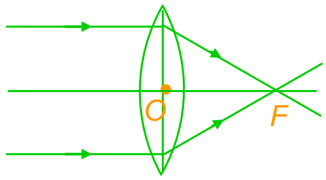
(iii) A ray through the focus or directed towards the focus, after refraction from the lens, becomes parallel to the principal axis. (Principle of reversibility of light)



Only two rays from the same point of an object are needed for image formation and the point where the rays after refraction through the lens intersect or appear to intersect, is the image of the object. If they actually intersect each-other, the image is real and if they appear to intersect the image is said to be virtual.

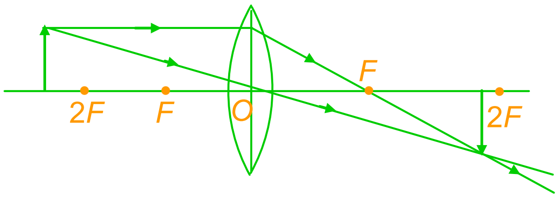
9.4 IMAGE FORMATION BY A CONVEX LENS OF THE LINEAR OBJECT

(i) When the object is at infinity:



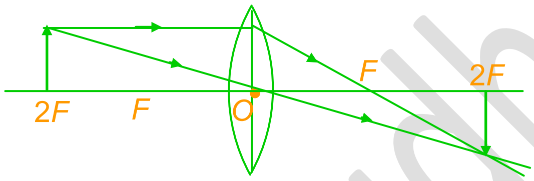
The image is formed at F. It is real, inverted and highly diminished.

(ii) When the object is beyond 2 F :



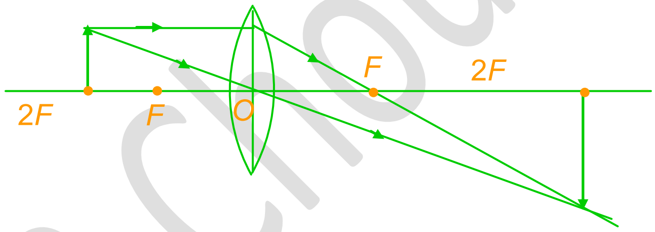
The image is formed between F and $2F$. It is real, inverted and diminished.

(iii) When the object is at $2F$:



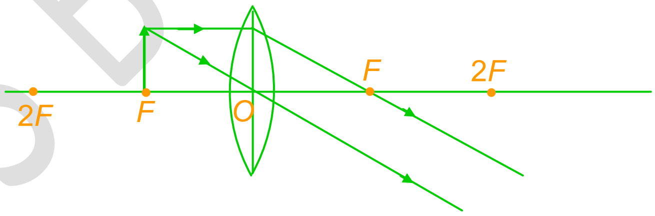
The image is formed at $2F$. It is real, inverted and of the same size.

(iv) When the object is between F and 2 F :



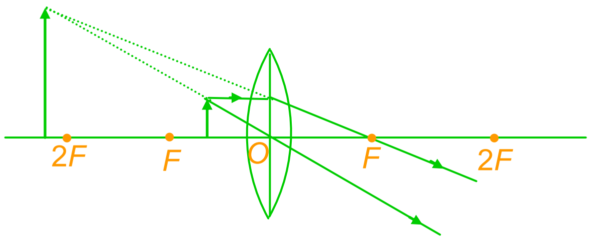
The image is formed beyond $2F$ (i.e., between $2F$ and ∞). It is real, inverted and enlarged.

(v) When the object is at F:



The image is formed at infinity. It is real, inverted and highly diminished.

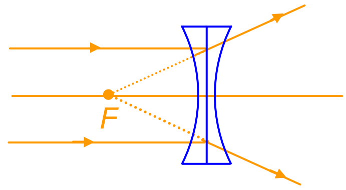
(vi) When the object is between F and O :



The image is on the same side as the object is. It is virtual, erect and magnified.

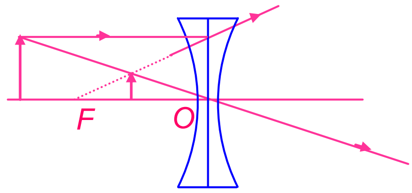
9.5 IMAGE FORMATION BY A CONCAVE LENS OF A LINEAR OBJECT

(i) When the object is at infinity:



The image is formed at the focus. It is virtual, erect and highly diminished.

(ii) When the object is infront of the lens:



The image is formed between F and the optical centre. It is virtual, erect and diminished.

9.6 LENS MAKERS FORMULA

The focal length (f) of a lens depends upon the refractive indices of the material of the lens and the medium in which the lens is present and the radii of curvature of both sides. The following relation giving focal length (f) is called as 'lens maker's formula.

$$\frac{1}{f} = \left(\frac{\mu}{\mu_0} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right], \qquad \text{... (32)}$$

where μ = refractive index of the material of the lens

μ_0 = Refractive index of the medium.

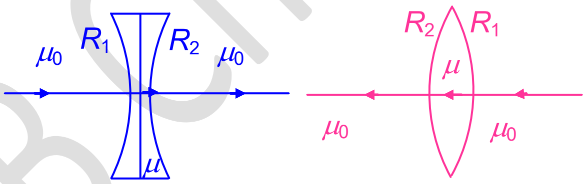
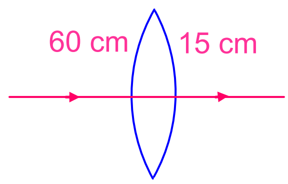


Illustration 29

Question: **Calculate the focal length of a biconvex lens in air if the radii of its surfaces are 60 cm and 15 cm. Refractive index of glass = 1.5**

Solution: Consider a light ray going through the lens as shown. It strikes the convex side of 60 cm radius and concave side of 15 cm radius while coming out.



$R_1 = +\,60$ cm

$R_2 = -\,15$ cm

$$\therefore \qquad \frac{1}{f} = \left[\frac{\mu}{\mu_0} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

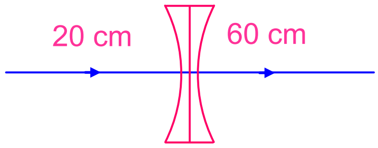
$$\text{or,} \qquad \frac{1}{f} = \left[\frac{1.5}{1} - 1\right]\left[\frac{1}{60} + \frac{1}{15}\right]$$

$\Rightarrow \qquad$ **$f = +\,24$ cm**

Illustration 30

Question: **Calculate the focal length of a concave lens in water ($\mu_w = \frac{4}{3}$) if the surface have radii equal to 60 cm and 20 cm. $\mu_g = 1.5$**

Solution: $R_1 = 20$ cm; $R_2 = +60$ cm



we have

$$\frac{1}{f} = \left(\frac{\mu}{\mu_0} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

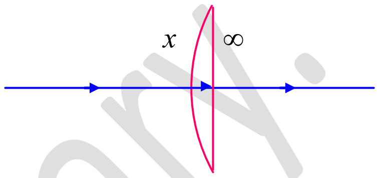
$$= \left[\frac{1.5}{4/3} - 1\right]\left[\frac{1}{-20} - \frac{1}{60}\right] \quad = \frac{1}{8} \times \left(\frac{-4}{60}\right) = -\frac{1}{120}$$

$\Rightarrow$ $f = -120$ **cm**

Illustration 31

Question: **A plane convex lens has a focal length 12 cm and is made up of glass with refractive index 1.5. Find the radius of curvature of its curved side.**

Solution: Let x = magnitude of the radius of curvature



Now, $R_1 = +x : R_2 = \infty \;\; = +12$ cm

We have $\frac{1}{f} = \left(\frac{\mu}{\mu_0} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

$$= \left(\frac{1.5}{1} - 1\right)\left[\frac{1}{x} - \frac{1}{\infty}\right] \qquad \text{or,} \quad \frac{1}{+12} = (.5) \times \frac{1}{x}$$

$\Rightarrow$ $x = 6$ **cm**

9.7 LENS FORMULA

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \qquad \ldots (33)$$

9.8 LINEAR MAGNIFICATION (*m*)

The ratio of the size of the image formed by a lens to the size of the object is called linear magnification produced by the lens. It is denoted by m.

If O and I are the sizes of the object and image respectively, then

$$m = \frac{I}{O} = \frac{v}{u} \qquad \ldots (34)$$

9.9 POWER OF A LENS

The power of a lens is defined as

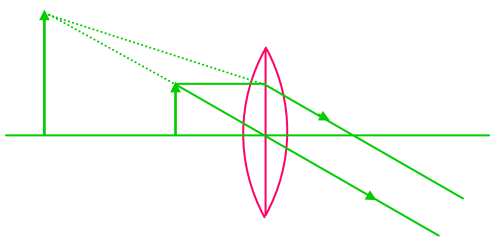
$$P = \frac{1}{f} \qquad \ldots (35)$$

where f must be expressed in metres. The SI unit of power of a lens is m^{-1}. It is also known as dioptre (D). The focal length of a convex lens is positive. So, the power of a convex lens is positive. The focal length of a concave lens is negative. So, the power fo a concave lens is negative.

Illustration 32

Question: **A magnifying lens has a focal length of 10 cm. (i) Where should the object be placed if the image is to be 30 cm from the lens? (ii) What will be the magnification?**

Solution: (i)



In case of magnifying lens, the lens is convergent and the image is erect, virtual and enlarged and between infinity and the object on the same side of the lens as shown in the above diagram.

So, here

$f = +10$ cm; $v = -30$ cm

Let 'x' be the object distance

Using lens formula

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

we have, $\frac{1}{-30} - \frac{1}{(-x)} = \frac{1}{10}$

$\Rightarrow \quad x = \mathbf{7.5\ cm}$

(ii) $m = \frac{I}{O} = \frac{v}{u} = \frac{-30}{-8.5} = +4$

Thus, the image is erect and virtual and four times of the object.

Illustration 33

Question: **An object 25 cm high is placed infront of a convex lens of focal length 30 cm. If the height of the image formed is 50 cm, find the distance between the object and the image?**

Solution: We have

$$|m| = \frac{I}{O} = \frac{v}{u} = \frac{50}{25} = 2$$

There are two possibilities

(i) If the image is inverted (i.e., real)

$$m = \frac{v}{u} = -2 \quad \text{or,} \quad v = -2u$$

Let x be the object distance in this case

We have

$$u = -x\ ;\ v = +2x\ ;\ f = +30 \text{ cm}$$

Using lens formula, we have

$$\frac{1}{2x} - \frac{1}{-x} = \frac{1}{30} \quad \text{or,} \quad x = 45 \text{ cm}$$

Hence, the distance between the object and the image = 45 + 90 = **135 cm.**

(ii) If the image is erect (i.e., virtual)

$$m = \frac{v}{u} = +2$$

Let x' be the object distance we have

$$u = -x'\ ;\ v = -2x'\ ;\ f = +30$$

Using the lens formula, we have $\frac{1}{-2x'} + \frac{1}{x} = \frac{1}{30}$

$\Rightarrow \quad x' = \mathbf{15\ cm}$

Hence, the distance between the object and the image = **15 cm**

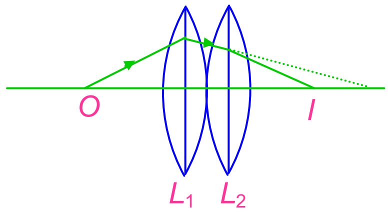
9.10 COMBINATION OF LENSES AND MIRRORS

When several lenses or mirrors are used co-axially, the image formation is considered one after another in steps. The image formed by the lens facing the object serves as object for the next lens or mirror; the image formed by the second lens (or mirror) acts as object for the third and so on. The total magnification in such situations will be given by

$$m = \frac{I}{O} = \frac{I_1}{O} \times \frac{I_2}{I_1} \times \ldots$$

or, $\quad m = m_1 \times m_2 \times m_3 \times \ldots\ldots \qquad \ldots (36)$

9.11 TWO THIN LENSES IN CONTACT



If two or more lenses of focal lengths f_1, f_2 and so on are placed in contact, then this combination can be replaced by a lens called **'equivalent lens'**. The focal length (F) of equivalent lens is given by

$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}+ \quad \ldots (37)$$

Also, $P = P_1 + P_2 + \ldots$ **… (38)**

If two thin lenses of focal lengths f_1 and f_2 are separated by a distance 'd', then the focal length of the equivalent lens is given by

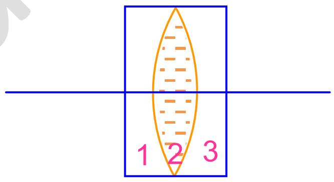
$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}-\frac{d}{f_1 f_2} \quad \ldots (39)$$

Also, $P = P_1 + P_2 - dP_1P_2$

Illustration 34

Question: **Two plano-concave lens of glass of refractive index 1.5 have radii of curvature 20 cm and 30 cm. They are placed in contact with curved surfaces towards each-other and the space between them is filled with a liquid of refractive index $\frac{4}{3}$. Find the focal length of the system.**

Solution: As shown in figure, the system is equivalent to combination of three lenses in contact,



i.e., $\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}+\frac{1}{f_3}$

By lens maker's formula $\frac{1}{f_1}=\left(\frac{3}{2}-1\right)\left[\frac{1}{\infty}-\frac{1}{20}\right]=\frac{1}{40}$ cm

$$\frac{1}{f_2}=\left(\frac{4}{3}-1\right)\left[\frac{1}{20}-\frac{1}{-30}\right]=\frac{5}{180} \text{ cm}$$

$$\frac{1}{f_3}=\left(\frac{3}{2}-1\right)\left[\frac{1}{-30}-\frac{1}{\infty}\right]=-\frac{1}{60} \text{ cm}$$

$\therefore$ $\frac{1}{F}=-\frac{1}{40}+\frac{5}{180}-\frac{1}{60}$

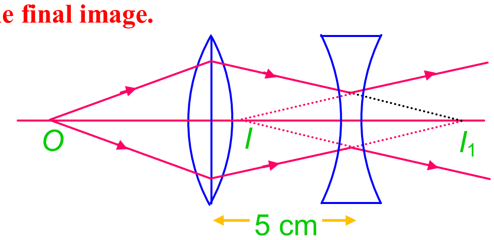
$\Rightarrow$ $F = $ **– 72 cm**

Thus, the system will behave as a concave lens of focal length 72 cm.

Illustration 35

Question: **Two thin lenses, both of 10 cm focal length- one convex and other concave, are placed 5 cm apart. An object is placed 20 cm in front of the convex lens. Find the nature and position of the final image.**

Solution:



For refraction at the convex lens, we have

$u = -20$ cm; $f_1 = +10$ cm; $v = v_1 = ?$

Using lens formula, we have

$$\frac{1}{v_1}-\frac{1}{(-20)}=\frac{1}{10}$$

⇒ $v_1 = 0 + 20$ cm

The convex lens produces converging rays trying to meet at I_1, 20 cm from the convex lens, i.e., 15 cm behind the concave lens.

I_1 will serve as a virtual object for the concave lens.

For refraction at the concave lens. We have

$u = +15$ cm; $v = ?$ $f = -10$ cm

Using lens formula, we have

$$\frac{1}{v}-\frac{1}{15}=-\frac{1}{10}$$

⇒ $v =$ **– 30 cm**

Hence the final image is virtual and is located at 30 cm to the left of concave lens.

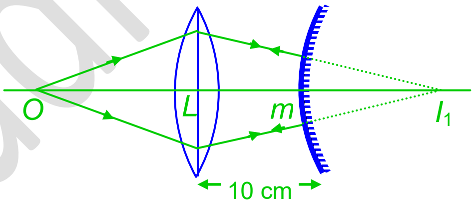
Illustration 36

Question: **A point object is placed at a distance of 12 cm on the axis of a convex lens of focal length 10 cm. On the other side of the lens, a convex mirror is placed at the distance of 10 cm from the lens such that the image formed by the combination coincides with the object itself. What is the focal length of the mirror?**

Solution: For the refraction at the convex lens, we have

$u = -12$ cm; $v = ?$ $f = +10$ cm

Using lens formula, we have



$$\frac{1}{v}-\frac{1}{(-12)}=\frac{1}{10}$$

or, $v = +60$ cm

Thus, in the absence of the convex mirror, convex lens will form the image I_1, at a distance of 60 cm behind the lens. As the mirror is at a distance of 10 cm from the lens, I_1 will be at a distance of (60 – 10) = 50 cm from the mirror, i.e., $MI_1 = 50$ cm.

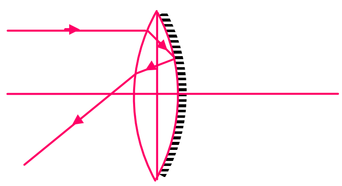
Now, as the final image I_2 is formed at the object itself, the rays after reflection from the mirror retraces its path, i.e., the rays on the mirror are incident normally, i.e., I_1 is the centre of the mirror so that

$R = MI_1 = +50$ cm

and $f = \frac{R}{2} = \frac{50}{2}$ = **+ 25 cm**

9.12 LENS WITH ONE SURFACE SILVERED

When one surface of a thin lens is silvered, the rays are reflected back at this silvered surface. The set up acts as a spherical mirror.



The focal length of the equivalent spherical mirror is given by

$$\frac{1}{f}=\Sigma\frac{1}{f_i}, \qquad \text{… (40)}$$

where f_i = focal length of the lens or mirror, to be repeated as many times as the refraction or reflection takes place.

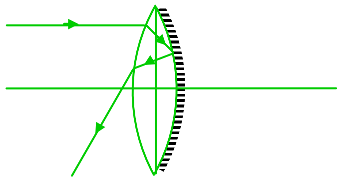
SIGN CONVENTION

In the above formula, the focal length of the converging lens or mirror is positive; and that of diverging lens or mirror is negative.

Illustration 37

Question: **One face of an equiconvex lens of focal length 60 cm made of glass (μ = 1.5) is silvered. Does it behave like a concave mirror or convex mirror?**

Solution: Let x be the radius of curvalue of each surface.



$$\frac{1}{60}=(1.5-1)\left[\frac{1}{x}-\frac{1}{-x}\right]$$

or, $$\frac{1}{60}=0.5\times\frac{2}{x}$$

⇒ $x = 60$ cm

Let 'f' be the focal length of the equivalent spherical mirror, Then

$$\frac{1}{f}=\frac{1}{f_l}+\frac{1}{f_m}+\frac{1}{f_l}$$

or, $$\frac{1}{f}=\frac{2}{f_l}+\frac{1}{f_m}$$

Here, $f_l = +60$ cm (convex lens)

$f_m = \frac{R}{2} = +30$ cm (concave mirror)

∴ $$\frac{1}{f}=\frac{2}{60}+\frac{1}{30}=\frac{2}{30}$$

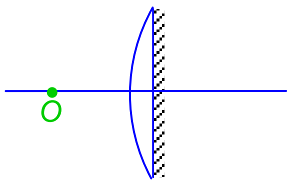
⇒ $f = $ **+ 15 cm**

The positive sign indicates that the resulting mirror is concave.

Illustration 38

Question: **The plane surface of a plano-convex lens of focal length 60 cm is silvered. A point object is placed at a distance 20 cm from the lens. Find the position and nature of the final image formed.**

Solution: Let f be the focal length of the equivalent spherical mirror.



we have $\frac{1}{f}=\frac{1}{f_l}+\frac{1}{f_m}+\frac{1}{f_l}$

or, $$\frac{1}{f}=\frac{2}{f_l}+\frac{1}{f_m}$$

Here, $f_l = +60$ cm

$f_m = \infty$

∴ $$\frac{1}{f}=\frac{2}{60}+\frac{1}{\infty}=\frac{1}{30}$$

or, $f = +30$ cm

The problem is reduced to a simple case where a point object is placed in front of a concave mirror.

Now, using the mirror formula

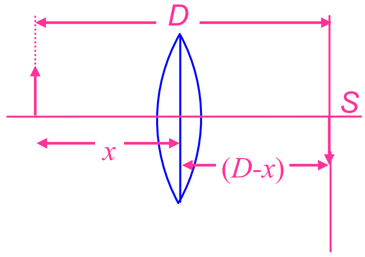
$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$, we have

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

⇒ $v = 60$ cm

The image is erect and virtual.

9.13 DISPLACEMENT METHOD



Let us consider a real object and a screen fixed at a distance D apart. A convex lens is placed between them.

Let x be the distance of the object from the lens when its real image is obtained on the screen.

We have , $u = -x$

$$v = +(D - x)$$

$$f = +f$$

Using lens formula, we have

$$\frac{1}{(D-x)} - \frac{1}{-x} = \frac{1}{f}$$

or, $$\frac{1}{(D-x)} + \frac{1}{x} = \frac{1}{f}$$

or, $$\frac{D}{(D-x)x} = \frac{1}{f}$$

or, $$x^2 - Dx + Df = 0$$

or, $$x = \frac{D \pm \sqrt{D^2 - 4Df}}{2} = \frac{D \pm \sqrt{D(D-4f)}}{2}$$

Now, there are three possibilities.

(i) If $D < 4f$; then in this case, x will be imaginary and so physically no position of lens is possible.

(ii) If $D = 4f$; then in this case, $x = \frac{D}{2} = 2f$. So only one position of the lens will be possible and in this situation.

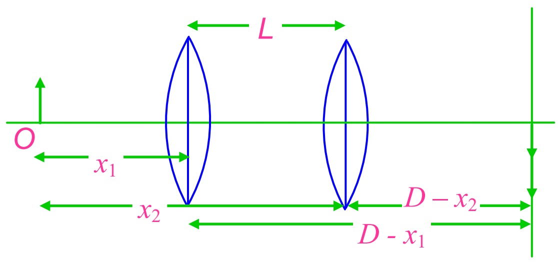
$$v = D - x = 4f - 2f = 2f \ (= x)$$

(iii) If $D > 4f$; in this situation both the roots of x will be real. Thus

$$x_1 = \frac{D - \sqrt{D(D-4f)}}{2}$$

and $$x_2 = \frac{D + \sqrt{D(D-4f)}}{2}$$

So if $D > 4f$, these are two positions of lens at distances x_1 and x_2 from the object for which real image is obtained on the screen. This method is called 'Displacement method' and is used in laboratory to determine the focal length of the convex lens.



In case of displacement method, if the distance between two positions of the lens is L, then

$$L = x_2 - x_1 = \sqrt{D(D-4f)}$$

or, $$L^2 = D^2 - 4Df$$

$$\Rightarrow \quad f = \frac{D^2 - L^2}{4D} \qquad \text{... (41)}$$

We have

$$L = (x_2 - x_1)$$

and $D = x_1 + x_2$

$\therefore \quad x_1 = \dfrac{D-L}{2};\ x_2 = \dfrac{D+L}{2}$

Now, $x_1 + x_2 = \dfrac{D-L}{2} + \dfrac{D+L}{2} = D$

$\Rightarrow \quad x_1 = D - x_2$ & $x_2 = D - x_1$

Hence object and image distances are interchanged in the two positions of the lens. Let the magnification be m_1 and m_2.

$\therefore \quad m_1 = \dfrac{(D-x_1)}{-x_1} = \dfrac{x_2}{x_1}$

and $m_2 = \dfrac{(D-x_2)}{-x_2} = -\dfrac{x_1}{x_2}$

Now,

$$m_1 m_2 = \frac{x_2}{-x_1} \times \frac{-x_1}{x_2} = 1$$

or, $\dfrac{I_1}{O}\dfrac{I_2}{O} = 1$

$\Rightarrow$ **O = object size = $\sqrt{I_1 I_2}$** **… (42)**

i.e., the size of the object is the geometric mean of the sizes of the two images.

Question: **An object is kept at a distance of 100 cm from a screen. A convex lens placed between them produces a real & magnified image on the screen. If the lens is shifted 30 cm towards the screen, real image is again obtained. Find the focal length of the lens. Also calculate the size of the object if the image sizes are 16 mm and 9 mm respectively.**

Solution: Here, $D = 100$ cm ; $L = 30$ cm

$\therefore \quad f = \dfrac{D^2 - L^2}{4D} = \dfrac{(100)^2 - (30)^2}{4(100)} = \dfrac{91}{4}$ cm

$I_1 = 16$ mm; $I_2 = 9$ mm

$\therefore \quad$ object size $= \sqrt{I_1 I_2} = \sqrt{16 \times 9}$ = **12 mm**

10 THE COMPOUND MICROSCOPE

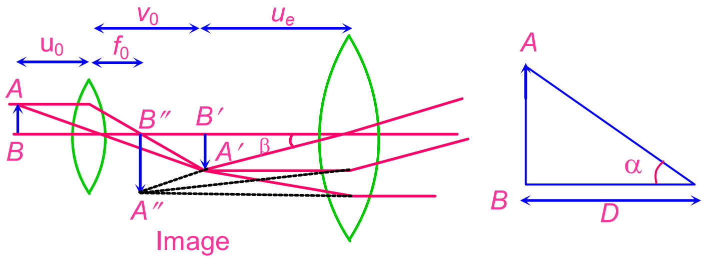
When a greater magnification than is obtained from a simple magnifier is needed, we usually use compound microscope.

10.1 CONSTRUCTION

A compound microscope consists of two convex lenses co-axially separated by some distance. The one facing the object is called the objective and the one close to the eye is called the eye piece or ocular. The objective has a smaller aperture and smaller focal length than those of the eye piece.

10.2 FORMATION OF IMAGE

The object AB to be viewed is placed slightly beyond the principal focus F_0 of the objective. The objective forms an enlarged, real inverted image $A'B'$. This image works as the object for the eyepiece. A very much enlarged virtual image $A''B''$ is formed by the eyepiece.



10.3. ANGULAR MAGNIFICATION OR MAGNIFYING POWER

Angular magnification of a compound microscope is defined as the ratio of the angle β subtended by the final image at the eye to the angle α subtended by the object seen directly, when it is placed at the least distance of distinct vision (D)

Angular magnification $m = \frac{\beta}{\alpha} = \frac{A'B'}{u_e} \times \frac{D}{AB}$

$$= \left(\frac{A'B'}{AB}\right) \times \left(\frac{D}{u_e}\right)$$

Also from figure $\frac{A'B'}{AB} = \frac{-v_0}{u_0}$

Now $\frac{D}{u_e}$ is the magnifying power of the eye piece treated as a simple microscope. This is equal to $\frac{D}{f_e}$ in normal adjustment (image at infinity) and $1 + \frac{D}{f_e}$ for the adjustment when the image is formed at the least distance for clear vision i.e. at *D*.

Thus, the magnifying power of the compound microscope is

$m = \frac{v}{u}\left(\frac{D}{f_e}\right)$ for normal adjustment and

$m = \frac{v}{u}\left(1 + \frac{D}{f_e}\right)$ for the adjustment when the final image is formed at the least distance of clear vision. Since the object is placed very close to the principal focus of the objective, therefore u_0 is nearly equal to f_0. Moreover, the focal length of the eyepiece is small. So, the image A′ B′ is formed very close to the eye piece. So v_0 is nearly equal to the length *L* of the microscope tube (separation between the two lenses)

$m = -\frac{L}{f_0}\left(1 + \frac{D}{f_e}\right)$ for image at *D* and

$m = -\frac{L}{f_0} \times \frac{D}{f_e}$ for normal adjustment

10.4 TELESCOPE

To look at distant objects such as a star, a planet or a distant tree etc. we use another instrument called a telescope.

(A) Astronomical refracting telescope: It consists of an objective lens system and an eyepiece. The one facing the distant object is called the objective and has a large aperture and a large focal length. The other is called the eyepiece, as the eye is placed close to it. It has a smaller aperture and a smaller focal length. The lenses are fixed in tube.

Light from the distant object enters the objective and a real image is formed within the tube. The eye piece used again as a simple magnifier, leaves the final image inverted.

(i) When the final image is formed at infinity (normal adjustment)

From the figure, we see that the objective forms image A′ B′ of an object *AB* placed at a distant place. If the point *P* is on the principal axis, the image point *P* is at the second focus of the objective. For normal adjustment image is formed at infinity.

Hence $u_e = f_e$

Angular magnification $m = \frac{\beta}{\alpha} = -\frac{A'B'/u_e}{A'B'/f_0} = -\frac{f_0}{u_e} = -\frac{f_0}{f_e}$

Where f_0 = focal length of objective

f_e = focal length of eye piece

(ii) When the final image is formed at the least distance of distinct vision. (near point)

If the telescope is adjusted, so that the final image is formed at the near point of the eye, the angular magnification is further increased.

Angular magnification $\Rightarrow -\frac{f_0}{v_e} = m$

But, for near point adjustment $v_e = -D$

So by lens formula

$$-\frac{1}{D} - \frac{1}{-u_e} = \frac{1}{f_e}$$

$$\frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{D} = \frac{f_e + D}{f_e D}$$

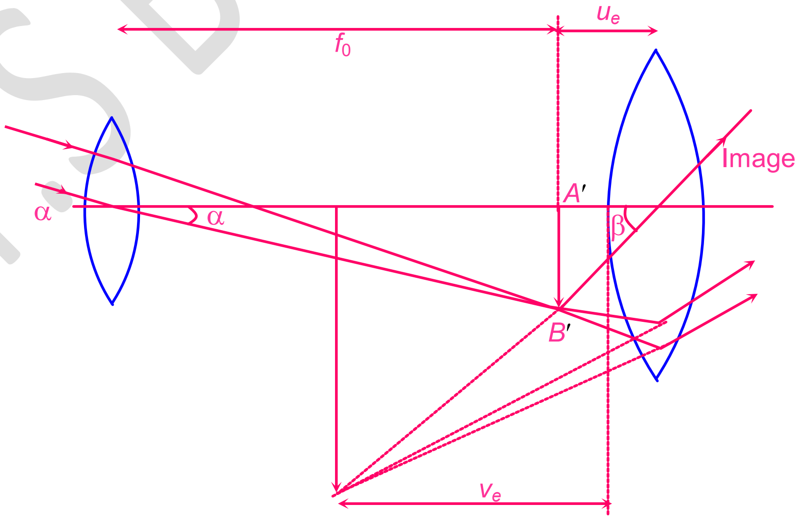
$$m = -\frac{f_0(f_e + D)}{f_e D} = -\frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$$

Length of telescope:

From the given figure, we see that the length of the telescope is $L = f_0 + u_e$

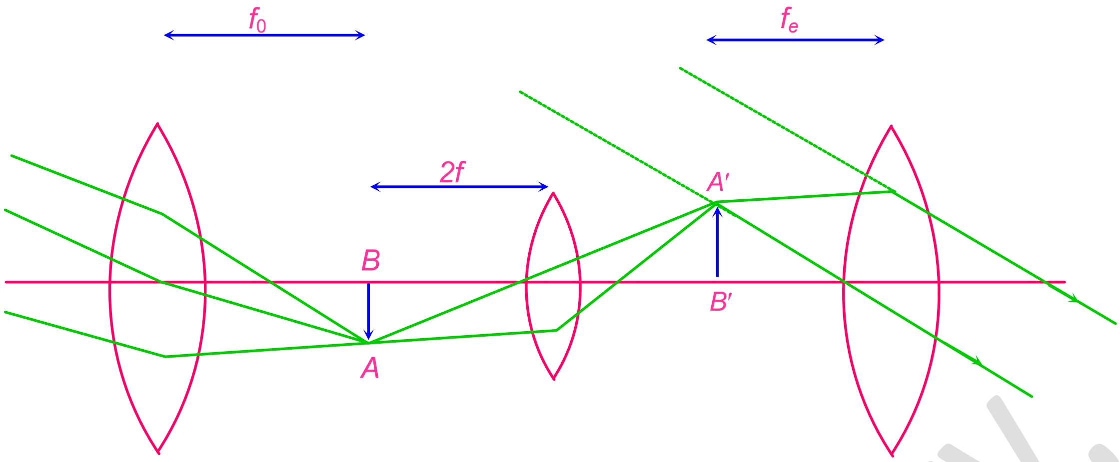
For normal adjustment $L = f_0 + f_e$

For near point adjustment $L = f_0 + u_e = f_0 + \frac{f_e D}{f_e + D}$



10.5 TERRESTRIAL TELESCOPE

The astronomical telescope produces an inverted image of an object viewed through it. So it is unsuitable for terrestrial use. The astronomical telescope can be converted into terrestrial telescope by introducing a converging lens between the objective and the eyepiece. This additional lens is called an erecting lens.



The erecting lens of focal length f is introduced in such a manner that the focal plane of the objective is a distance $2f$ away from this lens. An erect image $A'B'$ of same size is made by the new lens introduced. The length of the tube for normal adjustment is

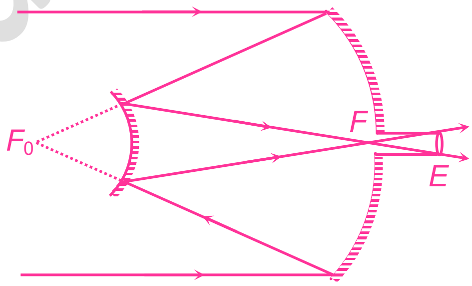
$$L = f_0 + 4f + f_e$$

Magnifying power $m = \frac{f_0}{f_e}$ for normal adjustment

$$= \frac{f_0}{f_e}\left(1 + \frac{v_e}{D}\right)$$

10.6 REFLECTING TELESCOPE (CASSEGRAIN)

Telescope with mirror objectives are called reflecting telescopes. The objective O of the telescope is a large parabolic mirror with a hole (small circular aperture) in the centre. A small convex parabolic mirror is placed in front of the objective. A convex lens acts as the eye piece. The eyepiece has a large focal length in a short telescope.



A beam of light parallel to the axis of the telescope from some distant light source is incident on the objective. The objective converges this light towards its principle focus F_0. The reflected beam is intercepted by the convex mirror. The convex mirror forms an inverted image at F. This inverted image is seen through the eye piece E.

Magnification of reflecting telescope $= \frac{f_0}{f_e}$

Where f_0 = focal length of objective mirrors
f_e = focal length of objective eye lens.

Advantages of reflecting telescope

(1) There is no chromatic aberration, because it is based on reflection.
(2) Spherical aberration can be removed by choosing parabolic reflector.
(3) Mechanical support required is much less of a problem since the mirror weighs much less than a lens of equivalent optical quality and can be supported over its entire back surface.

Illustration 40

Question: **An astronomical telescope consists of two thin lenses set 36 cm. apart and has a magnifying power of 8 in normal adjustment. Calculate the focal lengths of lenses.**

Solution: In the normal adjustment, the final image is formed at infinity.

$\therefore \quad f_0 + f_e = 36 \quad \ldots$ (i) and $-\frac{f_0}{f_e} = -8$

$\therefore$ $f_0 = 8f_e$ … (ii)

$\therefore$ From equation (1) and (2), we have

$8f_0 + f_e = 36$

$\therefore$ $9f_e = 36$

$\therefore$ $f_e = 4$ cm

and $f_0 = 8 \times 4 =$ **32 cm**

Illustration 41

Question: **A compound microscope has a magnification of 30. The focal length of its eye piece is 5 cm. Assuming the final image is to be formed at the least distance of distinct vision 25 cm, calculate the magnification produced by the objective.**

Solution: Given, $M = 30$, $f_e = 5$ cm, $D = 25$ cm

From $M = M_0 \times m_e \times \left(\frac{D}{f_e} + 1\right) = m_0\left(1 + \frac{25}{5}\right)$

$\therefore$ $30 = 60\, m_0$

$\therefore$ $m_0 = \frac{30}{6} =$ **5**

Illustration 42

Question: **A reflecting type telescope has a large mirror with a radius of curvature equal to 80cm. What is the magnifying power of telescope if the eye piece used has a focal length of 1.6 cm?**

Solution: Given, $R = 80$ cm

$\therefore$ $f_0 = \frac{80}{2} = 40$ cm

$f_e = 1.6$ cm

$\therefore$ $M = \frac{f_0}{f_e} = \frac{40}{1.6} =$ **25**

PROFICIENCY TEST– I

The following questions deal with the basic concepts of this section. Answer the following briefly. Go to the next section only if your score is at least 80%. Do not consult the Study Material while attempting these questions.

1. When light enters from air to water, then what will be the effect on velocity, frequency and wavelength of light

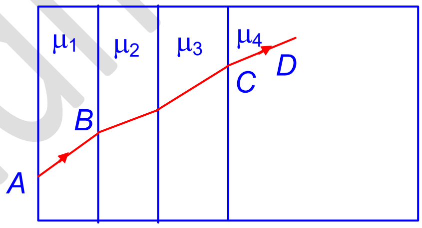
2. Two mirrors are kept at 60^0 to each other and a body is placed in the middle. The total number of images formed is

3. Yellow light is refracted through a prism producing minimum deviation. If i_1 and i_2 denote the angels of incidence and emergence for the prism, if $i_1 = 30^0$ then what is the value of i_2?

4. A convex mirror has a focal length $f = 30$ cm, A real object placed at a distance f in front of it from the pole at what distance from mirror image will formed?

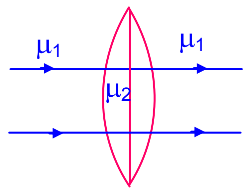
5. What is the time taken (in picoseconds) to cross a glass of thickness 4 mm and μ=3 by light

6. 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 diagram. The surfaces of all media are parallel. Find the ratio $\frac{\mu_4}{\mu_1}$ for the emergent ray CD to be parallel to AB.



7. The angel of a prism is 30^0. The rays incident at an angle of 60^0 at one refracting face suffer a deviation at 30^0. Then what will be the angle of emergence

8. What is the ratio of the refractive indices μ_1 to μ_2, if the behaviour of light rays is as shown in the figure?



9. What will be the power (in Dioptre) of a system consisting of a thin convex lens and a thin concave lens of the same focal length $f = 20$ cm (i) when they are put in contact (ii) when they are separated by a distance $d = f$ (iii) when they are separated by a distance $d = 3f$?

10. What is the equivalent focal length of a plano-convex lens of radius of curvature $R = 30$ cm and focal length $f = 30$ cm when
(i) its curved surface is silvered (ii) its plane surface is silvered

ANSWERS TO PROFICIENCY TEST– I

1. Frequency remain same velocity and wavelength will decrease

2. 5

3. $i_2 = 30^0$

4. 15 cm

5. 40 Ps

6. 1

7. $e = 0^0$

8. 1

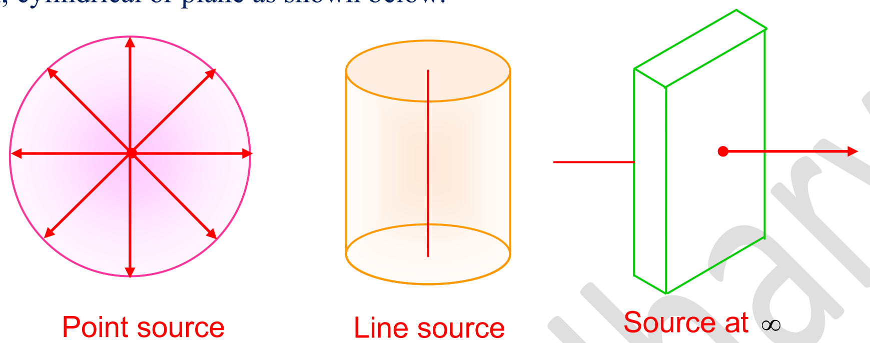
9. (i) zero
(ii) convergent lens of power $1/f = 5$ D
(iii) convergent lens with power $3/f = 15$ D

10. (i) 7.5 cm, mirror is concave
(ii) 15 cm, mirror is concave

11 WAVE OPTICS

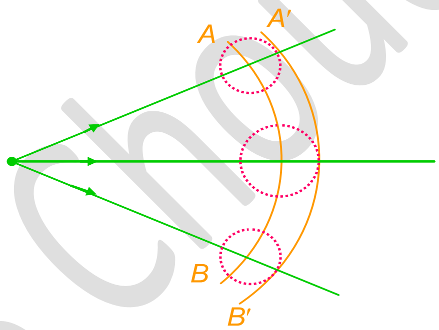
Wave optics concerns with the explanation of the observed phenomena such as interference. In wave optics, light is treated as a wave. Huygen was the first scientist who assumed that a body emits light in the form of waves. In his wave theory, Huygen used a term– the wave front. First of all, we will understand what he meant by the term, the wave front.

(i) **Wave front:** The locus of all the particles of the medium vibrating in the same phase at a given instant is called wavefront. The shape of the wavefront depends on the source producing the waves and is usually spherical, cylindrical or plane as shown below.



(ii) **Ray:** In a homogeneous medium, the wavefront is always perpendicular to the direction of wave propagation. Hence, a line drawn normal to the wavefront gives the directions of propagation of a wave and is called a ray.

11.1 HUYGEN'S WAVE THEORY



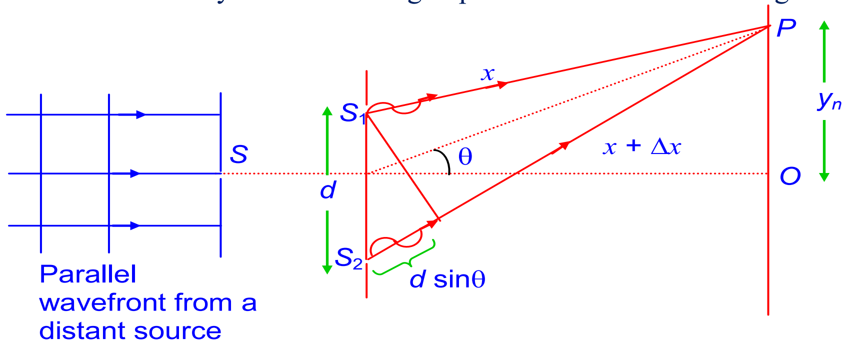
Each point of a source of light is a centre of disturbance from where waves spread in all directions. Each point on a wavefront is a source of new disturbance, called secondary wavelets. These wavelets are spherical and travel with speed of light in that medium. The forward envelope of the secondary wavelets at any instant gives the new wavefront.

12 INTERFERENCE

The terms interference in general, refers to any situation where two or more waves overlap each-other in the same region of space. But usually, interference refers to the superposition of two coherent waves of same frequency moving in the same direction.

12.1 YOUNG'S DOUBLE SLIT EXPERIMENT

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



Two slits S_1 and S_2 are made in an opaque screen, parallel and very close to each-other. These two are illuminated by another narrow slit S which in turn is lit by a bright source. Light wave spread out from S and fall on both S_1 and S_2. Any phase difference between S_1 and S_2 is unaffected and remain constant. The light waves going from S_1 and S_2 to any point P on the screen interfere with each other. At some point the waves superpose in such a way that the resultant intensity is greater than the sum of the intensities due to separate waves (CONSTRUCTIVE INTERFERENCE) while at some other point, it is lesser than the sum of the separate intensities (DESTRUCTIVE INTERFERENCE). Thus the overall picture is a pattern of dark and bright bands known as fringe pattern. The dark bands are known as dark fringes and the bright bands are known as bright fringes.

12.2 THEORY OF INTERFERENCE

Let the two waves each of angular frequency ω from sources S_1 and S_2 reach the point P. If the waves have amplitudes A_1 and A_2 respectively. then

$$y_1 = A_1 \sin(\omega t - kx) \quad \ldots \text{(i)}$$

and, $y_2 = A_2 \sin(\omega t - k(x + \Delta x))]$

or, $y_2 = A_2 \sin[\omega t - kx - \phi]$ … (ii)

where $\phi = k\,\Delta x = \frac{2\pi}{\lambda}(\Delta x)$ … (iii)

So, by the principle of superposition, the resultant wave at P will be

$$y = y_1 + y_2 = A_1 \sin(\omega t - kx) + A_2 \sin(\omega t - kx - \phi)$$

or, $y = [A_1 + A_2 \cos\phi) \sin[\omega t - kx] - [A_2 \sin\phi] \cos(\omega t - kx)$ … (iv)

Let $A_1 + A_2 \cos\phi = A \cos\alpha$

$A_2 \sin\phi = A \sin\alpha$

So, $A^2[\cos^2\alpha + \sin^2\alpha] = (A_1 + A_2\cos\phi)^2 + (A_2 \sin\phi)^2$

or, $A^2 = A_1^2 + A_2^2 + 2A_1A_2\cos\phi$

and $\alpha = \tan^{-1}\left[\frac{A_2 \sin\phi}{A_1 + A_2\cos\phi}\right]$

Hence, equation (iv) becomes

$$y = A \sin(\omega t - kx)\cos\alpha - A\cos(\omega t - kx)\sin\alpha$$

or, $y = A \sin(\omega t - kx - \alpha)$ … (v)

From above equation, it is clear that in case of superposition of two waves of equal frequencies propagating almost in the same direction, resultant is harmonic wave of same frequency ω and wavelength ($\lambda = \frac{2\pi}{k}$) but amplitude

$A^2 = A_1^2 + A_2^2 + 2A_1A_2\cos\phi$

Now as intensity of wave is given by

$$I = \frac{1}{2}\rho v\omega^2A^2 = KA^2 \quad [K = \frac{1}{2}\rho v\omega^2]$$

So the intensity of the resultant wave

$$I = K[A_1^2 + A_2^2 + 2A_1A_2\cos\phi]$$

or, $\boldsymbol{I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi}$ **… (43)**

$[\text{As } I_1 = KA_1^2;\ I_2 = KA_2^2]$

12.3 CONDITION FOR CONSTRUCTIVE INTERFERENCE

Intensity will be maximum when

$\cos\phi = \text{maximum} = 1$

$\Rightarrow$ $\boldsymbol{\phi = 0, \pm 2\pi, \pm 4\pi \ldots}$ **… (44)**

or, $\phi = \pm 2\pi n$

Where $n = 0, 1, 2, \ldots$

Now, $\frac{2\pi}{\lambda}(\Delta x) = \Delta\phi = \pm 2\pi n$

or, $\Delta x = \pm n\lambda$, where n = 0, 1, 2, **… (45)**

and, $I_{max.} = I_1 + I_2 + 2\sqrt{I_1 I_2}$

or, $I_{max.} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$

$\propto (A_1 + A_2)^2$

12.4 CONDITION FOR DESTRUCTIVE INTERFERENCE

Intensity will be minimum when

$\cos\phi = \text{minimum} = -1$

i.e., $\phi = \pm\pi, \pm 3\pi, \pm 5\pi$

or, $\phi = \pm(2n-1)\pi$, with $n = 1, 2, 3 \ldots$ **… (46)**

or, $\frac{2\pi}{\lambda}(\Delta x) = \pm(2n-1)\pi \; [\because \Delta\phi = \frac{2\pi}{\lambda}(\Delta x)]$

or, $\Delta x = \pm(2n-1)\frac{\lambda}{2}$ with $n = 1, 2, \ldots$ **… (47)**

also, $I_{min} = \left(\sqrt{I_1} \sim \sqrt{I_2}\right)^2$

$\propto (A_1 \sim A_2)^2$

Illustration 43

Question: **Two sources of intensity I and $4I$ [$I = 1 \text{w/m}^2$] are used in an interference experiment. Find the intensity at a point where the waves from the two sources superimpose with a phase difference of (i) zero (ii) $\frac{\pi}{2}$ (iii) π**

Solution: In case of interference,

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

(i) As $\phi = 0$, $\cos\phi = 1$

$\therefore I = 4I + I + 2\sqrt{4I \times I} \times 1 = 9I = \mathbf{9\ w/m^2}$

(ii) As $\phi = \frac{\pi}{2}$, $\cos\phi = 0$

$\therefore I = 4I + I + 2\sqrt{4I \times I} \times 0 = 5I = \mathbf{5\ w/m^2}$

(iii) As $\phi = \pi$ $\cos\phi = -1$

$\therefore I = 4I + I + 2\sqrt{4I \times I} \times -1 = I = \mathbf{1\ w/m^2}$

Illustration 44

Question: **In Young's experiment, the interference pattern is found to have an intensity ratio between the bright and the dark fringes as *I*. What is the ratio of**
(i) intensities (ii) amplitudes of the two interfering waves?

Solution: In case of interference,

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

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

and $I_{min} = I_1 + I_2 - 2\sqrt{I_1 I_2} = \left(\sqrt{I_1} \sim \sqrt{I_2}\right)^2$

According to given problem,

$$\frac{I_{max}}{I_{min}} = \frac{(\sqrt{I_1}+\sqrt{I_2})^2}{(\sqrt{I_1}-\sqrt{I_2})^2} = \frac{9}{1}$$

or, $$\frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}-\sqrt{I_2}} = \frac{3}{1}$$

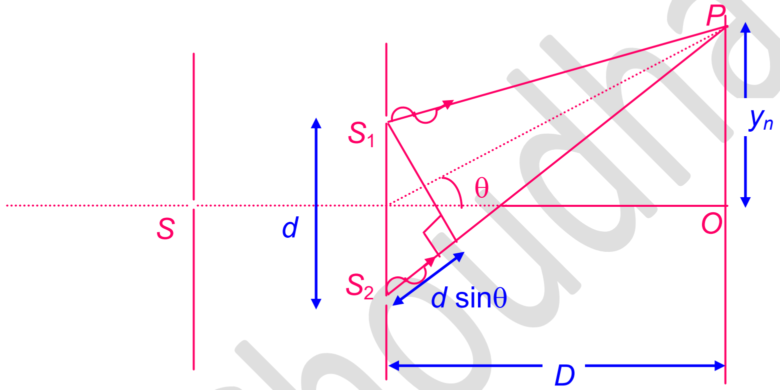
By componendo and dividendo, we have

$$\frac{\sqrt{I_1}}{\sqrt{I_2}} = \frac{3+1}{3-1} \qquad \text{or,} \quad \frac{I_1}{I_2} = \mathbf{4}$$

(b) As for a wave, $I \propto A^2$

$$\frac{I_1}{I_2} = \left[\frac{A_1}{A_2}\right]^2 = 4 \quad \text{or,} \quad \frac{A_1}{A_2} = \mathbf{2}$$

12.5 LOCATION OF BRIGHT FRINGES



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

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

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

Thus

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

or, $$p = d\sin\theta = d\left(\frac{y_n}{D}\right) \text{ for } n^{th} \text{ maxima,}$$

or, $$p = n\lambda$$

or, $$d\left(\frac{y_n}{D}\right) = n\lambda$$

or, $$y_n = n\lambda\frac{D}{d} \quad \text{where } n = 0, 1, 2, \ldots \qquad \ldots (48)$$

12.6 LOCATION OF DARK FRINGES

For n^{th} minima, we have

$$p = (2n-1)\frac{\lambda}{2} \qquad \text{or,} \quad d\left(\frac{y_n}{D}\right) = (2n-1)\frac{\lambda}{2}$$

$$\therefore \quad y_n = (2n-1)\frac{\lambda D}{2d} \quad \text{where } n = 1, 2, 3 \ldots \qquad \ldots (49)$$

12.7 FRINGE WIDTH (ω)

The separation between two consecutive dark (or bright) fringes is known as fringe width (ω).

∴ $\omega = y_{n+1} - y_n = (n+1)\dfrac{\lambda D}{d} - \dfrac{n\lambda D}{d}$

⇒ $\omega = \dfrac{\lambda D}{d}$ … (50)

Angular fringe width or angular separation between fringes is

$\theta = \dfrac{\omega}{D}$

⇒ $\theta = \dfrac{\lambda}{d}$ … (51)

Illustration 45

Question: **In Young's double slit experiment, the angular width of a fringe formed on a distant screen is 0.1°. The wavelength of the light used is 3140 Å. The spacing between the slits is $x \times 10^{-5}$ m. Find x?**

Solution: Angular width $= \dfrac{\omega}{D} = \dfrac{\lambda}{d}$

⇒ $\dfrac{\lambda}{d} = \dfrac{0.1\pi}{180}$

⇒ $d = \dfrac{180 \times 3140 \times 10^{-10}}{0.1\,\pi} = 18 \times 10^{-5}$ m

∴ x = **18**

Illustration 46

Question: **A double slits arrangement produces fringes for λ = 5890 Å that are 4° apart. what is the angular width if the entire arrangement is immersed in water? ($\mu_W = 4/3$)**

Solution: Let θ° be the angular width in water. We know

angular width $= \dfrac{\lambda}{d}$

⇒ angular width α λ

$\dfrac{\theta\pi}{180} \times \dfrac{180}{4\pi} = \dfrac{\lambda_{water}}{\lambda_{air}}$ or, $\dfrac{\theta}{0.4} = \dfrac{\lambda_W}{\lambda_a}$ … (i)

Now, $_a\mu_W = \dfrac{\lambda_a}{\lambda_W}$ ⇒ $\dfrac{\lambda_a}{\lambda_W} = 4/3$

Hence from equation (i), we have

$\dfrac{\theta}{4} = \dfrac{3}{4}$ ⇒ θ = **3°**

Illustration 47

Question: **A beam of light constituting of two wavelengths 6500 Å and 5200 Å is used to obtain interference fringes in a *YDSE*.**

(i) The distance of the third bright fringe on the screen from the central maximum for the wavelength of 6500 Å is y × 10^{-5} m. The value of *y* is

(ii) The least distance from the central maximum where the bright fringes due to both the wavelengths coincide is z × 10^{-5} m. The value of *z* is

The distance between the slits is 2 mm and the distance between the plane of the slits and the screen is 120 cm.

Solution: (i) D = 120 cm; d = 0.2 cm

Let $\lambda_1 = 6500$ Å; $\lambda_2 = 5200$ Å

Distance of the third bright fringe $= \dfrac{3\lambda D}{d} = \dfrac{3 \times 120 \times 6500 \times 10^{-8}}{0.2} = 117 \times 10^{-5}$ m

$\therefore$ $y = \mathbf{117}$

(ii) Let m^{th} bright fringe due to λ_1 and the n^{th} bright fringe due to λ_2 coincide at a distance x from the central maximum.

$\Rightarrow$ $x = \dfrac{mD\lambda_1}{d}$ and $x = \dfrac{nD\lambda_2}{d}$

$\therefore$ $m\lambda_1 = n\lambda_2 \Rightarrow 6500\,m = 5200\,n$

$\therefore$ $\dfrac{m}{n} = \dfrac{4}{5}$

$\Rightarrow$ 4^{th} bright fringe due to λ_1 coincides with 5^{th} bright fringe due to λ_2 at distance

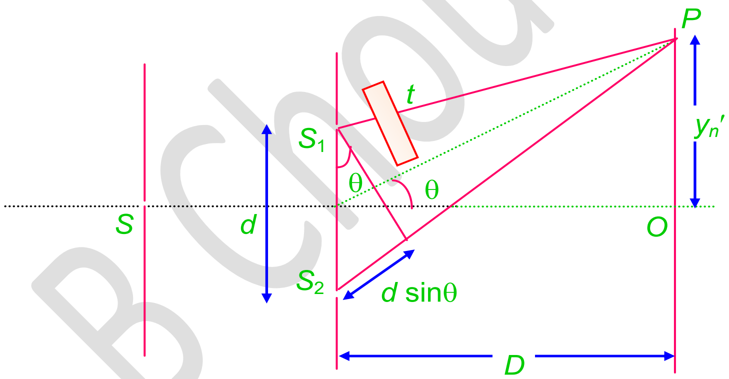
$x = \dfrac{4D\lambda_1}{d} = \dfrac{4 \times 120 \times 6500 \times 10^{-8}}{2} = 156 \times 10^{-5}$ m

$\therefore$ $z = \mathbf{156}$

12.8 DISPLACEMENT OF FRINGE PATTERN

Let us analyse what happens if a thin transparent plate of thickness t and refractive index μ is placed in front of one of sources, for example, in front of S_1. This changes the path difference because light from S_1 now takes longer time to reach the screen.

Time taken $= \dfrac{d_{air}}{V_{air}} + \dfrac{d_{plate}}{V_{plate}} = \dfrac{S_1P - t}{C} + \dfrac{t}{C/\mu}\left[\mu = \dfrac{C_{air}}{C_{medium}}\right] = \dfrac{S_1P + t(\mu - 1)}{C}$



Hence the effective path that is equivalently covered in air O is $S_1P + (\mu\text{-}1)\,t$

$\therefore$ path difference $p = S_2P - [S_1P + t\,(\mu\text{-}1)]$

$= S_2P - S_1P - (\mu\text{-}1)\,t$

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

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

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

$\therefore$ $p = \dfrac{dy'_n}{D} + (\mu - 1)t$ or, $y'_n = \dfrac{n\lambda D}{d} - (\mu - 1)\dfrac{tD}{d}$

In the absence of film, the position of the n^{th} maxima is given by

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

Therefore, the fringe shift is given by , $y_0 = y_n - y'_n = (\mu - 1)\dfrac{tD}{d}$ **… (52)**

When a transparent sheet is introduced, the fringe pattern shifts in the direction where the film is placed.

Illustration 48

Question: **In Young's double slit experiment using monochromatic light the fringe pattern shifts by a certain distance on the screen when a mica sheet of refractive index 1.6 and thickness 1.964 microns is introduced in the path of one of the interfering waves. The mica sheet is then removed and the distance between the plane of the slits and the screen is doubled. It is found that the distance between the successive maximum now is the same as the observed fringe shift upon the introduction of mica sheet. Calculate the wavelength of the light.**

Solution: Due to introduction of mica sheet, the shift on the screen

$$Y_0 = \frac{D}{d}(\mu - 1)t$$

Now, when the distance between the plane of slits and screen is changed from D to $2D$, fringe width will become, $\omega = \frac{2D}{d}(\lambda)$

According to given problem,

$$\frac{D}{d}(\mu - 1)$$

$$t = \frac{2D(\lambda)}{d}$$

or, $$\lambda = \frac{(\mu - 1)t}{2} = \frac{(1.6.1)\times 1.964\times 10^{-6}}{2}$$

$= \mathbf{5892\ Å}$

12.9 COHERENT WAVES

Two waves of same frequency are said to be 'coherent' if their phase difference does not change with time, i.e., their phase difference is independent of time.

For observing interference effects, waves (or sources) must be coherent.

In case of two coherent sources, the resultant intensity at any point is given by

$I_R = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$, where ϕ is the phase difference between the two coherent waves reaching the point.

In case of incoherent sources, the resultant intensity at any point is given by

$I_R = I_1 + I_2 + \ldots$

Illustration 49

Question: **In case of interference of 4 identical waves each of intensity I_0. Find the ratio of maximum intensity to I_0, if the interference is**

(i) coherent **(ii) incoherent**

Solution: (i) In case of two coherent sources,

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

I_R will be maximum when $\cos\phi$ = maximum = 1

$$\therefore \quad (I_{max})_{co} = I_1 + I_2 + 2\sqrt{I_1 I_2} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$$

So for n identical waves each of intensity I_0,

$$(I_{max})_{co} = (\sqrt{I_0} + \sqrt{I_0}\ \ldots)^2 = (n\sqrt{I_0})^2 = n^2 I_0 = 16\, I_0 \Rightarrow \frac{(I_{max})}{I_0} = \mathbf{16}$$

(ii) In case of incoherent sources,

$$I_R = I_1 + I_2 + \ldots.$$

$$= I_0 + I_0 + \ldots = nI_0 = \frac{I_R}{I_0} = \mathbf{4}$$

13 DIFFRACTION OF LIGHT

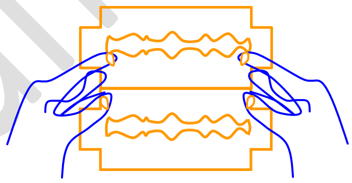
The phenomenon of bending of light around the corners of an obstacle or aperture is called the **diffraction of light**. On account of diffraction, light deviates from is linear path and enters into the regions of geometrical shadow of the obstacle.

In fact, diffraction is a characteristic of wave motion and all types of wave motions exhibit this effect.

A person sitting in a room can hear the sound of another person sitting outside the room, even though the speaker may not be visible. This is due to the bending of sound waves around the corners of the open door or window i.e. diffraction of sound. Similarly, radio waves too exhibit diffraction easily.

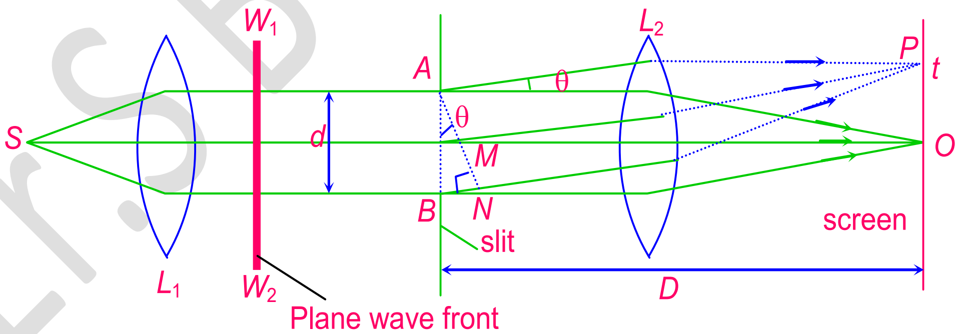
Experimental studies have revealed that diffraction occurs more prominently when the wavelength of the waves is comparable with the size of the obstacle or aperture. Since the wavelength of visible light is very small ($\lambda = 10^{-6}$m) and the size of the common obstacles or aperture is very large, the diffraction of visible light is not very common. However, when the size of the obstacle or aperture (slit) is made very small (comparable with the wavelength) even visible light shows this phenomenon. Diffraction is common in case of sound wave and radio waves because their wavelength is large and comparable to the size of common obstacle.

According to **Fresnel**, **diffraction** occurs on account of mutual interference of secondary wavelets starting from portions of the wavefront which are not blocked by the obstacle or from portions of the wavefront which are allowed to pass through the aperture.



13.1 DIFFRACTION AT A SINGLE SLIT

Consider a narrow slit *AB* of width *d* kept perpendicular to the plane of the paper. Let a plane wavefront of monochromatic light be incident normally on this slit. As the width *d* of the slit is comparable to the wavelength λ of the light, the light gets diffracted on passing through the slit. The converging lens L_2 helps in focusing the diffraction pattern on the screen. The diffraction pattern consists of a bright band at its centre (O) with alternate dark and bright bands on both sides. The intensity of the bright bands decreases very sharply as one move away from *O* on both sides.



Explanation: As the plane wavefront W_1 W_2 is incident normally on the slit, the entire slit *AB* gets, illuminated. According to Huygen's principle, each point on the portion *AB* of the wavefront becomes the source of secondary disturbance. The secondary wavelets start spreading from *AB* in all directions.

13.2 POSITION OF CENTRAL MAXIMA

The secondary wavelets travelling parallel to *MO* are focussed at *O* by the converging lens I_2. Actually, the secondary wavelets originating from any two points equidistant from the centre of the slit *M* (one each in *MA* and *MB*) cover equal distances before converging at *O*. Hence, the path difference between them is zero. As a result, they produce the brightest band at *O* on the screen. This is called the central maximum.

13.3 POSITION OF SECONDARY MAXIMA AND MINIMA

Consider the secondary wave travelling in a direction making an angle θ with *MO*. All these waves are focussed by lens L_1 at point *P*. Such waves start from all the points of slit *AB* in the same phase but travel different distances in reaching the point *P*. The intensity at point *P* will, therefore, depend on the path difference between the secondary waves emitted from the corresponding points (equidistant from *M*) of the wavefront *AB*.

Let us calculate the path difference between two secondary waves emitting from points *A* and *B* of the wavefront. Draw *AN* perpendicular to the wave coming from *B*.

∴ Path difference between the secondary wavelets which originate from *A* and *B* and reach point *P* on the screen, $BN = AB \sin\theta = d\sin\theta$.

Secondary minima: Let this path difference be equal to 1 λ i.e.

∴ $d\sin\theta = \lambda$

Hence the path difference between the wavelets originating from points *A* and *M* and reaching point *P* will be λ/2. Similarly, the path difference between the wavelets originating from *M* and *B* and reaching *P* will also be λ/2. Thus for each point in the upper half of the slit *AM*, there exists a corresponding point in its lower half *MB* such that the wavelets originating from such points reach point *P* out of phase i.e. having a phase difference of π. Therefore, destructive interference takes place at point *P* and it represents the first secondary minima.

Similarly, if $d\sin\theta = 2\lambda$.

The slit *AB* can be imagined to be divided into four equal parts. The path difference between the wavelets originating from corresponding points in two adjacent parts will be 2λ/4 = λ/2. Hence, the wavelets cause destructive interference and point *P* again represents the second minima.

In general, for n^{th} minima, we have $d\sin\theta = n\lambda$

Where *n* = 1, 2, 3,……

Hence, the direction of n^{th} secondary minima

$$\sin\theta = n\frac{\lambda}{d}$$

∴ For small values θ, $\sin\theta_n = \theta_n = n\frac{\lambda}{d}$

Secondary maxima: Let the path difference between the wavelets originating from *A* and *B* and reaching an off –point P_1 (not shown in the figure) be 3λ/2.

∴ $d\sin\theta = 3\lambda/2$

We assume that the slit *AB* is divided into three equal parts so that the difference between the wavelets originating from the corresponding points in the first two parts is λ/2. Such wavelets cause destructive interference at P_1. However, the wavelets originating from different point of the third part reinforce each other (not completely as for them, $0 > d\sin\theta < \lambda/2$) and give rise to the first secondary maxima at P_1. The intensity at the first secondary maxima is much smaller than that of the central maxima.

Similarly, $d\sin\theta = 5\lambda/2$ give the second secondary maxima with much lower intensity than the first maxima.

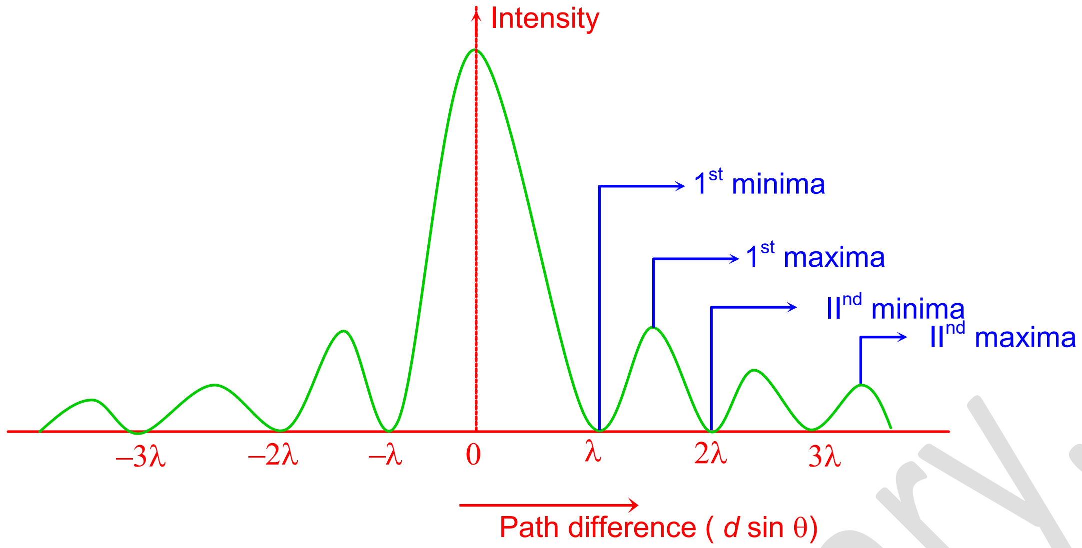
In general, for n^{th} secondary maxima the have $d\sin\theta = (2n+1)\lambda/2$

Where n = 1, 2, 3 ….

The direction of n^{th} secondary maxima is

$$\sin\theta = \theta_n = \frac{(2n+1)\lambda}{2d}$$

Thus, the diffraction pattern due to a single slit consists of central maxima flanked by alternate minima and secondary maxima. The intensity distribution in the pattern on the screen in shown in figure.



The graph shows that as we go away from the central maxima O on both sides, the intensity of secondary maxima decreases very rapidly.

13.4 WIDTH OF CENTRAL MAXIMA

It is the distance between the first secondary minimum an either side of the central maxima

Let y be the distance of a first minimum from the centre (O) of the central maxima.

$\therefore \quad d\sin\theta = \lambda$ and $\sin\theta = \theta = \dfrac{\lambda}{d}D$

Let f be the focal length of the converging lens L_2 (placed very close to slit AB) and D is the distance of the screen from AB.

$\therefore \quad D = f$

Hence , $\theta = \dfrac{y}{f} = \dfrac{y}{D}$

Comparing equation, we get $\dfrac{y}{D} = \dfrac{\lambda}{d}$, $y = \dfrac{\lambda}{d}$

$\therefore \quad$ width of central maxima $= 2y = \dfrac{2\lambda D}{d} = \dfrac{2\lambda f}{d}$

Figure shows the widths of the central maxima (CD) and the first secondary maximum (DE or CF)

Let y_1 and y_2 respectively be the distance of the first minima and the second minima from O. Then width of the first secondary maximum $= y_2 - y_1 = \dfrac{2\lambda D}{d} - \dfrac{\lambda D}{d} = \dfrac{\lambda D}{d}$.

The width of the central maxima is twice the width of the first secondary maximum.

13.5 DIFFRACTION PATTERN AT SINGLE SLIT DUE TO MONOCHROMATIC LIGHT AND WHITE LIGHT

When a parallel beam of monochromatic light is incident normally on the slit, the diffraction pattern obtained on the screen consists of alternate bright and dark bands of equal width. The intensity is maximum at the central bright band and it decreases very rapidly for successive secondary bright bands i.e. maximum.

When the beam of white light is incident on the slit, the diffraction pattern is coloured. The central maxima is white but the other bands are coloured. As the band width $\propto \lambda$ the red band will be wider than the violet band (as $\lambda_R > \lambda_V$).

FRESNEL DISTANCE (Z_F)

It is defined as the distance of the screen from the slit at which the spreading of light due to diffraction at single slit becomes equal to the width of the slit.

From the figure $\theta = \frac{y}{D} = \frac{d}{D}$ and for 1^{st} minima $\theta = \frac{\lambda}{d}$

$$\therefore \quad \frac{\lambda}{d} = \frac{d}{D}$$

$$\therefore \quad D = Z_F = \frac{d^2}{\lambda}$$

13.6 DIFFRACTION BETWEEN INTERFERENCE AND DIFFRACTION OF LIGHT

Inspite of the fact that interference and diffraction both are the consequence of the superposition of wave and also that mostly both occur simultaneously, they are different. Following are the main points of the difference between them.

INTERFERENCE	DIFFRACTION
1. It occurs due to the superposition of the secondary wavelets originating from two coherent sources.	*1. It occurs due to the superposition of the secondary wavelets originating from different points of the same wavefront.*
2. The width of all fringes is equal.	*2. The width of all fringes is not equal.*
3. All maxima are of the same intensity.	*3. Intensity of secondary maxima fall off rapidly as we go away from the central maxima.*
4. Interference pattern consists of a large number of bands.	*4. In diffraction pattern there are only a few bands.*

13.7 RESOLVING POWER OF MICROSCOPE OR TELESCOPE

Due to diffraction of light a point source can never give a point image. It gives an image in the from of a circular disc. This fact puts a limit on resolving two neighbouring points imaged by a lens, when two point objects are close to each other, their images i,e, diffraction patterns as seen through optical instruments, will also be close and overlap each other. If the overlapping is small both the point objects are seen separate in the optical instrument. However if the overlapping is large, the two points objects will not be seen as separate i.e. optical instrument is not able to resolve them.

Hence resolving power of an optical instrument is the power or ability of the instrument to produce distinct separate image of two close objects.

The minimum distance between the two objects which can just be seen as separate by the optical instrument is called the limit of resolution of the instrument. Smaller the limit of resolution of the optical instrument, greater is its resolving power and vice-versa.

Resolving power of a microscope: The resolving power of microscope is its ability to form separate images of two point objects lying close together. It is determined by the least distance between the two points which can be distinguished. This distance is given by $d = \frac{\lambda}{2\mu \sin\theta}$, where λ is the wavelength of light used to illuminate the object and μ is the refractive index of the medium between the object and the objective. The angle θ is the half angle of the cone of light from the point object.

Resolving power $= \frac{1}{d} = \frac{2\mu \sin\theta}{\lambda}$

13.8 RESOLVING POWER OF A TELESCOPE

The resolving power of a telescope is the reciprocal of the smallest angular separation between two distant objects whose images are separated in the telescope. This is given by $\theta = \frac{1.22\lambda}{a}$, where θ is the angle subtended by the point object at the objective, λ is the wavelength of light used and *a* is the diameter of the telescope objective. A telescope with a larger aperture objective gives a high resolving power.

13.9 POLARISATION AND PLANE POLARISED LIGHT

In writing equation for light wave, we assumed that the direction of electric field is fixed and the magnitude varies sinusoidally with space and time. The electric field in a light wave propagating in free space is perpendicular to the direction of propagation. However, there are infinite numbers of directions perpendicular to the direction of propagation and the electric field may be along any of these directions. For example, if the light propagates along the X-axis, the electric field may be along the *Y*-axis, or along the *Z*-axis or along any direction in the Y-Z plane. If the electric field at a point always remains parallel to a fixed direction as the time passes, the light is called linearly polarized along the direction. For example, if the electric field at a point is always parallel to the *Y*-axis, we say that the light is linearly polarized along the Y-axis. The same is also called plane polarized light. The plane containing the electric field and the direction of propagation is called the plane of polarization.

The phenomenon of restricting the vibrations of light in a particular direction perpendicular to direction of wave motion is called polarisation of light.

13.10 POLARISATION OF LIGHT BY REFLECTION:

When unpolarised light is reflected from a surface, the reflected light may be completely polarised, partially polarised or non-polarised. This would depend on the angle of incidence.

If angle of incidences is 0^0 or 90^0, the reflected beam remains unpolarised. For angles of incidence between 0^0 and 90^0, the reflected beam is polarized to varying degree.

The angle of incidence at which the reflected light is completely plane polarized is called polarising angle or Brewster's angle. It is represented by i_p. The value of i_p depends on the wavelength of light used. Therefore, complete polarisation is possible only for monochromatic light. If non-polarised light is incident along *AO* at angle i_p on the interface *XY* separating air from a medium of refractive index μ, the light reflected along *OB* is completely plane polarised. The light refracted along *OC* continues to be unpolarised.

Infact, the non-polarised light has two electric field components, one perpendicular to the plane of incidence (represented by dots) and the other in the plane of incidence (represented by arrows).

The vibrations of electric vector perpendicular to the plane of incidence remain always parallel to the reflecting surface, whatever be the angle of incidence. Therefore, condition of their reflection is not changed with the change in the angle of incidence. However, the other set of oscillations of electric vector in the plane of incidence make different angles with the reflecting surface, as angle of incidence of unpolarised light is changed. At the polarising angle (i_p), most of these vibration of electric vector get transmitted and are not reflected.

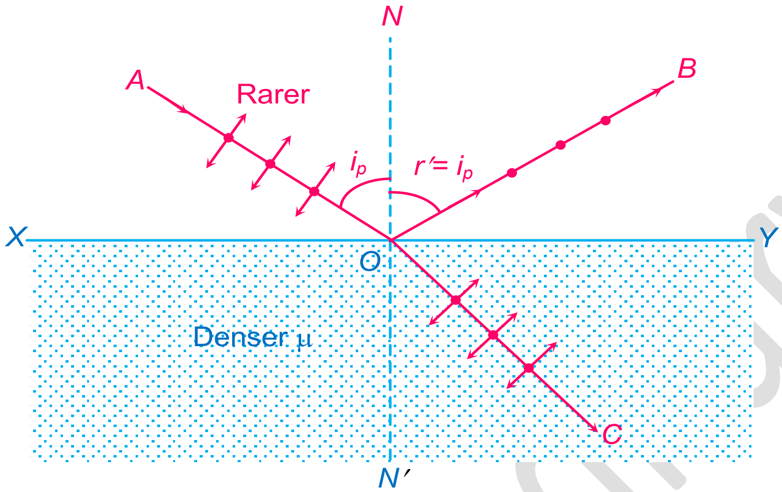
The reflected light therefore, contains vibrations of electric vector perpendicular to the plane of incidence. Hence the reflected light is completely plane polarised in a direction perpendicular to the plane of incidence.

13.11 BREWSTER'S LAW

According to this law, when unpolarised light is incident at polarising angle i_p on an interface separating air from a medium of refractive index μ, then the reflected light is fully polarized (perpendicular to the plane of incidence), provided.

$$\mu = \tan i_p$$

This relation represents Brewster's Law



$$\angle BOY + \angle YOC = 90^0$$

$$(90^0 - i_p) + (90^0 - r) = 90^0$$

where r is the angle of refraction

or $\quad 90^0 - i_p = r \qquad \ldots$ (i)

According to Snell's law,

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

When $i = i_p$, $i = (90^0 - i_p)$

$$\therefore \quad \mu = \frac{\sin i_p}{\sin(90^0 - i_p)} = \frac{\sin i_p}{\cos i_p} = \tan i_p$$

This proves Brewster's law.

Illustration 50

Question: **A slit of width 3 mm is illuminated by light of λ = 600 nm at normal incidence. If the distance of the screen from the slit is 60 cm, the distance between the first order minimum on both sides of central maximum is $y \times 10^{-2}$ mm. The value of *y* is**

Solution: Given $d = 3$ mm $= 3 \times 10^{-3}$ m

$\lambda = 600$ nm $= 6 \times 10^{-7}$ m, $D = 60$ cm $= 0.60$ cm

Distance of first order minima from central maximum

$$x_1 = 1 \times \frac{\lambda D}{d}$$

∴ distance between first order minimum on both sides of the central maximum

$$= 2x_1 = \frac{2\lambda D}{d} = \frac{2 \times 6 \times 10^{-7} \times 0.6}{3 \times 10^{-3}}$$

$= 0.24 \times 10^{-3}$ m or y = **24**

Illustration 51

Question: **A beam of wavelength 6000 Å is incident on a slit of width 0.2 mm. The angular spread of the central maximum is $x \times 10^{-3}$ radius. The value of x is**

Solution: Given $\lambda = 6000$ Å = 6000 Å = 6000×10^{-10} m

$d = 0.2$ mm = 0.2×10^{-3} m

Angular spread of the central maximum

$$\theta = \frac{\lambda}{d} = \frac{6000 \times 10^{-10}}{0.2 \times 10^{-3}} = 3 \times 10^{-3} \text{ radian.}$$

∴ x = **3**

Illustration 52

Question: **(a) A ray of light is incident on a glass surface at an angle of 45^0. If the reflected and refracted rays are perpendicular to each other, find the refractive index of glass.**

(b) what is the value of the refractive index of a medium of polarising angle 45^0.

Solution: (a) and (b) we know that if the reflected and refracted rays are perpendicular, the angle of incidence is equal to polarising angle.

∴ $i_p = 45^0$

∴ $\mu = \tan i_p = \tan 45^0 = 1$

or $\mu = 1$

14 SCATTERING OF LIGHT

When light passes though a medium, a part of it appears in directions other than the incident direction. The phenomenon is called **scattering of light**. The basic process in scattering is absorption of light by the molecules of gas and other particles of the medium followed by re-radiation in different directions. The strength of scattering can be measured by the loss of energy in the light beam as it passes through the medium. In absorption, the light energy is converted into internal energy of the medium whereas in scattering, the light energy is radiated in other directions.

There are two types of scattering. If these particles are smaller than the wavelength of incident light, then scattering is proportional to $\frac{1}{\lambda^4}$. This is known as Rayleigh's law of scattering

Thus, red light is scattered the least and violet is scattered the most law of scattering. This is the reason why danger signals are made of red colour so that they can be seen from far away. The blue appearance of sky is due to scattering of sunlight from the atmosphere. When we look at the sky, it is the scattered light that enters the eyes. Among the shorter wavelengths, the colour blue is present in larger proportion in sunlight. Light of shorter wavelengths are scattered by air molecules which because of there smaller size follow Rayleigh's scattering. Blue light is strongly scattered by the air molecules and reach the observer. This explains the blue colour of sky.

The appearance of red colour of sun at the sunset and at the sunrise is also because of scattering of sunlight due to air molecules. The blue and neighbouring colours are scattered away in the path and light reaching the observer is predominantly red.

The sky would appear black and stars could be seen during day hours, if the earth had no atmosphere and hence no scattering.

Clouds contain a high concentration of water droplets or ice crystals which due to their comparatively larger size scatter light uniformly of all wavelengths. Since light of all wavelength is eventually scattered out of the cloud, so the cloud looks white.

PROFICIENCY TEST– II

The following questions deal with the basic concepts of this section. Answer the following briefly. Go to the next section only if your score is at least 80%. Do not consult the Study Material while attempting these questions.

1. Is it possible to have coherence between light sources emitting light of different wavelengths?

2. Is it necessary to have intensities of waves equal in interference? What will happen if intensities of interfering waves are not equal?

3. In *YDSE*, the distance of the screen from the plane of the slits is 1.0 m. When light of wavelength 500 Å is allowed to fall on the slits, the width of the fringes obtained on the screen is 10 μm. Calculate the distance between the slits in mm.

4. Two slits are separated by a distance of 0.03 cm. An interference pattern is produced at a screen 1.5 m away. The fourth bright fringe is at a distance of 1 cm from the central maxima. Find the wavelength of the light used.

5. In *YDSE*, the slits are 0.589 mm apart and the interference is observed on a screen placed at a distance of 100 cm from the slits. It is found that 9^{th} bright fringe is at a distance of 7.5 mm from the dark fringe, which is second from the centre of the fringe pattern. Find the wavelength of light used.

6. In *YDSE*, the distance between the slits is 5.0 mm and the slits are 1.0 m from the screen. Two interference patterns can be seen on the screen, one due to light of wavelength 480 nm and the other due to light with wavelength 600 nm. What is separation on the screen between the third bright fringes of the two patterns?

7. In Young's double slit experiment arrangement produces interference fringes for sodium light (λ = 5890 Å) 8^0 apart. What is the angular fringe separation, if the entire arrangement is immersed in water ($\mu_W = \frac{4}{3}$)?

8. The interference fringes from sodium light (λ = 5890Å) in a double slits experiment have an angular width 0.2°. For what wavelength will this width be 10% greater?

ANSWERS TO PROFICIENCY TEST– II

1. No

2. No; contrast will become poor

3. 5 mm

4. 5000 Å

5. 5890 Å

6. 72 μm

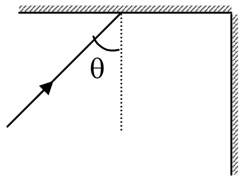
7. 6°

8. 6479 Å

SOLVED OBJECTIVE EXAMPLES

***Example* 1:**

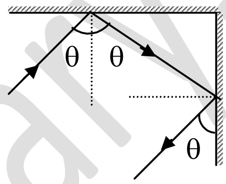
Two plane mirrors are arranged at right angles to each other as shown in figure. A ray of light is incident on the horizontal mirror at an angle θ. For what value of θ the ray emerges parallel to the incoming ray after reflection from the vertical mirror



(a) 60° **(b) 30°**
(c) 45° **(d) all of the above**

***Solution*:**

The incident and the second reflected ray make the same angle θ with vertical. Therefore, they are parallel for any value of θ.



∴ **(d)**

***Example* 2:**

A concave mirror has a focal length 20 cm. The distance between the two positions of the object for which the image size is double of the object size is

(a) 20 cm **(b) 40 cm** **(c) 30 cm** **(d) 60 cm**

***Solution*:**

For real image

$u = -u_1$, $v = -2u_1$ $f = 20$ cm

Substituting in $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$,

we get $\frac{1}{-2u_1}-\frac{1}{u_1}=\frac{1}{20}$

or $u_1 = 30$ cm

For virtual image

$u = -u_2$, $v = 2u_2$

$f = -20$ cm

∴ $\frac{1}{2u_2}-\frac{1}{u_2}=-\frac{1}{20}$

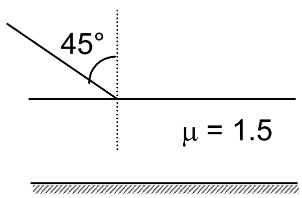
or $u_2 = 10$ cm

∴ Distance between two positions of the object are $u_1 - u_2$ or 30 cm – 10 cm = 20 cm

∴ **(a)**

***Example* 3:**

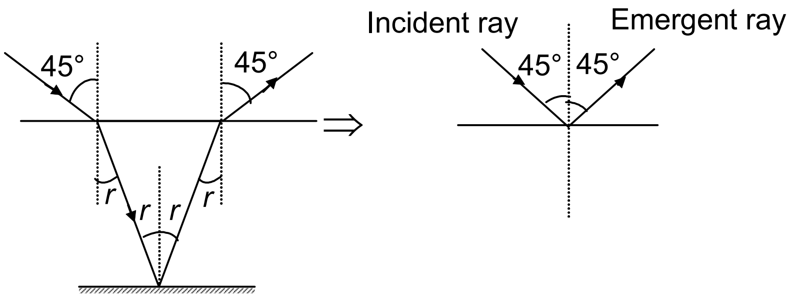
One side of the glass slab is silvered as shown. A ray of light is incident on the other side at an angle of incidence *i* = 45°. Refractive index of glass is given as 1.5. The deviation of the ray of light from its initial path when it comes out of the slab is



(a) 90° **(b) 180°**
(c) 120° **(d) 45°**

***Solution*:**

From the figure it is clear that the angle between incident ray and the emergent ray is 90°.



∴ **(a)**

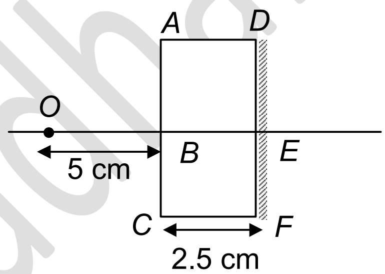
Example 4:

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

(a) 12 cm from unsilvered face **(b) 14.6 cm from unsilvered face**

(c) 5.67 cm from unsilvered face **(d) 8.33 cm from unsilvered face**

Solution:



Let I_1, I_2 and I_3 be the images formed by

(i) refraction from *ABC*

(ii) reflection from *DEF* and

(iii) again refraction from *ABC*

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

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

∴ $EI_2 = 10$ cm behind the mirror

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

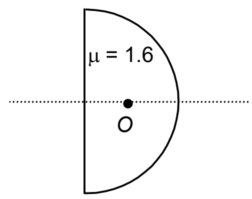
∴ $BI_3 = \dfrac{12.5}{\mu_g} = \dfrac{12.5}{1.5}$

$= 8.33$ cm

∴ **(d)**

Example 5:

A plastic hemisphere has a radius of curvature of 8 cm and an index of refraction of 1.6. On the axis halfway between the plane surface and the spherical one (4 cm from each) is a small object *O*. The distance between the two images when viewed along the axis from the two sides of the hemisphere is approximately.



(a) 1.0 cm **(b) 1.5 cm**

(c) 3.75 cm **(d) 2.5 cm**

Solution:

Distance of the image from the plane surface is

$$x_1 = \frac{4}{1.6} = 2.5 \text{ cm} \left(d_{app} = \frac{d_{actual}}{\mu} \right)$$

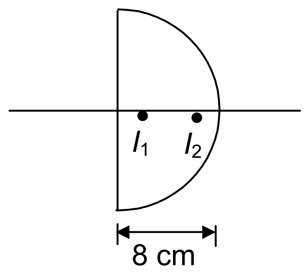
for the curved side

$$\frac{1.6}{4} + \frac{1}{x_2} = \frac{1 - 1.6}{-8}$$

∴ $x_2 = -3.0$ cm

The minus sign means the image is on the object side

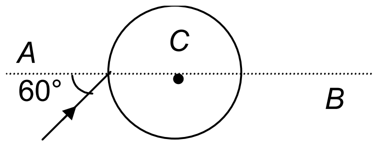
$I_1I_2 = (8 - 2.5 - 3.0)$ cm $= \mathbf{2.5}$ **cm**



∴ **(d)**

Example 6:

A ray of light falls on a transparent sphere with center at *C* as shown in figure. The ray emerges from the sphere parallel to line *AB*. The refractive index of the sphere is



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

(c) 3/2 (d) 1/2

Solution:

Deviation by a sphere is $2(i-r)$

Here deviation $\delta = 60° = 2(i-r)$

or $i - r = 30°$

$\therefore$ $r = i - 30° = 60° - 30° = 30°$

$\therefore$ $\mu = \frac{\sin i}{\sin r} = \frac{\sin 60°}{\sin 30°} = \sqrt{3}$

$\therefore$ **(b)**

Example 7:

Refraction takes place at a concave spherical boundary separating glass air medium. For the image to be real, the object distance ($\mu_g = 3/2$)

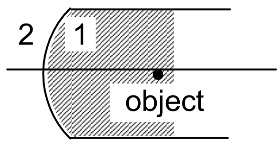
(a) should be greater than three times the radius of curvature of the refracting surface

(b) should be greater than two times the radius of curvature of the refracting surface

(c) should be grater than the radius of curvature of the refracting surface

(d) is independent of the radius of curvature of the refracting surface

Solution:



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

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

or $\frac{1}{v} + \frac{3}{2u} = \frac{1}{2R}$

for v to be positive, $\frac{1}{2R} > \frac{3}{2u}$

or $u > 3R$

$\therefore$ **(a)**

Example 8:

Two parallel rays are traveling in a medium of refractive index $\mu_1 = 4/3$. One of the rays passes through a parallel glass slab of thickness *t* and refractive index $\mu_2 = 3/2$. The path difference between the two rays due to the glass slab will be

(a) 4*t* /3 (b) 3*t* /2 (c) *t*/8 (d) *t* /6

Solution:

$\Delta x = \left(\frac{\mu_2}{\mu_1} - 1\right)t = \left(\frac{3/2}{4/3} - 1\right)t = \frac{t}{8}$

$\therefore$ **(c)**

Example 9:

Young's double slit experiment is made is a liquid. The 10th bright fringe in liquid lies where 6th dark fringe lies in vacuum. The refractive index of the liquid is approximately

(a) 1.8 (b) 1 mm (c) 0.5 mm (d) 4 mm

Solution:

Fringe width $\omega = \frac{\lambda D}{d}$. When the apparatus is immersed in a liquid, then λ will decrease μ times and hence ω is reduced μ (refractive index) times.

$10\omega' = (5.5)\omega$

or $\quad 10\lambda'\left(\frac{D}{d}\right) = (5.5)\frac{\lambda D}{d}$ $\quad$ or $\quad \frac{\lambda}{\lambda'} = \frac{10}{5.5} = \mu$ $\quad$ or $\quad \mu = 1.8$

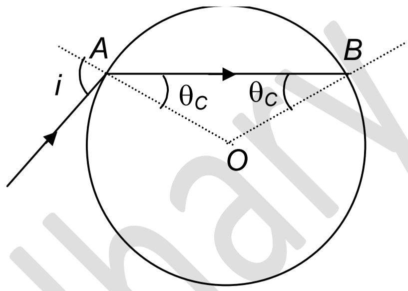
$\therefore$ **(a)**

***Example* 10:**

A ray of light is incident on a glass sphere of refractive index 3/2. What should be the angle of incidence so that the ray, which enters the sphere, the rays comes out tangentially from the surface of the sphere?

(a) $\tan^{-1}$ (2/3) **(b) $\sin^{-1}$(2/3)** **(c) 90°** **(d) $\cos^{-1}$ (1/3)**

***Solution*:**



$\angle ABO = \angle OAB = \theta_C$

$\sin\theta_C = \frac{1}{\mu} = \frac{2}{3}$

Applying snell's law at A

$$\frac{\sin i}{\sin\theta_C} = \frac{3}{2}$$

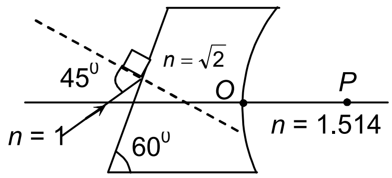
$$\sin i = \left(\frac{3}{2}\right)\sin\theta_C = \left(\frac{3}{2}\right)\left(\frac{2}{3}\right) = 1$$

or $\quad i = 90°$

$\therefore$ **(c)**

***Example* 11:**

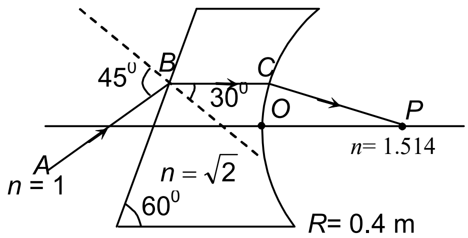
A ray is incident on a medium consisting of two boundaries, one plane and other curved as shown in the figure. The plane surface makes an angle 60^0 with horizontal and curved surface has radius of curvature 0.4 m. The refractive indices of the medium and its environment are shown in the figure. If after refraction at both the surfaces the ray meets the principle axis at *P*, find *OP*.



(a) 2.056 m **(b) 5.056 m**

(c) 6.056 m **(d) 4.056 m**

***Solution*:**



Using Snell's law, $1\sin 45^0 = \sqrt{2}\sin r \Rightarrow r = 30^0$

It indicates refracted ray BC is parallel to the principal axis as shown in figure.

Now for refraction at spherical surface, $u = \infty$

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

$$\Rightarrow \frac{1.514}{v} = \frac{1.514 - 1.414}{0.4}$$

$$\Rightarrow v = \frac{1.514 \times 0.4}{0.1}, v = 6.056 \text{ m}$$

$\therefore$ **(c)**

***Example* 12:**

A ray of light passing through a prism of refracting angle 60° has to deviate by at least 30°. Then refractive index of prism should be

(a) $\leq \sqrt{2}$ **(b) $\geq \sqrt{2}$** **(c) $\geq \sqrt{3}$** **(d) $\leq \sqrt{3}$**

***Solution*:**

$A = 60°$, $\delta_m = 30°$

Hence, $\mu = \dfrac{\sin\left(\dfrac{A+\delta_m}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$

$$= \frac{\sin\left(\dfrac{60+30}{2}\right)}{\sin\left(\dfrac{60}{2}\right)} = \sqrt{2}$$

i.e., at $\mu = \sqrt{2}$, minimum deviation is 30° i.e., deviation ≥ 30° if $\mu \geq \sqrt{2}$.

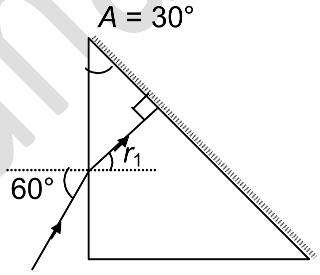
∴ **(b)**

***Example* 13:**

One of the refracting surfaces of a prism of angle 30° is silvered. A ray of light incident at an angle of 60° retraces its path. The refractive index of the material of prism is

(a) $\sqrt{2}$ **(b) $\sqrt{3}$** **(c) 3/2** **(d) 2**

***Solution*:**



$r_2 = 0°$

∴ $r_1 = A = 30°$

and $i_1 = 60°$

∴ $\mu = \dfrac{\sin i_1}{\sin r_1} = \dfrac{\sin 60°}{\sin 30°} = \sqrt{3}$

∴ **(b)**

***Example* 14:**

Angle of minimum deviation is equal to the angle of prism *A* of an equilateral glass prism. The angle of incidence at which minimum deviation will be obtained is

(a) 60° **(b) 30°** **(c) 45°** **(d) $\sin^{-1}$ (2/3)**

***Solution*:**

$A = \delta_m = 60°$

At minimum deviation $i = \left(\dfrac{A+\delta_m}{2}\right)$ **= 60°**

∴ **(a)**

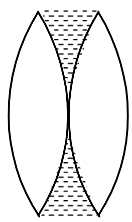
***Example* 15:**

Two identical glass ($\mu_g = 3/2$) equiconvex lenses of focal length *f* are kept in contact. The space between the two lenses is filled with water ($\mu_w = 4/3$). The focal length of the combination is

(a) *f* **(b) $\dfrac{f}{2}$** **(c) $\dfrac{4f}{3}$** **(d) $\dfrac{3f}{4}$**

***Solution*:**

Let *R* be the radius of curvature of each surface. Then



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

∴ $R = f$

For the water lens

$$\frac{1}{f'} = \left(\frac{4}{3}-1\right)\left(-\frac{1}{R}-\frac{1}{R}\right) = \frac{1}{3}\left(-\frac{2}{f}\right)$$

or, $\frac{1}{f'} = -\frac{2}{3f}$

Now using $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3}$ we have

$$\frac{1}{F} = \frac{1}{f} + \frac{1}{f} + \frac{1}{f'} = \frac{2}{f} - \frac{2}{3f} = \frac{4}{3f}$$

∴ $F = \frac{3f}{4}$

∴ **(d)**

***Example* 16:**

An object is kept at a distance of 16 cm from a thin lens and the image formed is real. If the object is kept at a distance of 6 cm from the same lens the image formed is virtual. If the size of the images formed are equal, the focal length of the lens will be

(a) 15 cm **(b) 17 cm** **(c) 21 cm** **(d) 11 cm**

***Solution*:**

Only convex lens can form a real as well as virtual image. So, the given lens is a convex lens.
Let f is the focal length of the lens and n the magnitude of magnification.
In the first case when the image is real

$u = -16$
$v = +16n$

So, applying $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$$\frac{1}{16n} + \frac{1}{16} = \frac{1}{f} \quad \text{or} \quad 1 + \frac{1}{n} = \frac{16}{f} \qquad \ldots \text{(i)}$$

In the second case when image is virtual

$u = -6$
$v = -6n$

∴ $f = +f$

∴ $$\frac{1}{-6n} + \frac{1}{6} = \frac{1}{f} \quad \text{or,} \quad -\frac{1}{n} + 1 = \frac{6}{f} \qquad \ldots \text{(ii)}$$

∴ Adding (i) and (2), we get

$2 = \frac{22}{f}$ or f **= 11 cm**

∴ **(d)**

***Example* 17:**

An equiconvex lens of glass ($\mu_g = 1.5$) of focal length 10 cm is silvered on one side. It will behave like a

(a) concave mirror of focal length 10 cm **(b) convex mirror of focal length 5.0 cm**
(c) concave mirror of focal length 2.5 cm **(d) convex mirror of focal length 20 cm**

***Solution*:**

For equiconvex lens $|R_1| = |R_2| = f = 10$ cm

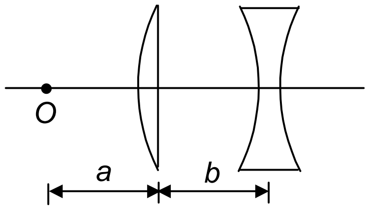
Now, $\frac{1}{f} = \frac{2}{f_l} + \frac{1}{f_m}$ or, $\frac{1}{f} = \frac{2}{10} + \frac{2}{10}$ or, $f = 2.5$ cm

Therefore, the system will behave like concave mirror of focal length 2.5 cm.

∴ **(c)**

Example 18:

A plano convex glass lens ($\mu_g = 3/2$) of radius of curvature R = 10 cm is placed at a distance of 'b' from a concave lens of focal length 20 cm. What should be the distance 'a' of a point object O from the plano convex lens so that the position of final image is independent of 'b'



(a) 40 cm **(b) 60 cm**
(c) 30 cm **(d) 20 cm**

Solution:

Focal length of plano convex lens is $\frac{1}{f} = \left(\frac{3}{2} - 1\right)\left(\frac{1}{10} - \frac{1}{\infty}\right)$ or $f = 20$ cm

If point object O is placed at a distance of 20 cm from the plano convex lens rays become parallel and final image is formed at second focus or 20 cm from concave lens which is independent of b.

∴ **(d)**

Example 19:

A point object is placed at a distance of 25 cm from a convex lens of focal length 20 cm. If a glass slab of thickness t and refractive index 1.5 is inserted between the lens and the object the image is formed at infinity. The thickness t is

(a) 10 cm **(b) 5 cm** **(c) 20 cm** **(d) 15 cm**

Solution:

Image will be formed at infinity if object is placed at focus of the lens i.e., at 20 cm from the lens. Hence,

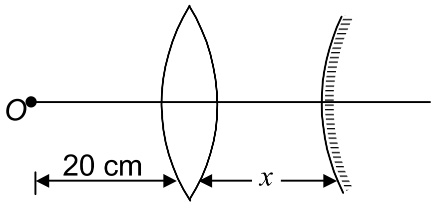
shift $= 25 - 20 = \left(1 - \frac{1}{\mu}\right)t$

or $5 = \left(1 - \frac{1}{1.5}\right)t$ or $t = \frac{5 \times 1.5}{0.5} = 15$ cm

∴ **(d)**

Example 20:

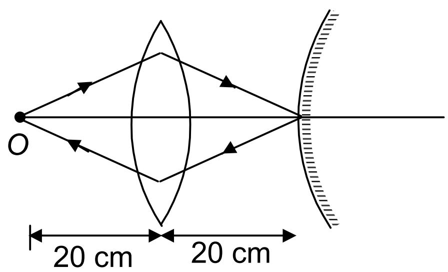
A point object O is placed at a distance of 20 cm from a convex lens of focal length 10 cm as shown in figure. At what distance x from the lens should a convex mirror of focal length 60 cm, be placed so that final image coincides with the object



(a) 10 cm
(b) 40 cm
(c) 20 cm
(d) final image can never coincide with the object in the given conditions.

Solution:

Object is placed at a distance of $2f$ from the lens (f = focal length of lens) i.e., the image formed by the lens will be at a distance of $2f$ or 20 cm from the lens. So, if the concave mirror is placed in this position, the first image will be formed at its pole and it will reflect all the rays symmetrically to other side as shown below and the final image will coincide with the object.



∴ **(c)**

***Example* 21:**

The maximum intensity in Young's double slit experiment is I_0. Distance between the slits is $d = 5\lambda$, where λ is the wavelength of monochromatic light used in the experiment. What will be the intensity of light in front of one of the slits on a screen at a distance $D = 10\,d$?

(a) $\frac{I_0}{2}$ **(b)** $\frac{3}{4}I_0$ **(c)** I_0 **(d)** $\frac{I_0}{4}$

***Solution*:**

Path difference $\Delta x = \frac{yd}{D}$

here $y = \frac{d}{2} = \frac{5\lambda}{2}$ (as $d = 5\lambda$) and $D = 10\,d = 50\,\lambda$

so $\Delta x = \left(\frac{5\lambda}{2}\right)\left(\frac{5\lambda}{50\,\lambda}\right) = \frac{\lambda}{4}$

corresponding phase difference will be

$$\phi = \left(\frac{2\pi}{\lambda}\right)(\Delta x) = \left(\frac{2\pi}{\lambda}\right)\left(\frac{\lambda}{4}\right) = \frac{\pi}{2}$$

or $\frac{\phi}{2} = \frac{\pi}{4}$

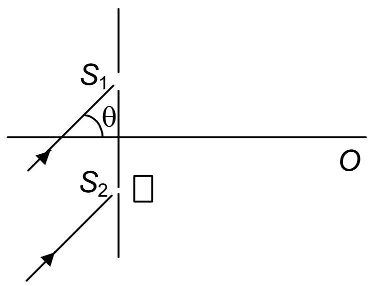
$\therefore$ $I = I_0 \cos^2\left(\frac{\phi}{2}\right)$

$I_0 \cos^2\left(\frac{\pi}{4}\right) = \frac{I_0}{2}$

$\therefore$ **(a)**

***Example* 22:**

A monochromatic beam of light falls on *YDSE* apparatus at some angle (say θ) as shown in figure. A thin sheet of glass is inserted in front of the lower slit s_2. The central bright fringe (path difference = 0) will be obtained



(a) at *O*
(b) above *O*
(c) below *O*
(d) anywhere depending on angle θ, thickness of plate t and refractive index of glass μ

***Solution*:**

If $d \sin\theta = (\mu - 1)\,t$, central fringe is obtained at O.
If $d\sin\theta > (\mu - 1)\,t$, central fringe is obtained above O and
If $d\sin\theta < (\mu - 1)\,t$, central fringe is obtained below ***O***.
$\therefore$ **(d)**

***Example* 23:**

In Young's double slit experiment how many maximas can be obtained on a screen (including the central maximum) on both sides of the central fringe if $\lambda = 2000$ Å and $d = 7000$ Å. Given that perpendicular distance of a screen from the mid point of two slits is 3.5 cm

(a) 12 **(b) 7** **(c) 18** **(d) 4**

***Solution*:**

For maximum intensity on the screen

$$d\sin\theta = n\lambda$$

or $\sin\theta = \frac{n\lambda}{d}$

$$= \frac{(n)(2000)}{(7000)} = \frac{n}{3.5}$$

Since, $\sin\theta \le 1$

$\therefore$ **n = 0, 1, 2, 3 only.**

Thus, only seven maxima's can be obtained on both sides of the screen.

$\therefore$ **(b)**

***Example* 24:**

In Young's double slit experiment $\frac{d}{D} = 10^{-4}$ (d = distance between slits, D = distance of screen from the slits). At a point P on the screen resulting intensity is equal to the intensity due to individual slit I_0. Then the distance of point P from the central maximum is (λ = 6000 Å)

(a) 2 mm **(b) 1 mm** **(c) 0.5 mm** **(d) 4 mm**

***Solution*:**

$$I = 4\, I_0 \cos^2\left(\frac{\phi}{2}\right)$$

$$I_0 = 4\, I_0 \cos^2\left(\frac{\phi}{2}\right)$$

$\therefore$ $\cos\left(\frac{\phi}{2}\right) = \frac{1}{2}$

or $\frac{\phi}{2} = \frac{\pi}{3}$

or $\phi = \frac{2\pi}{3} = \left(\frac{2\pi}{\lambda}\right) . \Delta x$

or $\frac{1}{3} = \left(\frac{1}{\lambda}\right) y . \frac{d}{D}$ $\left(\Delta x = \frac{yd}{D}\right)$

$\therefore$ $y = \frac{\lambda}{3 \times \frac{d}{D}} = \frac{6 \times 10^{-7}}{3 \times 10^{-4}}$

$= 2 \times 10^{-3}$ m = 2 mm

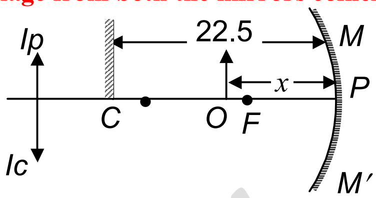
$\therefore$ **(b)**

SOLVED SUBJECTIVE EXAMPLES

***Example* 1:**

A plane mirror is placed 22.5 cm in front of a concave mirror of focal length 10 cm. Find where an object can be placed between the two mirrors, so that the first image from both the mirrors coincides.

***Solution*:**



As shown in figure, if the object is placed at a distance x from the concave mirror, its distance from the plane mirror will be $(22.5 - x)$. So plane mirror will form equal and erect image of object at a distance $(22.5 - x)$ behind the mirror.

Now as according to given problem the image formed by concave mirror coincides with the image formed by plane mirror, therefore for concave mirror

$$v = -[22.5 + (22.5 - x)] = -(45 - x) \text{ and } u = -x$$

So $$\frac{1}{-(45-x)} + \frac{1}{-x} = \frac{1}{-10} \quad \text{or} \quad \frac{45}{(45x - x^2)} = \frac{1}{10}$$

i.e., $x^2 - 45x + 450 = 0$ or $(x-30)(x-15) = 0$

i.e., $x = 30$ cm or $x = \mathbf{15}$ **cm**

But as the distance between two mirrors is 22.5 cm, x = 30 cm is not admissible. So the object must be at a distance of 15 cm from the concave mirror.

Example *2:*

The material of an equilateral prism has a refractive index 1.5. Find the angle of minimum deviation, when the angle of deviation is minimum and also the angle of refraction at first face. ($\sin^{-1} 0.75 = 48^0\ 30'$)

***Solution*:**

Given, $\mu = 1.5,\ A = 60°$

$$\mu = \frac{\sin\left(\frac{A+\delta}{2}\right)}{\sin\left(\frac{A}{2}\right)} \quad \text{or,} \quad \sin\frac{(60+\delta)}{2} = 1.5 \times 0.5 = 0.75$$

$$\frac{60+\delta}{2} = \sin^{-1}(0.75) = 48°30'$$

$60 + \delta = 97°$

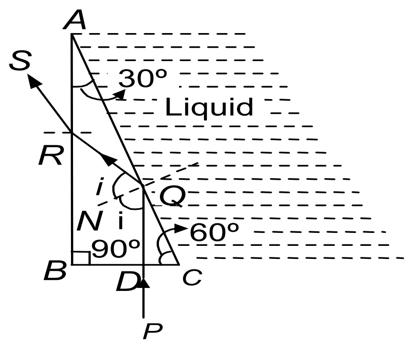
$\delta = 37°$

$r_1 = \frac{A}{2} = \mathbf{30°}$

***Example* 3:**

The angles of a prism are 30°, 60° and 90°. What should be the refractive index of a liquid to be kept in contact with the longest face so that a ray normally incident on the smallest face gets just internally reflected at the longest face? ($\mu_g = \frac{4}{\sqrt{3}}$)

***Solution*:**



The given prism ABC has the face AC the longest (opposite to 90°angle) and BC the shortest (opposite to 30° angle).

PQ is the normally incident ray at the face BC and just gets totally reflected at the longest face AC.

For the glass-liquid interface AC

$${}_g\mu_L = \frac{\mu_L}{\mu_g} = \frac{\sin i}{\sin 90°}$$

In ΔCQD, $\angle CQD = 30°$

$\therefore \quad \angle DQN = 60°$

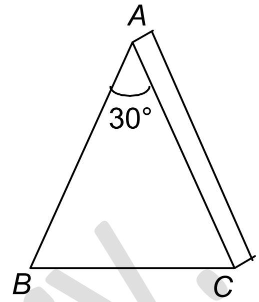
$\mu_L = \frac{4}{\sqrt{3}} \times \frac{\sqrt{3}}{2} = \mathbf{2}$

***Example* 4:**

The face AC of the prism is coated with a thin film of thickness 't' and refractive index 2.2. The refractive index of the material of the prism is $\sqrt{3}$. A ray of wavelength 550 nm is incident on the face AB at an angle of 60°.

(i) Find the angle of emergence.

(ii) The minimum value of 't' so that maximum intensity of light comes out of the prism is $x \times 10^{-9}$ m. The value of x is



***Solution*:**

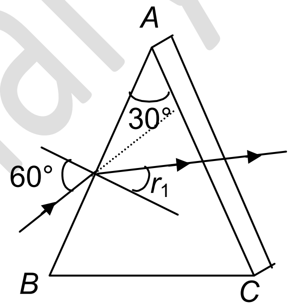
(i) For the refraction at the face AB, we have

$\mu_1 \sin i_1 = \mu_2 \sin r_1$

$1. \sin 60 = \sqrt{3} . \sin r_1$

$r_1 = 30$

Now, $A = r_1 + r_2$



$\Rightarrow \quad r_2 = A - r_1 = 0°$

Thus, the angle of incidence at the face AC is zero. So, the ray of light will emerge undeviated through the face AC, i.e., the angle of emergence e **= 0.**

(ii) For maxima in the transmitted region.

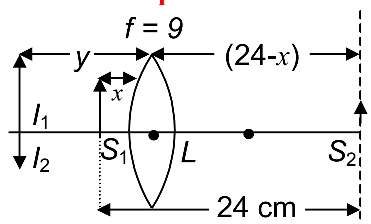
$t_{min} = \frac{\lambda}{2\mu \cos r_2} = \frac{550 \times 10^{-9}}{2 \times 2.2} = \mathbf{1.25 \times 10^{-7}\ m}$

$\therefore$ The value of x is 125

***Example* 5:**

The distance between two point sources of light is 24 cm. Find out where you will place a converging lens of focal length 9 cm, if the images of both sources are formed at the same point.

***Solution*:**



As images of both sources are coincident, the lens must be placed between the sources such that S_1 forms the virtual image on same side while S_2 real image on opposite side as shown in figure. Now if x and y are the distances of sources S_1 and its image from lens L respectively.

$$\frac{1}{-y} - \frac{1}{-x} = \frac{1}{9} \quad \ldots \mathbf{(1)}$$

Now as the distance between S_1 and S_2 is is 24 cm, the distance of S_2 from lens L, i.e., u will be $(24 - x)$ and as image of S_2 is coincident with that of S_1, $v = y$. So for S_2

$$\frac{1}{y} - \frac{1}{-(24-x)} = \frac{1}{9}$$

Adding Equation (1) and (2),

$$\frac{1}{x} + \frac{1}{(24-x)} = \frac{2}{9} \quad \text{i.e., } x^2 - 24x + 108 = 0$$

so that $x = \frac{1}{2}\left[24 \pm \sqrt{24^2 - 4 \times 108}\right]$ or, $x = 12 \pm 6$ i.e., $x =$ **6 cm** or **18 cm**

So the lens must be placed at a distance of 6 cm or 18 cm from one of the sources.

***Example* 6:**

A concave lens of focal length 20 cm is placed 15 cm in front of a concave mirror of radius of curvature 26 cm and further 10 cm away from the lens an object is placed. The principal axis of the lens and the mirror are coincident and the object is on this axis. Find the position and nature of the image.

***Solution*:**

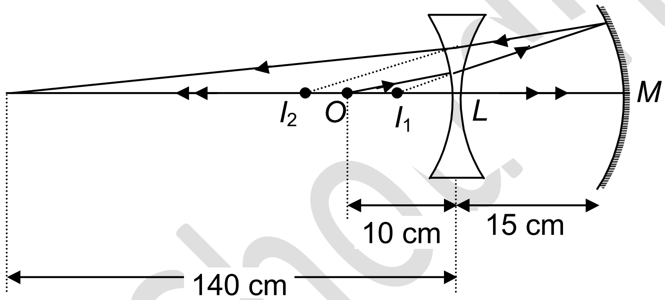
The lens will form the image I_1 of the object O at distance v from it such that

$$\frac{1}{v} - \frac{1}{-10} = \frac{1}{-20} \text{ i.e., } v = -\frac{20}{3} \text{ cm}$$

i.e., at a distance (20/3) cm in front of the lens. So the distance of this image I_1 from the mirror will be 15 + (20/3) = (65/3) cm.

The image I_1 will act as an object for the mirror, and hence the mirror will form image I_2 (of object I_1) such that

$$\frac{1}{v} + \frac{-3}{65} = \frac{1}{-13} \text{ i.e., } v = -32.5 \text{ cm}$$



i.e. The mirror will form image I_2 at a distance of 32.5 cm infront of it. However, as the lens is at a distance of 15 cm from the mirror, the image I_2 will act as an object for the lens again with u = 32.5 – 15 = 17.5 cm, so that

$$\frac{1}{v} - \frac{2}{+35} = \frac{1}{-20} \text{ i.e., } v = 140 \text{ cm}$$

i.e., final image I_3 is at a distance of 140 cm in front of the lens and as here

$$m = m_1 \times m_2 \times m_3$$

$$\text{i.e., } m = \left[\frac{(-20/3)}{(-10)} \times (-1) \frac{(-65/2)}{(-65/3)} \times \frac{(140)}{(35/2)}\right] = -\mathbf{8}$$

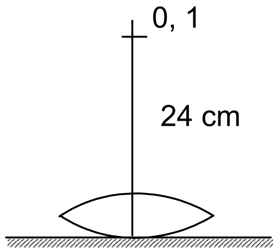
Final image will be inverted, real and 8 times of the object as shown in figure.

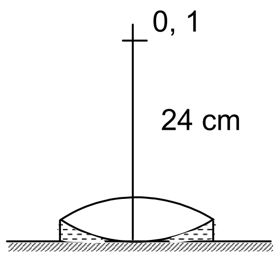
***Example* 7:**

An equiconvex lens is placed on a plane mirror. An object coincides with its image when it is at a height of 24 cm from the lens. The gap between the lens and the mirror is filled with water (μ_w = 4/3). By how much distance should the object be now shifted so that is again coincides with its image? (μ_g = 1.5)

Solution:

Let F_1 be the equivalent focal length of the lens-mirror combination





$$2F_1 = 24$$

$$F_1 = 12 \text{ cm}$$

$$\frac{1}{F_1} = \frac{2}{f_l} + \frac{1}{f_m} = \frac{2}{f_l} + \frac{1}{\infty}$$

$$\frac{1}{12} = \frac{2}{f_l}$$

f_l = focal length of lens = 24 cm

When water is filled, we have a combination of glass-lens, water-lens and a plane mirror. Let F_2 be the equivalent focal length, then $\frac{1}{F_2} = \frac{2}{f_l} + \frac{2}{f_w} + \frac{1}{f_m} = \frac{2}{f_l} + \frac{2}{f_w} + \frac{1}{\infty}$

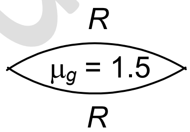
or, $$\frac{1}{F_2} = \frac{2}{24} + \frac{2}{f_w} \quad \ldots (1)$$

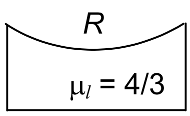
Applying lens maker's formula

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

glass lens: $$\frac{1}{f_l} = (1.5 - 1)\left(\frac{1}{+R} - \frac{1}{-R}\right)$$

$$\frac{1}{24} = \frac{1}{2} \times \left(\frac{2}{R}\right)$$





$$R = 24 \text{ cm}$$

Water lens $\frac{1}{f_w} = \left(\frac{4}{3} - 1\right)\left(\frac{1}{-R} - \frac{1}{\infty}\right)$ $\frac{1}{f_w} = -\frac{1}{3} \times \left(\frac{1}{R}\right)$

$$f_w = -72 \text{ cm}$$

Substituting the value of f_w in equation (1) $\frac{1}{F_2} = \frac{2}{24} + \frac{2}{-72}$

$F_2 = 18$ cm, $\quad 2F_2 = 36$ cm

Shift, s = (36 – 24) cm = **12 cm upwards**

The object will coincide with the image at a height of 36 cm from the lens and hence it should be shifted 12 cm upwards.

***Example* 8:**

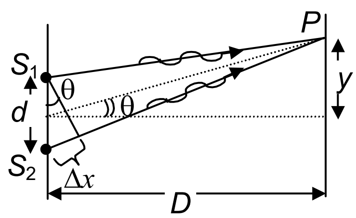
In an interference arrangement similar to Young's double-slit experiment, slit S_1 and S_2 are illuminated with coherent microwave sources each of frequency 1 Mhz. The sources are synchronized to have zero phase difference. The slits are separated by distance d = 150.0 m. The intensity $I_{(\theta)}$ is measured as a function of θ, where θ is defined as shown in figure. If I_0 = 1 W/m^2 is maximum intensity, calculate $I_{(\theta)}$ for (a) θ = 0° and (b) θ = 90°

Solution:

For microwaves, as $c = f\lambda$,

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{10^6} = 300 \text{ m}$$

and as $\Delta x = d\sin\theta$,



$$\phi = \frac{2\pi}{\lambda}(d \sin\theta) = \frac{2\pi}{300}(150 \sin\theta) = \pi\sin\theta$$

So, $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$ and $\phi = \pi \sin\theta$, $I_1 = I_2$

reduces to $I_R = 2I_1\,[1 + \cos(\pi \sin\theta)] = 4\,I_1 \cos^2(\pi \sin\theta/2)$

and as I_R will be maximum when $\cos^2[\pi \sin\theta/2]$ = maximum = 1

So that, $(I_R)_{max} = 4I_1 = I_0$ (given) and hence, $I = I_0 \cos^2[(\pi\sin\theta)/2]$

So (a) If $\theta = 0$ $I = I_0 \cos^2(0) = I_0$ **= 1 W/m²**

(b) If $\theta = 90°$ $I = I_0 \cos^2(\pi/2) = \mathbf{0}$

***Example* 9:**

In Young's double slit experiment using monochromatic light the fringe pattern shifts by a certain distance on the screen when a mica sheet of refractive index 1.6 and thickness 1.964 microns is introduced in the path of one of the interfering waves. The mica sheet is then removed and the distance between the plane of slits and the screen is doubled. It is found that the distance between successive maxima (or minima) now is the same as the observed fringe shift upon the introduction of the mica sheet. Calculate the wavelength of the light.

***Solution*:**

As due to introduction of mica sheet of thickness t and refractive index μ in the path of one of the interfering beams optical path increases by $(\mu - 1)t$, the shift on the screen

$$y_0 = \frac{D}{d}(\mu - 1)t \quad \ldots \text{(i)}$$

Now when the distance between the plane of slits and screen is charged from D to $2D$, fringe width will become

$$\beta = \frac{2D}{d}(\lambda) \quad \ldots \text{(ii)}$$

According to the given problem,

$$\frac{D}{d}(\mu - 1)t = \frac{2D}{d}(\lambda) \text{ i.e., } \lambda = \frac{1}{2}(\mu - 1)\,t$$

So, $\lambda = \frac{1}{2}(1.6 - 1) \times 1.964 \times 10^{-6}$ m = **5892 Å**

***Example* 10:**

In Young's experiment, the source is red light of wavelength 7×10^{-7} m. When a thin glass plate of refractive index 1.5 is put in the path of one of the interfering beams, the central bright fringe shifts by 10^{-3} m to the position previously occupied by the 5th bright fringe. Find the thickness of the plate. When the source is now changed to green light of wavelength 5×10^{-7} m, the central fringe shifts to a position initially occupied by the 6th bright fringe due to red central light. The change in fringe width due to the change in wavelength is $\frac{x}{7} \times 10^{-6}$m. Find x.

***Solution*:**

As due to presence of glass plate path difference changes by $(\mu - 1)\,t$, so according to given problem

$$(\mu_R - 1)\,t = 5\lambda_R \quad \text{i.e.} \quad t = \frac{5 \times 7 \times 10^{-6}}{(1.5 - 1)} = 7\ \mu\text{m}$$

Now when red light is replaced by green light, $(\mu_G - 1)t = 6\lambda_R$

So $\frac{\mu_R - 1}{\mu_G - 1} = \frac{5}{6}$ i.e., $\mu_G - 1 = \frac{6}{5}(1.5 - 1)$ or $\mu_G = 1.6$

Further $5\beta_R = 10^{-3}$ i.e., $\beta_R = 2 \times 10^{-4}$

So, $\frac{\beta_G}{\beta_R} = \frac{\lambda_G}{\lambda_R} = \frac{5}{7}$ i.e., $\frac{\beta_G - \beta_R}{\beta_R} = \frac{5}{7} - 1 = -\frac{2}{7}$

So, $\Delta\beta = -\frac{2}{7} \times 2 \times 10^{-4}$, $x = \mathbf{400}$

MIND MAP

1. Reflection of light:

- In case of reflection at a plane or curved mirror, $\angle i = \angle r$.
- The image formed by a plane mirror is at the same distance behind the mirror as the object is in front of it. It is virtual, erect and of the same size as the object. The image formed by a plane mirror is laterally inverted.
- Derivation produced by a plane mirror = 180° - 2*i* = 2g, where *g* is the glancing angle.
- Keeping the direction of the incident ray fixed, if the plane mirror is rotated through angle θ, then reflected ray gets rotated through 2θ in the same sense.
- If two plane mirrors are inclined at angle θ, then number of images formed

$= \frac{360°}{\theta} - 1$, if $\left(\frac{360°}{\theta}\right)$ is an even integer.

$= \frac{360°}{\theta}$, if $\left(\frac{360°}{\theta}\right)$ is an odd integer, and object is placed unsymmetrical to the mirrors.

$= \frac{360°}{\theta} - 1$, if $\left(\frac{360°}{\theta}\right)$ is an odd integer, and object is placed symmetrical to the mirrors.

- In case of a spherical mirror, $f = R/2$.
- The images formed by a concave mirror can be real as well as virtual. But the images formed by a convex mirror is always virtual.

Mirror formula

- $1/v + 1/u = 1/f$
- Magnification produced by a spherical mirror

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

2. Refraction of light at a plane surface

- In case of refraction of a ray at plane or spherical surface,

$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} = {}_1\mu_2$$

- Lateral shift produced by a glass slab is $d = \frac{t}{\cos r}\sin(i - r)$
- When an object in denser medium is viewed almost normally by an observer in rarer medium, we have

$${}_R\mu_D = \frac{\text{Real depth}}{\text{Apparent depth}}$$

- When an object in rarer medium is viewed almost normally by an observer in denser medium, we have

$${}_R\mu_D = \frac{\text{Apparent height}}{\text{Real height}}$$

- $\sin c = 1/{}_R\mu_D$
- In case of refraction through prism, $r_1 + r_2 = A$.
Deviation produced by a prism $\delta = (I + e) - A$
- Condition for minimum deviation for a prism
$i = e$ and $r_1 = r_2$
- $\mu = \frac{\sin(A + \delta_m/2)}{\sin(A/2)}$
- Deviation produced by a prism of small angle = (μ - 1) *A*.
- Angular dispersion=$(\mu_V - \mu_R)A$; Dispersive power= $\frac{\mu_V - \mu_R}{\mu - 1}$.
- Condition for dispersion without deviation is $\frac{A'}{A} = -\left(\frac{\mu - 1}{\mu' - 1}\right)$

Net angular dispersion produced = (μ - 1) A [ω - ω′).

- Deviation without dispersion is $\frac{A'}{A} = -\left(\frac{\mu_V - \mu_R}{\mu'_V - \mu'_R}\right)$

or, $\frac{\omega}{\omega'} = -\frac{\delta'}{\delta}$. Net deviation = (μ - 1) A $\left[1 - \frac{\omega}{\omega'}\right]$.

OPTICS

3. Refraction of light at spherical surfaces

- Refraction at a single spherical surface

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

Transverse magnification produced is $m = \frac{\mu_1}{\mu_2}\frac{v}{u}$

- Lens maker's formula $\frac{1}{f} = \left(\frac{\mu}{\mu_0} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$.
- Lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$
- Linear magnification produced by a lens $m = \frac{I}{O} = \frac{v}{u}$.
- Power of a lens $P = 1/f$.
- Two thin lenses in contact $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} + ...$

Two thin lenses separated by a distance *d*

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$$

- Lenses with a one surface silvered behaves as a spherical mirror. The equivalent focal length of the spherical mirror is given by $\frac{1}{F} = \Sigma\frac{1}{f_i}$, where f_i is to be repeated as many times as reflection or refraction is taking place.
- Displacement method:

$$f = \frac{D^2 - L^2}{4D}, O = \sqrt{I_1, I_2}$$

4. Wave optics

- In case of superposition of two waves,

$I_R = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$, or $I_R \,\alpha\, (A_1^2 + A_2^2 + 2A_1A_2\cos\phi)$.

- Condition for constructive interference
$\phi = \pm 2\pi n$, n = 1, 2, 3, ...
$(\Delta x) = \pm n\lambda$, n = 1, 2, 3, ...
- Condition for destructive interference
$\phi = \pm (2n - 1)\pi$, n = 1, 2, 3, ...
$(\Delta x) = \pm (2n - 1)\lambda/2$, n = 1, 2, 3, ...
- Distance of *n*th bright fringe from *C.B.F.* is

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

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

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

- Fringe width (ω) = $\lambda D/d$, Angular fringe width = $\omega/D = \lambda/d$
- Equivalent optical path of a medium of *R.I.* μ and distance *d* is μ*d*.
- Displacement of fringe pattern due to introduction of a transparent sheet of *R.I.* μ and thickness t in *YDSE* = Y_0 = (μ - 1) t (*D*/*d*), in the same side in which the transparent sheet is introduced.

EXERCISE – I

CBSE PROBLEMS

1. What should be the position of an object relative to biconvex lens so that it behaves like a magnifying glass?

2. What is total internal reflection? Under what condition does it take place?

3. What is meant by the term interference of light? Write any two conditions necessary for obtaining well defined and sustained interference pattern of light.

4. A ray of light while travelling from a denser to a rarer medium undergoes total internal reflection. Derive the expression for the critical angle in terms of the speed of light in the respective media.

5. Derive a relation between focal length of a double convex lens and its radii of curvature.

6. Derive lens maker's formula for a thin convex lens.

7. Four double convex lenses with the following specifications are available

Lens	Focal length	Aperture
A	100 cm	10 cm
B	100 cm	5 cm
C	10 cm	2 cm
D	5 cm	2 cm

Which two of the given four lenses should be selected as the objective and eye-piece to construct an astronomical telescope and why? What will be the magnifying power and normal length of the telescope tube so constructed?

9. Discuss the phenomenon of diffraction of light on the basis of Huygen's theory.

8. Differentiate between interference and diffraction of light.

10. How does the resolving power of a telescope change, when the aperture of the objective is increased?

11. Draw a labelled ray diagram for a reflecting type telescope. Write four advantages of a reflecting type telescope over a refracting type telescope.

12. What is wavefront? What is the geometrical shape of a wavefront of light emerging out of a convex lens, when point source is placed at its focus? Using Huygens' principle show that, for a parallel beam incident on a reflecting surface, the angle of reflection is equal to the angle of incidence.

13. In Young's experiment on interference, what shall happen if monochromatic source is replaced by a source of white light?

14. What is the ratio of intensities at two points x and y on a screen in Young's double slit experiment, where waves from S_1 and S_2 have path difference of (i) 0 and (ii) $\lambda/4$? Assume that the amplitudes of the waves from the two sources are equal.

15. Explain with reason, how the resolving power of an astronomical telescope will change when (i) frequency of the incident light on the objective lens is increased (ii) focal length of the objective lens is increased, and (iii) aperture of the objective lens is halved.

EXERCISE – II

NEET-SINGLE CHOICE CORRECT

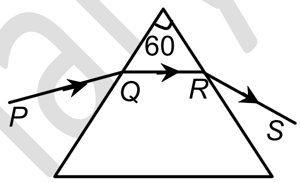
1. A man approaches a vertical plane mirror at speed of 2 m/s. Then the rate at which he approaches his image is

(a) 2 m/s (b) 4 m/s (c) 1 m/s (d) zero

2. A convex mirror of focal length *f* produces an image $(1/n)^{th}$ of the size of the object. Then the distance of the object from the mirror is

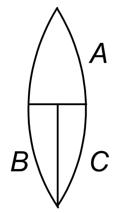
(a) $\frac{n}{f}$ (b) $\frac{n+1}{f}$ (c) $\frac{n}{f-1}$ (d) $(n-1)f$

3. An equilateral prism is kept as shown in the figure. A ray *PQ* is incident on one of the faces. For the minimum deviation of the incident ray,



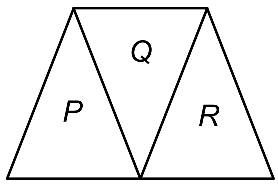
(a) *PQ* must be horizontal
(b) *QR* must be horizontal
(c)*RS* must be horizontal
(d) any one of them may be horizontal

4. A thin, symmetric double-convex lens of power *P* is cut into three parts *A*, *B* and *C* as shown. The power of



(a) *A* is *P*/2 (b) *A* is 2*P*
(c) *B* is *P*/2 (d) *B* is *P*/4

5. A given ray of light suffers minimum deviation in an equilateral prism *P*. Additional prisms *Q* and *R* of identical shape and of the same material as *P* are now added as shown in figure. The ray will now suffer



(a) greater deviation
(b) no deviation
(c) same deviation as before
(d) total internal reflection

6. An air bubble in glass slab (μ = 1.5) when viewed from one side appears to be at 6 cm and from opposite side 4 cm. The thickness of glass slab is

(a) 10 cm (b) 6.67 cm (c) 15 cm (d) none of these

7. If white light is used in a Young's double-slit experiment,

(a) bright white fringe is not formed at the centre of the screen
(b) fringes of different colours are not observed clearly only in the first order
(c) the first-order violet fringes are closer to the centre of the screen than the first-order red fringes.
(d) the first-order red fringes are closer to the centre of the screen than the first-order violet fringes

8. Two thin lenses, one concave and the other convex are placed in contact with each other. If their powers are in the ratio 2 / 3 and the effective focal length of the combination is 30 cm, then the individual focal lengths are

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

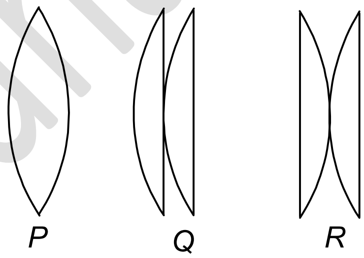
9. There is an equiconvex glass lens with radius of each face as R and ${}_a\mu_g = 3/2$ and ${}_a\mu_w = 4/3$. If there is water in object space and air in image space, then the focal length is

(a) $2R$ (b) R (c) $3R/2$ (d) $3R$

10. The plane face of plano-convex lens of focal length 20 cm is silvered. The type of mirror and focal length is

(a) convex, $f = 20$ cm (b) concave, $f = 20$ cm
(c) convex, $f = 10$ cm (d) concave, $f = 10$ cm

11. The diagrams show lenses which are either equiconvex or plano convex. All curvatures are the same and the glass of all the lenses are identical. What are the relative magnitudes of the resultant focal lengths of the lenses arranged as shown



	P	Q	R
(a)	1	1	1
(b)	1	1	–1
(c)	2	1	1
(d)	2	1	–1

12. A thin lens of focal length f produces an upright image of the same size as the object. What is the distance of the object from the optical centre of the lens?

(a) $2f$ (b) zero (c) $3f/2$ (d) infinity

13. 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, erect and reduced

14. For most distinct interference patterns to be observed the necessary condition is that the ratio of intensities of light waves from the two coherent sources should be:

(a) 1 : 1 (b) 1 : 2 (c) 1 : 3 (d) 1 : 4

15. In double slit experiment, the phase difference between the two waves reaching at the location of the third dark fringe is:

(a) π (b) 6π (c) 5π (d) 7π

16. A ray of light is incident normally on one of the faces of a prism of apex angle 30^0 and refractive index $\sqrt{2}$. The angle of deviation of the ray in degree is

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

17. The ratio of the intensity at the centre of a bright fringe to the intensity at a point one quarter of the distance between two fringes from the centre for a young's interference pattern is

(a) 2 (b) 1/2 (c) 4 (d) 16

18. 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 radiation in the glass slab will be respectively:

(a) $n, \frac{\lambda}{\mu}, v$ (b) $\frac{n}{\mu}, \lambda, \frac{v}{\mu}$ (c) $n, \frac{\lambda}{\mu}, \frac{v}{\mu}$ (d) $\frac{n}{\mu}, \frac{\lambda}{\mu}, \frac{v}{\mu}$

19. A diver in a swimming pool wants to signal his distress to a person lying on the edge of the pool by flashing his waterproof flash light:

(a) he must direct the beam vertically upwards.

(b) he has to direct the beam horizontally.

(c) he has to direct the beam at an angle to the vertical which is slightly less than the critical angle of incidence for total internal reflection.

(d) he has to direct the beam at an angle to the vertical which is slightly more than the critical angle of incidence for internal reflection.

20. A concave mirror of focal length f (in air) is immersed in water ($\mu = 4/3$). The focal length of mirror in water will be

(a) f (b) $\frac{4}{3}f$ (c) $\frac{3}{4}f$ (d) $\frac{7}{3}f$

21. Two lenses of power 6D and –2D are combined to form a single lens. The focal length of this lens will be:

(a) $\frac{3}{2}$ m (b) $\frac{1}{4}$ m (c) 4m (d) $\frac{1}{8}$ m

22. A ray of light is incident at 60° on a prism of refracting angle 30°. The emerging ray is at an angle 30° with the incident ray. The value of refractive index of the prism is:

(a) $\sqrt{2}$ (b) $\frac{\sqrt{3}}{\sqrt{2}}$ (c) $\sqrt{3}$ (d) $\sqrt{6}$

23. Angle of minimum deviation is equal to the angle of prism A of an equilateral glass prism. The angle of incidence at which minimum deviation will be obtained is:

(a) 60° (b) 30° (c) 45° (d) $\sin^{-1}\left(\frac{2}{3}\right)$

24. When a ray of light enters a glass slab from air

(a) its wavelength decreases

(b) its wavelength increases

(c) its frequency increases

(d) neither wavelength increases nor frequency changes

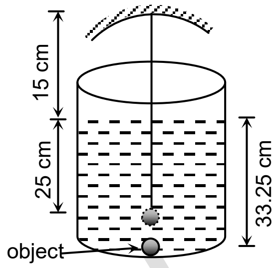
25. A thin convergent glass lens ($\mu_g = 1.5$) has a power of + 5.0 D. When this lens is immersed in a liquid of refractive index μ_l it acts as a divergent lens of focal length 100 cm. The value of μ_l must be

(a) 4/3 (b) 5/3 (c) 2 (d) 7/3

EXERCISE – III

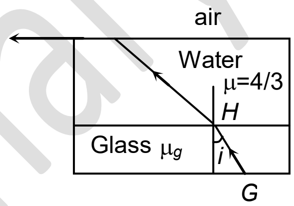
IIT-JEE- SINGLE CHOICE CORRECT

1. A concave mirror is placed over a beaker containing water of $\mu = 1.33$ and image of the object placed at the bottom of beaker is formed at a distance of 25 cm from the surface of water, then focal length of the mirror is:



(a) 10 cm (b) 15 cm
(c) 20 cm (d) 25 cm

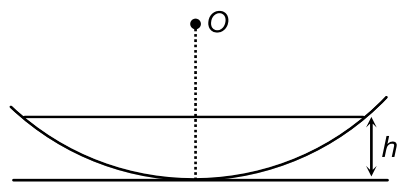
2. A ray of light travels in the fashion as shown in the figure. After passing through water, the ray grazes along the water air interface. The value of μ_g in terms of i is:



(a) $\frac{1}{\sin i}$ (b) $\frac{3}{4\sin i}$
(c) $\frac{4}{3\sin i}$ (d) none of the above

3. Two monochromatic coherent point sources S_1 and S_2 are separated by a distance L. Each source emits light of wavelength λ; where $L >> \lambda$. The line S_1S_2 when extended meets a screen perpendicular to it at a point A:
(a) the interference fringes on the screen are rectangular in shape.
(b) the interference fringes on the screen are straight lines perpendicular to the line S_1S_2A.
(c) the point A is an intensity maximum if $L = n\lambda$.
(d) the point A is always an intensity maxima for any separation L.

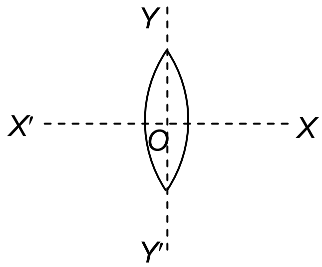
4. A concave mirror of radius R is kept on a horizontal table as shown. Water of refractive index μ is poured into it upto a height h. The height of the object O from water surface such that image is formed on itself is



(a) $\frac{R}{\mu}$ (b) $\frac{R-h}{\mu}$ (c) $R+h$ (d) $\mu(R-h)$

5. For constructive interference to take place between two monochromatic light waves of wavelength λ, the path difference should be:
(a) $(2n-1)\frac{\lambda}{4}$ (b) $(2n-1)\frac{\lambda}{2}$ (c) $n\lambda$ (d) $(2n+1)\frac{\lambda}{2}$

6. An equiconvex lens is cut into two halves along (i) XOX' and (ii) YOY' as shown in the figure. Let f, f', f'' be the focal lengths of complete lens, of each half in case (i), and of each half in case (ii), respectively. Choose the correct statement from the following:



(a) $f' = 2f$ and $f'' = f$ (b) $f' = f$ and $f'' = f$
(c) $f' = 2f$ and $f'' = 2f$ (d) $f' = f$ and $f'' = 2f$

7. 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

(a) $\cos^{-1}\left(\frac{\mu}{2}\right)$ (b) $2\cos^{-1}\left(\frac{\mu}{2}\right)$ (c) $2\sin^{-1}(\mu)$ (d) $2\sin^{-1}\left(\frac{\mu}{2}\right)$

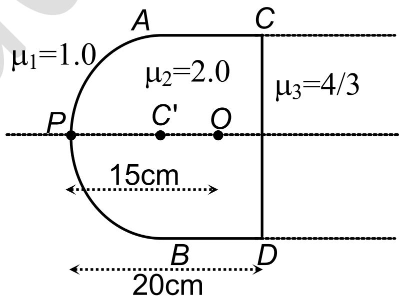
8. An air masked eye placed inside water (refractive index μ) sees the outside world. The vertical angle of the cone in which the eye will see the outside world is

(a) $2\sin^{-1}(1/\mu)$ (b) $2\cos^{-1}(1/\mu)$ (c) $2\sin^{-1}\left(\sqrt{\mu^2-1}\right)$ (d) $2\cos^{-1}\left(\sqrt{\mu^2-1}\right)$

9. A vessel of depth t 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

(a) $\frac{t(\mu_1+\mu_2)}{2\mu_1\mu_2}$ (b) $\frac{t(\mu_1-\mu_2)}{2\mu_1\mu_2}$ (c) $\frac{2t(\mu_1+\mu_2)}{\mu_1\mu_2}$ (d) $\frac{2t(\mu_1-\mu_2)}{\mu_1\mu_2}$

10. The slab of a material of refractive index 2 shown in figure has a curved surface APB of radius of curvature 10 cm and a plane surface CD. On the left of APB is air on the right of CD is water with refractive indices as given in the figure. An object O is placed at a distance of 15 cm from the pole P as shown. The distance of the final image of O from P, as viewed normally from the left is

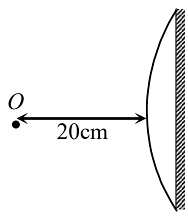


(a) 30 cm (b) 40 cm (c) 45 cm (d) 50 cm

11. A small object is enclosed in a sphere of solid glass 8 cm in radius. It is situated 2 cm from centre and is viewed from the side to which it is nearest. How far will it appear from the surface? (μ_g = 3/2)

(a) 6 cm (b) 4 cm (c) $5\frac{1}{3}$ cm (d) $3\frac{2}{3}$ cm

12. A thin plano-convex lens of focal length 15 cm has its plane side silvered. An object is placed on the principal axis of the lens at a distance 20 cm from it as shown. The final position of the image is



(a) 60 cm to the right of the lens (b) 60 cm to the left of the lens
(c) 30 cm to the left of the lens (d) 12 cm to the left of the lens

13. In Young's double slit experiment, the 8th maximum with wavelength λ_1 is at a distance d_1 from central maximum, and 6th maximum with wavelength λ_2 is at a distance d_2. Then d_1/d_2 is

(a) $\frac{4}{3}\left(\frac{\lambda_2}{\lambda_1}\right)$ (b) $\frac{4}{3}\left(\frac{\lambda_1}{\lambda_2}\right)$ (c) $\frac{3}{4}\left(\frac{\lambda_2}{\lambda_1}\right)$ (d) $\frac{3}{4}\left(\frac{\lambda_1}{\lambda_2}\right)$

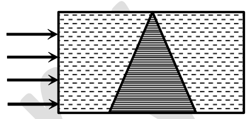
14. Wavelength of light used in an optical instrument are $\lambda_1 = 4000$ Å and $\lambda_2 = 5000$ Å, then ratio of their respective resolving power (corresponding to λ_1 and λ_2) is

(a) 16 : 25 (b) 9 : 1 (c) 4 : 5 (d) 5 : 4

15. A plano-convex lens fits exactly into a plano-concave lens. Their plane surfaces are parallel to each other. If the lenses are made of different materials of refractive indices μ_1 and μ_2 and R is the radius of curvature of the curved surfaces of the lenses, then the focal length of the combination is

(a) $\frac{R}{\mu_1 - \mu_2}$ (b) $\frac{2R}{\mu_2 - \mu_1}$ (c) $\frac{R}{2(\mu_1 - \mu_2)}$ (d) $\frac{R}{2-(\mu_1 + \mu_2)}$

16. A thin isosceles prism with angle 4^0 and refractive index 1.5 is placed inside a transparent tube with water $\left(\text{refractive index} = \frac{5}{4}\right)$ as shown. The deviation of light due to prism will be



(a) 0.8^0 upward (b) 0.8^0 downward (c) 0.67^0 upward (d) 0.67^0 downward

17. A concave mirror forms a real image of twice the linear dimensions of the object on a screen. Object and screen are then moved until the image is three times the size of the object. If the shift of the screen is 25 cm, then the focal length of the mirror is

(a) 5 cm (b) 16.66 cm (c) 25 cm (d) 37.5 cm

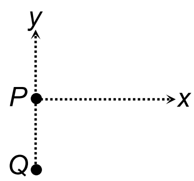
18. A ray of light falls normally on a refracting face of a prism of refractive index 1.5. What is the angle of prism if the ray just fails to emerge from the prism.

(a) 30° (b) $\sin^{-1}(1/3)$ (c) $\tan^{-1}(3/2)$ (d) $\sin^{-1}(2/3)$

19. When an object is at distance u_1 and u_2 from a lens, a real image and a virtual image is formed respectively have same magnification. The focal length of the lens is

(a) $u_1 - u_2$ (b) $\frac{u_1 - u_2}{2}$ (c) $\frac{u_1 + u_2}{2}$ (d) $u_1 + u_2$

20. Two identical sources P and Q emit waves in same phase and of same wavelength. Spacing between P and Q is 3λ. The maximum distance from P along the x–axis at which a minimum intensity occurs is given by



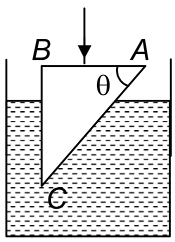
(a) 6.58λ (b) 2.25λ

(c) 8.75λ (d) 0.55λ

21. White light is used to illuminate the two slits in a Young's double slit experiment. The separation between the slits is b and the screen is at a distance $d(>>b)$ from the slits. At a point on the screen directly in front of one of slits, certain wavelengths are missing. Some of these missing wavelengths are

(a) $\lambda = \frac{b^2}{2d}$ (b) $\lambda = \frac{2b^2}{d}$ (c) $\lambda = \frac{b^2}{3d}$ (d) $\lambda = \frac{2b^2}{3d}$

22. A glass prism of refractive index 1.5 is immersed in water ($\mu = 4/3$). Light beam incident normally on the face AB is totally reflected to reach the face BC if



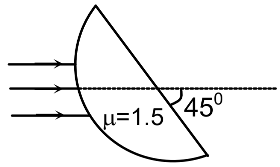
(a) $\sin\theta > 8/9$ (b) $2/3 < \sin\theta < 8/9$

(c) $\sin\theta \le 2/3$ (d) $\cos\theta \ge 8/9$

23. In double slit experiment with wavelength λ the distance between the slits is d. At a point on the central bright fringe the intensity is ¼ th of the maximum intensity. The angular position of the point is

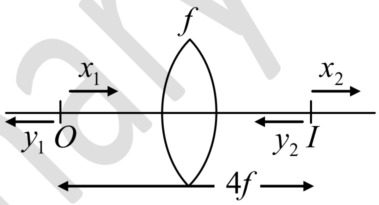
(a) $\sin^{-1}\left(\frac{\lambda}{d}\right)$ (b) $\sin^{-1}\left(\frac{\lambda}{2d}\right)$ (c) $\sin^{-1}\left(\frac{\lambda}{3d}\right)$ (d) $\sin^{-1}\left(\frac{\lambda}{4d}\right)$

24. A parallel narrow beam of light is incident on the surface of a transparent hemisphere of radius R and refractive index $\mu = 1.5$ as shown. The position of the image formed by refraction at the spherical surface only is



(a) $\frac{R}{2}$ (b) $3R$ (c) $\frac{R}{3}$ (d) $2R$

25. In a converging lens of focal length f and the distance between real object and its real image is $4f$. If the object moves x_1 distance towards lens its image moves x_2 distance away from the lens and when object moves y_1 distance away from the lens its image moves y_2 distance towards the lens, then choose the correct option



(a) $x_1 > x_2$ and $y_1 > y_2$ (b) $x_1 < x_2$ and $y_1 < y_2$

(c) $x_1 < x_2$ and $y_1 > y_2$ (d) $x_1 > x_2$ and $y_2 > y_1$

EXERCISE – IV

ONE OR MORE THAN ONE CHOICE CORRECT

1. Which of the following is/are incorrect statements in case of a concave mirror.
(a) An enlarged image is only formed when the object lies within focus and pole.
(b) A virtual image is always enlarged.
(c) Enlarged images are formed for two positions of object.
(d) Enlarged images are always erect.

2. When a light ray travelling in air enters into a medium of refractive index μ
(a) its speed decreases by a factor μ
(b) its frequency decreases by a factor μ
(c) its wavelength decreases by a factor μ
(d) all the above

3. The image of an object kept at a distance 20cm in front of a concave mirror is found to coincide with itself. If a glass slab (μ = 1.5) of thickness 3 cm is introduced between the mirror and the object, then in order that the final image again coincides with the object,
(a) the mirror should be displaced away from the object
(b) the mirror should be displaced towards the object
(c) the magnitude of displacement is 1 cm
(d) the magnitude of displacement is 0.5 cm

4. In a prism, the angle of incidence at which the emergent ray grazes the boundary is given by i_g. The light will come out of it,
(a) if the angle of incidence is greater than i_g
(b) if the angle of incidence is lesser than i_g
(c) at an angle lesser than i_g if the angle of prism is increased
(d) at an angle lesser than i_g if the angle of prism is decreased

5. In a prism of angle A and refractive index μ, the maximum deviation occurs when
(a) the angle of incidence is 90^0
(b) the angle of emergence is $\sin^{-1}\left[\sqrt{\mu^2-1}\sin A-\cos A\right]$
(c) the angle of emergence is $\sin^{-1}\left[\left(\mu\sin(A-\theta_C)\right)\right]$
(d) the angle of emergence is equal to the angle of incidence

6. In an experiment with a lens, the object distance *u* versus image distance *v* data were obtained. Which of the following graphs will be linear?
(a) 1/ *v* versus 1/*u*
(b) *u v* versus $(u+v)$
(c) *v*/*u* versus *v*
(d) *v* versus *u*

7. A planet is observed by an astronomical refracting telescope having an objective of focal length 16 m and an eyepiece of focal length 2 cm, for relaxed eye
(a) the distance between the objective and the eyepiece is 16.02 m
(b) the angular magnification of the planet is 800
(c) the image of the planet is inverted
(d) the objective is larger than eyepiece

8. Two monochromatic coherent point sources S_1 and S_2 are separated by a distance L. Each source emits light of wavelength λ; where $L >> \lambda$. The line S_1 S_2 when extended meets a screen perpendicular to it at a point A.

(a) the interference fringes on the screen are circular in shape
(b) the interference fringes on the screen are straight lines perpendicular to the line S_1S_2A.
(c) the point A is an intensity maxima if $L = n\lambda$
(d) the point A is always an intensity maxima for any separation L

9. A point object is placed at 30 cm from a convex glass lens $\left(\mu_g = \frac{3}{2}\right)$ of focal length 20 cm. The final image of object will be formed at infinity if

(a) another concave lens of focal length 60 cm is placed in contact with the previous lens
(b) another convex lens of focal length 60 cm is placed at a distance of 30 cm from the first lens
(c) the whole system is immersed in a liquid of refractive index $\frac{4}{3}$
(d) the whole system is immersed in a liquid of refractive index $\frac{9}{8}$

10. For which of the pairs of u and f for a mirror, size of image is smaller than the size of object

(a) $u = -10$ cm, $f = 20$ cm
(b) $u = -20$ cm, $f = -30$ cm
(c) $u = -45$ cm, $f = -10$ cm
(d) $u = -60$ cm, $f = 30$ cm

11. A ray of light travelling in a transparent medium falls on a surface separating the medium from air at an angle of incidence 45^0. The ray undergoes total internal reflection. If n is the refractive index of the medium with respect to air, select the possible value(s) of n from the following

(a) 1.3 (b) 1.4 (c) 1.5 (d) 1.6

12. Refractive index of an equilateral prism is $\sqrt{2}$

(a) minimum deviation from this prism can be 30^0
(b) minimum deviation from this prism can be 45^0
(c) at angle of incidence = 45^0; deviation is minimum
(d) at angle of incidence = 60^0, deviation is minimum

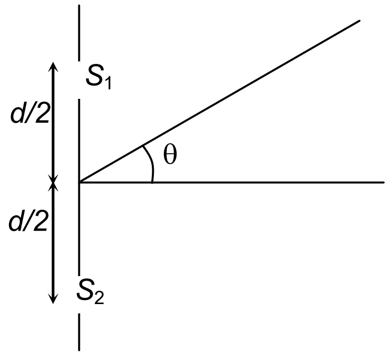
13. From a concave mirror of focal length f, image is 2 times larger. Then the object distance from the mirror is

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

14. In Young's double slit experiment, the interference pattern is found to have an intensity ratio between the bright and dark fringes as 9. This implies that

(a) the intensities at the screen due to the two slits may be 5 units and 4 units respectively
(b) the intensities at the screen due to the two slits may be 4 units and 1 unit respectively
(c) the amplitude ratio is 3
(d) the amplitude ratio is 2

15. In an interference arrangement similar to Young's double-slit experiment, the slits S_1 and S_2 are illuminated with coherent microwave sources, each of frequency 10^6Hz. The sources are synchronized to have zero phase difference. The slits are separated by a distance $d = 150.0$ m. The intensity $I(\theta)$ is measured as a function of θ, where θ is defined as shown. If I_0 is the maximum intensity, then $I(\theta)$ for $0 \le \theta \le 90^0$ is given by



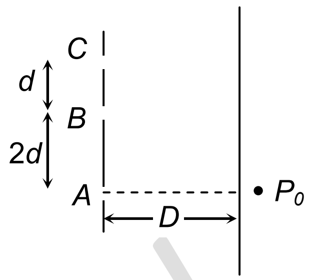
(a) $I(\theta) = I_0/2$ for $\theta = 30^0$ (b) $I(\theta) = I_0/4$ for $\theta = 90^0$
(c) $I(\theta) = 0$ for $\theta = 90^0$ (d) $I(\theta)$ is constant for all value of θ

EXERCISE –V

MATCH THE FOLLOWING

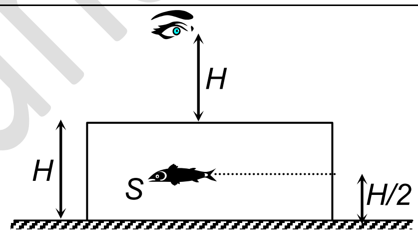
Note: Each statement in column – I has only one match in column –II

1. In the figure shown A, B and C are the three slits each of which individually produces the same intensity I_0, at point P_0 when they are illuminated by parallel beam of light of wavelength λ. (Given: $BP_0 - AP_0 = \frac{\lambda}{2}$, $d << D$, I_0=4 W/m^2, Amplitude of each wave = 2 units, λ = 6000Å). Match the quantities of column I with their values in column II.



Column I	Column II
I. Resultant intensity at P_0 in (W/m^2)	**A.** 4
II. Resultant amplitude at P_0 (in unit)	**B.** zero
III. If slit C is closed then resultant intensity at P_0	**C.** 2
IV. If slit B is closed resulting amplitude at P_0 (in SI unit)	**D.** $2\sqrt{2}$

2. Consider the situation in figure. The bottom of the pot is reflecting plane mirror, S is a small fish and T is a human eye. Refractive index of water is μ. Fish can see two images of human eye, first due to refraction only and other due to reflection and then refraction. Distance of these images from fish are S_1 and S_2 respectively. Human eye can also see the two images of fish, first due to refraction only and other due to, reflection and then refraction. Distance of these images from human eye are S_3 and S_4 respectively. Match the quantities of column – I (with their values in column-II)



Column I	Column II
I. S_1	**A.** $H\left[1+\frac{1}{2\mu}\right]$
II. S_2	**B.** $H\left[\mu+\frac{1}{2}\right]$
III. S_3	**C.** $H\left[1+\frac{3}{2\mu}\right]$
IV. S_4	**D.** $H\left[\mu+\frac{3}{2}\right]$

Note: Each statement in column – I has one or more than one match in column –II.

3. Match the following

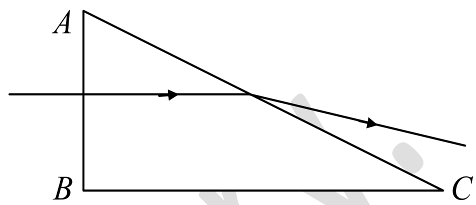
Column -I	Column -II
I. Convex mirror, virtual object	**A.** Real image
II. Concave mirror, virtual object	**B.** Virtual image
III. Concave lens, real object	**C.** Magnified image
IV. Convex lens, real object	**D.** Diminished image

REASONING TYPE

Directions: Read the following questions and choose

(A) If both the statements are true and statement-2 is the correct explanation of **statement-1**.
(B) If both the statements are true but statement-2 is not the correct explanation of **statement-1**.
(C) If statement-1 is True and **statement-2** is False.
(D) If statement-1 is False **and statement-2** is True.

1. **Statement-1:** A beam of light containing radiations of only two wavelengths is incident on a prism. It is found that radiations of one wavelength come out from the face AC of the prism but radiations of other wavelength does not.



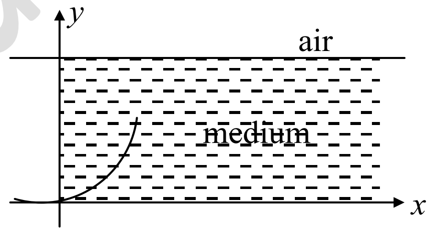
Statement-2: The condition of total internal reflection is satisfied for one wavelength and not for the other.

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

2. **Statement-1:** In YDSE number of bright fringe or dark fringe can not be unlimited
Statement-2: In YDSE path difference between the superposing waves can not be more than the distance between the slits.

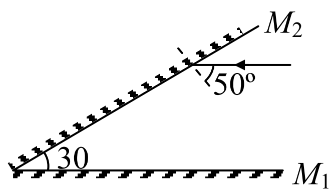
(a) (A) (b) (B) (c) (C) (d) (D)

3. **Statement-1:** A ray of light traveling in air is incident at grazing angle on a long rectangular slab of a transparent medium and instead of moving straight it follows a curved path as shown in the figure.
Statement-2: Refractive index of the medium is increasing along y axis.



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

4. **Statement-1:** The net deviation suffered by a light ray, incident on a plane mirror as shown in the figure is $360^0 - 2\times 30^0 = 300^0$



Statement-2: A ray of light is incident on a plane mirror at an angle i with the normal to the mirror. It strikes another plane mirror inclined at an angle θ with the first mirror. It is given that $i < \theta$. The net deviation produced after reflection once from each mirror is $2\pi - 2\theta$.

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

5. **Statement-1:** In Young's double slit experiment if wavelength of incident monochromatic light is just doubled, number of bright fringe on the screen will increase.
Statement-2: Maximum number of bright fringe on the screen is inversely proportional to the wavelength of light used

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

LINKED COMPREHENSION TYPE

When two coherent sources interact with each other there will be production of alternate bright and dark fringes on the screen. The young's double slit experiment demonstrates the idea of making two coherent sources. For better visibility, one has to choose proper amplitude for the sources. The phenomena is good enough to satisfy the conservation of energy principle. The pattern formed in YDSE is of uniform thickness and is nicely placed on a long distance screen.

1. Law of conservation of energy is satisfied because
(a) equal loss and gain in intensity is observed
(b) all bright fringes are equally bright
(c) all dark fringes are of zero brightness
(d) the average intensity on screen is equal to the sum of intensities of the two sources.

2. The best combination of independent sources to produce sustained pattern among the following is

$$Y_1 = a\sin\omega t\ ,\ Y_2 = a\cos\omega t\ ,\ Y_3 = a\sin\left(\omega t + \frac{\pi}{4}\right),\ Y_4 = 2a\sin(\omega t + \pi)$$

(a) Y_1, Y_2 only (b) Y_2, Y_3 only (c) Y_3, Y_4 only (d) none of these

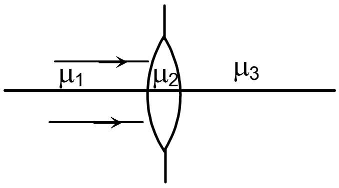
3. On introducing a transparent slab (μ) the central fringes shifts to the point originally occupied by the fifth bright fringe. The thickness of the slab is
(a) $\frac{5\lambda}{\mu - 1}$ (b) $\frac{4\lambda}{\mu - 1}$ (c) $\frac{\mu - 1}{4\lambda}$ (d) $\frac{\mu - 1}{5\lambda}$

4. The YDSE apparatus in air is immersed inside a liquid of refractive index μ_0. The fringe width of the fringes obtained on the screen
(a) increases (b) decreases
(c) remains same (d) no such judgment can be made

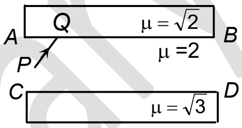
EXERCISE – VI

SUBJECTIVE PROBLEMS

1. A thin glass lens of refractive index $\mu_2 = 1.5$ behaves as a interface between two media of refractive indices $\mu_1 = 1.4$ and $\mu_3 = 1.6$ respectively. Determine the reciprocal of the focal length of the lens for the shown arrangement of radius of curvature of both the surfaces is 20 cm.

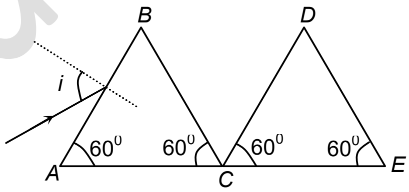


2. Find the minimum value of angle of incidence on *AB* so that total internal reflection takes place at both the surfaces *AB* and *CD*.

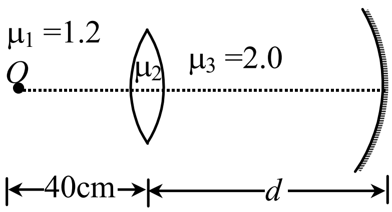


3. (a) A light ray is incident on the prism *ABC* at an angle of incidence *i*, as shown in figure. Find the value of *i* so that deviation produced by the prism *ABC* is minimum.

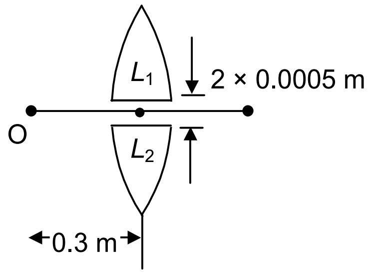
(b) Another similar prism *DCE* is now fixed at point *C* which can rotate about the axis passing through *C* and perpendicular to the plane of paper. By what angle will the prism *DCE* be rotated, so that the final emergent ray should have minimum deviation from the second prism also? If it is given that the refractive index of material of both the prisms is $\sqrt{3}$.



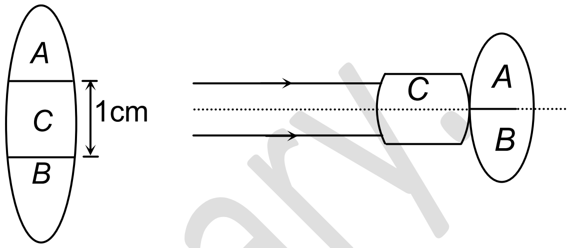
4. The figure shows an arrangement of an equiconvex lens of refractive index $\mu_2 = 1.5$ and a concave mirror. A point object *O* is placed on the principal axis at a distance 40 cm from the lens such that the final image is also formed at the position of the object. If the radius of curvature of the concave mirror is 80 cm, find the distance *d*. The focal length of the lens in air is 20 cm.



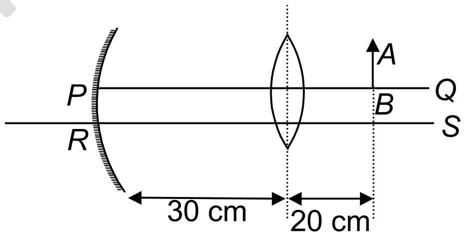
5. A point object O is placed at a distance of 0.3 m from a convex lens of focal length 0.2m. It then cut into two halves each of which is displaced by 0.0005 m as shown in figure. Find the position of the image. If more than one image is formed, find their number and the distance between them in mm.



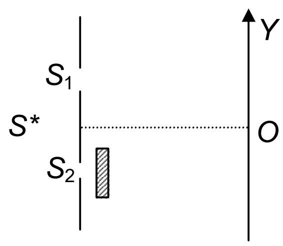
6. A thin convex lens of focal length 1 m is cut into three parts A, B and C as shown in figure. The height of the middle layer C is 1 cm. The middle layer is now removed and the two parts A and B are put together to form a composite lens. Then the part C is also placed in front of this composite lens symmetrically. A paraxial beam of light is incident along the axis of the part C. Find the distance between the two images in mm.



7. A convex lens of focal length 15 cm and a concave mirror of focal length 30 cm are kept with their optic axis PQ and RS parallel but separated in vertical direction by 0.6 cm as shown. The distance between the lens and the mirror is 30 cm. An upright object AB of height 1.2 cm is placed on the optic axis PQ of the lens at a distance of 20 cm from the lens. If A' B' is the image after refraction from the lens and reflection from the mirror, find the distance of $A'B'$ from the pole of the mirror. Also locate positions of A' and B' with respect to optic axis RS in mm.



8. The Young's double slit experiment is done in a medium of refractive index 4/3. A light of 600 nm wavelength is falling on the slits having 0.45 mm separation. The lower slits S_2 is covered by a thin glass sheet of thickness 10.4 μm and refractive index 1.5. The interference pattern is observed on a screen placed 1.5 m from the slits as shown

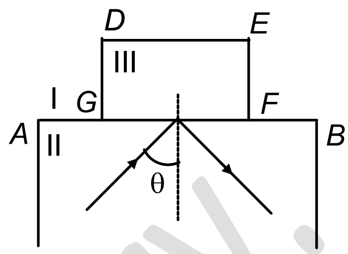


(a) The location of the central maxima (bright fringe with zero path difference) on the y-axis is $x \times 10^{-2}$ mm. The value of x is

(b) Find the ratio of light intensity at point O relative to the fringe intensity I_0, if maximum intensity is $4I_0$.

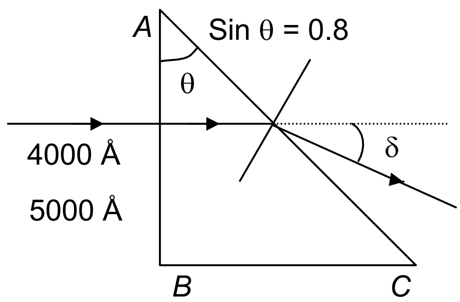
All wavelengths in this problem are for the given medium of refractive index 4/3. Ignore dispersion.

9. Monochromatic light is incident on a plane interface AB between two media of refractive indices n_1 and n_2 ($> n_1$) at an angle of incidence θ as shown in figure. The angle θ is infinitesimally greater than the critical angle for the two media so that total internal reflection takes place. Now if a transparent slab $DEFG$ of uniform thickness and of refractive index n_3 is introduced on the interface (as shown in figure), show that for any value of n_3 all light will ultimately be reflected back again into medium II. Consider separately the case (i) $n_3 < n_1$ and (ii) $n_3 > n_1$.



10. A beam of light which contains radiation of wavelength 4000 Å and 5000 Å is incident normally on a prism as shown in figure. The refractive index of the prism as a function of wavelength is given by

$\mu(\lambda) = 1.20 + \frac{b}{\lambda^2}$, where λ is in Å and b is a positive constant. The value of b is such that the condition for total internal reflection at an face AC is just satisfied for one wavelength and not for the other. The value of b is $x \times 10^5$ $(\text{Å})^2$. Find x.



ANSWERS

EXERCISE – II

NEET-SINGLE CHOICE CORRECT

1. (b)	2. (d)	3. (b)	4. (c)	5. (c)
6. (c)	7. (c)	8. (b)	9. (c)	10. (d)
11. (a)	12. (b)	13. (c)	14. (a)	15. (c)
16. (a)	17. (a)	18. (c)	19. (c)	20. (a)
21. (b)	22. (c)	23. (a)	24. (a)	25. (b)

EXERCISE – III

IIT-JEE-SINGLE CHOICE CORRECT

1. (c)	2. (a)	3. (c)	4. (b)	5. (c)
6. (d)	7. (b)	8. (a)	9. (a)	10. (a)
11. (c)	12. (d)	13. (b)	14. (d)	15. (a)
16. (b)	17. (c)	18. (d)	19. (c)	20. (c)
21. (c)	22. (a)	23. (c)	24. (b)	25. (c)

EXERCISE – IV

ONE OR MORE THAN ONE CHOICE CORRECT

1. (a,c,d)	2. (a,c)	3. (a,c)	4. (a,d)	5. (a,b,c)
6. (a,b,c)	7. (a,b,c,d)	8. (a,c)	9. (a,d)	10. (a,c,d)
11. (c,d)	12. (a,c)	13. (a,b)	14. (b,d)	15. (a,c)

EXERCISE – V

MATCH THE FOLLOWING

1. I – A, II – C, III – B, IV – D
2. I – B, II – D, III – A, IV – C
3. I – A,B,C,D, II – A,D, III – B,D, IV – A,B,C,D

REASONING TYPE

1. (a)	2. (a)	3. (a)	4. (d)	5. (d)

LINKED COMPREHENSION TYPE

1. (d)	2. (d)	3. (a)	4. (b)	

EXERCISE – VI

SUBJECTIVE PROBLEMS

1. zero

2. 60^0

3. (a) 60^0
(b) clockwise or anticlockwise through 60°.

4. 30 cm

5. 60 cm from the lens on the other side; no. of images = 2;
Separation between the two images = 3 mm

6. 5 mm

7. $A'B'$ is 15 cm infront of the concave mirror. $m = -\frac{3}{2}$

The point B' is 3 mm above RS
The point A' is 15 mm below RS.

8. (a) 433 (b) 3

10. $x = 8$

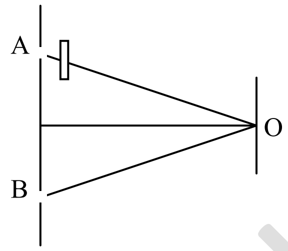
IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 1

Q.1 If a transparent medium of refractive index $\mu = 1.5$ and thickness $t = 2.5 \times 10^{-5}$ m is inserted in front of the slits of Young's Double slit experiment, how much will be the shift in the interference pattern ? The distance between the slits is 0.5 mm and that between slits and screen is 100 cm :

(1) 5 cm (2) 2.5 cm (3) 0.25 cm (4) 0.1 cm

Q.2 In Young's experiment, monochromatic light is used to illuminate the two slits A and B. Interference fringes are observed on a screen placed in front of the slits.

Now if a thin glass plate is placed normally in the path of the beam coming from the slit then :



(1) The fringes will disappear

(2) The fringe width will decrease

(3) The fringe width will increase

(4) There will be no change in the fringe width

Q.3 What is the path difference of destructive interference : -

(1) $n\lambda$ (2) $n(\lambda + 1)$

(3) $\frac{(n+1)\lambda}{2}$ (4) $\frac{(2n+1)\lambda}{2}$

Q.4 A double slit experiment is performed with light of wavelength 500 nm. A thin film of thickness 2 μm and refractive index 1.5 is introduced in the path of the upper beam. The location of the central maximum will :

(1) Remain unshifted

(2) Shift downward by nearly two fringes

(3) Shift upward by nearly two fringes

(4) Shift downward by 10 fringes

Q.5 A monochromatic beam of light is used for the formation of fringes on the screen by illuminating the two slits in the Young's double slit interference experiment. When a thin film of mica is interposed in the path of one of the interfering beams then :

(1) The fringe width increases

(2) The fringe width decreases

(3) The fringe width remains the same but the pattern shifts

(4) The fringe pattern disappears

Q.6 When exposed to sunlight, thin films of oil on water often exhibit brilliant colors due to the phenomenon of -

(1) interference (2) diffraction

(3) dispersion (4) polarisation

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 2

Q.1 The phenomenon of interference is shown by:
(1) Longitudinal mechanical waves only
(2) Transverse mechanical waves only
(3) Electromagnetic waves only
(4) All the above type of waves

Q.2 In Young's double slit experiment, if the width of the slits are in the ratio 4 : 9 the ratio of the intensity of maxima to intensity at minima will be :
(1) 169 : 25 (2) 81 : 16
(3) 25 : 1 (4) 9 : 4

Q.3 Soap bubble appears coloured due to the phenomenon of :
(1) Interference (2) Diffraction
(3) Dispersion (4) Reflection

Q.4 In an interference experiment, the spacing between successive maxima or minima is :
(1) $\frac{\lambda d}{D}$ (2) $\frac{\lambda D}{d}$ (3) $\frac{dD}{\lambda}$ (4) $\frac{\lambda d}{4D}$

Q.5 Two coherent sources must have the same :
(1) Amplitude (2) Phase difference
(3) Frequency (4) Both (2) and (3)

Q.6 For the sustained interference of light, the necessary condition is that the two sources should :
(1) Have constant phase difference
(2) Be narrow
(3) Be close to each other
(4) Of same amplitude

Q.7 In Young's double slit experiment using sodium light (λ = 5898Å), 92 fringes are seen. If given colour (λ = 5461Å) is used, how many fringes will be seen :
(1) 62 (2) 67
(3) 85 (4) 99

Q.8 Young's experiment is performed in air and then performed in water, the fringe width :
(1) Will remain same (2) Will decrease
(3) Will increase (4) Will be infinite

Q.9 In Young's experiment, one slit is covered with a blue filter and the other (slit) with a yellow filter. Then the interference pattern :
(1) Will be blue (2) Will be yellow
(3) Will be green (4) Will not be formed

Q.10 In Young's double slit experiment, a mica sheet of thickness t and refractive index μ is introduced in the path of ray from the first source S_1. By how much distance the fringe pattern will be displaced :

(1) $\frac{d}{D}(\mu-1)t$ (2) $\frac{D}{d}(\mu-1)t$

(3) $\frac{d}{(\mu-1)D}$ (4) $\frac{D}{d}(\mu-1)$

Q.11 If light of low wavelength is used in Young's double slit experiment, then width of the fringe will :

(1) Decrease (2) Increase

(3) Not fixed (4) No change

Q.12 In Young's experiment, light of wavelength 6000Å is used to produce fringes of width 0.8 mm at a distance of 2.5 m. If the whole experiment is deep in a liquid of refractive index 1.6, then fringe width will be :

(1) 0.5 mm (2) 0.6 mm

(3) 0.5 mm (4) 0.2 mm

Q.13 In double slit experiment, the angular width of the fringes is 0.20º for the sodium light (λ = 5890Å). In order to increase the angular width of the fringes by 10%, the necessary change in the wavelength is :

(1) Increase of 589Å (2) Decrease of 589Å

(3) Increase of 6479Å (4) Zero

Q.14 Young's experiment establishes that :

(1) Light consists of waves

(2) Light consists of particles

(3) Light consists of neither particles nor waves

(4) Light consists of both particles and waves

Q.15 Two coherent light beams of intensity I and 4I are superposed. The maximum and minimum possible intensities in the resulting beam are :

(1) 5I and 3I (2) 51 and I

(3) 9I and 3I (4) 91 and I

Q.16 In Young's double slit experiment, if monochromatic light is replace by white light :

(1) All bright fringes become white

(2) All bright fringes have coloures between violet and red

(3) Only the central fringe is white, all other fringes are coloured

(4) No fringes are observed

Q.17 The fringe width in Young's double slit experiment increases when :

(1) Wavelength increases

(2) Distance between the slits increases

(3) Distance between the source and screen decreases

(4) The width of the slits increases

Q.18 Young's double slit experiment is performed with light of wavelength 550 nm. The separation between the slits is 1.10 mm and screen is placed at distance of 1m. What is the distance between the consecutive bright or dark fringes.

(1) 1.5 mm (2) 1.0 mm
(3) 0.5 mm (4) None of these

Q.19 Two coherent sources of intensities I_1 and I_2 produce an interference pattern. The maximum intensity in the interference pattern will be :

(1) $I_1 + I_2$ (2) $I_1^2 + I_2^2$
(3) $(I_1 + I_2)^2$ (4) $(\sqrt{I_1} + \sqrt{I_2})^2$

Q.20 In the Young's double slit experiment, for which colour the fringe width is least

(1) Red (2) Green
(3) Blue (4) Yellow

Q.21 Two wave are represented by the equations $y_1 = a \sin \omega t$ and $y_2 = a \cos \omega t$. The first wave :

(1) Leads the seconds π
(2) Lags the second by π
(3) Leads the second by $\frac{\pi}{2}$
(4) Lags the seconds by $\frac{\pi}{2}$

Q.22 The resultant amplitude of a vibrating particle by the superposition of the two waves $y_1 = a\sin\left(\omega t + \frac{\pi}{3}\right)$ and $y_2 = a \sin \omega t$ is : -

(1) a (2) $\sqrt{2}$ a
(3) 2a (4) $\sqrt{3}$ a

Q.23 Two coherent sources of different intensities send waves which interfere. If the ratio of maximum and minimum intensity in the interference pattern is 25 then find ratio of intensity of source :

(1) 25 : 1 (2) 5 : 1
(3) 9 : 4 (4) 25 : 16

Q.24 In a Young's double slit experiment with sodium light, slits are 0.589 m apart. The angular separation of the third maximum from the central maximum will be (given λ = 589 nm) :

(1) $\sin^{-1}(0.33 \times 10^{8})$ (2) $\sin^{-1}(0.33 \times 10^{-6})$
(3) $\sin^{-1}(3 \times 10^{-8})$ (4) $\sin^{-1}(3 \times 10^{-6})$

Q.25 If the sodium light in Young's double slit experiment is replaced by red light, the fringe width will :

(1) Decrease
(2) Increase
(3) Remain unaffected
(4) First increase, then decrease

Q.26 If an interference pattern have maximum and minimum intensities in 36 : 1 ratio then what will be the ratio of amplitudes

(1) 5 : 7 (2) 7 : 4
(3) 4 : 7 (4) 7 : 5

Q.27 When a thin transparent plate of thickness t and refractive index μ is placed in the path of one of the two interfering waves of light, then the path difference changes by :

(1) $(\mu + 1)t$ (2) $(\mu - 1)t$
(3) $\frac{(\mu+1)}{t}$ (4) $\frac{(\mu-1)}{t}$

Q.28 Due to effect of interference, floating oil layer in water is visible coloured, due to observation of this event the thickness of oil layer should be :

(1) 10 nm (2) 1000 nm
(3) 1 mm (4) 10 mm

Q.29 In fresnel biprism if prism angle $\alpha = 1º$, $\mu = 1.54$, distance between screen and prism b = 0.7 m, distance between prism & source a = 0.3 m, $\lambda = 180\,\pi$ nm then find the value of β (fringe width):-

(1) 10^{-4}m (2) 10^{-3}m
(3) $10^{-4} \times \pi$m (4) $\pi \times 10^{-3}$m

Q.30 If intensity ratio of two interfering waves is 9 : 1 then ratio of maximum to minimum amplitude of resultant wave is :

(1) 2 : 1 (2) 3 : 2
(3) 1 : 3 (4) 5 : 2

Q.31 For coherent sources :

(1) λ same (2) ϕ constant
(3) v same (4) Amplitude same

Q.32 In YDSE experiment, when two light rays make third minima, then they have : -

(1) Phase difference of 3π
(2) Phase difference of $\frac{5\pi}{2}$
(3) Path difference of 3λ
(4) Path difference of $\frac{5\lambda}{2}$

Q.33 On increasing, prism angle in fresnel biprism, the fringe width will : -

(1) Increase
(2) Decrease
(3) Unchanged
(4) Depends on position of object

Q.34 Two waves $Y_1 = a\sin\omega t$ and $Y_2 = a\sin(\omega t + \delta)$ are producing interference, then resultent intensity is : -

(1) $a^2\cos^2\delta/2$ (2) $2a^2\cos^2\delta/2$

(3) $3a^2\cos^2\delta/2$ (4) $4a^2\cos^2\delta/2$

Q.35 If in a Young's double slit experiment, width between the slits is 3 cm, the separation between slits and screen is 7 cm and wavelength of light is 1000 Å, then fringe width will be

(1) 2×10^{-5} m (2) 2×10^{-9} m

(3) 0.02×10^{-6} m (4) 2.3×10^{-7} m

Q.36 In an interference experiment, third bright fringe is obtained at a point on the screen with a light of 700 nm. What should be the wavelength of the light in order to obtain 5^{th} bright fringe at the same point ?

(1) 500 nm (2) 630 nm

(3) 750 nm (4) 420 nm

Q.37 In the young's double slit experiment the central maxima is observed to be I_0. If one of the slits is covered, then intensity at the central maxima will become :

(1) $I_0/2$ (2) $I_0/\sqrt{2}$

(3) $I_0/4$ (4) I_0

Q.38 In young experiment ratio of maximum and minimum intensity is 9 : 1 in fringe system then the ratio of amplitude of coherent source is :

(1) 9 : 1 (2) 3 : 1

(3) 2 : 1 (4) 1 : 1

Q.39 In a double slit experiment if light of wavelength 5000Å is used then fringe width of 1 mm is obtained. If now light of wavelength 6000Å is used without altering the system then new fringe width will be :

(1) 1 mm (2) 0.5 mm

(3) 1.2 mm (4) 1.5 mm

Q.40 If $\frac{I_1}{I_2} = \frac{9}{1}$ then $\frac{I_{max}}{I_{min}} = ?$

(1) 100 : 64 (2) 64 : 100

(3) 4 : 1 (4) 1 : 4

Q.41 Monochromatic green light has wavelength 5×10^{-7} m. The separation between slits is 1 mm. The fringe width of interference pattern obtained on screen at a distance of 2 meter is :

(1) 1 mm (2) 0.5 mm

(3) 2 mm (4) 0.1 mm

Q.42 Which light source is used in fresnel Biprism experiment : -

(1) Sodium lamp + Laser source

(2) Polarised

(3) Incoherent

(4) Coherent polarised

Q.43 In Young's double slit experiment when wavelength of 700 nm is used then fringe width of 0.7 mm is obtained. If wavelength of 500nm is used then what is the fringe width ?

(1) 0.35 mm (2) 0.5 mm
(3) 3.5 mm (4) 5 mm

Q.44 Soap bubble appears coloured due to the phenomenon of :

(1) Total internal reflection
(2) Interference by division of amplitude
(3) Interference by division of wavefront
(4) Diffraction of light

Q.45 In Young double slit experiment if distance between sources is made double then central fringe width will be : -

(1) Half (2) Double
(3) Unchanged (4) Nothing can be say

Q.46 Two coherent Light sources emit light of the -

(1) same intensity
(2) same pitch
(3) constant but different wavelengths
(4) same frequency having constant phase difference

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 3

Q.1 The energy in the phenomenon of interference :
(1) is conserved, gets redistributed
(2) is equal at every point
(3) is destroyed in regions of dark fringes
(4) is created at the place of bright fringes

Q.2 The resultant amplitude in interference with two coherent sources depends upon :
(1) only amplitude
(2) only phase difference
(3) on both the above
(4) none of the above

Q.3 Phenomenon of interference is observed :
(1) only for light waves
(2) only for sound waves
(3) for both sound and light waves
(4) none of above

Q.4 The phenomenon of interference in light was studied first by :
(1) Newton (2) Young
(3) Fresnel (4) Huygen

Q.5 Which of following nature of light waves is supported by the phenomenon on interference :
(1) longitudinal
(2) transverse
(3) both transverse and longitudinal
(4) None of the above

Q.6 For distinct interference pattern to be observed, necessary condition is that ratio of intensity of light emission by both the sources should be :
(1) 2 : 1 (2) 1 : 2 (3) 1 : 1 (4) 1 : 4

Q.7 The phase difference corresponding to path difference of x is :
(1) $\frac{2\pi x}{\lambda}$ (2) $\frac{2\pi\lambda}{x}$ (3) $\frac{\pi x}{\lambda}$ (4) $\frac{\pi\lambda}{x}$

Q.8 The coherent source of light produces constructive interference when phase difference between them is :
(1) π (2) $\frac{1}{2}\pi$ (3) $\frac{3}{2}\pi$ (4) 2π

Q.9 Phenomenon of interference is not observed by two sodium lamps of same power. It is because both waves have :
(1) not constant phase difference
(2) zero phase difference
(3) different intensity
(4) different frequencies

Q.10 Coherent sources can be obtained :
(1) only by division of wave front
(2) only by division of amplitude
(3) both by division of amplitude and wave front
(4) none of these

Q.11 In light waves emitted by an ordinary source, for what period of time, the phase remains constant
(1) 10 sec (2) 1 sec
(3) 10^{-3} sec (4) 10^{-8} sec

Q.12 In Young's double slit experiment, width of fringes can be increase if we decrease the :
(1) separation of slits
(2) slit width
(3) distance between the slit and the screen
(4) wavelength of sources

Q.13 In Young's experiment, if the amplitude of interferring waves are unequal then the :
(1) contrast in the fringes decreases
(2) contrast in the fringes increase
(3) number of fringes will increase
(4) number of fringes will decrease

Q.14 Young's experiment proves which of following fact :
(1) light is made up of particles
(2) light is made up of waves
(3) light is made up of neither waves nor particles
(4) fringe width doesn't depend upon the spacing between slits

Q.15 Which of following is a true statement, if in Young's experiment, separation between the slits is gradually increased :
(1) fringe width increase and fringes disappear
(2) fringe width decreases and fringes disappear
(3) fringes become blurred
(4) fringe width remains constant and fringes are more bright

Q.16 In Young's double slit experiment :
(1) only interference occurs
(2) only diffraction occurs
(3) both interference and diffraction occurs
(4) none of the above

Q.17 In Young's double slit experiment, one of the slits is so painted that intensity of light emitted from it is half of that of the light emitted from other slit. Then :
(1) fringe system will disappear
(2) bright fringes will become brighter and dark fringes will be darker
(3) both bright and dark fringes will become darker
(4) dark fringes will become less dark and bright fringes will become less bright

Q.18 In white light interference, nearest to the central (bright) fringe, will have which of the following colour
(1) violet (2) yellow
(3) red (4) green

Q.19 In an interference of light derived from two slit apertures, if at some point on the screen, yellow light has a path difference of $\frac{3\lambda}{2}$, then the fringe at that point will be :

(1) yellow in colour (2) white in colour
(3) dark (4) bright

Q.20 In Young's experiment small gap between the two slits is d, and distance of screen from the slits is D. Then the number of fringes per metre that will appear on screen by mono-chromatic source of wavelength of λ, will be :

(1) $\frac{\lambda D}{d}$ (2) $\frac{d}{\lambda D}$ (3) $\frac{2d\lambda}{D}$ (4) $\frac{2dD}{\lambda}$

Q.21 In Young's experiment, if X_{mr} and X_{mv} denotes the distances of m^{th} red and violet fringe from the central fringe. Then :

(1) $X_{mr} > X_{mv}$ (2) $X_{mr} < X_{mv}$
(3) $X_{mr} = X_{mv}$ (4) $X_{mr} + X_{mv} = 0$

Q.22 In an interference pattern of two wave fringe width is β. If the frequency of source is doubled then fringe width will become :

(1) $\frac{1}{2}\beta$ (2) β (3) 2β (4) $\frac{3}{2}\beta$

Q.23 If ratio of amplitude of two interferring source is 3 : 5. Then ratio of intensity of maxima and minima in interference pattern will be:

(1) 25 : 16 (2) 5 : 3
(3) 16 : 1 (4) 25 : 9

Q.24 In an interference pattern the $(n+4)^{th}$ blue bright fringe and n^{th} red bright fringe are formed at the same spot. If red and blue light have the wavelength of 7800Å and 5200 Å then value of n should be :

(1) 2 (2) 4 (3) 6 (4) 8

Q.25 In Young's double slit experiment, wavelength of light is 6000Å. Then the phase difference between the light waves reaching the third bright fringe from the central fringe will be :

(1) zero (2) 2π (3) 4π (4) 6π

Q.26 In a biprism experiment, coherent sources are obtained by which of the following phenomenon :

(1) refraction (2) reflection
(3) interference (4) diffraction

Q.27 In Fresnel's biprism, coherent sources are obtained by :

(1) division of wavefront
(2) division of amplitude
(3) division of wavelength
(4) none of the above

Q.28 In Fresnel's birprism experiment, the two coherent sources are :

(1) real
(2) imaginary
(3) one is real and other is imaginary
(4) none of the above

Q.29 In Fresnel's biprism experiment, which of the following light sources used to locate central fringe :
(1) sodium lamp
(2) mono-chromatic source
(3) white light
(4) none of the above

Q.30 In Fresnel's biprism experiment, separation between the slits is halved and the distance between screen and the slit is doubled
(1) remain unchanged (2) be halved
(3) be doubled (4) be four times

Q.31 Fringe width equal to 1 mm is observed in the interference pattern of biprism experiment. Then the distance of nearest bright fringe from the central bright fringe will be :
(1) 1 mm (2) 0.5 mm
(3) 2 mm (4) 0.25 mm

Q.32 In above question, the distance of the nearest dark fringes from the central bright fringe will be :
(1) 1 mm (2) 0.5 mm
(3) 2 mm (4) 0.25 mm

Q.33 In the above question the distance of 4^{th} dark fringe from first dark fringe will be :
(1) 0.5mm (2) 1mm (3) 2mm (4) 3mm

Q.34 In the above question, the distance of the first bright fringe from the fourth dark fringe will be :
(1) 1.5mm (2) 2.5mm
(3) 3.5mm (4) 4.5mm

Q.35 If intensity of each wave in the observed interference pattern in Young's double slit experiment is I_0. Then for some point P where the phase difference is ϕ, intensity I will be :
(1) $I = I_0 \cos \phi$ (2) $I = I_0 \cos^2 \phi$
(3) $I = I_0 (1 + \cos \phi)$ (4) $I = 2I_0(1 + \cos\phi)$

Q.36 Amplitude of waves observed by two light sources of same wavelength are a and 2a have a phase difference of π between them. Then minimum intensity of light will be :
(1) 0 (2) $5a^2$ (3) a^2 (4) $9a^2$

Q.37 If the intensity of the waves observed by two coherent sources is I. Then the intensity of resultant wave in constructive interference will be :
(1) 2I (2) 4I (3) I (4) None of the above

Q.38 If intensity of each of the two waves is I and they are having phase difference of 120º, when the waves are superposed, then the resultant intensity will be :
(1) I (2) 2I (3) I/2 (4) 4I

Q.39 Ratio of intensity of two waves is 25 : 1. If interference occurs, then ratio of maximum and minimum intensity should be :
(1) 25 : 1 (2) 5 : 1
(3) 9 : 4 (4) 4 : 9

Q.40 The intensity of two waves is 2 and 3 unit, then average intensity of light in the overlapping region will have the value :
(1) 2.5 (2) 6 (3) 5 (4) 13

Q.41 The light waves from two independent monochromatic light sources are given by -
$y_1 = 2 \sin \omega t$ and $y_2 = 3 \cos \omega t$,
then the following statement is correct
(1) Both the waves are coherent
(2) Both the waves are incoherent
(3) Both the waves have different time periods
(4) None of the above

Q.42 Four independent waves are represented by the equations :
$y_1 = a_1 \sin \omega t$, $y_2 = a_2 \sin \omega t$,
$y_3 = a_3 \cos \omega t$, $y_4 = a_4 \sin (\omega t + \pi/3)$
Then the waves for which phenomenon of interference will be observed are -
(1) 1 and 3 (2) 1 and 4
(3) all 1, 2, 3 and 4 (4) None

Q.43 In Young's double slit experiment, the interference bright fringes are of :
(1) equal widths and unequal intensities
(2) unequal width and equal intensities
(3) equal widths and equal intensities
(4) unequal widths and unequal intensities

Q.44 In Young's double slit experiment, if width (aperture) of the slit S is increased keeping other parameters constant, then the interference frings will :
(1) remain unchanged (2) from closer
(3) from further away (4) gradually disappear

Q.45 In Young's experiment, monochromatic light through a single slit S is used to illuminate the two slits S_1 and S_2. Interference fringes are obtained on a screen. The fringe width is found to be w. Now a thin sheet of mica (thickness t and refractive index μ) is placed near and in front of one of the two slits. Now the fringe width is found to be w', then :
(1) $w' = w/\mu$ (2) $w' = w\mu$
(3) $w' = (\mu-1)\, tw$ (4) $w' = w$

Q.46 In Fresnel's biprism experiment if the screen is moved away from the biprism, then the fringe width will :
(1) increase
(2) decrease
(3) remain same
(4) cover the entire screen uniformly

Q.47 If the refracting angle of a biprism is increased then the effect on the interference pattern will be :
(1) fringes will be closer
(2) fringe pattern will disappear
(3) fringe width will increase
(4) fringe pattern will not be effected

Q.48 The intensity of the central fringe obtained in the interference pattern due to two identical slit sources is I. When one of the slits is closed then the intensity at the same point is I_0. Then the correct relation between I and I_0 is :
(1) $I = I_0$ (2) $I = 2I_0$
(3) $I = 4I_0$ (4) $I = I_0/4$

Q.49 Two coherent sources of equal intensities produce a maximum of 100 units. If the amplitude of one of the sources is reduced by 20%, then the maximum intensity produced will be :

(1) 100 (2) 81
(3) 89 (4) 60

Q.50 In a biprism experiment, when sodium light of wavelength 5890Å is used then twenty fringes are observed in 23 mm distance on screen. In order to obtain 30 fringes in 28 mm of the interference pattern, one should use light of wavelength :

(1) 4780 Å (2) 6161 Å
(3) 8835 Å (4) 4381 Å

Q.51 A very thin transparent film of soap solution (thickness $\rightarrow$ 0) is seen under reflection of white light. Then the colour of the film appear to be :

(1) blue (2) black
(3) red (4) yellow

Q.52 In Young's double slit experiment, the two slits act as coherent sources of equal amplitude A and wavelength λ. In another experiment with the same set up the two slits are sources of equal amplitude A and wavelength λ but are incoherent. The ratio of the intensity of light at the mid-point of the screen in the first case to that in the second case is :

(1) 4 : 1
(2) 2 : 1
(3) 1 : 1
(4) None of the above

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 4

These questions consists of two statements each, printed as Assertion and Reason. While answering these questions you are required to choose any one of the following four responses.
(A) If both Assertion & Reason are true & the Reason is a correct explanation of the Assertion.
(B) If both Assertion and Reason are true but Reason is not a correct explanation of the Assertion.
(C) If Assertion is true but the Reason is false.
(D) If Assertion & Reason both are false.

Q.1 **Assertion :** When two coherent waves of intensity I_1 and I_2 are superimposed with a constant phase difference ϕ, then the intensity of resultant wave is given by $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$

Reason : For two incoherent sources, resultant intensity is given by $I = I_1 + I_2$.

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

Q.2 **Assertion :** YDSE, the intensity at the maxima is observed to be I_0. If one of the slits is closed, then the intensity at the location of the maxima reduces to $I_0/4$.

Reason : In YDSE, fringes with blue light are thicker than those for red light

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

Q.3 **Assertion :** If white light is used in YDSE, then the central bright fringe will be white.

Reason : Because all the wavelengths produce their zero order maxima at the same position.

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

Q.4 **Assertion :** In YDSE, the fringe width (β) depends on the medium in which the experiment is carried out.

Reason : Because $\beta = \frac{\lambda D}{d}$ and λ depends on the medium

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

Q.5 **Assertion :** In YDSE, if $I_1 = 9I_0$ and $I_2 = 4I_0$ then $\frac{I_{max}}{I_{min}} = 25$.

Reason : In YDSE $I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$ & $I_{min} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2$

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

Q.6 **Assertion :** In YDSE, if a thin film is introduced in front of the upper slit, then the fringe pattern shifts in the downward direction.

Reason : In YDSE if the slit widths are unequal, the minima will be completely dark.

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

Q.7 **Assertion :** The fringe visibility will be maximum when amplitude of light waves from two coherent sources is exactly same.

Reason : Fringe visibility = $\frac{I_{max} - I_{min}}{I_{max} + I_{min}}$.

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

Q.8 **Assertion :** In YDSE interference pattern disappears when one of the slits is closed.

Reason : Interference occurs due to superimposition of light wave from two coherent sources.

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

Q.9 **Assertion :** Light added to light can produce darkness.

Reason : The destructive interference of two coherent light sources may give dark fringe.

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

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 5

Q.1 The ratio of diameters of fourth and ninth half period zone is :
(1) 2/3 (2) 1/18
(3) 1/3 (4) 1/27

Q.2 For a zone plate, the value of $\frac{f_2}{f_1}$ is :
(1) $\frac{2}{5}$ (2) $\frac{5}{2}$ (3) $\frac{3}{9}$ (4) 4

Q.3 The area of third half period zone initiated from a source of wavelength 5000Å at point of projection one metre from the plane wave front will be :
(1) $15.7 \times 10^{-7} m^2$ (2) $47.1 \times 10^{-7} m^2$
(3) $5.1 \times 10^{-7} m^2$ (4) none of the above

Q.4 Diffraction and interference of light refers to :
(1) quantum nature of light
(2) wave nature of light
(3) transverse nature of light
(4) electromagnetic nature of light

Q.5 Two Fresnel's successive half period zones are such that secondary waves originating from corresponding points and approaches towards the observation point have a :
(1) path difference $\lambda/2$ (2) phase difference π
(3) time difference T/2 (4) all of the above

Q.6 A zone plate behave like a :
(1) concave lens (2) convex lens
(3) concave mirror (4) convex mirror

Q.7 Direction of the first secondary maximum in the Fraunhofer diffraction pattern at a single slit is given by (a is the width of the slit) :
(1) $a \sin \theta = \frac{\lambda}{2}$ (2) $a \cos \theta = \frac{3\lambda}{2}$
(3) $a \sin \theta = \lambda$ (4) $a \sin \theta = \frac{3\lambda}{2}$

Q.8 The phenomenon of diffraction of light was discovered by :
(1) Huygens (2) Newton
(3) Fresnel (4) Grimaldi

Q.9 Angular width (θ) of central maximum of a diffraction pattern of a single slit does not depend upon :
(1) Distance between slit and source
(2) Wavelength of light used
(3) Width of the slit
(4) Frequency of light used

Q.10 Red light is generally used to observe diffraction pattern from single slit. If green light is used instead of red light, then diffraction pattern **:**
(1) Will be more clear (2) Will be contract
(3) Will be expanded (4) Will not visualize

Q.11 A zone plate of focal length 60 cm, behaves as a convex lens, If wavelength of incident light is 6000Å, then radius of first half period zone will be :

(1) 36×10^{-8} m (2) 6×10^{-8} m

(3) $\sqrt{6} \times 10^{-8}$ m (4) 6×10^{-4} m

Q.12 In diffraction radius of half period zone is proportional to :

(1) $n^{-1/2}$ (2) $n^{1/2}$ (3) n^2 (4) n

Q.13 A plane progressive wave of diffraction pattern are obtained from the edges of a disc. If screen is taken near to the disc then the intensity of diffraction pattern will be :

(1) Increases
(2) Decreases
(3) First remain unchanged
(4) First increases and then decreases

Q.14 Diffraction of sound waves is more evident than light waves in daily life because : -

(1) $\lambda_{sound} > \lambda_{light}$
(2) $\lambda_{sound} = \lambda_{light}$
(3) $\lambda_{sound} < \lambda_{light}$
(4) Sound waves are longitudinal but light waves are transverse

Q.15 Choose incorrect statement regarding zone plate and convex lens : -

(1) Focal length of both depends upon wavelength λ
(2) Both show chromatic aberration
(3) Both have **single** focal length
(4) None of these

Q.16 Sound waves shows more diffraction as compare to light rays -

(1) Wavelength of sound waves is more as compare to light rays
(2) Wavelength of light rays is more as compare to sound waves
(3) Wavelength of sound waves and light ray is same
(4) None of these

Q.17 If zone plate is used in place of convex lens then intensity

(1) increases (2) decrease

(3) unchanged (4) can't say anything

Q.18 Calculate angular width of central maxima if λ = 6000Å, a = 18×10^{-5} cm :

(1) 20º (2) 40º

(3) 30º (4) 260º

Q.19 If radius of first H.P.Z. is 0.5 mm on zone plate and wavelength of light 500 nm is used. Then distance of maxima bright point from the zone plate will be : -

(1) 40 cm. (2) 20 cm.

(3) 10 cm. (4) 50 cm.

Q.20 In single slit Fraunhoffer diffraction which type of wavefront is required :

(1) cylindrical (2) spherical

(3) elliptical (4) plane

Q.21 A light ray whose wavelength 8000Å is diffracted. Their angular width is 60º. If wavelength of light ray is 4000Å then angular width will be :
(1) more than 60º
(2) 60º
(3) 30º
(4) In between 20º and 30º

Q.22 If diffraction occurs through a single slit then intensity of first secondary maxima become …….. % of central maxima
(1) 4% (2) 25%
(3) 75% (4) 50%

Q.23 In diffraction experiment, intensity at centre of a circular disc will be : -
(1) Maximum at centre
(2) Minimum at centre
(3) Lines parallel to diffraction fringes
(4) Size of fringe increases by increasing size of disc

Q.24 If in Fraunhoffer diffraction due to a single slit, the slit width is increased, the width of the central maximum will -
(1) increase
(2) decrease
(3) not change
(4) change depending upon the wavelength of light used

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 6

Q.1 The conversation going on, in some room, can be heared by the person outside the room. The reason for it is :
(1) Interference of sound (2) Reflection of sound
(3) Diffraction of sound (4) Refraction of sound

Q.2 Diffraction initiated from obstacle, depends upon the :
(1) size of obstacle
(2) wave length, size of obstacle and its distance from screen
(3) wave length and distance of obstacle from screen
(4) size of obstacle and its distance from screen

Q.3 Phenomenon of diffraction occurs :
(1) only in case of light and sound waves
(2) for all kinds of waves
(3) for electro-magnetic waves and not for matter waves
(4) for light waves but not in case of X rays

Q.4 Diffraction of light is observed only, when the obstacle size is :
(1) very large
(2) very small
(3) of the same order that of wavelength of light (4) any size

Q.5 Which of the following rays gives more distinct diffraction :
(1) X-ray (2) light ray
(3) γ-ray (4) Radio wave

Q.6 All fringes of diffraction are of :
(1) the same intensity (2) unequal width
(3) the same width (4) full darkness

Q.7 The point of minimum intensity in interference are perfectly dark while the point of minimum intensity in diffraction pattern are :
(1) also perfectly dark
(2) of uniform intensity
(3) not perfectly dark
(4) none of the above

Q.8 What happens, when the width of the slit aperture is increased in an experiment of single slit diffraction experiment :
(1) spread of diffraction region is increased
(2) spread of diffraction region is decreased
(3) spread of diffraction region will be decreased and mid-band becomes narrow
(4) none of the above

Q.9 Light waves travels not strictly in straight line, can be best explained by :
(1) Newton's corpuscular theory
(2) Diffraction
(3) Interference
(4) Polarisation

Q.10 If you peer through very small cracks between your fingers at a tubelight far distance away. You will see :
(1) uniform illumination
(2) bright and dark fringes due to interference
(3) bright and dark Fresnel's diffraction fringes
(4) bright and dark Fraunhofer's diffraction fringes

Q.11 What is true between Fresnel's and Fraunhofer's diffraction ?
(1) In Fresnel diffraction, source and screen are at finite distance, while in Fraunhofer's theory they are at infinite distance
(2) Fresnel and Fraunhofer's theory both explains the diffraction phenomenon
(3) In Fresnel class the light disturbance emitted from every HPZ is added while in Fraunhoffer class the whole disturbance is brought to focus by a lens
(4) All of the above

Q.12 Amplitude of successive half period zones are :
(1) of the same sign
(2) of opposite sign
(3) in same phase
(4) having a path difference of λ

Q.13 By increasing the order of zone :
(1) there is increase in radius and area of the zone
(2) the radius increases but area remains constant
(3) radius remains constant but area increases
(4) radius and area both remains constant

Q.14 Half period zones are so termed because the path difference between two consecutive zones is :
(1) λ (2) $\lambda/2$ (3) 2λ (4) 0

Q.15 Phase difference between two consecutive half period zones is :
(1) π (2) 2π (3) 3π (4) 4π

Q.16 The time difference between two successive half period zones of time period T :
(1) T/2 (2) T/4
(3) T (4) 2T

Q.17 The phase difference between two successive odd numbered half period zones is :
(1) π (2) 2π
(3) 3π (4) 5π

Q.18 The exact formula for the area of n^{th} half period zone, for large value of n is :
(1) $nb\lambda$ (2) $\pi b\lambda$
(3) $\pi b\lambda + n^2\lambda^2/4$ (4) $\pi[b\lambda + (2n-1)\lambda^2/4]$

Q.19 If r_n is radius of n^{th} half period zone, λ is wavelength, then area of n^{th} half period zone of plane wavefront will be :
(1) $\pi(r_n - r_{n-1})^2$ (2) $\pi(r_n^2 - r^2_{n-1})$
(3) $\pi(r_n^2 - r^2_{n+1})$ (4) πr_n^2

Q.20 If n = 1, 2, 3, 4 …… represents the number of successive zones then approximate area of half period zones is proportional to :
(1) n^0 (2) $n^{1/2}$
(3) n (4) n^2

Q.21 The area of the 5^{th} half period zone will be :
(1) area formed between circles of radii $\sqrt{4b\lambda}$ and $\sqrt{5b\lambda}$
(2) area of circle having radius of $\sqrt{5b\lambda}$
(3) area of circle with radius $5b\lambda$
(4) area formed between circles of radius $4b\lambda$ and $5b\lambda$

Q.22 If λ = 5000Å and distance of screen from the wave front is 1 metre then the number of half period zones in an area of 1.57 cm^2, will be :
(1) 1 (2) 10
(3) 100 (4) 1000

Q.23 The ratio of radii of half period zones is :
(1) $1 : \sqrt{2} : \sqrt{3}$ …. (2) 1 : 2 : 3 ….
(3) 1 : 4 : 9 …. (4) 1 : 3 : 5 ….

Q.24 If the radius of second half period zone is r, what will be the radius of fourth half period zone :
(1) r (2) $r\sqrt{2}$ (3) 2r (4) 4r

Q.25 In Fresnel's diffraction experiment at a point 2m away from the wave front the radii of 4^{th} and 5^{th} HP zones, corresponding to wavelengths λ_4 and λ_5 are equal, then the ratio of λ_4 and λ_5 is :
(1) $\frac{1}{1}$ (2) $\frac{5}{4}$ (3) $\frac{4}{5}$ (4) $\sqrt{\frac{5}{4}}$

Q.26 For a given adjustment, if r_R and r_B are the radii of second half period zone for red and blue light, then
(1) $r_R = r_B$ (2) $r_R > r_B$
(3) $r_R < r_B$ (4) data incomplete

Q.27 The radius of second half period zone of a wave front of wavelength 7200 Å for a point of observation one metre from it, will be :
(1) 0.1×10^{-3} m (2) 0.5×10^{-3} m
(3) 1.0×10^{-3} m (4) 1.2×10^{-3} m

Q.28 If size of a disc is very small, then its geometrical shadow will possess one of the following :
(1) Centre of geometrical shadow is always bright
(2) Centre is surrounded by black and bright rings
(3) By increasing size of disc, diffraction effect decreases
(4) All of the above is correct

Q.29 Diffraction pattern is observed on a screen using a opaque circular disc. When radius of disc is increased, the intensity at the centre will :
(1) Increase
(2) Decrease
(3) remain unchanged
(4) Uncertain

Q.30 A circular disc is placed in front of a narrow light source. When observation point is 1 metre from the disc, then the disc covers first half period zone and intensity at this point is I_0. The intensity at a point 25 cm from the disc will be : Ratio for successive amplitude is given below

$$\left(0.9 = \frac{R_2}{R_1} = \frac{R_3}{R_2} = \frac{R_4}{R_3} = ...\frac{R_n}{R_{n-1}}\right).$$

(1) 0.73 I_0 (2) 0.53 I_0
(3) 0.33 I_0 (4) 0.13I_0

Q.31 Diameter of a circular disc is 1 cm. The disc is placed 1 metre from a light source of λ = 6000Å. If a screen is placed 2 metre away from the disc. Then the number of half period zones covered by the disc will be :
(1) 21 (2) 25 (3) 42 (4) 30

Q.32 A circular disc is placed in front of a narrow source. The disc covers first half period zone when the point of observation is 1 m away from disc. The intensity at this point is I. When the point of observation is 20 cm from disc, the intensity will be :

(1) $\left(\frac{R_6}{R_2}\right)I$ (2) $\left(\frac{R_6}{R_2}\right)^2 I$

(3) $\left(\frac{R_2}{R_6}\right)^2 I$ (4) $\left(\frac{R_2}{R_6}\right)I$

Q.33 The intensity at a point due to narrow light source is I_0. When a circular disc, covering first two half period zones is introduced between source and the point, then intensity at the same point will be (where R_1, R_2, R_3..... are amplitude of light due to 1^{st}, 2^{nd}, 3^{rd} zones)

(1) $I_0\left(\frac{R_3}{R_1}\right)^2$ (2) $I_0\left(\frac{R_2}{R_3}\right)^2$

(3) $I_0\left(\frac{R_2}{R_1}\right)^2$ (4) $I_0\left(\frac{R_1}{R_2}\right)^2$

Q.34 A screen is moved along the axis of a small circular aperture which is illuminated by a monochromatic light. The centre of screen will appear :
(1) always bright
(2) always dark
(3) bright and dark alternately
(4) uniformly illuminated

Q.35 A small transparent circular aperture is placed between the monochromatic light source and the screen. At axial points, amplitude of light will be :
(1) maximum
(2) minimum
(3) maximum or minimum depends upon the radius of aperture
(4) maximum or minimum depends upon both the radius of aperture as well as the distance between screen and the aperture

Q.36 The radius of varying circular aperture is increased from zero onwards. When a monochromatic light beam is made incident on it. The intensity of the light on screen will :
(1) decrease continuously
(2) increase continuously
(3) remains unchanged
(4) decrease and increase alternately

Q.37 Intensity at a point of observation will be zero, when the number of half period zones exposed through the aperture, are :
(1) even
(2) odd
(3) any integer
(4) none of the above

Q.38 A light from a plane wave front is incident on a circular aperture of size 1HPZ. Then the ratio of intensity of light on the screen using aperture and without using aperture will be :
(1) 4 : 1 (2) 2 : 1 (3) 1 : 2 (4) 1 : 4

Q.39 In an experiment of diffraction due to a circular aperture if the radius is gradually increased from zero then maximum intensity on the screen will be observed for the first time, when the number of HP zones passing through the aperture is :
(1) 1 (2) 2 (3) 3 (4) 4

Q.40 In the above question, for obtaining n^{th} bright position, the number of zones exposed through aperture should be :
(1) n (2) 2n (3) n + 1 (4) 2n–1

Q.41 In above question, for obtaining, n^{th} dark position on the screen, the number of zones passing through aperture should be :
(1) n (2) 2n (3) 2n + 1 (4) 2n – 1

Q.42 An aperture of radius r is illuminated by light source of wave length λ and diffraction pattern so formed is observed on the screen at b distance. If n is the number of zones passing through the aperture then n is equal to :
(1) $\frac{r}{b\lambda}$ (2) $\frac{r^2}{b\lambda}$ (3) $\frac{r}{b^2\lambda}$ (4) $\frac{\lambda^2}{br}$

Q.43 A hole is illuminated with a monochromatic light source. Diffracted light is observed on the screen and the screen is gradually moved towards the hole. When the screen is maximum 20 cm from hole the centre becomes dark. The maximum distance in cm, where the centre would become bright is :
(1) 10 (2) 40 (3) 60 (4) 80

Q.44 In the diffraction pattern of a single slit aperture, the width of the central fringe compared to widths of the other fringes, is :
(1) equal (2) less
(3) little more (4) double

Q.45 Diffracted fringes obtained from the slit aperture are of : -
(1) same width
(2) different width
(3) uniform intensity
(4) non-uniform width & non uniform intensity

Q.46 Central fringe obtained in diffraction pattern due to a single slit :
(1) is of minimum intensity
(2) is of maximum intensity
(3) intensity does not depend upon slit width
(4) none of the above

Q.47 In a single slit diffraction pattern, if the light source is used of less wave length then previous one. Then width of the central fringe will be :
(1) less (2) increase
(3) unchanged (4) none of the above

Q.48 In the laboratory, diffraction of light by a single slit is being observed. If slit is made slightly narrow, then diffraction pattern will :
(1) be more spreaded than before
(2) be less spreaded than before
(3) be spreaded as before
(4) be disappeared

Q.49 For Fraunhoffer single slit diffraction :
(1) width of central maxima is proportional to λ
(2) on increasing the slit width, the width of central maxima decreases
(3) on making the list width a $=\lambda$, central fringe spreads in the range ± 90º
(4) all of the above are correct

Q.50 In a fraunhofer's diffraction by a slit, if slit width is a, wave length λ, focal length of lens is f, linear width of central maxima is ;
(1) $\frac{f\lambda}{a}$ (2) $\frac{fa}{\lambda}$ (3) $\frac{2f\lambda}{a}$ (4) $\frac{f\lambda}{2a}$

Q.51 In a Fraunhofer's diffraction obtained by a single slit aperture, the value of path difference of n^{th} order of minima is :
(1) $n\lambda$ (2) $2n\lambda$
(3) $(2n - 1)\lambda/2$ (4) $(2n-1)\lambda$

Q.52 A light source of 5000Å wave length produces a single slit diffraction. The first minima in diffraction pattern is seen, at a distance of 5mm from central maxima. The distance between screen and slit is 2 metre. The width of slit in mm will be :
(1) 0.1 (2) 0.4 (3) 0.2 (4) 2

Q.53 A plane wave front of wave length 6000Å is incident upon a slit of 0.2mm width, which enables Fraunhofer's diffraction pattern to be obtained on a screen 2 metre away. Width of the central maxima in mm will be
(1) 10 (2) 12 (3) 8 (4) 2

Q.54 What will be the value of slit width, if the first dark line is observed at an angle of 1º when plane light of 6000Å is incident : [sin 1º = 0.0175]
(1) 0.34 mm (2) 0.35 mm
(3) 0.034 mm (4) None of the above

Q.55 The waves of 600 μm wave length are incident normally on a slit of 1.2 mm width. The value of diffraction angle corresponding to the first minima will be (in radian) :
(1) $\frac{\pi}{2}$ (2) $\frac{\pi}{6}$
(3) $\frac{\pi}{3}$ (4) $\frac{\pi}{4}$

Q.56 A light wave is incident normally over a slit of width 24×10^{-5}cm. The angular position of second dark fringe from the central maxima is 30º. What is the wave length of light ?
(1) 6000Å (2) 5000Å
(3) 3000Å (4) 1500Å

Q.57 In a negative zone plate :
(1) Even zones are transparent while odd zones are opaque
(2) Even zones opaque while odd zones are transparent
(3) Both even & odd zones are transparent
(4) Both even & odd zones are opaque

Q.58 How many focii are there in a zone plate ?
(1) one focii
(2) two focii
(3) multi focii
(4) none of the above

Q.59 Which of the following statement is true for a zone plate :
(1) Intensity at a point due to a circular aperture of uniform radius is less than intensity due to zone plate
(2) Zone plate have so many focii in it
(3) Light observed from transparent HP zone have same phase
(4) All of the above

Q.60 Resultant amplitude in a negative zone plate is :
(1) $R_1 - R_2 + R_3 - R_4 + R_5 - R_6 + ...$
(2) $R_2 + R_4 + R_6 + R_8 + ...$
(3) $-R_2 + R_4 - R_6 + R_8 ......$
(4) $-R_1 - R_3 - R_5 - R_7$

Q.61 Resultant amplitude in a positive zone plate is :
(1) $R_1 + R_2 + R_3 - R_4 + ...$
(2) $R_1 + R_3 + R_5 + R_7 + ...$
(3) $R_2 + R_4 + R_6 + R_8 + ...$
(4) $R_1 - R_3 + R_5 - R_7 + ...$

Q.62 Formula for the focal length of a zone plate is :
(1) $\frac{1}{a} + \frac{1}{b} = \frac{r_n}{\lambda} = \frac{1}{f}$ (2) $\frac{1}{a} + \frac{1}{b} = \frac{r_n^2}{\lambda} = \frac{1}{f}$
(3) $\frac{1}{a} + \frac{1}{b} = \frac{n\lambda}{r_n^2} = \frac{1}{f}$ (4) $\frac{1}{a} + \frac{1}{b} = \frac{r_n}{n\lambda} = \frac{1}{f}$

Q.63 If we have a zone plate in which all the zones except first, third and the sixth is blocked, then the resultant amplitude of the diffraction pattern will be :
(1) $R = R_1 + R_3 + R_6$
(2) $R = R_1 - R_3 + R_6$
(3) $R = R_1 + R_3 - R_6$
(4) $R = R_1 - R_3 - R_6$

Q.64 If in the above question, all the zones except first, second and fifth have been blocked, then resultant amplitude will be :
(1) $R = R_1 + R_2 + R_5$
(2) $R = R_1 - R_2 + R_5$
(3) $R = R_1 + R_2 - R_5$
(4) $R = R_1 - R_2 - R_5$

Q.65 The radius of the first circle for a zone plate is 0.1 mm, then for the light of 5000Å wavelength the main focal length will be :

(1) 1cm (2) 2cm
(3) 10cm (4) none of these

Q.66 The zone plate is illuminated by light of wave length 6000Å. If the radius of the first circle is 0.6 mm then maximum focal length will be :

(1) 60cm (2) 6cm
(3) 6mm (4) 6Å

Q.67 For the wavelength of 5000Å, the principal focal length of the zone plate is 12cm. For a wavelength λ = 6000Å its value will be :

(1) 12cm (2) 10 cm
(3) 6cm (4) 14.4 cm

Q.68 In Fraunhoffer diffraction the centre of diffraction image is :

(1) always bright
(2) always dark
(3) sometimes bright and sometimes dark
(4) bright for large wavelength and dark for low wavelength

Q.69 To observe diffraction the size of an aperture :

(1) Should be of the same order as wavelength
(2) Should be much larger than the wave length
(3) Have no relation to wavelength
(4) Should be exactly $\frac{\lambda}{2}$

Q.70 A single slit of width d is placed in the path of beam of wavelength λ. The angular width of the principal maximum obtained is :

(1) $\frac{d}{\lambda}$ (2) $\frac{\lambda}{d}$ (3) $\frac{2\lambda}{d}$ (4) $\frac{2d}{\lambda}$

Q.71 A circular aperture of variable radius at a distance b from the screen is illuminated by a plane wave front of wave length λ. The opening is enlarged from zero radius. When the intensity of light on the screen becomes zero for the first time, the radius of aperture is :

(1) $\sqrt{b\lambda}$ (2) $\sqrt{2b\lambda}$
(3) $\sqrt{3b\lambda}$ (4) $\sqrt{4b\lambda}$

Q.72 Area of every Fresnel's half period zones is (where b is the distance from the screen and λ is the wave length of light) :

(1) $\pi b\lambda$ (2) $\sqrt{\pi b\lambda}$
(3) $b\lambda$ (4) $\pi\lambda$

Q.73 Bending of light waves at the sharp edges of an opaque obstacle is known as

(1) refraction (2) reflection
(3) diffraction (4) interference

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 7

These questions consists of two statements each, printed as Assertion and Reason. While answering these questions you are required to choose any one of the following four responses.
(A) If both Assertion & Reason are true & the Reason is a correct explanation of the Assertion.
(B) If both Assertion and Reason are true but Reason is not a correct explanation of the Assertion.
(C) If Assertion is true but the Reason is false.
(D) If Assertion & Reason both are false.

Q.1 **Assertion :** Diffraction takes place for all types of waves mechanical or non-mechanical, transverse or longitudinal.
Reason : Diffraction's effects are perceptible only if wavelength of wave is comparable to dimensions of diffracting device.
(1) A (2) B (3) C (4) D

Q.2 **Assertion :** In Fraunhofer diffraction central observation point is always bright where as in fresnel diffraction observation point may bright or dark.
Reason : In fresnel light waves approaches at observation point are always in same phase, whereas in Fraunhofer light waves approaches at central observation point may be in same phase or in opposite phase.
(1) A (2) B (3) C (4) D

Q.3 **Assertion :** Diffraction of sound waves are more easily observed as compare to light waves.
Reason : Wavelength of sound waves is more as compare to light.
(1) A (2) B (3) C (4) D

Q.4 **Assertion :** If distance between aperture and screen decreases continuously, then observation point becomes bright and dark in alternate order.
Reason : When even HPZ passess from the aperature then observation point becomes bright and when odd HPZ passess from the aperature then this point becomes dark.
(1) A (2) B (3) C (4) D

Q.5 **Assertion :** In the diffraction pattern of small circular disc, as the size of disc increases, brightness at the centre of its geometrical shadow decreases.
Reason : According to fresnel's theory, resultant amplitude at centre is $\pm \frac{R_{n+1}}{2}$. If n increases then R_{n+1} decreases.
(1) A (2) B (3) C (4) D

Q.6 **Assertion :** Waves emitted from alternate HPZ are in same phase.
Reason : Path difference of waves emitted from successive HPZ and approaching at observation point is $\lambda/2$.
(1) A (2) B (3) C (4) D

Q.7 **Assertion :** Resultant intensity at observation point due to complete wavefront is $\frac{I_0}{4}$, where I_0 is the intensity due to first HPZ.
Reason : If n is too high then resultant amplitude at observation point is $\frac{R_1}{2}$.
(1) A (2) B (3) C (4) D

Q.8 **Assertion :** When more number of odd HPZ allow from the aperature, then intensity at observation point continuously decreases.
Reason : Amplitude of higher order HPZ is more than amplitude of lower order HPZ

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

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 8

Q.1 Polarisation of light proves the -
(A) corpuscular nature of light
(B) quantum nature of light
(C) transverse wave nature of light
(D) longitudinal wave nature of light

Q.2 Waves that cannot be polarised are -
(A) light waves
(B) electromagnetic waves
(C) transverse waves
(D) longitudinal waves

Q.3 The angle of incidence at which reflected light is totally polarised for reflection from air to glass (refractive index n) is –

(A) $\sin^{-1}$ (n) (B) $\sin^{-1}$ (1/n)
(C) $\tan^{-1}$ (1/n) (D) $\tan^{-1}$ (n)

Q.4 The polaroid glass is used in sunglasses as -
(A) it is a fashion
(B) this reduce glare
(C) this is cheaper than other types
(D) this looks more beautiful

Q.5 In propagation of electromagnetic waves the angle between the direction of propagation and plane of polarisation is -
(A) 0º (B) 45º
(C) 90º (D) 180º

Q.6 A beam of light strikes a piece of glass at an angle of incidence of 60º and the reflected beam is completely plane polarised. The refractive index of the glass is -
(A)1.5 (B) $\sqrt{3}$
(C) $\sqrt{2}$ (D) (3/2)

Q.7 A polaroid is place at 45º to an incoming light of intensity I_0. Now the intensity of light passing through the polaroid after polarisation would be -
(A) I_0 (B) $I_0/2$ (C) $I_0/4$ (D) zero

Q.8 Two Nicol prism are first crossed and then one of them is rotated through 60º. The percentage of incident light transmitted is -
(A) 1.25 (B) 25.0 (C) 37.5 (D) 50

Q.9 A ray of unpolarised light is incident on a glass plate at the polarising angle 57º. Then -
(A) the reflected ray and the transmitted ray both will be completely polarised
(B) the reflected ray will be completely polarised and the transmitted ray will be partially polarised
(C) the reflected ray will be partially polarised and the transmitted ray will be completely polarised

(D) the reflected and transmitted both rays will be partially polarised

Q.10 A ray of light is incident on the surface of a glass plate at an angle of incidence equal to Brewster's angle ϕ. If μ represents the refractive index of glass with respect to air, the angle between the reflected and refracted rays is -

(A) $(90 + \phi)$ (B) $\sin^{-1}(m \cos \phi)$

(C) 90º (D) $\sin^{-1}\left(\frac{\sin \phi}{\mu}\right)$

Q.11 The fact that light is a tranverse wave phenomenon derives its evidencial support from the observation that -

(A) light is a wave-motion

(B) light is characterised by interference

(C) light shows polarising effects

Each of the questions given below consist of Statement – I and Statement – II. Use the following Key to choose the appropriate answer.

(A) If both Statement- I and Statement- II are true, and Statement - II is the correct explanation of Statement– I.

(B) If both Statement - I and Statement - II are true but Statement - II is not the correct explanation of Statement – I.

(C) If Statement - I is true but Statement - II is false.

(D) If Statement - I is false but Statement - II is true.

Q.12 **Statement I :** Light waves can be polarised.

Statement II: It is because light waves are transverse in nature.

Q.13 **Statement I :** Diffraction of sound waves is difficult to observe then diffraction of light waves.

Statement II: Wavelength of light is very small as compared to the wavelength of sound.

Q.14 The angle of incidence at which reflected light in totally polarized for reflection from air to glass(refractive index n), is –

(A) $\sin^{-1}(n)$ (B) $\sin^{-1}(1/n)$

(C) $\tan^{-1}(1/n)$ (D) $\tan^{-1}(n)$

Q.15 When an unpolarized light of intensity I_0 is incident on a polarizing sheet, the intensity of the light which does not get transmitted is -

(A) I_0 (B) I_0 (C) zero (D) I_0

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 9

Q.1 The unit of luminous efficiency of an electric bulb is -
(1) watt (2) lumen
(3) lumen/watt (4) lux

Q.2 5 lumen/W is the luminous efficiency of a lamp and its luminous intensity is 35 candela. The power of the lamp is -
(1) 80 watt (2) 176 watt
(3) 88 watt (4) 36 watt

Q.3 A source of light emits a continuous stream of light energy which fall on a given area. Luminous intensity is defined as -
(1) Luminous energy emitted by the source per second
(2) Luminous flux emitted by the source per unit solid angle
(3) Luminous flux falling per unit area of a given surface
(4) Luminous flux coming per unit area of an illuminated surface

Q.4 Candela is the unit of
(1) Magnetic intensity
(2) Gravitational intensity
(3) Electric intensity
(4) Luminous intensity

Q.5 1 lux is equal to -
(1) 1 lumen/m^2 (2) 1 lumen / cm^2
(3) 1 candela / m^2 (4) 1 candela / cm^2

Q.6 An isotorpic source of 2 candela produces flux equal to -
(1) 2π lumen
(2) 4π lumen
(3) 6π lumen
(4) 8π lumen

Q.7 The illumination of a surface is measured in the unit-
(1) lumen (2) Candela
(3) lux (4) lux / m^2

Q.8 Venus looks brighter than other stars because -
(1) It has higher density then other stars
(2) It is closer to the earth than other stars
(3) It has no atmosphere
(4) Atomic fission takes place on its surface

Q.9 The illumination from the sun is greater at noon than in morning because -
(1) The sun is brighter at noon
(2) The sun is nearer to the earth at noon
(3) The atmosphere is thinner in the noon than in the evening
(4) The rays of the sun are less oblique at the noon than in the morning

Q.10 The intensity of direct sunlight on a surface normal to the rays is I_0. What is the intensity of direct sunlight on a surface, whose normal makes an angle of 60º with the rays of the sun ?

(1) I_0 (2) $I_0\left(\frac{\sqrt{3}}{2}\right)$

(3) $\frac{I_0}{2}$ (4) $2I_0$

Q.11 Inverse-square law for illumination is valid for -
(1) Isotopic point source
(2) Search light
(3) Beam of light
(4) All types of light sources

Q.12 The intensity of light at a distance r from the axis of a long cylindrical source is proportional to -

(1) r (2) r^2 (3) $\frac{1}{r}$ (4) $\frac{1}{r^2}$

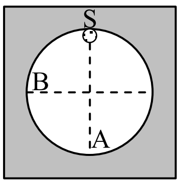
Q.13 A parallel beam of light produces an illuminance of 40 lux when the light is incident normally on a wall 1 *m* away. The illuminance produced when it is incident normally on a wall 2 *m* away -
(1) 40 lux (2) 20 lux
(3) 10 lux (4) 5 lux

Q.14 Two stars situated at distances of 1 and 10 light years respectively from the earth appear to possess the same brightness. The ratio of their real brightness is -
(1) 1 : 10 (2) 10 : 1 (3) 1 : 100 (4) 100 : 1

Q.15 The distance between a point source of light and a screen which is 60 cm is increased to 180 cm. The intensity on the screen as compared with the original intensity will be -
(1) (1/9) times (2) (1/3) times
(3) 3 times (4) 9 times

Q.16 A book placed at 1 *m* from a source of 1 candle power can just be read. The maximum distance at which a lamp of 40 candle power be placed for reading the book is -
(1) 40 *m* (2) 40^2 *m* (3) $\sqrt{40}$ *m* (4) 1/40 *m*

Q.17 An electric lamp is fixed at the upper point S of a tunnel. Compare the illumination produced by the bulb at points A and B –



(1) 1 : 2 (2) 2 : $\sqrt{2}$ (3) $\sqrt{2}$: 1 (4) 1 : $\sqrt{2}$

Q.18 A small lamp is hung at a height of 8 ft above the centre of a round table of diameter 16 ft. The ratio of the intensities of a illumination at the centre and at a point on the circumference of the table will be -
(1) 1 : 1 (2) $2\sqrt{2}$: 1(3) 1 : 3 (4) 3 : 2

Q.19 In a cinema hall the distance between the projector and the screen is increased by 2%, everything else remaining unchanged; then the intensity of illumination of the screen is -
(1) Decreased by 4%
(2) Decreased by 2%
(3) Increased by 2%
(4) Increased by 4%

Q.20 A lamp is at a height of 4*m* from a table. If the height is increased by 1 *m*, the illumination on the table will decrease by -
(1) 20% (2) 40%
(3) 64% (4) 36%

Q.21 A lamp of 250 candela power is hanging at a distance of 6*m* from a wall. The illuminance at a point on the wall at a minimum distance from the lamp will be -
(1) 9.64 lux (2) 4.69 lux
(3) 6.94 lux (4) None of these

Q.22 The illuminance of a surface distant 10 *m* from a light source is 10 lux. The luminous intensity of the source for normal incidence will be -
(1) 10^1 Cd (2) 10^2 Cd
(3) 10^3 Cd (4) None of these

Q.23 Light from a lamp is falling normally on a surface distant 10*m* from the lamp and the luminous intensity on it is 10 lux. In order to increase the intensity 9 times, the surface will have to be placed at a distance of -
(1) 10 *m* (2) $\frac{10}{3}$ *m*
(3) $\frac{10}{9}$ *m* (4) 10 × 9 *m*

Q.24 1% of light of a source with luminous intensity 50 candela is incident on a circular surface of radius 10 cm. The average illuminance of the surface is -
(1) 100 Lux (2) 200 Lux
(3) 300 Lux (4) 400 Lux

Q.25 Two lamps of luminous intensity of 8 Cd and 32 Cd respectively are lying at a distance of 1.2*m* from each other. Where should screen be placed between two lamps such that its two faces are equally illuminated due to the two sources ?
(1) 10 cm from 8 Cd lamp
(2) 10 cm from 32 Cd lamp
(3) 40 cm from 8 Cd lamp
(4) 40 cm from 32 Cd lamp

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 1 (ANSWERS)

Q.No.	1	2	3	4	5	6
Ans.	2	4	4	3	3	1

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 2 (ANSWERS)

Q.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	4	3	1	2	4	1	4	2	4	2	1	1	1	1	4	3	1	3	4	3
Q.No.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Ans.	4	4	3	4	2	4	2	2	1	1	2	4	2	4	4	4	3	3	3	3
Q.No.	41	42	43	44	45	46														
Ans.	1	1	2	2	1	4														

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 3 (ANSWERS)

Q.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	1	3	3	2	4	3	1	4	1	3	4	1	1	2	2	3	4	1	3	2
Q.No.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Ans.	1	1	3	4	4	1	1	2	3	4	1	2	4	2	4	3	2	1	3	3
Q.No.	41	42	43	44	45	46	47	48	49	50	51	52								
Ans.	2	4	3	4	4	1	1	3	2	1	2	2								

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 4 (ANSWERS)

Q.No.	1	2	3	4	5	6	7	8	9
Ans.	2	3	1	1	1	4	1	1	1

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 5 (ANSWERS)

Q.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	1	3	1	2	4	2	4	4	1	2	4	2	2	1	3	1	2	2	4	4
Q.No.	21	22	23	24																
Ans.	3	1	1	2																

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 6 (ANSWERS)

Q.No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Ans.	3	2	2	3	4	2	3	3	2	4	4	2	2	2	1	1	2	4	2	1
Q.No.	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Ans.	1	3	1	2	2	2	4	4	2	2	1	2	1	3	4	4	1	1	1	4
Q.No.	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**
Ans.	2	2	2	4	4	2	1	1	4	3	1	3	2	3	2	1	1	3	4	2
Q.No.	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**							
Ans.	2	3	3	2	2	1	2	1	1	3	2	1	3							

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 7 (ANSWERS)

Q.No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Ans.	2	3	1	3	1	1	1	3

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 8 (ANSWERS)

Q.No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Ans.	3	4	4	2	1	2	2	3	2	3	3	1	4	4	1

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 9 (ANSWERS)

Q.No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Ans.	3	3	2	4	1	4	3	2	4	3	1	3	1	3	1
Q.No.	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**					
Ans.	3	4	2	1	4	3	3	2	2	3					