6A

RAY OPTICS

REFLECTION FROM PLANE SURFACES

DEFINITION

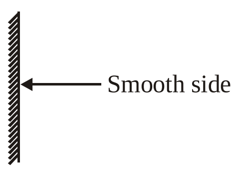
When a light ray strikes the surface separating two media, a part of it gets reflected, i. e., returns back in the initial medium, it is known as reflection.

TERMS RELATED TO REFLECTION

1. Ray : A ray of light is the straight line path of transfer of light energy.

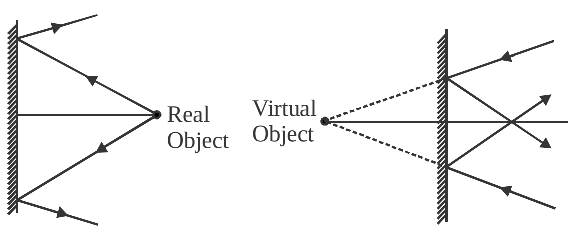
It is represented by a straight line an arrow - head indicating the direction of propagation.

2. Mirror : It is a highly polished smooth surface from which most of the incident light gets reflected. It is represented by a line with hatches in the reverse side of the smooth surface.



3. Object :

(a) Point from which incident ray actually diverge is called real object. Point at which incident rays appear to converge is called virtual object.

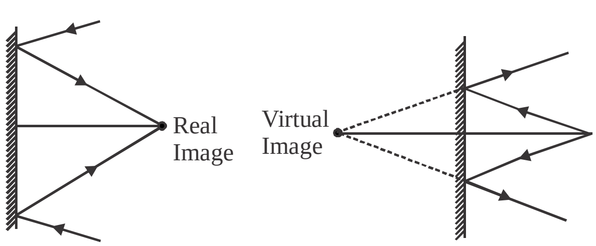


(b) Object is defined on the basis of incident ray.

(c) Minimum two rays are required to show the position of object.

4. Image :

(a) Point at which reflected or refracted rays actually converge is called real image. Point from which reflected or refracted rays appear to diverge is called virtual image.



(b) Minimum two reflected or refracted rays are required to determine the image position.

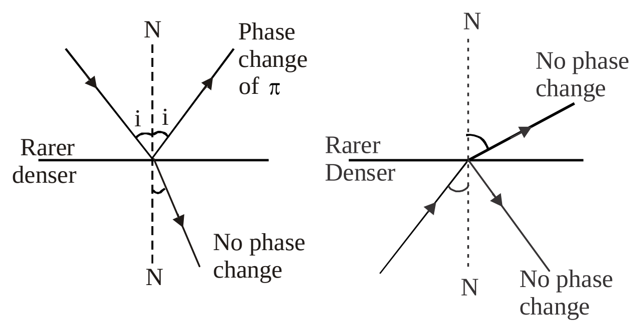
LAWS OF REFLECTION

There are three laws of reflection :

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

(ii) The incident ray, the normal and the reflected ray lie in the same plane.

(iii) There is a phase change of π radians when light wave is reflected by permeable denser medium surface but no phase change occurs if it is reflected by rarer medium surface.



REFLECTION BY PLANE MIRROR

(a) The image formed by the plane mirror is always erect, of the same size and at the same distance as the object is.

(b) To see the full image in a plane mirror, its length is just half the height of the man and it has to be kept in specific position.

(c) When the plane mirror or any reflecting surface is turned through an angle θ and if incident ray remains stationary, then the reflected ray will turn through 2θ.

(d) Image of an object formed by a plane mirror is perverted & if object is real then virtual image formed.

(e) When the two plane mirrors are parallel to each other, the number of images is infinity.

(f) When two plane mirror are held at angle θ with their reflecting surfaces facing each other and an object is placed between them, images are formed by successive reflections.

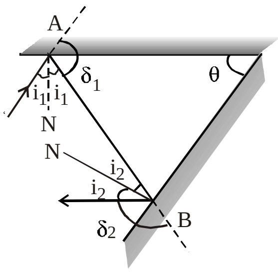
First of all we will calculate, $n = \dfrac{360}{\theta}$ then –

(i) If n is fraction, number of images will be whole part of this number. Ex. If n = 7.2, number of images = 7

(ii) If n is even whole number then no. of images = n – 1

(iii) If n is odd whole number then no. of images = n – 1 (for symmetric object), n (for asymmetric object).

(g) If the angle between the two mirrors is θ, the deviation produced by successive reflections is $\delta = \delta_1 + \delta_2 = 2\pi - 2\theta$.

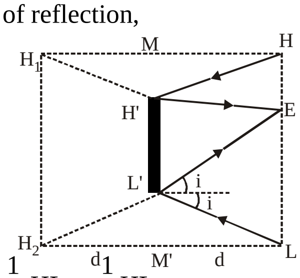


Note : When reflection takes place by a smooth surface, it is called regular reflection but when reflection takes place by a rough surface, it is called diffused reflection.

Example 1 :

Find the minimum height of a mirror where one can see his full image.

Sol. Let HL is the height of the person and E is the position of his eyes. Now applying laws of reflection,



we have, $M'L' = \frac{1}{2} EL$

and $MH' = \frac{1}{2} HE$

$H'L' = MM' - MH' - L'M'$

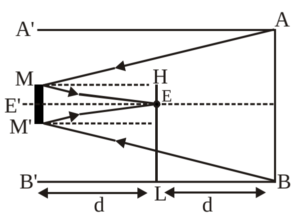
$= HL - \frac{1}{2}HE - \frac{1}{2} EL = HL - \frac{1}{2} HL = \frac{1}{2}HL$

So the required height of the mirror be half of the height of the person

Example 2 :

Find the minimum height of a mirror required to see the complete wall behind him.

Sol. From, $\Delta AA'M$ and $\Delta MEE'$ we have



$$\frac{A'M}{2d} = \frac{ME'}{d}$$

$\Rightarrow A'M = 2ME'$

Again from, $\Delta EE'M'$ and $\Delta M'B'B$ we have

$$\frac{E'M'}{d} = \frac{M'B'}{2d} \Rightarrow M'B' = 2E'M'$$

Now, $MM' = A'B' - A'M - M'B'$

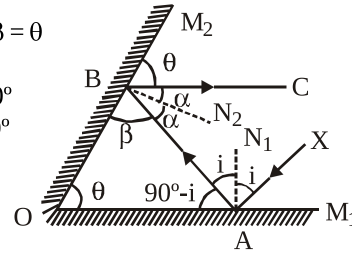
$= AB - 2(ME' + E'M') = AB - 2MM' \Rightarrow MM' = (1/3)AB$

Thus, minimum height of the mirror be 1/3 of the wall and the person must be in the middle of the mirror and the wall.

Example 3 :

Two plane mirrors are inclined at an angle θ . A ray of light is incident on one mirror at an angle of incidence i. The ray is reflected from this mirror, falls on the second mirror from where it is reflected parallel to the first mirror. What is the value of i, the angle of incidence in term of θ ?

Sol. The situation is illustrated in figure. XA is the incident ray. BC is the final reflected ray. It is given that BC is parallel to mirror M_1. Look at the assignment of the angles carefully.



Now N_2 is normal to mirror M_2. Therefore $\beta = \theta$

Then from ΔOAB

$\theta + \beta + 90° - i = 180°$

or $\theta + \theta + 90° - i = 180°$

or $i = 2\theta - 90°$

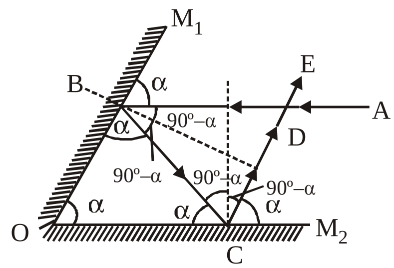
Thus if the angle of incidence is $i = 2\theta - 90°$, then the final reflected ray will be parallel to the first mirror.

Example 4 :

Two plane mirrors are placed at an angle α so that a ray parallel to one mirror gets reflected parallel to the second mirror after two consecutive reflections. Find the value of α

Sol. As shown in figure, ray AB goes to mirror M_1 , gets reflected and travels along BC and then gets reflected by M_2 and goes in CD direction. It the angle between M_1 and M_2 be α, then ∠OBC and ∠OCB are equal to α

$\therefore 3\alpha = 180° \therefore \alpha = 60°$



TRY IT YOURSELF - 1

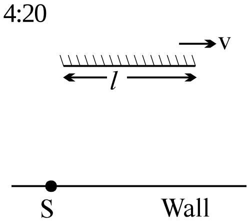
Q.1 A man 2m tall stands 5m in front of a large vertical plane mirror. Then the angle subtended at his eye by his image in the plane mirror is nearly :

(A) 0.4 rad (B) 0.2rad
(C) 0.2° (D) 0.4°

Q 2 A clock hung on a wall has marks instead of numbers on its dial. On the opposite wall there is a mirror, and the image of the clock in the mirror if read, indicates the time as 8:20. What is the time in the clock.

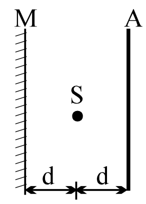
(A) 3:40 (B) 4:40
(C) 5:20 (D) 4:20

Q 3 A point source of length S is located on a wall. A plane mirror . . . . l is moving parallel to the wall with constant velocity *v*. The bright patch formed on the wall by reflected light will



(A) move with uniform velocity v and will have a length 2l.
(B) move with uniform velocity 2v and will have a length l.
(C) move with uniform velocity 2v & will have a length 2l.
(D) move with uniform velocity but will have a changing length.

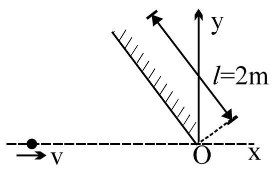
Q 4 A point source of light 'S' at a distance d from the screen A produces light intensity I_0 at the centre of the screen. If a completely reflecting mirror M is placed at a distance d behind the source as shown in the figure, find the intensity at the centre of the screen –



(A) $\frac{9}{10}I_0$ (B) $\frac{10}{9}I_0$

(C) $\frac{8}{9}I_0$ (D) $\frac{9}{8}I_0$

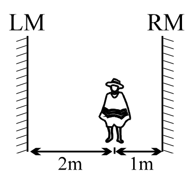
Q.5 A plane mirror of length 2 m is kept along the line y= –x as shown in the figure. An insect having velocity of $4\hat{i}$ cm/s is moving along the x-axis from far away. The time span for which the insect can see its image will be



(A) 50 sec (B) 25 sec

(C) $25\sqrt{2}$ sec (D) $50\sqrt{2}$ sec

Q.6 Two mirrors, labeled LM for left mirror and RM for right mirror in the adjacent figure, are parallel to each other and 3.0 m apart. A person standing 1.0 m from the right mirror (RM) looks into this mirror and sees a series of images. How far from the person is the second closest image seen in the right mirror (RM)?



(A) 10.0 m
(B) 4.0 m
(C) 6.0 m
(D) 8.0 m

Q.7 An object is moving with a velocity of $2\hat{i}+3\hat{j}+6\hat{k}$. A plane mirror whose reflecting surface is parallel to y-z plane is moving with a velocity of $\hat{i}+\hat{j}+\hat{k}$. What is the velocity of image as seen by a stationary observer?

(A) $\hat{j}+4\hat{k}$ (B) $3\hat{j}+6\hat{k}$

(C) $-\hat{j}-4\hat{k}$ (D) $-\hat{i}+3\hat{j}+6\hat{k}$

Q.8 A student holds a hand plane mirror to observe the back of her head while standing in front of and looking into a wall plane mirror. If she is standing 4 ft away from wall mirror in front of the wall mirror and she holds the hand mirror vertically 1 ft behind her head, she will see the back of her head approximately how far behind the wall mirror?

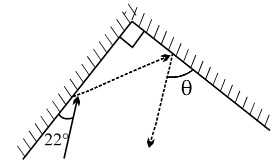
(A) 6 ft (B) 5 ft
(C) 4 ft (D) 3 ft

Q.9 A plane mirror approaches a stationary person with some acceleration 'a'. The acceleration of his image, as seen by the person, will be

(A) a (B) 2a
(C) a/2 (D) none

Q.10 A ray of light is reflected by two mirrors placed normal to each other. The incident ray makes an angle of 22° with one of the mirrors. At what angle θ does the ray emerge?

(A) 22°
(B) 68°
(C) 44°
(D) None



ANSWERS

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

REFLECTION AT CURVED SURFACES

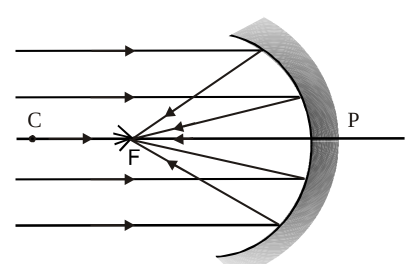
TYPES OF CURVED MIRROR

1. A curved mirror is a smooth reflecting part (in any shape) of a symmetrical curved surface such as paraboloidal, ellipsoidal, cylindrical of spherical.
2. **Concave Mirror :** If the reflection takes place from the inner surface of a spherical mirror, then the mirror is called mirror.
3. **Convex Mirror :** If the outer surface of the spherical mirror acts as a reflector then the mirror is called convex mirror.

TERMS RELATED TO SPHERICAL MIRROR

1. **Centre of Curvature (C) :** It is the centre of sphere of which the mirror is a part.
2. **Radius of Curvature (R) :** It is the radius of the sphere of which the mirror is a part.
3. **Pole (P) :** It is the geometrical centre of the spherical reflecting surface.
4. **Principal Axis :** It is the straight line joining the curvature to the pole.
5. **Focus (F) :** When a narrow beam of rays of light, parallel to the principal axis and close to it (know as paraxial rays), is incident on the surface of a mirror, the reflected beam is found to converge (concave mirror) or appear to diverge (convex mirror) from a point principal axis. This point is called focus.
6. **Focal Length (F) :** It is the distance the pole and the principal focus. For spherical mirrors, f = R/2

REFLECTION THROUGH CONCAVE MIRROR :



Concave mirror

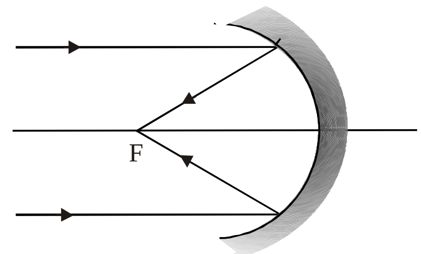
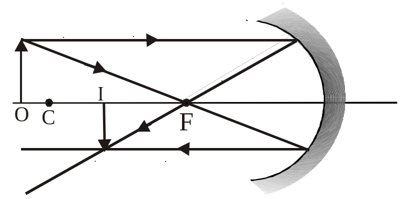
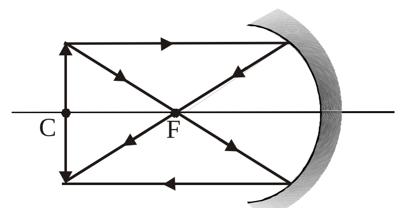
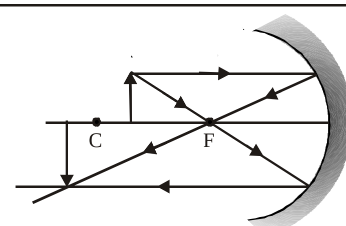
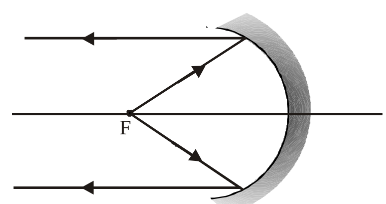
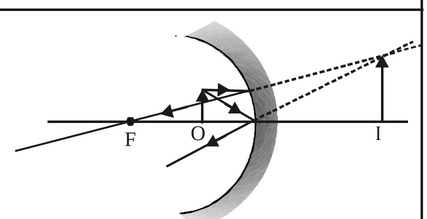
F → Principal focus P → Pole of mirror
C → Centre of curvature. PC = Radius of curvature.
PF = Focal length.

When a narrow beam of light travelling parallel to the principal axis is incident on the reflecting surface of the concave mirror, the beam after reflection converge at a point on the principal axis.

RULES FOR RAY DIAGRAMS

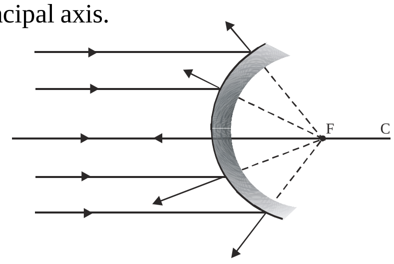
1. When a ray falls in the direction of centre of curvature of mirror then it reflects back along the same path.
2. A ray, parallel to the principal axis will after reflection, pass through the focus.
3. A ray, passing through the focus is reflected parallel to the principal axis.

4. Image formed by the concave mirror :

Position of object	Position of image	Nature	Figure
At infinity	At the focus	Real, inverted & diminished	
Between infinity & Centre of Curvature	Between focus & centre of curvature	Real inverted small in size	
At centre of curvature	At centre of curvature	Real, inverted and of the same size	
Between Focus & centre of curvature	Beyond centre of curvature	Real, inverted and enlarged	
At Focus	At infinity	Real, inverted and very large	
Between Focus & Pole	Behind the mirror	Erect virtual & enlarged	

REFLECTION THROUGH CONVEX MIRROR

When a narrow beam of light travelling parallel to the principal axis is incident on the reflecting surface of the mirror, the beam after reflection appear to diverge from a point on the principal axis.



CONVEX MIRROR

Note :

(i) When a ray incident on convex mirror in the direction of centre of curvature after reflection comes back along the same path.

(ii) When a ray incident on convex mirror parallel to the principal axis, after reflection, appears to come from the focus.

(iii) A ray appearing to pass through the focus is reflected parallel to the principal axis.

Image formed by convex mirror :

A convex mirror forms only virtual images for all positions of the real object. The image is always virtual, erect, smaller than the object and is located between the pole & the focus. The image becomes smaller and moves closer to the focus as the object is moved away from the mirror.

SIGN CONVENTION

(i) All distances are measured from the pole.

(ii) The distance measured along the direction of propagation of light are taken as positive and the direction opposite to the propagation of light is taken as negative.

(iii) The distance (heights) measured above the principal axis i.e. along positive Y axis, are taken as positive while distances below the principal axis i.e. along negative Y axis are taken as negative.

MIRROR FORMULAE

1. If an object is placed at a distance u from the pole of a mirror and its images is formed at a distance v (from the pole) then $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

In this formula to calculate unknown, known quantities are substituted with proper sign.

2. If a thin object linear size O situated vertically on the axis of a mirror at a distance u from the pole and its image of size I is formed at a distance v (from the pole), magnification (transverse) is defined as

$$m=\left[\frac{I}{O}\right]=-\left[\frac{v}{u}\right]$$

→ (+ve Erect image)
→ (–ve inverted image)
→ (|m| >1 large image)
→ (|m| < 1 Small image)

Here-ve magnification implies that image is inverted with respect to object while +ve magnification means that image is erect with respect to object

3. Other formulae of magnification

$$m=\frac{f}{f-u},\quad m=\frac{f-v}{f}$$

4. The power of a mirror is defined as

$$P=-\frac{1}{f\,(\text{in m})}=-\frac{100}{f\,(\text{in cm})}$$

The unit of power is diopter.

5. The focal-length of a spherical mirror of radius R is given by $f=(R/2)$

In sign convention, f (or R) is negative for concave or converging mirror and positive for convex or diverging mirror.

6. Newton's formula $f^2=x_1x_2$

f = focal length of mirror] x_1=Position of object with respect to focus] x_2 = Position of image with respect to focus.

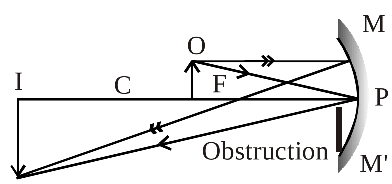
Uses :

(a) Concave mirror : Searh lights, Motor head lights, Shaving mirror, by dentists, in solar cookers, etc.

(b) Convex mirror : As rear view mirror because their field of view is large, Reflectors for street light, etc.

NOTE

1. As every part of a mirror forms complete image, if a part of mirror (say half) is obstructed (say converted with black paper) full image will be formed but intensity will be reduced.



2. If an object moved at constant speed towards a concave mirror from infinity to focus, the image will move slower in the beginning and faster in the last, away from the mirror. This is because in the time object moves from ∞ to C the image will move from F to C and when object moves from C to F the image will move from C to ∞. At C the speed of object and image will be equal.

$$v_i=-\left(\frac{v^2}{u^2}\right)v_o \quad \text{[Where } v_i \text{ velocity of image]}$$

$$v_i=-\left(\frac{v}{u}\right)^2 v_0 \quad [v_o \text{ velocity of object}]$$

3. Identification of mirror on the basis of images :

If the image of a real object placed near the mirror is

(i) Virtual, erect and of same size, the mirror is plane.

(ii) Virtual, erect and magnified, the mirror is concave.

(iii) Virtual, erect and diminished, the mirror is convex.

Example 5 :

A concave mirror of focal length f produces a real image n time the size of the object. What is the distance of the object from the mirror.

Sol. $m = -n$; $m = \dfrac{f}{f-u}$; $-n = \dfrac{-f}{-f-u}$ $\Rightarrow nf + nu = -f$

$nu = -f - nf \Rightarrow u = \dfrac{-(n+1)}{n} f$

Example 6 :

The focal length of a concave mirror is 30 cm. Find the position of the object in front of the mirror, so that the image is three times the size of the object.

Sol. Here image can be real or virtual. If the image is real

$f = -30, u = ?, m = -3$

$$m = \frac{f}{f-u} \Rightarrow -3 = \frac{-30}{-30-u} ; u = -40 \text{ cm.}$$

If the image is virtual

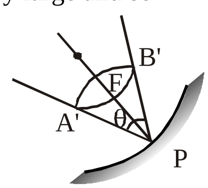
$$m = \frac{f}{f-u} \Rightarrow 3 = \frac{-30}{-30-u} \Rightarrow u = -20 \text{ cm.}$$

Example 7 :

The sun (diameter D) subtends an angle θ radian at the pole of a concave mirror of focal length f. What is the diameter of the image of the sun formed by the mirror.

Sol. Since the sun is very distant, u is very large and so

$\dfrac{1}{u}$ is practically zero



$\dfrac{1}{u} \approx 0$; $\dfrac{1}{v} + \dfrac{1}{u} = \dfrac{1}{f}$; $\dfrac{1}{v} = -\dfrac{1}{f}$

$v = -f$

The image of sun will be formed at the focus and will be real, inverted and diminished

A'B' = height of image

$$\theta = \frac{\text{arc}}{\text{radius}} = \frac{A'B'}{FP} \Rightarrow \theta = \frac{d}{f} \Rightarrow d = f\theta$$

Example 8 :

A beam of light converges towards a point O, behind a convex mirror of focal length 20 cm. Find the nature and position of image if the point O is -

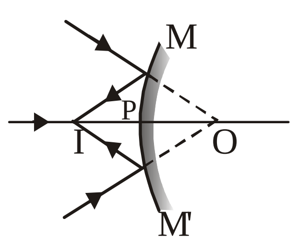
(i) 10 cm behind the mirror (ii) 30 cm behind the mirror

Sol. Here object is virtual

(i) $u = +10$ cm

$f = +20$ cm

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



$$\Rightarrow v = \frac{10 \times 20}{10-20} = -20 \text{ cm.}$$

magnification $m = -\left(\dfrac{v}{u}\right)$; $m = -\left(\dfrac{-20}{10}\right) = +2$

(ii) $u = +30$ cm, $f = 20$cm

$$v = \frac{uf}{u-f} = \frac{30 \times 20}{30-20} ;\ v = +60 \text{ cm} ;\ m = -\left(\frac{60}{30}\right) = -2$$

TRY IT YOURSELF - 2

Q.1 An object of height h = 5cm is located at a distance a = 12 cm from a concave mirror with focal length 10 cm. Find the height of the image.

(A) 10 cm (B) 15 cm
(C) 20 cm (D) 25 cm

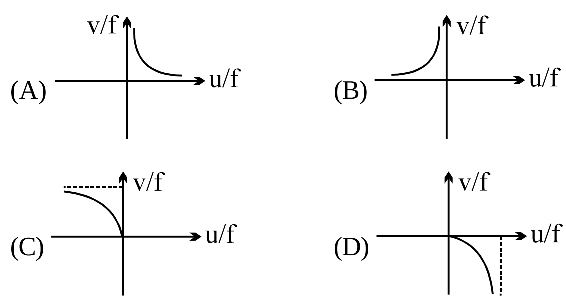
Q.2 The distance of an object from a spherical mirror is equal to the focal length of the mirror. Then the image:

(A) must be at infinity (B) may be at infinity
(C) may be at the focus (D) none

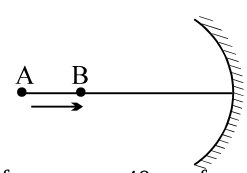
Q.3 Find the incorrect statement/s for a concave mirror producing a virtual image of the object.

(A) The linear magnification is always greater than one. Except at the pole
(B) The linear magnification is always less than one.
(C) The magnification tends to one as the object move nearer to the pole of the mirror.
(D) The distance of the object from the pole of the mirror is less than the focal length of mirror.

Q.4 A virtual erect image in a concave mirror is represented, in the given figure, by



Q.5 A linear object AB is placed along the axis of a concave mirror. The object is moving towards the mirror with speed U. The speed of the image of the point A is 4U and the speed of the image of B is also 4U. If the center of the line AB is at a distance L from the mirror then find out the length of the object.



(A) 3L/2
(B) 5L/3
(C) L
(D) None

Q.6 A concave mirror of radius of curvature 40 cm forms an image of an object placed on the principal axis at a distance 45 cm in front of it. Now if the system is completely immersed in water (μ = 1.33) then

(A) the image will shift towards the mirror.
(B) the magnification will reduce.
(C) the image will shift away from the mirror and magnification will increase.
(D) the position of the image and magnification will not change.

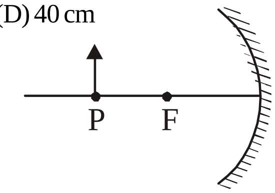
Q.7 A point object is placed on the axis of a concave mirror of focal length 24cm such that the image is formed at a distance of 48cm from the pole. Distance of the object from pole may be

(A) 48 cm (B) 16 cm
(C) 32 cm (D) 20 cm

Q.8 A convex mirror has a radius of curvature of 20 cm. An object is placed at such a distance from the mirror that the size of the image is exactly half that of the object. The object distance must be

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

Q.9 The diagram shows an object located at point P, 0.25meter from a concave spherical mirror with principal focus F. The focal length of the mirror is 0.10 m



How does the image change as the object is moved from point P toward point F ?

(A) Its distance from the mirror decreases
(B) The size of image decreases
(C) Its distance from the mirror increases
(D) The size of images increases

Q.10 A pin 10 mm tall is used as an object in front of a mirror and the image formed is erect and 2mm tall.

(A) Moving the pin closer to the mirror will make the image larger.
(B) The image must be real.
(C) The mirror must be converging.
(D) Both (B) and (C) are correct.

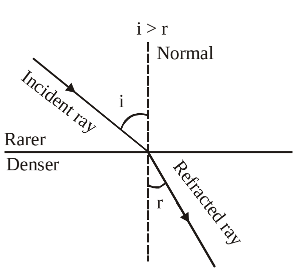
ANSWERS

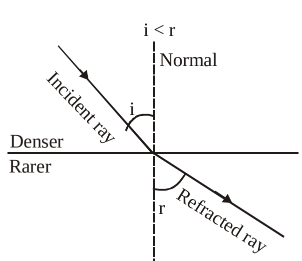
(1) (D)	**(2)** (B)	**(3)** (B)
(4) (D)	**(5)** (C)	**(6)** (D)
(7) (AB)	**(8)** (C)	**(9)** (CD)
(10) (A)		

REFRACTION AT PLANE SURFACES

The bending of the light ray from its path in passing from one medium to the other medium is called refraction of light.

If the refracted ray bends towards the normal relative to the incident ray, then the second medium is said to be denser than the first medium. But if the refracted ray bends away from the normal, then the second medium is said to be rarer than the first medium.





REFRACTIVE INDEX

(a) Refractive index of second medium w.r.t. first medium

$$_1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{c/v_2}{c/v_1} = \frac{v_1}{v_2}$$

$$= \frac{\text{Velocity of light in first medium}}{\text{Velocity of light in second medium}}$$

(b) Absolute refractive index of medium (n or μ) :

$$\frac{\text{Velocity of light in vaccum}}{\text{Velocity of light in medium}} = \frac{c}{v} = \frac{\text{Sin i}}{\text{Sin r}} = n = \mu$$

(c) Refractive index is the relative property of two media. If the first medium carrying the incident ray is a vacuum, then the ratio $\frac{\text{Sin i}}{\text{Sin r}}$ is called the 'absolute refractive index of the second medium'. The relative refractive index of any two media is equal to the ratio of their absolute refractive indices. Therefore, if the absolute refractive indices of media 1 & 2 be n_1 & n_2 respectively, then the refractive index of medium 2 with respect to medium 1 is-

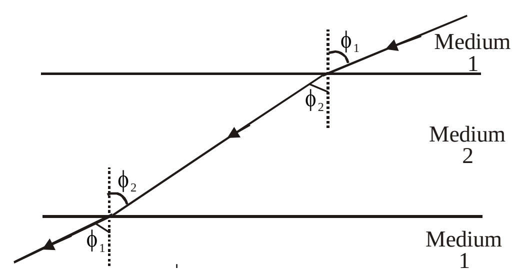
$$_1n_2 = n_{12} = \frac{n_2}{n_1} = \frac{\text{Sin i}}{\text{Sin r}} \; ; \; n_1 \sin i = n_2 \sin r$$

(d) $_1n_2 = \dfrac{1}{_2n_1}$

(e) For three medium 1, 2, 3 due to successive refraction.

$$_1n_2 \times {_2n_3} \times {_3n_1} = 1 \; ; \; \frac{n_2}{n_1} \times \frac{n_3}{n_2} \times \frac{n_1}{n_3} = 1$$

(f) For two medium, n_1 & n_2 are refractive indices with respect to vacuum, the incident and emergent rays are parallel then $n_1 \sin\phi_1 = n_2 \sin\phi_2$.



LAW OF REFRACTION

(a) Snell's Law : For any two media and for light of a given wave length, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant.

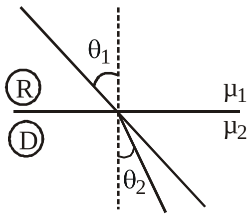
$\frac{\sin i}{\sin r}$ = constant, where i=incidence angle, r=refraction angle.

(b) The incident ray, the refracted ray and the normal at the incident point all lie in the same plane.

(c) Frequency (and hence colour) and phase do not change (while wavelength and velocity changes)

APPLICATION OF SNELL'S LAW

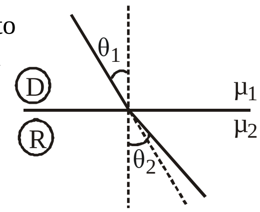
(a) When light passes from rarer to denser medium it bends toward the normal. Using Snell's Law $\mu_1 \sin\theta_1 = \mu_2 \sin\theta_2$



$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{\mu_2}{\mu_1}$$

Thus If $\mu_2 > \mu_1$ then $\theta_2 < \theta_1$

(b) When light passes from denser to rarer medium it bends away from the normal.
From Snell's law



$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{\mu_2}{\mu_1}$$

Thus If $\mu_2 < \mu_1$ then $\theta_2 > \theta_1$

(c) When light propagates through a series of layers of different medium, then according to Snell's law
$\mu_1 \sin\theta, = \mu_2 \sin\theta_2 = \mu_3 \sin\theta_3 = ...= \text{constant}$

(d) **Conditions of no refraction**

(i) If light is incident normally on a boundary i.e., $\angle i = 0°$
Then from Snell's law
$\mu_1 \sin 0 = \mu_2 \sin r \Rightarrow \sin r = 0$ i.e. $\angle r = 0$ i.e.,
light passes undeviated from the boundary.
(so boundary will be invisible)

(ii) If the refractive indices of two media are equal i.e., if, $\mu_1 = \mu_2 = \mu$
Then from Snell's law
$\mu_1 \sin i = \mu \sin r \Rightarrow \angle i = \angle r$ i.e.,
ray passes undeviated from the boundary with $\angle i = \angle r \neq 0$ and boundary will not be visible.
This is also why a transparent solid is invisible in a liquid if $\mu_s = \mu_L$

(e) **Relation between object and image distance :**
An object O placed in first medium (refractive index μ_1) is viewed from the second medium (refractive index μ_2). Then the image distance d_{AP} and the object distance d_{AC} are

related as $d_{AP} = \left(\frac{\mu_2}{\mu_1}\right) d_{AC}$

(i) If $\mu_2 > \mu_1$, i.e., when the object is observed from a denser medium, it appears to be farther away from the interface, i.e. $d_{AP} > d_{AC}$

(ii) If $\mu_2 < \mu_1$, i.e., when the object is observed from a rarer medium, it appears to be closer to the interface, i.e. $d_{AP} < d_{AC}$

Note : The above formula is applicable only for normal view or paraxial ray assumption.

(f) **Relation between object and image Velocities :**

(i) If an object O moves toward the plane boundary of a denser medium then the image appears to be farther but moves faster to an observer in denser medium. If $v_0 = v$ then $v_1 = \mu v$ Where , v_0 & v_1 represents object and image velocities w respectively.

(ii) If an object O moves toward the plane boundary of a rarer medium then the image appears to be closer but moves slower to an observer in rarer medium. If $v_0 = v$ then $v_1 = v/\mu$

(g) **Deviation (¢) :**

(i) A light ray travelling from a denser to a rarer medium at an angle $\alpha < \theta_C$ then deviation.

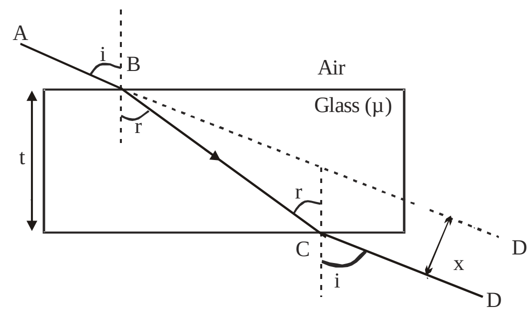
$$\delta = \beta - \alpha = \sin^{-1}(\mu \sin\alpha) - \alpha \text{ and } \delta_{max} = \frac{\pi}{2} - \theta_c$$

(ii) If light is incident at an angle $\alpha > \theta_C$, Then the angle of deviation is $\delta = \pi - 2\alpha$ and $\delta_{max} = \pi - 2\theta_c$

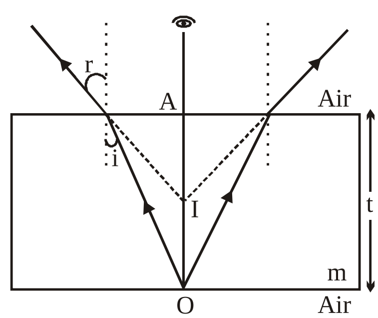
REFRACTION THROUGH SLAB

Refractive index & thickness of glass slab is μ & t respectively. One light ray AB incidents on slab, Displacement produced, in emergent ray due to refraction.

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



1. **When object in denser medium & observer in rarer medium:**
Thickness of denser medium is t, in which a object is at a point O. Due to refraction, image may be seen at a point I.



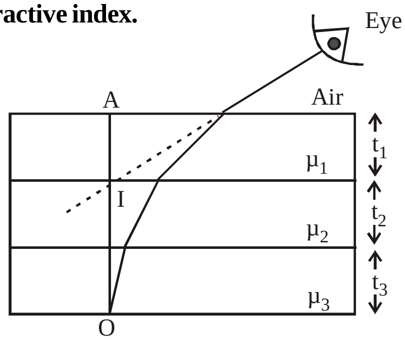
Refractive index

$$\mu = \frac{\text{Real depth}}{\text{Virtual depth}} = \frac{AO}{AI} = \frac{t}{AI}$$

$$\text{Virtual depth} = \frac{t}{\mu}$$

$$\text{Virtual displacement (OI)} = OA - AI = t\left(1 - \frac{1}{\mu}\right)$$

2. Refraction through successive slab of different thickness & refractive index.

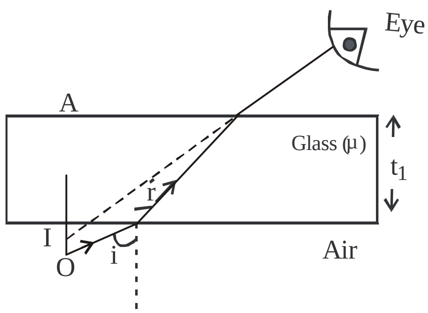


Virtual depth (AI) = $\dfrac{t_1}{\mu_1}+\dfrac{t_2}{\mu_2}+\dfrac{t_3}{\mu_3}+$...............

Virtual displacement (OI)

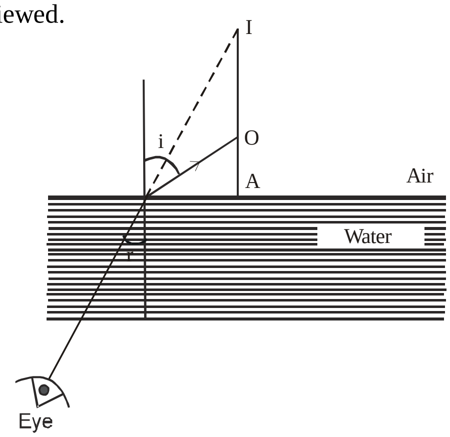
$$= t_1\left(1-\frac{1}{\mu_1}\right)+t_2\left(1-\frac{1}{\mu_2}\right)+t_3\left(1-\frac{1}{\mu_3}\right)+\text{..............}$$

3. When object & observer both are in rarer medium.



Let observer is in air & object is at a point O in air, as shown in figure. A glass is there in between observer & object. Images forms at point I Refractive index of glass is μ. Virtual displacement = OI = $\left(t-\dfrac{1}{\mu}\right)$

4. When object in rarer medium & Observer in denser medium. Refractive index of water is μ. Observer is in water, Image may be seen at a point I when a object at a point O is viewed.



$$\frac{\text{Real height}}{\text{Virtual height}}=\frac{1}{\mu}$$

Virtual displacement (OI) = AI – AO = $(\mu-1)$AO.

Example 9 :

Light waves of 5895 Å wavelength travels from vacuum to a medium of refractive index of 1.5. Velocity of light and wavelength in medium will be

(1) 2×10^8 m/sec, 3330Å (2) 3×10^8 m/sec, 3930 Å

(3) 2×10^8 m/sec, 3390 Å (4) None

Sol. **(2).** If velocity of light in vacuum is c then velocity of light

in medium is $v=\dfrac{c}{n}=\dfrac{3\times10^8}{1.5}=2\times10^8$ m/sec

Wavelength of light in medium is

$$\lambda_w=\frac{\lambda}{n}=\frac{5895}{1.5}=3930\ \text{Å}.$$

Example 10 :

When a glass slab is placed on a dot on a paper. It appears displaced by 4 cm, viewed normally. What is the thickness of slab if the refractive index 1.5.

Sol. Displacement $=t\left(1-\dfrac{1}{\mu}\right)$. So $4=t\left(1-\dfrac{1}{\mu}\right)$

$$t=\frac{\mu\times4}{\mu-1}=\frac{1.5\times4}{1.5-1}=12\text{ cm}$$

Example 11 :

A mark at the bottom of a beaker is focussed by a microscope. When water is poured in the beaker up to a height of 16 cm, the microscope has to be raised through a distance of 4 cm in order to bring the mark to focus again. Calculate the refractive index of water.

Sol. Let d be the real depth of water. The apparent depth will be d/μ. So the microscope has to be raised through a distance

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

Now $d\left(1-\dfrac{1}{\mu}\right)=4$ or $16\left(1-\dfrac{1}{\mu}\right)=4$ $\therefore$ $\mu=4/3$

TOTAL INTERNAL REFLECTION

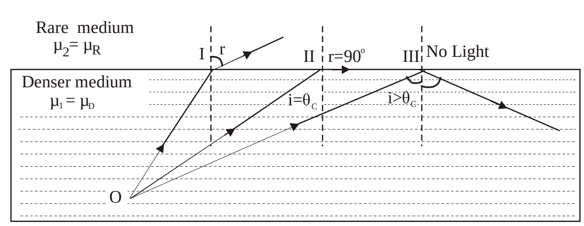
The phenomenon : In case of refraction of light, from snell's law we have $\mu_1\sin i=\mu_2\sin r$ ....(1)

If light is passing from denser to rarer medium through a plane boundary then $\mu_1=\mu_D$ and $\mu_2=\mu_R$ so with

$\mu=(\mu_D/\mu_R)$

$\sin i=\dfrac{\mu_R}{\mu_D}\sin r$ i.e. $\sin i=\dfrac{\sin r}{\mu}$ .... (2)

i.e. $\sin i \propto \sin r$ with $(\angle i)<(\angle r)$ (as $\mu>1$)



So as angle of incident i increase angle of refraction r will also increase and for certain value of i (< 90°) r will become 90°. The value of angle of incidence for which r = 90° is called critical angle and is denoted by θ_c.

From eq. (2), $\sin\theta_C = \dfrac{\sin 90}{\mu}$ i.e., $\sin\theta_C = \dfrac{1}{\mu}$ .... (3)

And hence eqn. (2) in terms of critical angle can be written as $\sin i = \sin r \times \sin\theta_c$ i.e. , $\sin r = \dfrac{\sin i}{\sin\theta_C}$ .... (4)

So if $i > \theta_c$ $\sin r > 1$. This means that r is imaginary (as the value of sin of any angle can never be greater than unit) physically this situation implies that refracted ray does not exist. So the total light incident of the boundary will be reflected back in to the same medium from the boundary. This phenomena is called total internal reflection.

Note :

1. For total internal reflection to take place light must pass from denser to rarer medium thus light from air to water (or glass) and from water to glass total internal reflection can-never take place.
Total internal reflection will take place only if angle of incidence is greater than critical angle.

2. In case of total internal reflection as all (i.e. 100%) incident light is reflected back into the same medium there is no loss of intensity while in case reflection from mirror or refraction from lenses there is some loss of intensity as all light can never be reflected or refracted. This is why image formed by TIR are much bright than formed by mirror or lenses.

Critical angle (θ_c) : In case of propagation of light from denser of rate medium through a plane boundary critical angle is the angle of incidence for which angle of refraction is 90° and so from snell's law, $\mu \sin i = \mu_2 \sin r$

$$\mu_D \sin\theta_C = \mu_R \sin 90$$

i.e. $\sin\theta_C = \dfrac{\mu_R}{\mu_D} = \left[\dfrac{1}{\mu}\right]$ with $\mu = \dfrac{\mu_D}{\mu_R}$ or $\theta_C = \sin^{-1}\left(\dfrac{1}{\mu}\right)$

(1) For a given pair of medium critical angle depends on wavelength of light used and critical angle is maximum for red and minimum for violet rays. $\left[\text{as a } \mu \alpha \dfrac{1}{v} \alpha \dfrac{1}{\lambda}\right]$

(2) For a given light is depends on nature of pair of medium lesser the μ greater will the critical angle and vice–versa.

Glass air : As $\mu_g = \dfrac{3}{2}$ and $\mu_A = 1$ i.e., $\mu = \dfrac{\mu_G}{\mu_A} = \dfrac{3}{2}$

So $(\theta_C)_{GA} = \sin^{-1}\left[\dfrac{2}{3}\right] = 42^o$

Water air : As $\mu_W = \dfrac{4}{3}$ and $\mu_A = 1$ i.e., $\mu = \dfrac{\mu_W}{\mu_A} = \dfrac{4}{3}$

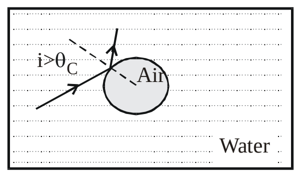
So $(\theta_C)_{WA} = \sin^{-1}\left[\dfrac{3}{4}\right] = 49^o$

Glass Water : As $\mu_G = \dfrac{3}{2}$ and $\mu_W = \dfrac{4}{3}$ i.e., $\mu = \dfrac{\mu_G}{\mu_W} = \dfrac{9}{8}$

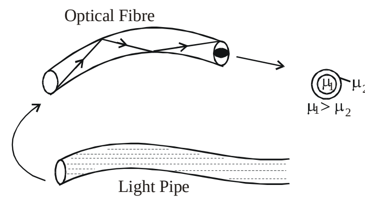
So, $(\theta_C)_{GW} = \sin^{-1}\left(\dfrac{8}{9}\right) \approx 63^o$

Some illustration of total internal reflection :

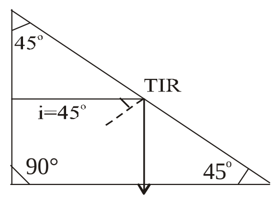
(1)	Shining of air bubble	(2) Sparking of diamond
(3)	Optical - fibre	(4) Action of 'Porro' prism
(4)	Duration of suns visibility	(6) Mirage and looming



(A)

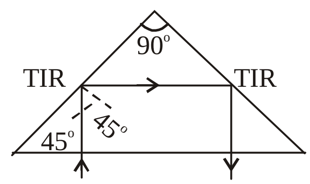


(B)



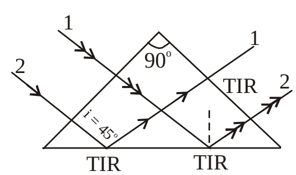
(A)

Bending of rays by 90°



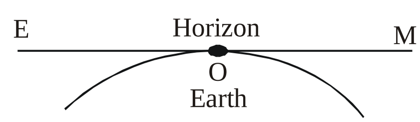
(B)

Bending of rays by 180°

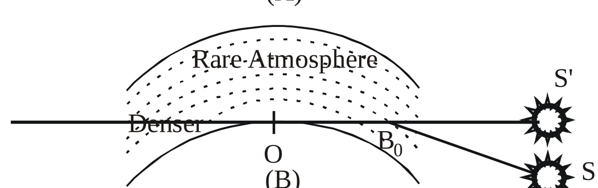


(C)

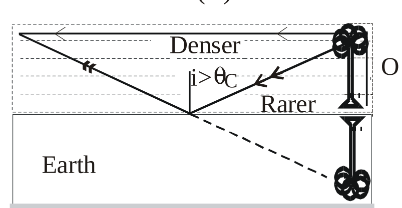
Bending of Image



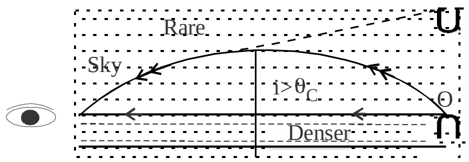
(A)



(B)



(A) Mirrage

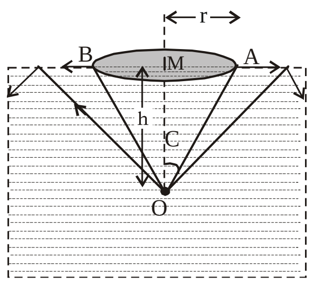


(B) Looming

NOTE

A fish inside water cannot see the entire surface of the pond. It sees only a circular patch of light because only those light rays which are incident within a cone of semi vertex angle C (critical angle) are refracted out of the water surface all other rays suffer total internal reflection from the figure in ΔAMO

$$\text{Sin C} = \frac{r}{\sqrt{r^2+h^2}}$$



But $\text{Sin C} = \frac{1}{\mu}$

where r is the radius of circular patch of light and h is depth of the fish.

$$\therefore \quad \frac{1}{\mu} = \frac{r}{\sqrt{r^2+h^2}} \qquad \therefore \quad r = \frac{h}{\sqrt{\mu^2-1}}$$

Example 12 :

One light wave is incident upon a plate of refracting index μ. Incident angle i, for which refractive & reflective waves are mutually perpendicular will be

(1) $i = 45^o$ (2) $i = \sin^{-1}(\mu)$

(3) $i = \text{cosec}^{-1}(\mu)$ (4) $i = \tan^{-1}(\mu)$

Sol. (4). $\frac{\sin i}{\sin r} = \mu$

Angle between refractive & reflective waves
$= 180^o - (i+r) = 90^o \Rightarrow i + r = 90^o ; r = 90° - i$

$$\therefore \quad \mu = \frac{\sin i}{\sin(90-i)} = \frac{\sin i}{\cos i} = \tan i \Rightarrow i = \tan^{-1}(\mu)$$

TRY IT YOURSELF - 3

Q.1 A ray of light passes from vacuum into a medium of refractive index n. If the angle of incidence is twice the angle of refraction , then the angle of incidence is :

(A) $\cos^{-1}(n/2)$ (B) $\sin^{-1}(n/2)$

(C) $2\cos^{-1}(n/2)$ (D) $2\sin^{-1}(n/2)$

Q.2 A parallel beam of light, travelling in air, is incident at an angle of 60° on a plane boundary of refractive index $\sqrt{3}$. The angle between incident and refracted wavefronts, is

(A) 0° (B) 30°

(C) 60° (D) 150°

Q.3 A plane sound wave travels from air to water. The angle of incidence is α_1 and the angle of refraction is α_2. Assuming Snell's law to be valid

(A) $\alpha_2 < \alpha_1$ (B) $\alpha_2 > \alpha_1$

(C) $\alpha_2 = \alpha_1$ (D) $\alpha_2 = 90°$

Q.4 Light passes from air into flint glass with index of refraction n. What angle of incidence must the light have so that the component of its velocity perpendicular to the interface remains same in both medium?

(A) $\tan^{-1}(1/n)$ (B) $\sin^{-1}(1/n)$

(C) $\cos^{-1}(1/n)$ (D) $\tan^{-1} n$

Q.5 If atmospheric refraction did not occur, how would the apparent time of sunrise and sunset be changed?

(A) sunrise would be later and sunset earlier

(B) sunrise would be later and sunset later

(C) both would be later

(D) both would be earlier

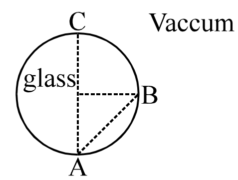
Q.6 It is found that electromagnetic signals sent inside glass sphere from A towards B reach diametrically opposite point C. Speed of electromagnetic signals in glass cannot be:

(A) 1.0×10^8 m/s

(B) 2.4×10^8 m/s

(C) 2×10^7 m/s

(D) 4×10^7 m/s



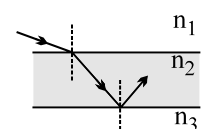
Q.7 Light traveling through three transparent substances follows the path shown in figure. Arrange the indices of refraction in order from smallest to largest. Note that total internal reflection does occur on the bottom surface of medium 2.

(A) $n_1 < n_2 < n_3$

(B) $n_2 < n_1 < n_3$

(C) $n_1 < n_3 < n_2$

(D) $n_3 < n_1 < n_2$



Q.8 A ray of light travelling in a medium of refractive index μ is incident at an angle θ on a composite transparent plate consisting of 50 plates of refractive indices 1.01μ, 1.02μ, 1.03μ.....1.50μ. They ray emerges from the composite plate into a medium of refractive index 1.6μ at angle x. Then

(A) $\sin x = \left(\frac{1.01}{1.5}\right)^{50} \sin\theta$ (B) $\sin x = \frac{5}{8}\sin\theta$

(C) $\sin x = \frac{8}{5}\sin\theta$ (D) $\sin x = \left(\frac{1.5}{1.01}\right)^{50} \sin\theta$

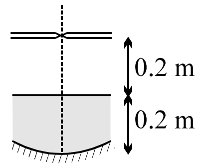
Q.9 A vessel of depth d is half filled with a liquid of refractive index μ_1 and the other half is filled with a liquid of refractive index μ_2. The apparent depth of the vessel, when looked at normally from air is

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

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

Q.10 When a pin is moved along the principal axis of a small concave mirror, the image position coincides with the object at a point 0.5 m from the mirror, refer figure. If the mirror is placed at a depth of 0.2 m in a transparent liquid, the same phenomenon occurs when the pin is placed 0.4 m from the mirror. The refractive index of the liquid is

(A) 6/5
(B) 5/4
(C) 4/3
(D) 3/2



ANSWERS

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

REFRACTION AT CURVED SURFACES

REFRACTION AT A SINGLE SPHERICAL SURFACE

Let the object is placed in a medium of the refractive index μ_1. The spherical curved surface (convex or concave) separate it from another medium of refractive index μ_2. Then if v, u and R are respectively, the object distance, the image distance and the radius of curvature of the refracting surface, then the formula connecting u, v and R is

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

This formula is applicable for convex as well as concave spherical curved surfaces.

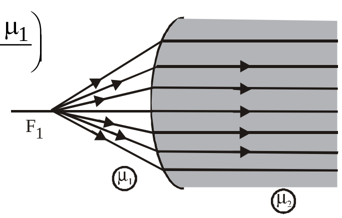
1. Focal length of a single spherical surface

A single spherical surface as two principal focus points which are as follows–

(i) First focus: The first principal focus is the point on the axis where when an object is placed, the image is formed at infinity.

That is when, $u = f_1$, $v = \infty$, then from

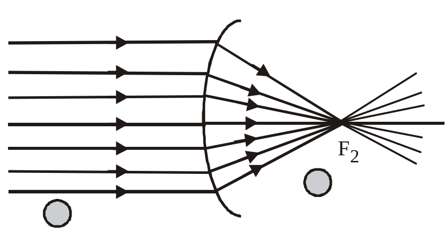
$$-\frac{\mu_1}{u}+\frac{\mu_2}{v}=\left(\frac{\mu_2-\mu_1}{R}\right)$$



$$-\frac{\mu_1}{(f_1)}=\frac{\mu_2-\mu_1}{R}$$

or $$f_1=\frac{-\mu_1 R}{(\mu_2-\mu_1)}$$

(ii) Second focus: Similarly, the second principal focus is the point where parallel rays focus.



That is, $u_1 = -\infty$, $v_1 = f_2$, then

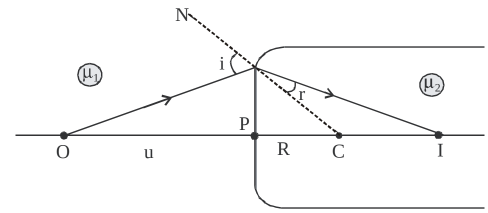
$$\frac{\mu_2}{f_2}=\frac{\mu_2-\mu_1}{R};\quad f_2=\frac{\mu_2 R}{(\mu_2-\mu_1)}$$

(iii) Ratio of Focal length : $\frac{f_1}{f_2}=-\frac{\mu_1}{\mu_2}$

Example 13 :

A small point object is placed at O, at a distance of 0.60 metre in air from a convex spherical surface of refractive index 1.5. If the radius of the curvature is 25 cm, then what is the position of the image on the principal axis.

Sol. According to sign convention, it is given that



$u = -0.6$m, $R = 0.25$m ; $\mu_1 = 1$(air), $\mu_2 = 1.5$

Therefore, using

$$-\frac{\mu_1}{u}+\frac{\mu_2}{v}=\frac{\mu_2-\mu_1}{R},\ \text{we get}\ \frac{1.5}{v}=\frac{1}{(-0.6)}+\frac{1.5-1}{0.25}$$

$$=-\frac{1}{0.6}+\frac{0.5}{0.25}=-\frac{5}{3}+2=\frac{1}{3}\qquad\Rightarrow v=4.5\text{ m}$$

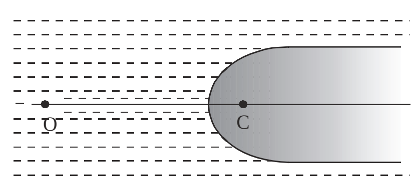
The image is formed on the other side of the object (i.e. inside the refracting surface).

Example 14 :

One end of a cylindrical rod is grounded to a hemispherical surface of radius R = 20 mm. It is immersed in water ($\mu = 4/3$). If the refractive index of the rod is 1.5 and an object is placed in water on the axis at a distance of 10cm from the pole, then the position of the image is .... (determine)

Sol. Using sign convention,

$u = -10$ cm, $R = +0.2$ cm
$\mu_1 = 1.33$ $\mu_2 = 1.50$



Therefore, using

$$-\frac{\mu_1}{u}+\frac{\mu_2}{v}=\frac{\mu_2-\mu_1}{R};\quad \frac{-1.33}{-10}+\frac{1.5}{v}=\frac{1.5-1.33}{0.2}$$

or $$\frac{1.5}{v}=-\frac{1.33}{10}+\frac{0.17}{0.2}=-0.133+0.085=-0.048$$

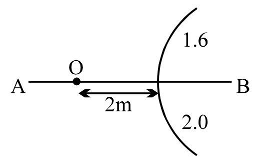
or $$v=-\frac{1.5}{0.048}=-31.25\text{ cm}$$

Thus, the image is formed at a distance of 31.25 cm form the pole on the axis, inside the water.

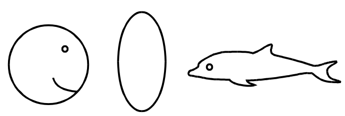
TRY IT YOURSELF - 4

Q.1 In the figure shown a point object O is placed in air. A spherical boundary separates various media of radius of curvature 1.0 m. AB is principal axis. The refractive index above AB is 1.6 and below AB is 2.0. The separation between the images formed due to refraction at spherical surface is:

(A) 12 m
(B) 20 m
(C) 14 m
(D) 10 m



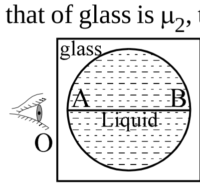
Q.2 A fish sees the smiling face of a scuba diver through a bubble of air between them, as shown. Compared to the face of the diver, the image seen by the fish will be –



(A) smaller and erect
(B) smaller and inverted
(C) larger and erect
(D) Can be either of above depending on the distance of the diver.

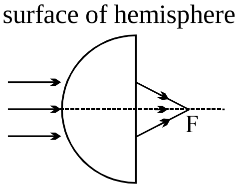
Q.3 A secondary rainbow is formed when light rays coming from the sun undergo the following through spherical water droplets: (IR = internal reflection)
(A) a refraction, IR and then refraction
(B) two refractions only
(C) a refraction, IR, again IR and then refraction
(D) a refraction, IR and again IR

Q.4 The observer 'O' sees the distance AB as infinitely large. If refractive index of liquid is μ_1 and that of glass is μ_2, then μ_1/μ_2 is:
(A) 2
(B) 1/2
(C) 4
(D) None of these

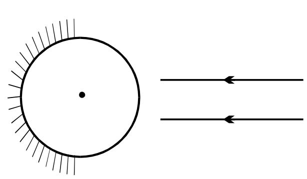


Q.5 A paraxial beam is incident on a glass (n = 1.5) hemisphere of radius R = 6 cm in air as shown. The distance of point of convergence F from the plane surface of hemisphere is

(A) 12 cm
(B) 5.4 cm
(C) 18 cm
(D) 8 cm



Q.6 A glass sphere of index 1.5 and radius 40 cm has half its hemispherical surface silvered. The point where a parallel beam of light, coming along a diameter, will focus (or appear to) after coming out of sphere, will be:



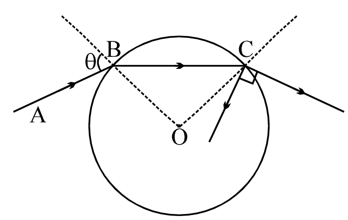
(A) 10 cm to the left of centre (B) 30cm to the left of centre
(C) 50 cm to the left of centre (D) 60cm to the left of centre

Q.7 A concave mirror is placed on a horizontal surface and two thin uniform layers of different transparent liquids (which do not mix or interact) are formed on the reflecting surface. The refractive indices of the upper and lower liquids are μ_1 and μ_2 respectively. The bright point source at a height 'd' (d is very large in comparison to the thickness of the film) above the mirror coincides with its own final image. Radius of curvature of the reflecting surface therefore is

(A) $\frac{\mu_1 d}{\mu_2}$ (B) $\mu_1\mu_2 d$
(C) $\mu_1 d$ (D) $\mu_2 d$

Q.8 A solid transparent sphere (μ = 1.5) has a small dot at its center. When observed from outside, the apparent position of the dot will be
(A) closer to the eye than its actual position
(B) same as its actual position
(C) farther away from the eye than its actual position
(D) at infinity

Q.9 A ray incident at a point B at an angle of incidence θ enters into a glass sphere and is reflected and refracted at the farther surface of the sphere, as shown. The angle between the reflected and refracted rays at this surface is 90°. If refractive index of material of sphere is $\sqrt{3}$, value of θ is–



(A) $\pi/3$ (B) $\pi/4$
(C) $\pi/6$ (D) $\pi/12$

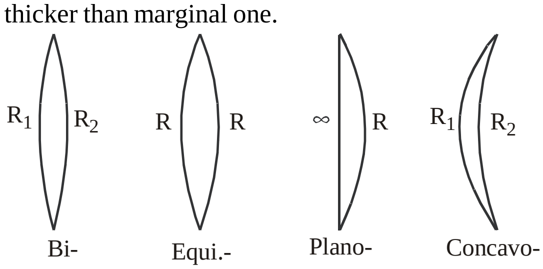
Q.10 A convex spherical surface with radius r separates a medium with index of refraction 2 from air. The rays are refracted into denser medium. As an real object is moved toward the surface from far away along the central axis, its image:
(A) changes from virtual to real when it is r/2 away from the surface.
(B) changes from virtual to real when it is r away from the surface.
(C) changes from real to virtual when it is r/2 away from the surface.
(D) changes from real to virtual when it is r away from the surface.

ANSWERS

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

LENS THEORY

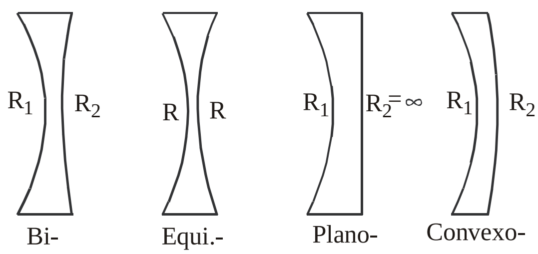
A lens is a piece of transparent material with two refracting surface such that least one is curved and refractive index of use material is different from that of the surroundings. A thin spherical lens with refractive index greater than that of surrounding behaves a convergent or convex lens i.e. converges parallel rays its central (i.e. paraxial) portion is thicker than marginal one.



Convex lens

If $\mu_L > \mu_M$ Converging lens

If $\mu_{LM} < \mu$ Diverging lens



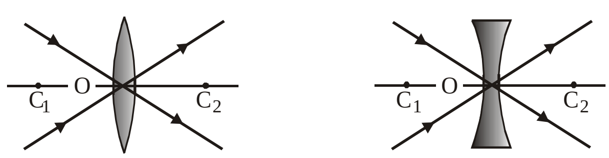
Concave lens

If $\mu_L > \mu_M$ Diverging lens

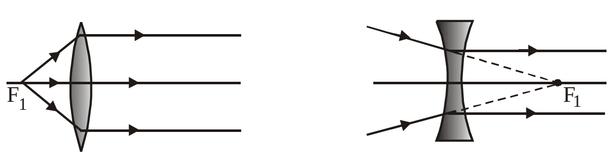
If $\mu_{LM} < \mu$ Converging lens

TERMS RELATED TO THIN SPHERICAL LENS

1. **Optical -** O is a point for given lens through which any ray passes undeviated.
2. .... $C_1 C_2$ is a line passing through optical and perpendicular to the lens. The centre of curvature of curved surface always lie on the principal axis (as in a sphere is always perpendicular to surface)



3. **Principle - Focus -** A lens has two surface and hence two focal points first focal point is an object on the principal axis for which image is at infinite while



Second focal point is an image point on the principle axis for which object is at infinity.

4. **Focal - Length f -** is defined as the distance between optical centre of a lens and the point where the parallel beam of light converges or appear to converge.
5. **Aperture -** In reference to lens aperture means to effective diameter of its light transmitting area so that brightness i.e. intensity of image formed by a lens which depends on the light passing through the lens will depends on the square of aperture i.e. $I \propto (\text{Aperture})^2$

Sign - Convention

1. Whenever and where possible, rays of light are taken to travel from left to right.
2. Transverse distance measured from optical centre and are taken to be positive while those below it negative.
3. Longitudinal distances are measured from optical centre and are taken to be positive if in the direction of light propagation and negative if opposite to it e.g., according to our convention case of a

$R_1(=OC_1)$=Positive
$R_2(=OC_2)$=Negative
$f(=OF)$=Positive

$R_1(=OC_1)$=Negative
$R_2(=OC_2)$=Positive
$f(=OF)$=Negative

While using the sign convention it must be kept in mind that-

(i) To calculate an unknown quantity the known quantities are substituted with sign in a given formula.

(ii) In the result sign must be interpreted as there are number of sign conventions and same sign has different meaning in different conventions.

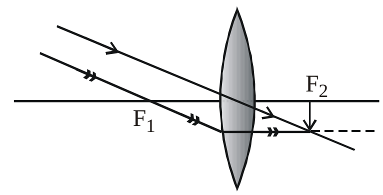
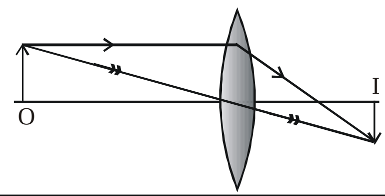
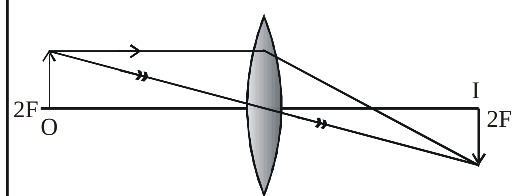
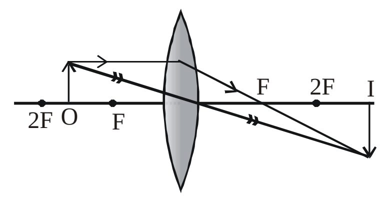
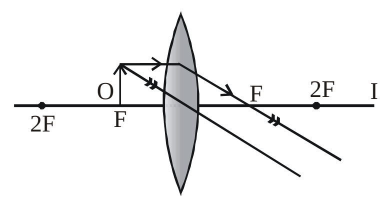
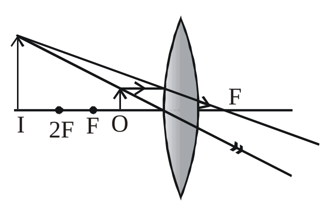
RULES FOR IMAGE FORMATION

In order locate the image formed by a lens graphically following rules are adopted -

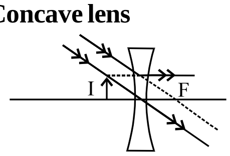
1. A ray passing through optical centre proceeds undeviated through the lens. (by definition of optical centre).
2. A ray passing through first focus or directed towards it, after refraction from the lens becomes parallel to the principal axis. (by definition of F_1)
3. A ray passing parallel to the principal axis after refraction through the lens passes or appear to pass through F_2 (by definition of F_2).
4. 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.

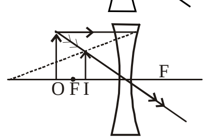
Image formation by a lens

(a) For convergent or Convex Lens

Position of object	Details of image	Figure
At infinity	Real, inverted diminished ($m << -1$) At F	
Between ∞ and 2F	Real, inverted diminished ($m < -1$) Between F and 2F	
At 2F	Real, inverted diminished $m = -1$ at 2F	
Between 2F and F	Real, inverted enlarged ($m > -1$) Between 2F and ∞	
At F	Real, inverted enlarged ($m >> -1$) At infinity	
Between focus and pole	Virtual, erect enlarged ($m > +1$) Between ∞ and object on same side	

(b) For Divergent or Concave lens

If object at infinity  image will be formed at focus

In front of lens  Virtual, erect

REFRACTION THROUGH A THIN LENS

If an object is placed at a distance u from the optical centre of a lens and its images is formed at a distance v (from the optical centre) and focal length of this length is f then

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

NOTE

1. Focal length of lens (lens maker formula)

$$\frac{1}{f}=({}_m\mu_\ell-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

where ${}_m\mu_\ell$ refractive index of lens with respect to medium.
R_1 = radius of curvature of first surface of lens,
R_2 = radius of curvature of second surface of lens

2. The power of a lens is defined as

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

The unit of power is diopter.

3. If a thin object linear size O situated vertically on the axis of a lens at a distance u from the optical centre and its image of size I is formed at a distance v (from the optical centre). magnification (transverse) is defined as

$$m=\left[\frac{I}{O}\right]=\left[\frac{v}{u}\right]$$

→ (+ve Erect image)
→ (–ve inverted image)
→ (|m| >1 large image)
→ (|m| < 1 Small image)

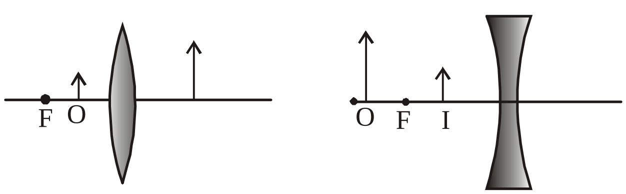
Here-ve magnification implies that image is inverted with respect to object while +ve magnification means that image is erect with respect to object

4. Other formulae of magnification

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

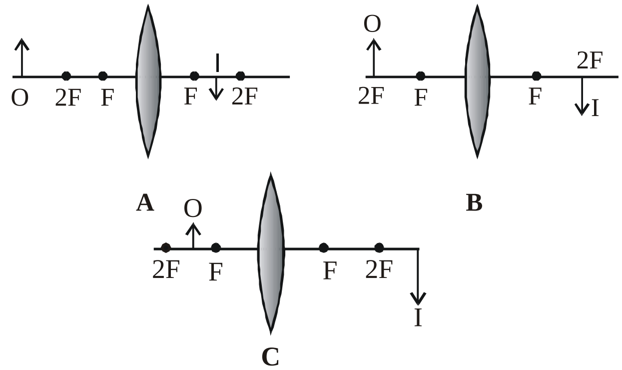
SPECIAL POINTS

For real extended objects if the image formed by a single lens is erect (i.e., m is positive) it is always virtual. In this situation if the image is enlarged the lens is converging (i.e. convex) with object between focus and optical centre and if diminished the lens is diverging (i.e. concave) with image between focus and optical centre.

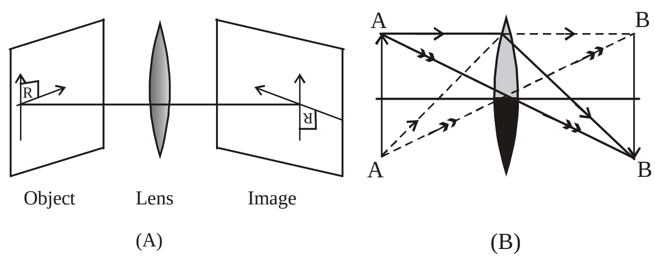


* For real extended object, if the image formed by a single lens in inverted (i.e., m is negative) it is always real and the lens is convergent i.e., convex. In this situation if the size of image is

Smaller than object	Equal to object	Larger than object
Object between ∞ and 2F	Object is at 2F	Object is between 2F and F
Image is between F and 2F	Image is at 2F	Image is between 2F and ∞



* In case of inverted image formed by a lens the inversion is true i.e., left is turned right and up, down.



* A very small part of a lens forms complete image, if a portion (say lower half) is obstructed (say covered with black paper) Full image will be formed but brightness i.e., intensity will be reduced (to half). Also if a lens is painted with black strips and a donkey is seen through it, the donkey will not appear zebra but will remain donkey with reduced intensity.

* If L is the distance between a real image by a lens. then as

$$L=(|u|+|v|)=\left((\sqrt{u}-\sqrt{v})^2+2\sqrt{uv}\right)$$

So L will be minimum when

$$\left(\sqrt{u}-\sqrt{v}\right)^2=\min=0 \text{ i.e., } u=v$$

On substituting u = – u and v = + u in lens formula, we get

$$\frac{1}{u}-\frac{1}{-u}=\frac{1}{f}\qquad \text{i.e., } u=2f$$

So that $(L)_{min}=2f+2f=4f$ [as for L_{min} u = v]
i.e., the minimum distance between a real object and its real image formed by a single lens is 4f.

* If an object is moved at constant speed towards a convex lens from infinity to Focus, the image will move slower in the beginning and faster later - on, away from the lens. This is because in the time object moves from infinity to 2F, the image will move from F to 2F and when the object moves from 2F to F, The image will move from 2F to infinity. At 2F the speed of object and image will be equal.

$$V_i = V_0\left[\frac{f}{u+f}\right]^2$$; Where V_0 is the speed of object

(u and f are to be substituted with proper sign)

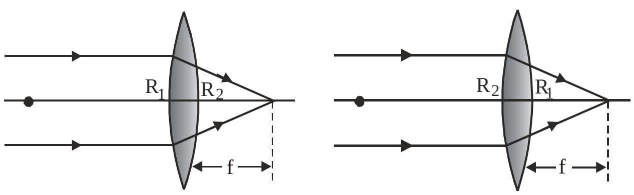
* In case of sun - goggles, the radii of curvature of two surface are equal with centre on same side i.e.,

$$R_1 = R_2 + R. \ \text{So}\ \frac{1}{f} = (\mu-1)\left[\frac{1}{+R} - \frac{1}{+R}\right] = 0$$

i.e., $f = \infty$ and $P = (1/f) = 0$

This is why sun - goggles have no power or infinite focal length. Same is true for a transparent sheet with the difference that here $R_1 = R_2 = \infty$

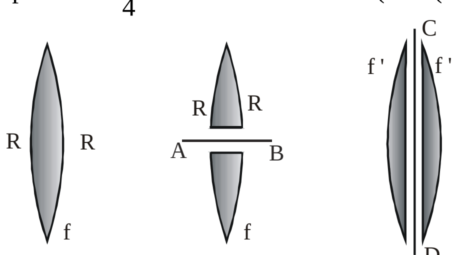
* If the two radii of curvatures of a thin lens are not equal, the focal length remains unchanged whether the light is incident on first face or the other. This is because if we substitute R_1 and R_2 with proper sign in lens - makers formula, we always have $\frac{1}{f} = (\mu-1)\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$



* If an equiconcave lens of focal length f is cut into equal parts by a horizontal plane AB then as none of μ, R_1 and R_2 will change the focal length of each part will be equal to that of initial lens i.e. $\frac{1}{f} = (\mu-1)\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$

If $R_1 = R_2 = R \Rightarrow \frac{1}{f} = \frac{2(\mu-1)}{R}$

However in this situation as light transmitting area of each part becomes half of initial so intensity will reduce to half and aperture to $\frac{1}{4}$ time of its initial value (as $\propto$ (Aperture)^2)



(A) (B) (C)

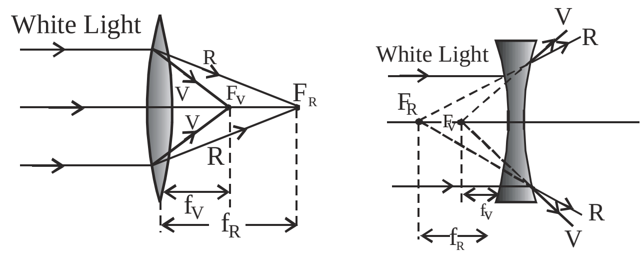
However if the same lens in cut into equal parts by a vertical plane CD the focal length of each part will become

$$\frac{1}{f'} = (\mu-1)\left[\frac{1}{R} - \frac{1}{\infty}\right] = \frac{\mu-1}{R} = \frac{1}{2f} \Rightarrow f' = 2f$$

i.e., focal length of each part will be double of initial value. In this situation as the light transmitting area of each part of lens of remains equal to initial intensity and aperture will not change.

* If a lens is made of number of layers of different refractive indicate as shown in fig. for given wavelength of light it will have as many wave lengths so form as many image as there are μ 's as $\frac{1}{f} \propto (\mu-1)$

* As focal length of a lens depends on μ i.e. $(1/f) \propto (\mu - 1)$ the focal length of given lens is different for different wavelengths ($\mu = A + \frac{B}{\lambda^2}$) and is maximum for red and minimum for violet whatever be the nature of lens.



(A) (B)

* If a lens of glass ($\mu = 3/2$) is shifted form air ($\mu = 1$) to water ($\mu = 4/3$) then as.

$$\frac{1}{f_a} = \left[\frac{3/2}{1} - 1\right]K \quad \text{and} \quad \frac{1}{f_w} = \left[\frac{(3/2)}{(4/3)} - 1\right]K$$

$$\text{With}\ K = \left[\frac{1}{R_1} - \frac{1}{R_2}\right]; \qquad \frac{F_w}{f_A} = \left[\frac{8}{K}\right] \times \left[\frac{K}{2}\right]$$

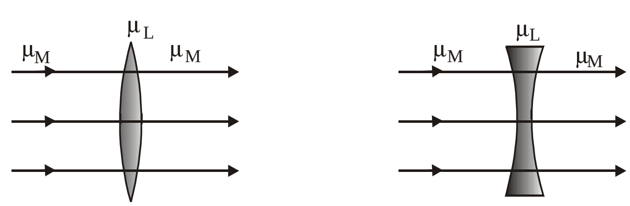
i.e., $F_w = 4f_A$

i.e. focal length of a lens in water becomes four times of its value in air and so power one fourth [as p = (1/f)].

* If a lens is shifted from one medium to the other depending on the refractive index of the lens and medium following three situation are possible.

(a) $\mu_m < \mu_L$ but μ_m increase : In this situation $\mu = (\mu_L / \mu_m)$ will remain greater than unity but will decrease and $(1/f) \propto (\mu - 1)$ (1/f) will decrease i.e. f will increase (without change in nature of lens) as explained in previous point.

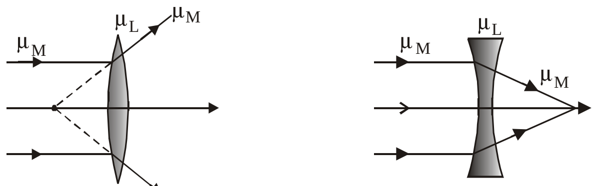
(b) $\mu_m = \mu_L$: In this situation $\mu = (\mu_L / \mu_M) = 1$, so that $(1/f) \propto (\mu - 1) = 0$ i.e. $f = \infty$ i.e., lens will neither converge nor diverge but will behave as a plane glass. plate.



(A) (B)

$\mu_L = \mu_M$

(c) $\mu_M > \mu_L$: In this situation $\mu = (\mu_L / \mu_M) < 1$
So in lens-maker's formula sign of f and hence nature of lens will change i.e.......... a convergent lens will behave as divergent and vice-versa.



(A) (B)

$\mu_M > \mu_L$

Example 15 :
An object is situated at a distance of f/2 from a convex lens of focal length f. Find the distance of image

Sol. For a spherical lens, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

For convex lens, u = – f/2 and f is + ve

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

Example 16 :
An object of length 1 cm is placed at a distance of 15 cm from a concave mirror of focal length 10 cm. The nature and size of the image are –
(1) real, inverted, 1.0 cm (2) real, inverted, 2.0 cm
(3) virtual, erect, 0.5 cm (4) virtual, erect, 1.0 cm

Sol. **(2).** Given u = – 15 cm, f = – 10 cm, O = 1 cm

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}, \ \frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-10} - \frac{1}{-15} \ \therefore v = -30 \text{ cm}$$

$$\frac{I}{O} = -\frac{v}{u} = -\frac{-30}{-15} = -2 \ ; \ I = -2 \times 1 = -2 \text{ cm}$$

Image is inverted and on the same side (real) of size 2 cm.

Example 17 :
A biconvex lens whose both the surfaces have same radii of curvature has a power of 5D. The refractive index of material of lens is 1.5. The radius of curvature of each surface is –
(1) 20 cm (2) 15 cm
(3) 10 cm (4) 5 cm

Sol. **(1).** $P = \frac{1}{f}, \ \therefore \ f = \frac{1}{P} = \frac{1}{5} \text{ m} = 20 \text{ cm}$

For an equiconvex lens

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

$$\therefore \quad R = 2(\mu - 1) f = 2 \times 0.5 \times 20 = 20 \text{ cm}$$

Example 18 :
A lens placed at a distance of 20 cm from an object produces a virtual image 2/3 the size of the object. Find the position of the image, kind of lens and its focal length.

Sol. Virtual image means, I is positive and it is given that

$I = \frac{2}{3} O$. Thus, $m = + \frac{2}{3}$

Further because u = –20 cm (given), using

$$m = \frac{f}{f+u}, \text{ we get, } \frac{2}{3} = \frac{f}{f + (-20)} \quad \text{or } f = -40 \text{ cm}$$

The f is negative, thus the lens is a concave lens. Again

$$\text{using} \quad m = \frac{v}{u}, \text{ we get } \frac{2}{3} = \frac{v}{-20} \quad \text{or } v = -\frac{2}{3} = -1.33 \text{ cm}$$

The virtual image is on the same side of the object.

Example 19 :
An object is placed at a distant of 1.50 m from a screen and a convex lens placed in between produces an image magnified 4 times on the screen. What is the focal length and the position of the lens.

Sol. The information given in the question ray diagram. It is given that m = (I/O) = – 4
Let lens is placed at a distance of x from the object. Then
u = – x, and v = (1.5 – x)

$$\text{using } m = \frac{v}{u}, \text{ we get } -4 = \frac{1.5 - x}{-x}$$

or 4x = 1.5 – x or 5x = 1.5. Thus, x = 0.3 metre
The lens is placed at a distance of 0.3m from the object (or 1.20m from the screen)
For focal length, we may use

$$m = \frac{f}{f+u} \quad \text{or } -4 = \frac{f}{f + (-0.3)}$$

or – 4f + 1.2 = f or 5f = 1.2. Thus, f = 1.5/5 = 0.24
The focal length is 0.24m (or 24 cm)

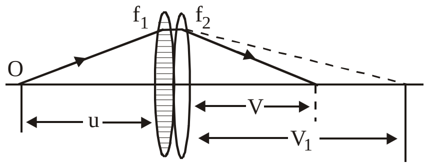
COMBINATION OF LENSES

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 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 is such situations will be given by

$$m = \frac{I}{o} = \frac{I_1}{o} \times \frac{I_2}{I_1} \times \ldots\ldots\ldots\ldots\ldots \quad \text{i.e. } m = m_1 \times m_2 \times \ldots\ldots\ldots\ldots$$

In case of two thin lens in contact if the first lens of focal length f_1 forms the image I_1 (of an object)at a distance v_1 from it.

$$\frac{I}{v_1} - \frac{1}{u} = \frac{1}{f_1} \qquad \ldots..(1)$$



now the image I_1 will act as object for second lens and if the second lens forms image. I at a distance v from it

$$\frac{I}{v}-\frac{1}{v_1}=\frac{1}{f_2} \quad ...(2)$$

So adding Eqn. (1) and (2) we have

$$\frac{I}{v}-\frac{1}{u}=\frac{1}{f_1}+\frac{1}{f_2} \quad \text{or} \quad \frac{I}{v}-\frac{1}{u}=\frac{1}{f} \quad \text{with} \quad \frac{I}{f}=\frac{1}{f_1}+\frac{1}{f_2}$$

i.e. the combination behave as a single lens of equivalent focal length f given by

$$\frac{I}{F}=\frac{1}{f_1}+\frac{1}{f_2} \quad \text{or} \quad P=P_1+P_2 \quad .....(3)$$

If the two thin lens are separated by a distance d apart F is given by $\frac{I}{F}=\frac{1}{f_1}+\frac{1}{f_2}-\frac{d}{f_1 f_2}$, so $P = P_1 + P_2 - P_1P_2d$.

NOTE

* If two thin lens of equal focal length but of opposite nature (i.e. one convergent and other divergent) are put in contact, the resultant focal length of the combination be

$$\frac{I}{F}=\frac{1}{+f}+\frac{1}{-f}=0 \quad \text{i.e.} \quad F=\infty \quad \text{and } P=0$$

i.e. the system will behave as a plane, glass plate.

* If two thin lens of same nature are put in contact then as

$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}\ ; \quad \frac{1}{F}>\frac{1}{f_1} \quad \text{and} \quad \frac{1}{F}>\frac{1}{f_2}$$

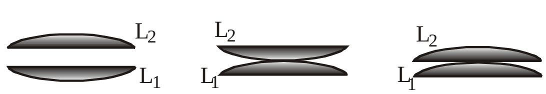
i.e. $F < f_1$ and $F < f_2$ i.e. the resultant focal length will be lesser than smallest individual.

* If two thin lenses of opposite nature with different focal lengths are put in contact the resultant focal length will be of same nature as that of the lens of shorter focal length but its magnitude will be more than that of shorter focal length.

* If a lens of focal length f is divided into two equal parts as in figure (A), each part has a focal length f′ then as

$$\frac{1}{f}=\frac{1}{f'}+\frac{1}{f'} \ ; \ f'=2f$$

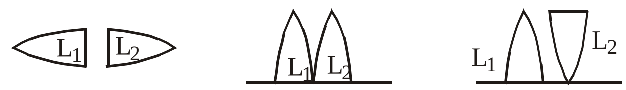
i.e. each part have focal length 2f now if these parts are put in contact as in (B) or (C) the resultant focal length of the combination will be $\frac{1}{F}=\frac{1}{2f}+\frac{1}{2f}$ i.e. F=f (=initial value)



(A) (B) (C)

* If a lens of focal length f is cut in two equal part as shows in each will have focal length f. Now of these parts are put in contact as shown in the resultant length will be

$$\frac{1}{F}=\frac{1}{f}+\frac{1}{f} \qquad \text{i.e. } F=(f/2)$$



(A) (B) (C)

However if the two parts are put in contact as shown in first will behave as convergent lens of focal length f while the other divergent of same focal length (being thinner near the axis) so in this situation.

$$\frac{1}{F}=\frac{1}{+f}+\frac{1}{-f} \qquad \text{i.e. } -F=\infty \text{ or } P=0$$

Example 20 :

A convex lens of focal length 10.0 cm is placed in contact with a convex lens of 15.0 cm focal length. What is the focal length of the combination.

Sol. For combination of lenses

$$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}=\frac{1}{10}+\frac{1}{15}=\frac{25}{150}=\frac{1}{6}. \text{ Therefore, } f=6\text{ cm}$$

Example 21 :

A 20 cm convex lens is placed in contact with a diverging lens of unknown focal length. The lens combination acts as a converging lens and has a focal length of 30 cm. What is the focal length of the diverging lens.

Sol. Let f_2 is the focal length of the diverging lens. Then,

$$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}$$

It is given that f_1 = +20 cm, f = 30 cm

$$\frac{1}{30}=\frac{1}{20}+\frac{1}{f_2} \quad \text{or} \quad \frac{1}{f_2}=\frac{1}{30}-\frac{1}{20}=\frac{2-3}{60}=-\frac{1}{60}.$$

Thus, f_2 = – 60 cm

Comment. If we change the question and claim that the combination acts as a diverging lens and has a focal length of 30 cm, then f_1 = + 20cm, f_2 = ?, f = – 30 cm

$$-\frac{1}{30}=\frac{1}{20}+\frac{1}{f_2} \ \therefore \ \frac{1}{f_2}=-\frac{1}{30}-\frac{1}{20}=-\frac{5}{60} \text{ or } f_2=-12\text{ cm}$$

Example 22 :

Ten identical converging thin lenses, each of focal length 10 cm, are in contact. What is the power of the combined lens.

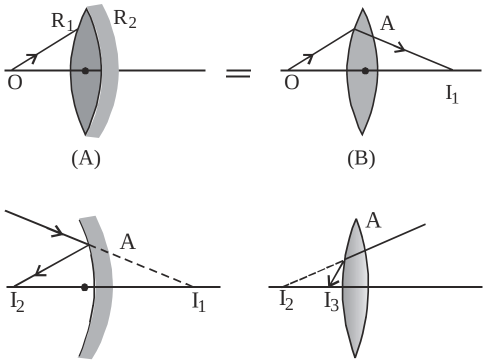
Sol. For thin lenses in contact

$$P=P_1+P_2+........=10\,P_1=\frac{10\times 100}{10}=100\text{ D}$$

LENS WITH ONE SILVERED SURFACE

If the back surface of a lens is silvered and an object is placed in front of it then :

* First, light will pass through the lens and it will form the image I_1.



(A) (B) (C) (D)

* The image I_1 will act as an object for silvered surface which acts as curved mirror and forms an image I_2 of object I_1.
* The light after reflection from silvered surface will again pass through the lens and lens will form final image I_3 of object I_2.

This all is shown in Fig. In such situation power of the silvered lens will be

$$P = P_L + P_M + P_L$$

with $P_L = \frac{1}{f_L}$ where $\frac{1}{f_L} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

and $P_M = -\frac{1}{f_M}$ where $f_M = \frac{R_2}{2}$

So the system will behave as a curved mirror of focal length F given by $F = -1/P$

CASES :

(A) When the plane surface is silvered and the object is in front of curved surface : In this situation,

$$\frac{1}{f_L} = (\mu - 1)\left[\frac{1}{R} - \frac{1}{\infty}\right] = \frac{(\mu-1)}{R} \quad \text{and} \quad F_M = \frac{\infty}{2} = \infty$$

So $P_L = \frac{1}{f_L} = \frac{(\mu-1)}{R}$ and $P_M = -\frac{1}{f_M} = \frac{1}{\infty} = 0$

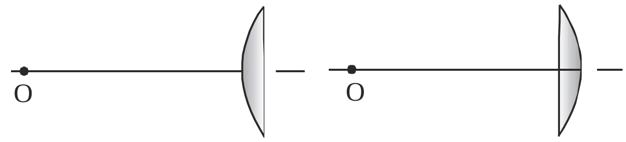
And hence power of system

$$P = P_L + P_M + P_L = 2P_L + P_M$$

i.e., $P = 2\frac{(\mu-1)}{R} + 0 = \frac{2(\mu-1)}{R}$ ....(1)

So $F = -\frac{1}{P} = -\frac{R}{2(\mu-1)}$ ....(2)

i.e., the lens will behave as a concave mirror of focal length $[R/2(\mu-1)]$.



(A) (B)

(B) When the curved surface is silvered and the object is in front of plane surface : In this situation

$$\frac{1}{f_L} = (\mu - 1)\left[\frac{1}{\infty} - \frac{1}{-R}\right] = \frac{(\mu-1)}{R} \quad \text{and} \quad f_M = \frac{(-R)}{2}$$

So $P_L = \frac{1}{f_L} = \frac{(\mu-1)}{R}$ and $P_M = -\frac{1}{f_M} = \frac{2}{R}$

And hence power of system

$$P = P_L + P_M + P_L = 2P_L + P_M$$

i.e. $P = \frac{2(\mu-1)}{R} + \frac{2}{R} = \frac{2\mu}{R}$ ....(3)

So $F = -\frac{1}{P} = -\frac{R}{2\mu}$ ....(4)

i.e., the lens equivalent to a concave mirror of focal length $(R/2\mu)$.

Example 23 :

The radius of curvature of the convex face of a plano–convex lens is 12 cm and its refractive index is 1.5. (a) Find the focal length of this lens. The plane surface of the lens is now silvered. (b) At what distance from the lens will parallel rays incident on the convex face converge ?
(c) Sketch the ray diagram to locate the image, when a point object is placed on the axis 20 cm from the lens.
(d) Calculate the image distance when the object is placed as in (c).

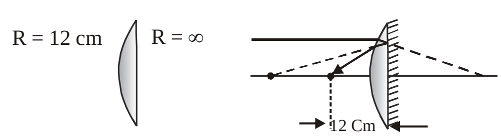
Sol. (a) As for a lens, by lens-maker's formula

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

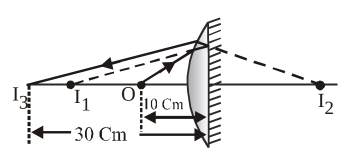
Here $\mu = 1.5$; $R_1 = 12$ cm and $R_2 = \infty$

So $\frac{1}{f} = (1.5 - 1)\left[\frac{1}{12} - \frac{1}{\infty}\right]$ i.e., $f = 24$ cm

i.e., the lens as convergent with focal length 24 cm.



(A) (B)



(C)

(b) As light after passing through the lens will be incident on the mirror which will reflect it back through the lens again, so $P = P_L + P_M + P_L = 2P_L + P_M$

But $P_L = \frac{1}{f_L} = \frac{1}{0.24}$ and $P_M = -\frac{1}{\infty} = 0$

So $P = 2 \times \frac{1}{0.24} + 0 = \frac{1}{0.12} D \quad \left[\text{as } f_M = \frac{R}{2} = \infty \right]$

The system is equivalent to a concave mirror of focal length F, $P = -\frac{1}{F}$ i.e., $F = -\frac{1}{P} = -0.12\,m = -12\,cm$

i.e., the rays will behave as a concave mirror of focal length 12 cm. So as for parallel incident rays $u = -\infty$, from mirror formula

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ we have $\frac{1}{v} + \frac{1}{-\infty} = \frac{1}{-12}$ i.e., $v = -12$ cm

i.e., parallel incident rays will focus will at a distance of 12 cm in front of the lens as shown in Fig.

(c) and (d) When object is at 20 cm in front of the given silvered lens which behaves as a concave mirror of focal length 12 cm, from mirror formula

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ we have $\frac{1}{v} + \frac{1}{-20} = \frac{1}{-12}$, i.e., $v = -30$ cm,

i.e., the silvered lens will form image at a distance of 30 cm in front of it as shown in Fig. (C).

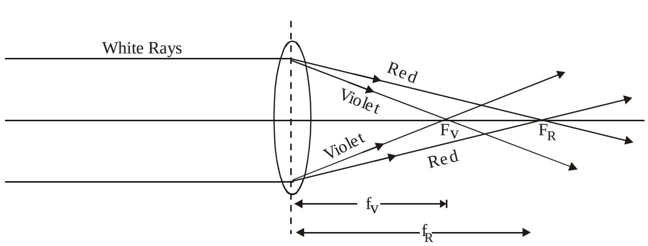
DEFECTS OF IMAGE

CHROMATIC ABERRATION

The image of a white object (or illuminated by white light) formed by a lens is usually coloured and blurred. This defect of the image produced by a lens is called 'chromatic aberration'. This defect arises because the refractive index of the material of the lens and hence the focal length of the lens, is different for different colours of light for a thin lens, the focal length f and the refractive index n are related

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

where R_1 and R_2 are the radii or curvature of the surface of the lens. Since the value of n is largest for the violet light and least for red; the focal length f_V of the lens for the violet light is least and the focal length f_R for the red light is largest. Therefore, when a parallel beam of white light passes through a lens,

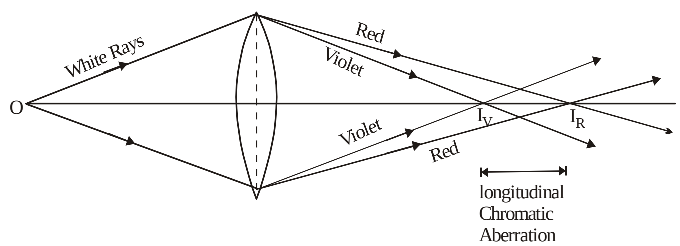


it is dispersed into its constituent colours. The violet rays are focussed at a point F_V closer to the lens, while the red rays are focussed at a point F_R farther from the lens. The rays of intermediate colours are focused between F_V and F_R. If a screen be placed at F_V, the centre of the image will be violet while the outer edge will be red. At F_R, the centre of the image will be red and outer edge violet further, the image is blurred because it is not where in perfect focus.

Chromatic aberration is of two types.

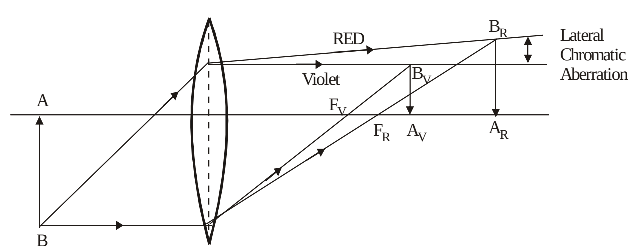
(a) Longitudinal or Axial Chromatic Aberration :-

When a white point O is situated on the axis of a lens, then images of different colours are formed at different points along the axis. The formation of images of different colours at different positions is called 'axial or longitudinal chromatic aberration'. The axial distance between the red and the violet images ($I_R - I_V$) is a measure of this aberration. If the object is at infinity; then the longitudinal chromatic aberration is equal to the difference in focal - lengths ($f_R - f_V$) for the red and the violet rays.



(b) Lateral Chromatic Aberration :

As the focal-length of the lens varies from colour to colour, the magnification $\left[m = \frac{f}{u+f}\right]$ produced by the lens also varies from colour to colour. Therefore, for a finite-size white object AB(fig.), the images of different colours formed by the lens are of different sizes. The formation of images of different colours in different sizes is called lateral chromatic aberration. The difference in the sizes of the red image B_RA_R and the violet image B_VA_V is a measure of this aberration.



(c) Expression for the longitudinal chromatic aberration of a lens : $f_R - f_V = \left(\frac{n_V - n_R}{n_y - 1}\right) f_y$

$\left(\frac{n_V - n_R}{n_y - 1}\right)$ is the dispersive power of the material of the lens which is denoted by ω. Thus, the longitudinal chromatic aberration (where object is at infinity) of the lens is given by

$$f_R - f_V = \omega \times f_y$$

For a lens neither ω nor f_y can be zero. Therefore, for single lens the chromatic aberration cannot be zero. It is also clear from the above formula that smaller the focal length of a lens (i.e. greater the power), smaller is the chromatic aberration in the lens.

ACHROMATISM

When as white object is placed in front a lens, then its images of different colours are formed at different positions and are of different sized. There defects are called 'longitudinal chromatic aberration' and 'lateral chromatic aberration' respectively. If two or more lenses be difference colours are same position and of the same size, then the combination is called 'achromatic combination of lenses' and this property is called 'achromatism'.

In practice, both types of chromatic aberrations can not be removed for all colours. We can remove both types of chromatic aberration only for two colours by placing in contact two lenses of appropriate focal lengths and of appropriate different material. On the other hand, only lateral chromatic aberration can be removed for all colours when two lenses of appropriate different material. On the other hand, only lateral chromatic aberration can be removed for all colours when two lenses of the same material are placed at a particular distance apart.

(a) Condition of Achromatism for two thin lenses in contact :

Suppose two thin lenses are placed in contact. Suppose the dispersive powers of the materials of these lenses between violet and red respectively n_V, n_R, n_y and n'_V, n'_R, n'_y. If for these rays the focal lengths of the first lens are respectively f_V, f_R, f_y and the focal lengths of the second lens are f_V', f_R', f_y', then for the first lens, we have

$$\frac{1}{f_V} = (n_V - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad .....(1)$$

$$\frac{1}{f_R} = (n_R - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad ....(2)$$

Subtracting the second equation from the first, we get

$$\frac{1}{f_V} - \frac{1}{f_R} = (n_V - n_R)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$= \frac{(n_V - n_R)}{(n_y - 1)}(n_y - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{f_v} - \frac{1}{f_r} = \omega\frac{1}{f_y} \quad ...(3)$$

because $\frac{n_V - n_R}{n_y - 1} = \omega$ and $(n_y - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f_y}$

Similarly, for the second lens, we have

$$\frac{1}{f_v'} - \frac{1}{f_R'} = \omega\frac{1}{f_y'} \quad .....(4)$$

Adding equations (3) and (4), we get

$$\left(\frac{1}{f_V} + \frac{1}{f_V'}\right) - \left(\frac{1}{f_R} + \frac{1}{f_R'}\right) = \frac{\omega}{f_y} + \frac{\omega'}{f_y'} \quad .....(5)$$

If the focal lengths of this lens-combination for the violet and the red rays be F_V and F_R respectively, then

$$\frac{1}{f_V} + \frac{1}{f_V'} = \frac{1}{F_V} \quad \text{and} \quad \frac{1}{f_R} + \frac{1}{f_R'} = \frac{1}{F_R}$$

$\therefore$ from eq. (5), we have $\frac{1}{F_V} - \frac{1}{F_R} = \frac{\omega}{f_y} + \frac{\omega}{f_y'}$

But for the achromatism of the lens combination, the focal-length must be the same for all colours of light i.e. $F_V = F_R$. Hence from the above equation, we have

$$\frac{\omega}{f_y} + \frac{\omega'}{f_y'} = 0 \quad ......(6) \text{ or } \quad \frac{\omega}{f_y} = -\frac{\omega'}{f_y'} \quad ....(7)$$

This is the condition for a lens combination to achromatic. It gives us the following information :

* Both the lenses should be of different material. If both the lenses are of the same material, then $\omega = \omega'$ and then from equation (6). We have

$$\frac{1}{f_y} + \frac{1}{f_y'} = 0 \quad \text{or} \quad \frac{1}{F_y} = 0 \quad \text{or} \quad F_y = \infty$$

that is the combination will then behave like a plane glass-plate.

* ω and ω' are positive quantities. Hence, according to eq. (7), f_y and f_y' should be of opposite signs, i.e., if one lens is convex, the other should be concave.

* For the combination of behaviour like a convergent (convex) lens–system, the power of the convex lens should be greater than that of the concave lens. On other words, the focal length of the convex lens should be smaller than the concave lens. According to eq. (7), we have $\frac{f_y}{f_y'} = -\frac{\omega}{\omega'}$

If f_y is less than f_y' then ω should be less than ω' . Hence for a converging lens-system, the convex lens should be made of a material of smaller dispersive power.

The dispersive power of crown glass is smaller than that of flint glass. Hence in an achromatic lens-doublet the convex lens is of crown glass and the concave lens is of flint glass, and they are cemented together by Canada Balsam (a transparent cement). This achromatic combination is used in optical instruments such as microscope, telescope, camera, etc. In the condition for achromatism

$$\frac{f_y}{f_y'} = -\frac{\omega}{\omega'}$$

Example 24 :

Focal lengths of two lens are f and f ' and dispersive powers are ω_0 and $2\omega_0$. To form achromatic combination from these–

(1) f ' = 2f (2) f ' = – 2f
(3) f ' = f/2 (4) f ' = – f/2

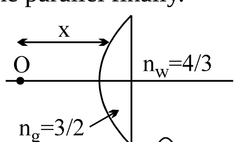
Sol. **(2).** For achromatic combination

$$\frac{\omega}{\omega'} = -\frac{\omega}{\omega'} \quad \text{but} \quad \frac{\omega}{\omega'} = \frac{\omega_0}{2\omega_0} = \frac{1}{2} \; ; \; -\frac{f}{f'} = \frac{1}{2} \quad \text{or } f' = -2f$$

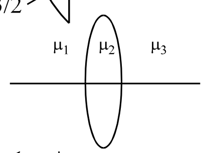
TRY IT YOURSELF - 5

Q.1 A concave lens with unequal radii of curvature made of glass (μ_g = 1.5) has a focal length of 40 cm. In air if it is immersed in a liquid of refracive index μ_l = 2, then
(A) it behaves like convex lens of 80 cm focal length
(B) it behave like a convex lens of 20 cm focal length
(C) its focal length becomes 60 cm
(D) nothing can be said.

Q.2 An object 'O' is kept in air in front of a thin plano convex lens of radius of curvature 10 cm. It's refractive index is 3/2 and the medium towards right of plane surface is water of refractive index 4/3. What should be the distance 'x' of the object so that the rays become parallel finally.
(A) 5 cm
(B) 10 cm
(C) 20 cm
(D) none of these



Q.3 The diagram shows an equiconvex lens. What should be the condition on the refractive indices so that the lens become diverging?



(A) $2\mu_2 > \mu_1 - \mu_3$ (B) $2\mu_2 < \mu_1 + \mu_3$
(C) $2\mu_2 > 2\mu_1 - \mu_3$ (D) $2\mu_2 > \mu_1 + \mu_3$

Q.4 In the case of a converging lens, a real object is at a finite distance L from the lens. It is moving with speed 5m/s. The image is formed at one of the focus of the lens. What is the speed of the image?
(A) 5 m/s (B) infinite
(C) 10 m/s (D) 20 m/s

Q.5 A converging lens is used to produce an image on a screen of an object. What change is needed for the real image to be formed nearer to the lens ?
(A) increase the focal length of the lens (lens and position of object is fixed).
(B) insert a diverging lens between the lens and the screen (converging lens and position of object is fixed).
(C) increase the distance of the object from the lens.
(D) move the object closer to the lens.

Q.6 A nearsighted person cannot clearly see beyond 250 cm. Find the power of the lens needed to see objects at large distances.
(A) –0.4 D (B) 2.5/11 D (C) 2.5/9 D (D) –0.4 D

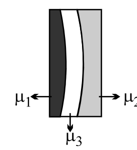
Q.7 A real object is placed 1 cm above the optical axis of a convex lens of focal length 40cm. The object distance is 60cm. If the object now starts moving perpendicularly away from the optical axis with a speed = 10 cm/s, the speed of the image is
(A) 5 cm/sec (B) 10 cm/sec
(C) 20 cm/sec (D) 40 cm/sec

Q.8 Which of the following quantities related to a lens depend on the wavelength of the incident light ?
(A) Refractive index (B) Focal length
(C) Power (D) Radii of curvature

Q.9 The adjacent figure shows a thin plano-convex lens of refractive index μ_1 and a thin plano-concave lens of refractive index μ_2, both having same radius of curvature R of their curved surfaces. The thin lens of refractive index μ_3 has radius of curvature R of both its surfaces. This lens is so placed in between the plano-convex and plano-concave lenses that the plane surfaces are parallel to each other. The focal length of the combination is

(A) $\frac{R}{(\mu_1+\mu_2-\mu_3-1)}$ (B) $\frac{R}{(\mu_1+\mu_2+\mu_3)}$

(C) $\frac{R}{(\mu_1-\mu_2)}$ (D) $\frac{R}{(\mu_1-\mu_2-\mu_3-3)}$



Q.10 A camera lens with a focal length of 5.5 cm is used to take the picture of a person 1.68 m tall. What is the person's distance from the lens, if the image just fills the 24 mm vertical dimension of the film ?
(A) 2.4 m (B) 5.6 m
(C) 3.9 m (D) 1.6 m

Q.11 Dispersive powers of materials used in lenses of an achromatic doublet are in the ratio 5 : 3. If the focal length of concave lens is 15 cm, then the focal length of the other lens will be –
(A) – 9 cm (B) + 9 cm
(C) – 12 cm (D) + 12 cm

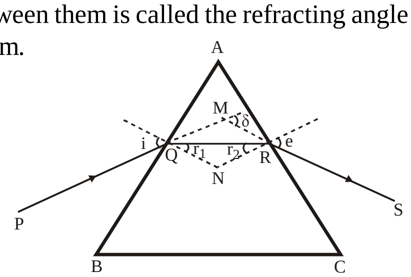
ANSWERS

(1) (A)	**(2)** (C)	**(3)** (B)
(4) (D)	**(5)** (C)	**(6)** (A)
(7) (C)	**(8)** (ABC)	**(9)** (C)
(10) (C)	**(11)** (B)	

PRISM

REFRACTION BY A PRISM :

1. **Prism :** Prism is a homogeneous, transparent medium enclosed by two plane surfaces inclined at an angle. These surfaces are called the refracting surfaces and the angle between them is called the refracting angle or the angle of prism.



PQ incident ray, QR refracted ray, RS emergent ray, δ angle of deviation and e angle of emergence.

2. **Angle of deviation :** Angle between the incident rays & emergent ray is called angle of deviation.

In the quadrilateral AQNR, two of the angles (at the vertices Q and R) are right angles. Therefore, the sum of the other angles of the quadrilateral is 180º.

$\angle A + \angle QNR = 180^\circ$

$\ldots_1 + r_2 + \angle QNR = 180^\circ$

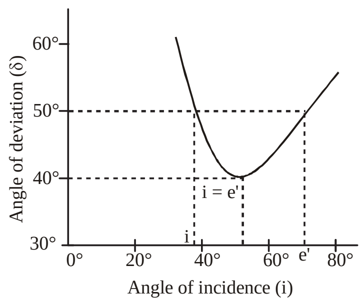
Comparing these two equations, we get

$r_1 + r_2 = A$ .... (1)

The total deviation δ is the sum of deviations at the two faces, $\delta = (i - r_1) + (e - r_2)$

that is, $\delta = i + e - A$ .... (2)

3. **Minimum deviation :** For a given prism, the angle of deviation depends upon the angle of incidence of the light-ray falling on the prism. It is seen from the curve that as the angle of incidence i increases, the angle of deviation first decreases, becomes minimum for a particular angle of incidence and then again increases. Thus, for one and only one, particular angle of incidence the prism produce minimum deviation. At the minimum deviation δ_m, the refracted ray inside the prism becomes parallel to its base.



4. **Formula for the refractive index of the prism**

We have $d = \delta_m$, i = e which implies $r_1 = r_2$.

Eq. (1) gives 2r = A or r = A/2

Eq. (2) gives, $\delta_m = 2i - A$, or $i = (A + \delta_m)/2$

$$n = \frac{\text{Sin}\, i}{\text{Sin}\, r} = \frac{\text{Sin}\left(\frac{A + \delta_m}{2}\right)}{\text{Sin}\left(\frac{A}{2}\right)}$$

Where A is prism angle & δ_m is minimum deviation.

Note :

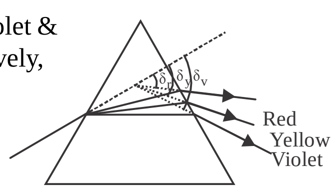
(a) When prism is thin, then value of A will be small ($\leq 10°$)

$\delta_m = (n - 1)A$

(b) Condition for maximum deviation i_1 or $i_2 = 90°$.

5. **Angular dispersion for prism :** White light splits into its constituent colours, on passing through prism. This is known as dispersion. The angle between the emergent rays of any two colours is called angular dispersion between those colours.

If deviation angle for violet & red are δ_V & δ_R respectively, then angular dispersion.



$\theta = \delta_v - \delta_R$

$\delta_R = (n_R - 1)\, A,$

$\delta_v = (n_v - 1)\, A$

$\theta = (n_v - 1)\, A - (n_R - 1)\, A = (n_v - n_R)A.$

6. **Dispersive power of prism**

$$\omega = \frac{\delta_V - \delta_R}{\delta_Y} = \frac{(n_V - n_R)\, A}{(n_Y - 1)\, A}$$

Where S_y is deviation angle for yellow colour.

$$\omega = \frac{n_V - n_R}{n_Y - 1}$$

7. **Combination of Prisms :**

As the dispersive powers of the different materials are different, two or more prisms of different materials can be combined such that the rays of composite light on passing through the combination may suffer either dispersion without deviation or deviation without dispersion.

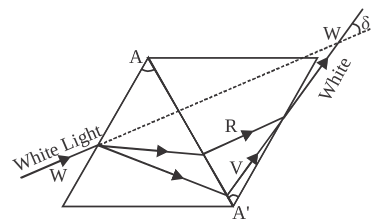
(i) Achromatic combination (deviation without dispersion):

Condition for achromatic combination : $\theta_1 + \theta_2 = 0$

$$(n_v - n_r)\, A = -(n_v' - n_r')A'$$

$$\text{Net mean deviation} = \left[\frac{n_v + n_R}{2} - 1\right]A - \left[\frac{n_v' + n_R'}{2} - 1\right]A'$$

or $\omega\delta + \omega'\delta' = 0$, where ω, ω′ are dispersive powers for the two prisms and δ, δ′ are the mean deviation.

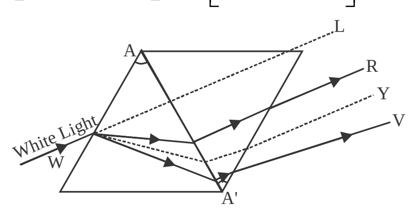


(ii) Dispersion without deviation(Direct vision combination)

This combination is used for dispersion without deviation.

Condition $\delta = 0$

$$\text{i.e.,}\ \left[\frac{n_v + n_R}{2} - 1\right]A + \left[\frac{n_v' + n_R'}{2} - 1\right]A' = 0$$



Net angle of dispersion

$$\theta = (n_v - n_r)A + (n_v' - n_r')A'.$$

Problems solving tips :

Steps 1 : Draw a ray diagram starting from the object passing through all refracting surfaces. Label all the angles.

Steps 2 : Apply the relevant formula at each of the refracting surfaces. (Snell rules)

Steps 3 : Develop any additional equations based on geometry.

Steps 4 : Solve the simultaneous equations systematically.

Example 25 :

Prism angle of a prism is 10^o. Their refractive index for red & violet colour is 1.51 & 1.52 respectively, then find the dispersive power.

Sol. Dispersive power of prism, $\omega = \left(\frac{\mu_v - \mu_r}{\mu_y - 1}\right)$

but $\mu_y = \frac{\mu_v + \mu_r}{2} = \frac{1.52 + 1.51}{2} = 1.515$

Therefore $\omega = \frac{1.52 - 1.51}{1.515 - 1} = \frac{0.1}{1.515} = 0.019.$

Example 26 :

Prism angle & refractive index for a prism for a 60^o & 1.414. Find the angle of minimum deviation.

Sol. $\mu = \frac{\sin(A + \delta_m)/2}{\sin 30^0} \Rightarrow 1.414 = \frac{\sin(60 + \delta_m)/2}{\sin 30^0}$

$\Rightarrow \quad \text{Sin}\left(\frac{60^\circ + \delta_m}{2}\right) = 0.707 = \sin 45^o$

$\Rightarrow \quad \frac{60 + \delta_m}{2} = 45^o \Rightarrow \delta_m = 30^o$

Example 27 :

The angle of crown glass (μ =1.52) prism is 5°. What should be angle flint glass (μ = 1.63). Prism, so that the two prism together may be used in direct vision spectroscope ?

Sol. For a direct vision spectroscope

$\delta_1 + \delta_2 = 0 \ \therefore \ (\mu_1 - 1) A_1 + (\mu_2 - 1) A_2 = 0$

or $A_2 = -\left(\frac{\mu_1 - 1}{\mu_2 - 1}\right) A_1 = -\left(\frac{1.52 - 1}{1.63 - 1}\right) \times 5^o = -4.12^o$

Example 28 :

The refracting angle of the prism is 60^o. What is the angle of incidence for minimum deviation ? The refractive index of material of prism is $\sqrt{2}$.

Sol. For minimum deviation $r = A/2 = 60/2 = 30^o$

From snell's law $\frac{\sin i}{\sin r} = \mu$ or $\sqrt{2} = \frac{\sin i}{\sin 30^\circ}$

$\therefore \quad \sin i = \frac{1}{2} \times \sqrt{2} = \frac{1}{\sqrt{2}} = \sin 45^o$ or $i = 45^o$

Example 29 :

A ray monochromatic light is incident on the refracting face of prism angle 75^o. It passes through the prism and is incident on the other face at the critical angle. If the refractive index of the prism is $\sqrt{2}$, then determine the angle of incidence on the first face of the prism.

Sol. $\mu = \frac{1}{\sin C}$ and $\sqrt{2} = \frac{1}{\sin C}$ or $\sin C = \frac{1}{\sqrt{2}}$ or $C = 45^o$

Now, $A = r_1 + r_2 = r_1 + C \quad (\because r_2 = C)$

or $75^o = r_1 + 45^o \quad \therefore r_1 = 30^o$

further $\mu = \frac{\sin i_1}{\sin r_1}$ or $\sin i_1 = \mu \times \sin r_1 = \sqrt{2} \times \sin 30^o$

or $\sin i_1 = \sqrt{2} \times \frac{1}{2} = \frac{1}{\sqrt{2}} \Rightarrow i_1 = 45^o$

Example 30 :

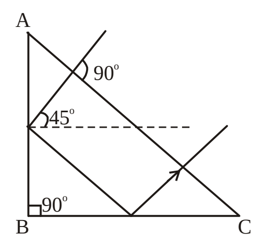
Angle of a prism is A and its one surface is silvered. Light ray falling at an angle of incidence 2A on first surface return back through the same path after suffering reflection at second silvered surface. Refractive index of material is.

Sol. Given $i = 2A$; figure $r = A$

$\therefore \mu = \frac{\sin i}{\sin r} = \frac{\sin 2A}{\sin A} = \frac{2 \sin A \cos A}{\sin A} = 2 \cos A$

Example 31 :

A ray falls on a prism ABC (AB = BC) and travels as shown in adjoining figure. Find the minimum refraction index of the prism material.



Sol. Angle of incidence C = 45° $\therefore \ \mu = \frac{1}{\sin C} = \frac{1}{\sin 45^\circ} = \sqrt{2}$

TRY IT YOURSELF - 6

Q.1 A trihedral prism with refracting angle 60° deviates a light ray by 30°. The refractive index of the material of prism

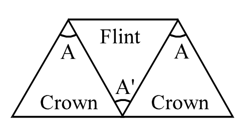
(A) may be equal to $\sqrt{2}$ (B) can not be greater than $\sqrt{2}$

(C) can not be less than $\sqrt{2}$ (D) none of these

Q.2 Three thin prisms are combined as shown in figure. The refractive indices of the crown glass for red & violet rays are μ_r and μ_v respectively & those for the flint glass are μ'_r and μ'_v respectively. The ratio (A'/A) for which there is no net angular dispersion

(A) $\frac{\mu_v - \mu_r}{2(\mu'_v - \mu'_r)}$ (B) $\frac{2(\mu_v - \mu_r)}{\mu'_v - \mu'_r}$

(C) $\frac{\mu_v - \mu_r}{\mu'_v - \mu'_r}$ (D) None of these



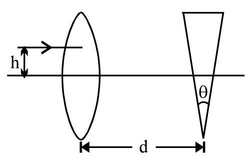
Q.3 Dispersion occurs when
(A) some material bend light more that other material.
(B) a material changes some frequencies more than other.
(C) light has different speeds in different materials.
(D) a material slows down some wavelengths more than others.

Q.4 White light is dispersed by the prism, and falls on a screen to form a visible spectrum. Which of the following is/are true?
(A) The frequency changes for each colour, but the speed stays the same.
(B) Red wavelengths are deviated through larger angles than green wavelengths.
(C) Violet light propagates at a higher speed than green light while in the prism.
(D) The speed of all colours is reduced in the prism, with maximum reduction for violet light.

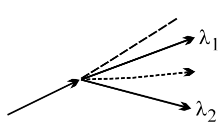
Q.5 A ray of light parallel to the axis of a converging lens (having focal length f) strikes it at a small distance 'h' from its optical centre. A thin prism having angle θ and refractive index μ is placed normal to the axis of lens at a distance 'd' from it. What should be the value of μ so that the ray emerges parallel to the lens axis.

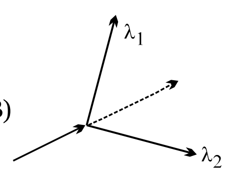
(A) $\frac{h}{f\theta}$ (B) $\frac{h}{f\theta}+1$

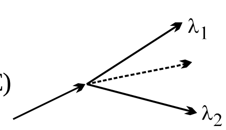
(C) $\frac{h}{(d+f)\theta}$ (D) $\frac{h}{(d+f)\theta}+1$

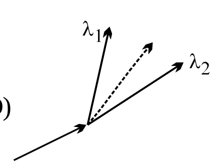


Q.6 Consider the four different cases of dispersion of light ray which has all the wave lengths from λ_1 to λ_2 ($\lambda_1 > \lambda_2$). The dotted represents the light ray of wave length λ_{avg}. Which ray diagram is showing maximum dispersive power?

(A)


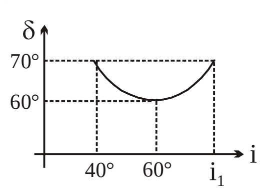
(B)


(C)


(D)


Q.7 For a prism kept in air it is found that for an angle of incidence 60°, the angle of refraction 'A', angle of deviation 'δ' and angle of emergence 'e' become equal. Then the refractive index of the prism is
(A) 1.73 (B) 1.15
(C) 1.5 (D) 1.33

Q.8 The curve of angle of incidence versus angle of deviation shown has been plotted for prism. The value of refractive index of the prism used is



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

Q.9 In the given curve of **above question**. Find the value of angle i_1 in degrees is
(A) 40° (B) 60°
(C) 70° (D) 90°

Q.10 A parallel beam of white light falls on a convex lens. Images of blue, red and green light are formed on other side of the lens at distances x, y and z respectively from the pole of the lens. Then :
(A) $x > y > z$ (B) $x > z > y$
(C) $y > z > x$ (D) None

Q.11 The focal length of a lens is greatest for which colour?
(A) violet (B) red
(C) yellow (D) green

ANSWERS

(1) (AB)	**(2)** (B)	**(3)** (D)
(4) (D)	**(5)** (B)	**(6)** (B)
(7) (A)	**(8)** (A)	**(9)** (D)
(10) (C)	**(11)** (B)	

SCATTERING OF LIGHT

* As sunlight travels through the earth's atmosphere, it gets scattered (changes its direction) by the atmospheric particles.

* Light of shorter wavelengths is scattered much more than light of longer wavelengths.

* The amount of scattering is inversely proportional to the fourth power of the wavelength. This is known as **Rayleigh scattering**. Hence, the bluish colour predominates in a clear sky, since blue has a shorter wavelength than red and is scattered much more strongly. In fact, violet gets scattered even more than blue, having a shorter wavelength. But since our eyes are more sensitive to blue than violet, we see the sky blue.

$$\text{Intensity of scattered light} \propto \frac{1}{\lambda^4}$$

* At sunset or sunrise, the sun's rays have to pass through a larger distance in the atmosphere. Most of the blue and other shorter wavelengths are removed by scattering. The least scattered light reaching our eyes, therefore, the sun looks reddish. This explains the reddish appearance of the sun and full moon near the horizon.

RAINBOW

* Rainbow is sunlight spread out into its spectrum of colors and diverted to the eye of the observer by water droplets. The "bow" part of the word describes the fact that the rainbow is a group of nearly circular arcs of color all having a common center.

* Rainbows are generated through refraction and reflection of light in small rain drops. The sun is always behind you when you face a rainbow, and that the center of the circular arc of the rainbow is in the direction opposite to that of the

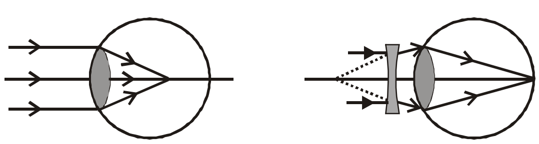
sun. The rain, of course, is in the direction of the rainbow i.e. rain drops must be ahead of you and the angle between your line-of-sight and the sunlight will be 40°-42°.

* The **primary and secondary rainbows** are phenomena that formed by the reflection and refraction of sunlight in tiny water droplets. When a sunbeam is being refracted twice and reflected once by the droplet, a primary rainbow will form (Its inner and outer edges subtend angles of 41° and 43° with theaxis of the rainbow respectively).
* If the beam is being refracted twice and reflected twice, a **secondary** rainbow will form (Its inner and outer edges subtend angles of 51° and 54° with theaxis of the rainbow respectively). As the secondary rainbow is formed by one more reflection than the primary rainbow, it is much fainter and rare to see. On the other hand, since the paths of sunbeams in a primary rainbow and a secondary rainbow are different, the colors of the secondary rainbow are arranged in just the reverse order of the primary one.

OPTICAL INSTRUMENTS

THE EYE

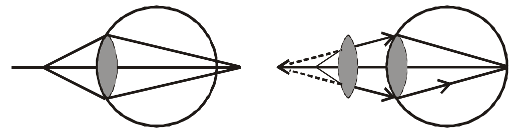
* **Power of Accommodation :** The ability of the lens to change its shape to focus near and distant objects is called accommodation.
* The minimum distance, at which objects can be seen most distinctly without strain, is called the **least distance of distinct vision**. It is also called the **near point (N.P.)** of the eye. For a young adult with normal vision, the near point is about 25 cm.
* The **farthest point** upto which the eye can see objects clearly is called the far point (F.P.) of the eye. It is infinity for a normal eye. Thus a normal eye can see objects clearly that are between 25 cm and infinity.
* **Nearsightedness:** If the eyeball is too long or the lens too spherical, the image of distant objects is brought to a focus in front of the retina and is out of focus again before the light strikes the retina. Nearby objects can be seen more easily. Eyeglasses with concave lenses correct this problem by diverging the light rays before they enter the eye. Nearsightedness is called **myopia**. Myopia most commonly develops in childhood (between 8 and 14).



If deflected far point is at a distance d from eye then focal length of use lens f = – d = – (deflected far point)

A person can see upto distance → x, wants to see distance → y(y > x) so $f = \frac{xy}{x-y}$ or power of the lens $P = \frac{x-y}{xy}$

* **Farsightedness :** If the eyeball is too short or the lens too flat or inflexible, the light rays entering the eye — particularly those from nearby objects — will not be brought to a focus by the time they strike the retina. Eyeglasses with convex lenses can correct the problem.



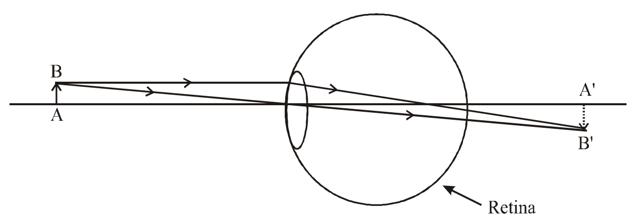
Farsightedness is called hypermetropia or **hyperopia**. Squinting, eye rubbing, lack of interest in school, and difficulty in reading are often seen in children with hyperopia. If a person cannot see before distance d but wants to see the object placed at distance D from eye so

$f = \frac{dD}{d-D}$ and power of the lens $P = \frac{d-D}{dD}$.

* **Astigmatism:** Astigmatism is the most common refractive problem responsible for blurry vision. Most of the eyeball's focusing power occurs along the front surface of the eye, involving the tear film and cornea (the clear 'window' along the front of the eyeball). The ideal cornea has a perfectly round surface. Anything other than perfectly round contributes to abnormal corneal curvature - this is astigmatism. Here's a good way to demonstrate the effects of astigmatism. Look at your reflection in the curved surface of a round soup spoon and compare it with your reflection in an oval teaspoon. Cylindrical lens is use to correct astigmatism.

Example 32 :

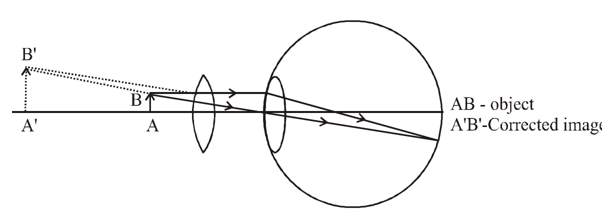
Make a diagram to show how hypermetropia is corrected. The near point of a hypermetropic eye is 1 m. What is the power of the lens required to correct this defect? Assume that the near point of the normal eye is 25 cm.



Sol. To correct the defect, the image of an object at 25 cm. should be brought at 100 cm.

$$\therefore \quad \frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{-100} - \frac{1}{-25}$$

$$\frac{1}{f} = \frac{-1}{100} + \frac{1}{25} = \frac{-1+4}{100} = \frac{3}{100} \quad \therefore \; f = +\frac{100}{3} = +33.3 \text{ cm.}$$



So a convex lens of focal length 33.3 cm. is required.

Power, $P = \frac{100}{33.3} = 3.0$ D

Example 33 :

A farsighted person cannot focus clearly an objects that are less than 145cm. from his eyes. To correct this problem, the person wear eyeglasses that are located 2.0 cm. in front of his eyes. Determine the focal length that will permit this person to read a newspaper at a distance of 32.0 cm. from his eyes.

Sol. The near point is 145 cm. and eyeglasses are 2.0 cm. in front of the eyes. Therefore, v = – 143 cm.
The object is placed 32.0cm. from the eyes so u = +30.0 cm.
The focal length is obtained from equation

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} = \frac{1}{(30.0\text{cm})} + \frac{1}{-143\text{cm}} = 0.026\ \text{cm}^{-1}.$$

Hence, f = 38 cm.

CAMERA

(a) Pinhole Camera : It is bases on rectilinear propagation of light and forms the so called image on the screen which is real and inverted. If an object of size O is situated at a distance u from the pinhole and its image of size I is formed at a distance v from the pin hole -

$$\theta = \frac{O}{u} = \frac{I}{v} \quad \text{i.e.,} \quad \frac{I}{O} = \frac{v}{u}$$

(b) Lens-Camera : In it a converging lens whose aperture and distance from the film can be adjusted, is used. Usually object is real and between ∞ and 2F; so the image is real, inverted diminished and between F and 2F as shown in Fig.
Here lens formula

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \qquad \text{with} \qquad m = \frac{I}{O} = \frac{v}{u} \text{ is applicable.}$$

In photographing an object, the image is first focused on the film by adjusting the distance between lens and film (called focusing). After focusing, aperture is set to a specific value (for desired effect) and then film is exposed to light for a given time through a shutter. For proper exposure of a particular film, a definite amount of light energy must be incident on the film. So if I is the intensity of light, S is the light transmitting area of lens and t is the exposure time, then for proper exposure, I × S × t = constant
Light transmitting area of a lens is proportional to the square of its aperture D; so above expression reduces to

$$I \times D^2 \times t = \text{constant}$$

NOTE

* If aperture is kept fixed, for proper exposure,
  $I \times t = \text{constt.}$ i.e., $I_1 t_1 = I_2 t_2$
  and if the source of light is a point

$$\frac{L_1}{r_1^2} \times t_1 = \frac{L_2}{r_2^2} \times t_2 \qquad \left[\text{as } I = \frac{L}{r^2}\right]$$

* If intensity is kept fixed, for proper exposure,
  $D^2 \times t = \text{constant}$

i.e., Time of exposure $\propto \dfrac{1}{(\text{Aperture})^2}$

* The ratio of focal length to the aperture of lens is called f-number of the camera, i.e., f-number = $\dfrac{\text{Focal length}}{\text{Aperture}}$

If focal length = constant

$$\text{Aperture} \propto \frac{1}{f-\text{number}}$$

Time of exposure ∝ $(\text{f-number})^2$

Example 34 :

Photograph of the ground are taken from an air-craft, flying at an altitude of 2000 m, by a camera with a lens of focal length 50 cm. The size of the film in the camera is 18 cm × 18 cm. What area of the ground can be photographed by this camera at any one time.

Sol. As here u = – 2000m, f = 0.50m, so from lens formula

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}, \text{ we have } \frac{1}{v} - \frac{1}{(-2000)} = \frac{1}{0.5}$$

$$\text{i.e., } \frac{1}{v} = \frac{1}{0.5} - \frac{1}{2000} \cong \frac{1}{0.5} \qquad \left[\text{as } \frac{1}{0.5} >> \frac{1}{2000}\right]$$

v = 0.5m = 50 cm = f
Now as in case of a lens

$$m = \frac{v}{u} = \frac{0.5}{-2000} = -\frac{1}{4} \times 10^{-3}$$

So $I_1 = (ma)(mb) = m^2 A$ [∵ A = ab]

$$\text{i.e., } A = \frac{I_1}{m^2} = \frac{18\text{cm} \times 18\text{cm}}{\left[(1/4) \times 10^{-3}\right]^2} = (720\ \text{m} \times 720\ \text{m})$$

Example 35 :

The proper exposure time for a photographic print is 20 s at a distance of 0.6 m from a 40 candle power lamp. How long will you expose the same print at a distance of 1.2 m from a 20 candle power lamp ?

Sol. In case of camera, for proper exposure

$$I_1 D_1^2 t_1 = I_2 D_2^2 t_2$$

As here D is constant and $I = (L/r^2)$

$$\frac{L_1}{r_1^2} \times t_1 = \frac{L_2}{r_2^2} \times t_2$$

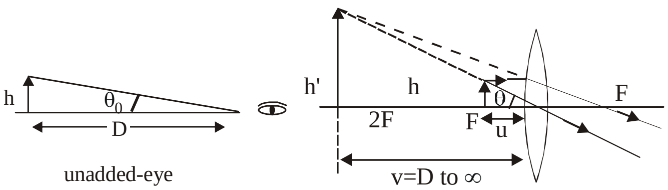
$$\text{So} \quad \frac{40}{(0.6)^2} \times 20 = \frac{20}{(1.2)^2}\ t$$

i.e., t = 160 sec

MICROSCOPE

It is an optical instrument used to increase the visual angle of neat objects which are too small to be seen by naked eye.

1. Simple Microscope : It is also known as magnifying glass or simply magnifier and consists of a convergent lens with object between its focus and optical centre and eye close to it. The image formed by it is erect, virtual enlarged and on same side of lens between object and infinity.



unadded-eye (A) eye with Instrument (B)

The magnifying power (MP) or angular magnification of a simple microscope (or an optical instrument) is defined as the ratio of visual angle with instrument to the maximum visual angle for clear vision when eye is unadded (i.e., when the object is at least distance of distinct vision)

i.e., $MP = \dfrac{\text{Visual angle with instrument}}{\text{Max. visual angle for unadded eye}} = \dfrac{\theta}{\theta_0}$

If an object of size h is placed at a distance u (<D) from the lens and its image size h' is formed at a distance V ($\geq$ D)

from the eye $\theta = \dfrac{h'}{v} = \dfrac{h}{u}$ with $\theta_0 = \dfrac{h}{D}$

So $MP = \dfrac{\theta}{\theta_0} = \dfrac{h}{u} \times \dfrac{D}{h} = \dfrac{D}{u}$ ....(1)

Now there are two possibilities

(a) If their image is at infinity [Far point]

In this situation from lens formula -

$\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f}$ we have $\dfrac{1}{\infty} - \dfrac{1}{-u} = \dfrac{1}{f}$ i.e., u = f

So $MP = \dfrac{D}{u} = \dfrac{D}{f}$ ....(2)

As here u is maximum [as object is to be with in focus], MP is minimum and as in this situation parallel beam of light enters the eye, eye is least strained and is said to be normal, relaxed or unstrained.

(b) If the image is at D [Near point]

In this situation as v = D, from lens formula

$\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f}$ we have $\dfrac{1}{-D} - \dfrac{1}{-u} = \dfrac{1}{f}$ i.e., $\dfrac{D}{u} = 1 + \dfrac{D}{f}$

So $MP = \dfrac{D}{u} = \left[1 + \dfrac{D}{f}\right]$ ....(3)

As the minimum value of v for clear vision is D, in this situation u is minimum and hence this is the maximum possible MP of a simple microscope and as in this situation final image is closest to eye, eye is under maximum strain.

NOTE

(1) Simple magnifier is an essential part of most optical instruments (such as microscope or telescope) in the form of eye piece or ocular.

(2) The magnifying power (MP) have no unit. It is different from power of a lens which is expressed in diopter (D) and is equal to the reciprocal of focal length in meter.

(3) With increase in wavelength of light used, focal length of magnifier will increase and hence its MP will decrease.

Example 36 :

A man with normal near point (25 cm) reads a book with small print using a magnifying a thin convex lens of focal length 5 cm. (a) What is the closest and farthest distance at which he can read the book when viewing through the magnifying glass ? (b) What is the maximum and minimum MP possible using the above simple microscope ?

Sol. (a) As for normal eye far and near point are ∞ and 25 cm respectively, so for magnifier $v_{max} = -\infty$ & $v_{min} = -25$ cm. However, for a lens as

$\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f}$ i.e., $u = \dfrac{f}{(f/v) - 1}$

So u will be minimum when v = min = –25 cm

i.e., $(u)_{min} = \dfrac{5}{-(5/25) - 1} = -\dfrac{25}{6} = -4.17$ cm

Ans u will be maximum when v = max = ∞

So the closest and farthest distance of the book from the magnifier (or eye) for clear viewing are 4.17 cm and 5 cm respectively.

(b) As in case of simple magnifier MP = (D/u). So MP will be minimum when u = max = 5 cm

i.e., $(MP)_{min} = \dfrac{-25}{-5} = 5$ $\left[= \dfrac{D}{f}\right]$

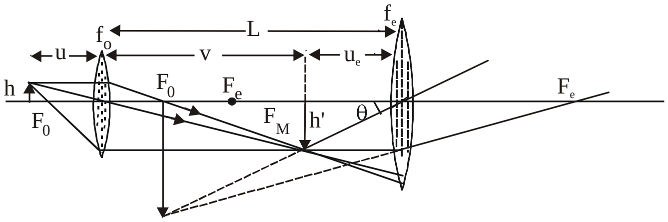
And MP will be maximum when u = min = (25/6) cm

i.e., $(MP)_{max} = \dfrac{-25}{-(25/6)} = 6$ $\left[= 1 + \dfrac{D}{f}\right]$

COMPOUND - MICROSCOPE

Construction : It consists of two convergent lenses of short focal lengths and apertures arranged co-axially lens (of focal length f_o) facing the object is called objective or field lens while the lens (of focal length fe) facing the eye, eye-piece or ocular. The objective has a smaller aperture and smaller focal length than eye-piece the separation between objective and eye-piece can be varied.

Image Formation : The object is placed between F and 2F of objective so the image IM formed by objective (called intermediate image) is inverted, real enlarged and at a distance greater than f_0 on the otherside of the lens. This image IM acts as object for eye-piece and is with in its focus. So eye-piece forms final image I which is erect, Virtual & enlarged with respect to intermediate image I_M. So the final image I with respect to object is Inverted, virtual, enlarged & at a distance D to ∞ from eye on the same side of eye-piece as I_M.



Magnifying power (MP)

magnifying Power of an optical instrument is defined as –

$$MP = \frac{\text{Visual angle with instrument}}{\text{Max. Visual angle for unadded eye}} = \frac{\theta}{\theta_0}$$

If the size of object is h and least distance of distinct vision is D. $\theta_0 = \frac{h}{D}$; $\theta = \frac{h'}{u_e}$

$$MP = \frac{\theta}{\theta_0} = \left[\frac{h'}{u_e}\right] x \left[\frac{D}{h}\right] = \left[\frac{h'}{h}\right]\left[\frac{D}{u_e}\right]$$

But for objective $m = \frac{I}{O} = \frac{v}{u}$ i.e., $\frac{h'}{h} = -\frac{v}{u}$ [as u is – ve]

So $MP = -\frac{v}{u}\left[\frac{D}{u_e}\right]$ with length of tube

$L = v + u_e$ ....(1)

now there are two possibilities –

(a) If the final image is at infinity (far point) :

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

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

Substitution this value of u_e in Eqn. (1), we have

$$MP = -\frac{v}{u}\left[\frac{D}{f_e}\right] \quad \text{with } L = v + f_e \quad ....(2)$$

(b) If the final image is at D (near point) :

In this situation as for eye - piece v = D

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

Substituting this value of ue in Eqn. (1), we have

$$MP = -\frac{v}{u}\left[1 + \frac{D}{f_e}\right] \text{ with } L = v + \frac{f_e D}{f_e + D} \quad ....(3)$$

In this situation as u_e is minimum, MP is maximum and eye is most strained.

In microscope focal length of objective lens f_o is small and object is placed very closed to objective lens so–

$u \approx f$; $L = v + u_e$ $[u_e << v]$

$L \approx v$; $|MP| = \frac{LD}{ff_e}$

NOTE

1. Magnifying power of microscope is negative so it produces final image always inverted.
2. $m_e = \frac{v_e}{u_e} = \frac{D}{u_e} = \left[1 + \frac{D}{f_e}\right]$, $m_o = \frac{v_o}{u_o} = \frac{v}{u} \Rightarrow MP = m_o \times m_e$
3. $(MP)_{min} = -\frac{v}{u}\frac{D}{f_e}$; $(MP)_{max} = -\frac{v}{u}\left[1 + \frac{D}{f_e}\right]$
4. $|MP| = -\frac{LD}{f_0 f_e}$
5. MP does not change appreciably if objective lens and eye-piece are interchanged [MP ~ $(LD/f_0 f_e)$]. MP is increased by decreasing the focal length of both the lenses.
6. If distance between eye and eye-piece lens is D then distance between final image in eye-piece lens D' = (D – d)

$$MP = \frac{LD'}{f_0 f_e} = \frac{L(D-d)}{f_0 f_e} = MP\left[1 - \frac{d}{D}\right] < MP$$

7. $RP = \frac{1}{RL} \propto \frac{1}{\lambda}$ (Resolving power)
8. In electron microscope

$$\lambda = \sqrt{(150/V)}\ \text{Å}, \quad \text{where V = Potential difference}$$

Example 37 :

The length of a microscope is 14 cm and for relaxed eye the magnifying power is 25. The focal length of the eyepiece is 5cm. Calculate the distance of the object and the focal length of the objective.

Sol. Length of microscope is :

$L = v_0 + f_e$, $14 = v_0 + 5$, $v_0 = 9$ cm–

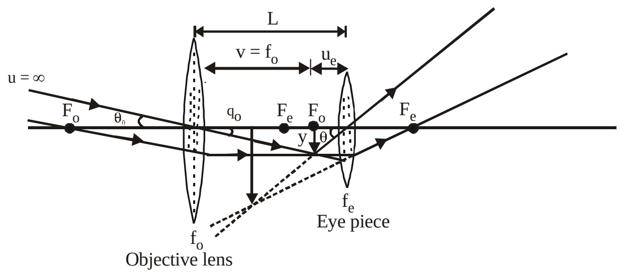
$$M = -\frac{v_0}{u_0} \times \frac{D}{f_e}, \text{ or } 25 = -\frac{9}{u_e} \times \frac{25}{5} \text{ or } u_0 = -\frac{9}{5} = -1.8 \text{ cm}$$

Now, $\frac{1}{f_0} = \frac{1}{v_0} - \frac{1}{u_0}$ but u_0 is negative, therefore

$$\frac{1}{f_0} = \frac{1}{9} + \frac{5}{9} = \frac{6}{9} \quad \text{or} \quad f_0 = 1.5 \text{ cm}$$

TELESCOPE

It is an optical instrument used to increase the visual angle of distant large objects. In it object is between ∞ and 2F of objective and hence image formed by objective is real, inverted, and diminished and is between F and 2F on the other side of it. This image (called intermediate image) acts as object for eye - piece.



Magnifying Power (MP)
magnifying Power of a telescope is defined as

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

But from fig. $\theta_0 = (y/f_0)$ and $\theta = (y/-u_e)$

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

$L = (f_0 + u_e)$ ...... (1)

Now there are two possibilities –

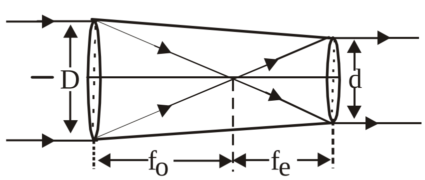
1. If the final image is at infinity (far point)

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

So substituting this value of ue in Eqn. (1) we have

$MP = -(f_0 / f_e)$ and $L = (f_0 + f_e)$ ...... (2)

In this case object and final image are at infinity so both total light entering and leaves the telescope are parallel to its axis as shown in fig.



2. If the final image is at D(Near point)

In this situation as for eye - piece v = D

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

So substituting this value of ue in Eqn. (1), we have

$$MP = \frac{f_0}{f_e}\left[1 + \frac{f_e}{D}\right] \text{ with } L = f_0 + \frac{f_e D}{f_e + D}$$

.........(3)

In this situation u_e is minimum so for a given telescope MP is maximum while length of tube minimum

Note: $\frac{f_0}{f_e} = \frac{\text{Aperture of object}}{\text{Aperture of eye piece}}$ i.e., $MP = \frac{f_0}{f_e} = \frac{D}{d}$

Reflecting telescopes : Modern telescopes use a concave mirror rather than a lens for the objective. Telescopes with mirror objectives are called reflecting telescopes. They have several advantages. First, there is no chromatic aberration in a mirror. Second, if a parabolic reflecting surface is chosen, spherical aberration is also removed. Mechanical support is much less of a problem since a mirror weighs much less than a lens of equivalent optical quality, and can be supported over its entire back surface, not just over its rim. One obvious problem with a reflecting telescope is that the objective mirror focusses light inside the telescope tube.

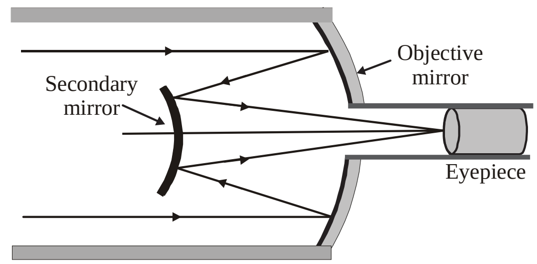


Figure : Schematic diagram of a reflecting telescope (Cassegrain).

Example 38 :

Diameter of the moon is 3.5×10^3 km and its distance from earth is 3.8×10^5 km. It is seen by a telescope whose objective and eyepiece have focal lengths 4m and 10cm respectively. The angular diameter of the image of the moon will be nearly

(1) 5° (2) 10°
(3) 20° (4) 25°

Sol. (3). $M = -\frac{f_0}{f_e} = -\frac{400}{10} = -40$

Angle subtended by the moon at the objective

$$= \frac{3.5 \times 10^3}{3.8 \times 10^5} = 0.009 \text{ radian.}$$

Thus angular diameter of the image = M × visual angle

$$= 40 \times 0.009 = 0.36 \text{ radian} = \frac{0.36 \times 180}{3.14} = 20°$$

Example 39 :

A telescope consisting of an objective of focal length 60 cm and a single–lens eyepiece of focal length 5 cm is focussed at a distant object in such a way that parallel rays emerge from the eye piece. If the object subtends an angle of 2° at the objective, then the angular width of the image will be –

(1) 10° (2) 24°
(3) 50° (4) 1/6°

Sol. (2). $m = \frac{f_0}{f_e} = \frac{\beta}{\alpha} \quad \therefore \quad \beta = \alpha\frac{f_0}{f_e} = 2 \times \frac{60}{5} = 24°$

NOTE

1. Magnifying power of telescope is negative so it produces always inverted image.

2. $(MP)_{min} = -\left[\frac{f_0}{f_e}\right]$; $(MP)_{max} = -\frac{f_0}{f_e}\left[1 + \frac{f_e}{D}\right]$

3. MP becomes $(1/m^2)$ times of its initial value if objective and eye-piece are interchanged as $MP \sim [f_o / f_e]$

4. MP is increased by increasing the focal length of objective lens and by decreasing the focal length of eye piece lens.

TRY IT YOURSELF - 7

Q.1 A small telescope has an objective lens of focal length 144cm and an eyepiece of focal length 6.0cm. What is the magnifying power of the telescope? What is the separation between the objective and the eyepiece?

Q.2 A giant refracting telescope at an observatory has an objective lens of focal length 15m. If an eyepiece of focal length 1.0cm is used, what is the angular magnification of the telescope?

Q.3 If the telescope (of above question) is used to view the moon, what is the diameter of the image of the moon formed by the objective lens? The diameter of the moon is 3.48×10^6m, and the radius of lunar orbit is 3.8×10^8m.

Q.4 A person with a normal near point (25cm) using a compound microscope with objective of focal length 8.0 mm and an eyepiece of focal length 2.5cm can bring an object placed at 9.0mm from the objective in sharp focus. What is the separation between the two lenses? Calculate the magnifying power of the microscope.

Q.5 For a normal eye, the far point is at infinity and the near point of distinct vision is about 25cm in front of the eye. The cornea of the eye provides a converging power of about 40 dioptres, and the least converging power of the eye-lens behind the cornea is about 20 dioptres. From this rough data estimate the range of accommodation (i.e., the range of converging power of the eye-lens) of a normal eye.

Q.6 A patient can't see objects beyond 2m. What corrective lens will you suggest?

Q.7 A compound microscope with an objective of 1.0cm. focal length and an eyepiece of 2.0cm. focal length has a tube length of 20cm. Calculate the magnifying power of microscope, if the final image is formed at the near point of the eye.

Q.8 The magnifying power of an astronomical telescope in the normal adjustment position is 100. The distance between the objective and the eyepiece is 101cm. Calculate the focal lengths of the objective and of the eyepiece.

Q.9 Here three lenses have been given. Which two lenses will you use as an eyepiece and as an objective to construct an astronomical telescope ?

Lenses	Power (P)	Aperture (A)
L_1	3D	8 cm.
L_2	6D	1 cm.
L_3	10D	1 cm.

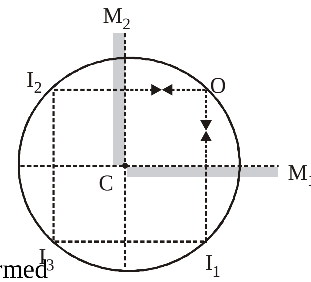
ANSWERS

(1) 24, 150cm
(2) 1500
(3) 13.7 cm
(4) 9.47cm, 88
(5) 20 to 24 dioptre
(6) –0.5 dioptre lens
(7) 250
(8) $f_e = 1$cm. and $f_0 = 100$cm.
(9) L_1 objective, L_3 eyepiece

ADDITIONAL EXAMPLES

Example 1 :

Find the number of images formed by two mutually perpendicular mirrors.



Sol. Here, $n = \frac{360}{\theta} = \frac{360}{90} = 4$

$\therefore$ n is an even number

Thus, number of images formed = n – 1 = 3. All these three images lie on a circle with centre at C (The point of intersection of mirrors M, and M_2) and whose radius is equal to the distance between C and object.

Example 2 :

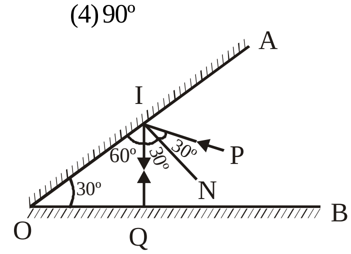
Two plane mirrors are inclined to each other at some angle. A ray of light incident at 30º on one, after reflection form the other retraces its path. The angle between the mirrors is -

(1) 30º (2) 45º
(3) 60º (4) 90º

Sol. **(1).** $\angle i = \angle r = 30^\circ$

$\therefore \quad \angle OIQ = 60^\circ$

$\therefore \quad IOQ = 90^\circ - 60^\circ = 30^\circ$



Example 3 :

The refractive index of a piece of glass is 1.5 and it accommodates as many waves as are accommodated in 18 cm width of water column. If the refractive index of water is 1.33 then the thickness of glass piece will be -

(1) 20 cm (2) 10 cm
(3) 12 cm (4) 16 cm

Sol. **(4).** $n_{glass} = 1.5$, $N_{water} = 1.33$, $t_{water} = 18$ cm, $t_{glass} = ?$

$$\because n_{glass}\, t_{glass} = n_{water}\, t_{water}\ ;\ t_{glass} = \frac{1.33 \times 18}{1.5} = 16 \text{ cm}$$

Example 4 :

The magnify power of the objective of a compound microscope is 7 if the magnifying power of the microscope is 35, then the magnifying power is eyepiece will be

(1) 245 (2) 5
(3) 28 (4) 42

Sol. **(2).** $m = m_0\, m_e\ ;\ 35 = 7\, m_e\ ;\ \therefore m_e = 5$

Example 5 :

Two lenses of power + 2.50 D and – 3.75 D are combined to form a compound lens. Its focal length in cm. will be

(1) 40 (2) – 40
(3) – 80 (4) 160

Sol. **(3).** $P = P_1 + P_2\ ;\ P = 2.50 - 3.75 = -1.25$ D

$$\because f = \frac{1}{P} \quad \text{or} \quad f = \frac{1}{(-1.25)} = -0.8 \text{ m} = -80 \text{ cm.}$$

Example 6 :

The focal length of lens of refractive index 1.5 in air is 30 cm. When it is immersed in water of refractive index 4/3, then its focal length will be

(1) 120 cm (2) 60 cm
(3) 30 cm (4) 240 cm

Sol. **(1).** $\because \frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad \because \frac{1}{30} = (1.5 - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

Refractive index of glass with respect to water

$$\mu_{wg} = \frac{\mu_{ag}}{\mu_{aw}} = \frac{1.5}{4} \times 3 = 1.125 \because \frac{1}{f'} = (\mu_{wg} - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

or $\frac{1}{f'} = [1.125 - 1]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

or $\frac{f'}{30} = \frac{0.50}{0.125} \quad \therefore f' = 120 \text{ cm}$

Example 7 :

At what distance from a convex lens of focal length 30 cm. an object should be placed so that the size of image be 1/4 that of object ?

(1) 30 cm (2) 60 cm
(3) 15 cm (4) 90 cm

Sol. **(4).** $m = -\frac{v}{u} = \frac{1}{4} \qquad \because \frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

or $-\frac{1}{30} = \frac{1}{u} - \frac{4}{u}$; $-\frac{1}{30} = -\frac{3}{u}$; $u = 90$

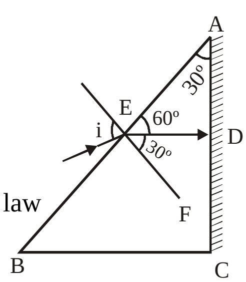
Example 8 :

The refractive index of the material of a prism is $\sqrt{2}$ and its prism angle is 30°. One of its refracting faces is polished. The incident beam of light will return back for the angle of incidence

(1) 60° (2) 45°
(3) 30° (4) 0°

Sol. **(2).** The ray of light returns back from the polished face AC

$\therefore$ $\angle ADE = 90°$. From the figure it is clear that the angle of refraction at face AB is 30°. Hence from shell's law



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

$\mu = \sqrt{2}$ or $r = 30°$ $\qquad \therefore \sqrt{2} = \frac{\sin i}{\sin 30°}$

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

Example 9 :

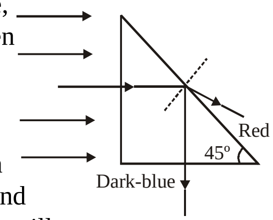
A white ray of light emerges out of a prism of angle 5°. If the refractive indices of blue and red colours are 1.659 and 1.641 respectively, the angle of dispersion between two colours will be -

(1) 0.09° (2) 9°
(3) 0.9° (4) 90°

Sol. $\theta = (\mu_B - \mu_R)A = (1.659 - 1.641) \times 5 = 0.09°$

Example 10 :

A beam of light containing blue, green and red colours, is inciden on a right angled prism as shown in the (figure). If the refractive indices of the material of prism for blue, green and red colours are 1.47 , 1.44 and 1.39 respectively then this prism will



(1) separate some part of blue colour from red & green colours
(2) separate all the three colours from other two colours
(3) not separate any of the colours from other two colours
(4) separate some part of red colour from green & blue colours

Sol. **(4).** $n = \frac{1}{\sin i_c} = \frac{1}{\sin 45°} = 1.4142$

As μ_g and μ_b are 1.44 and 1.47 respectively are more than μ = 1.41142 hence the green and blue colours will undergo total internal reflection. For colour $i < i_c$ hence this colour will get refracted in air

Example 11 :

A thin prism P of angle 4° and made of glass of refractive index 1.54 is combined with another thin prism P of refractive index 1.72 for dispersion without deviation. The angle of prism P will be

(1) 2.6° (2) 4°
(3) 5.33° (4) 3°

Sol. **(4).** $A' = \frac{A(\mu - 1)}{(\mu' - 1)} = \frac{4(0.54)}{0.72} \Rightarrow A' = 3°$

Example 12 :

A person can not see the objects beyond 50 cm. The power of a lens to correct this vision will be

(1) + 2 D (2) – 2 D
(3) + 5 D (4) 0.5 D

Sol. **(2).** As the person can see objects upto 50 cm. it means that the image of an object situated at infinity must be formed at 50 cm. i.e.

$u = \infty$, $v = -50$ cm. therefore from $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$

or $f = v = -50$ cm

$\because \quad P = \frac{1}{f}$ meter or $P = -\frac{1}{0.50} = -2D$

Example 13 :

The focal length of field achromatic combination of a telescope is 90cm. The dispersive powers of lenses are 0.024 and 0.036 respectively. Their focal lengths will be -

(1) 30 cm and 60 cm (2) 45 cm and 90 cm

(3) 15 cm and 45 cm (4) 30 cm and – 45 cm

Sol. (4). $\because \frac{\omega_1}{f_1}+\frac{\omega_2}{f_2}=0$; $\frac{1}{f_2}=-\frac{0.024}{0.036f_1}$; $\frac{1}{f_2}=-\frac{2}{3f_1}$

$\because \frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}$ $\because$ F = 90 cm

$\therefore \frac{1}{90}=\frac{1}{f_1}-\frac{2}{3f_1}$; f_1 = 30 cm or $f_2=-\frac{3\times 30}{2}$ = – 45 cm

Example 14 :

An achromatic doublet is formed by combining two lenses. If the focal length of the lenses and their dispersive powers are f, f′ and ω ω′ respectively, then

(1) $\omega=\omega_0,\ \omega'=2\omega_0,\ f'=-2f$ (2) $\omega=\omega_0, \omega'=2\omega_0,\ f'=2f$

(3) $\omega=\omega_0,\ \omega'=2\omega_0,\ f'=-\frac{f}{2}$ (4) $\omega=\omega_0,\ \omega'=2\omega_0,\ f'=\frac{f}{2}$

Sol. (1). From the condition of achromatic, $\frac{\omega}{\omega'}+\frac{f}{f'}=0$

as in all four options $\omega=\omega_0$ and $\omega'=2\omega_0$

$\therefore \frac{\omega}{\omega'}=\frac{\omega_0}{2\omega_0}=\frac{1}{2}$ $\therefore \frac{1}{2}+\frac{f}{f'}=0$ or $\frac{f}{f'}=-\frac{1}{2}$ or f′ = – 2f

Example 15 :

A person cannot see an object lying beyond 80cm whereas a normal person can easily see the object distant 160 cm. The focal length and the nature of the lens used to rectify this defect will be -

(1) – 160 cm concave (2) – 160 cm, convex

(3) 60 cm concave (4) 160 cm convex

Sol. (1). $\because \frac{1}{f}=\frac{1}{v}-\frac{1}{u}$; $\frac{1}{f}=\frac{-1}{80}+\frac{1}{60}$ $\therefore$ f = – 160

Example 16 :

The focal length of the objective and the eyepiece of an astronomical telescope are 16 m and 2 cm respectively. A planet is viewed with its help, then

(1) The angular magnification of the planet is – 800

(2) The image of the planet is inverted

(3) The distance between the objective and the eye piece is 16.02

(4) All the of the above

Sol. (4). $\therefore$ Distance between objective and eyepiece

$= f_0 + f_e = 16.02$ m.

Angular magnification $M=-\frac{f_0}{f_e}$ or $M=\frac{-16}{0.02}=-800$

The image formed by a telescope is always inverted

Example 17 :

The focal length of the objective and the eyepiece of a microscope are 4mm and 25mm respectively. If the final image is formed at infinity and the length of the tube is 16cm. the magnifying power of the microscope will be

(1) – 327.5 (2) –32.75

(3) 3.275 (4) 32.75

Sol. (1). $M=-\frac{V_0}{u_0}\frac{D}{f_e}$; $u_0=-\left(\frac{54}{131}\right)$ cm

$M=\frac{-13.5}{\left(\frac{54}{131}\right)}\times\frac{25}{2.5}=-327.5$

Example 18 :

An astronomical telescope of magnifying power 8 is made using two lenses spaced 45 cm apart. The focal length of the lenses used are

(1) F = 40 cm f = 5cm (2) F = 8cm f = 5cm

(3) F = 5cm. f = 40 cm (4) F = 20 cm, f = 5cm

Sol. (1). $M=\frac{F}{f}$ and L = F + f = 45 cm

$\because$ M = 8 ; F = 8f ; 8f + f = 45 $\therefore$ f = 5 cm $\therefore$ F = 40 cm

Example 19 :

A transparent thin film of uniform thickness and refractive index n_1 = 1.4 is coated on the convex spherical surface of radius R at one end of a long solid glass cylinder of refractive index n_2 = 1.5, as shown in the figure. Rays of light parallel to the axis of the cylinder traversing through the film from air to glass get focused at distance f_1 from the film, while rays of light traversing from glass to air get focused at distance f_2 from the film. Then choose the correct option

(a) $|f_1|$ = 3R

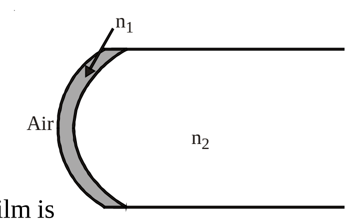
(b) $|f_1|$ = 2.8 R

(c) $|f_2|$ = 2R

(d) $|f_2|$ = 1.4 R

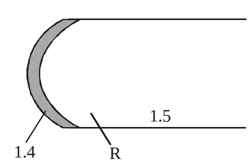
(A) a, c (B) b, d

(C) c, d (D) a, d



Sol. (A). As thickness of film is uniform, the effective power of the film is zero.

$\therefore$ We can find the answer just by considering glass-air interface.



In case 1, $\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$

Gives $\frac{1.5}{f_1}-0=\frac{1.5-1}{R}\Rightarrow f_1=3R$

In case 2, $\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$

Gives, $\frac{1}{f_2}-0=\frac{1-1.5}{-R}\Rightarrow f_2=2R$

6B

WAVE OPTICS

NATURE OF LIGHT

PROPERTIES OF LIGHT

(1) Light exist in form of energy.
(2) Velocity of light in vacuum is 3×10^8 m/s.
(3) Velocity of light depends upon medium.
(4) Light exhibits the phenomenon of reflection, refraction, Interference, diffraction, polarisation, photo electric effect etc.

THEORIES TO EXPLAIN THE BEHAVIOUR OF LIGHT

1. Newton's corpuscular theory.
2. Huygen's theory of waves.
3. Electro Magnetic wave theory.
4. Quantum nature of light.
5. Dual nature of light.

Newton's corpuscular theory:

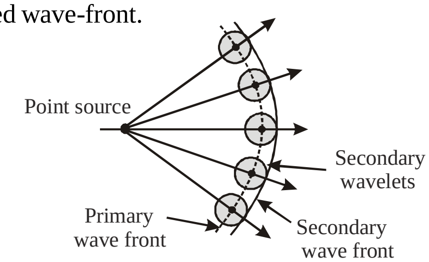
(1) Light consists of extremely small, very light weighed material particles called corpuscles.
(2) The corpuscles travel with the velocity of light.
(3) When the corpuscles strike out retina, they produce the sensation of vision.
(4) This theory explains the reflection, rectilinear propagation of light.

Fails to explain following :

(1) According to this theory, velocity of light is more in denser medium rather than rarer medium, which is wrong.
(2) It fails to explain the phenomena of interference diffraction, & polarisation of light.
(3) Corpuscles of different colours are of different sizes.
(4) In one medium, corpuscle of one colour travels with uniform velocity & when it enter in another medium it travels with different uniform velocity.

WAVE FRONT

The locus of all particles vibrating in the same phase is called wave-front.



(a) Each point of wavefront is considered as source of secondary wavelets.
(b) The ray of light is considered in the direction of out-ward normal to the wave front.

Form of wave front : Form of wavefront depends on nature of light source.

Three types of wavefront :

Spherical wavefront :

(a) Light source is point source.
(b) Effective distance should be finite.
(c) Intensity $\propto 1/r^2$

Cylindrical wavefront :

(a) Light source is line source.
(b) Effective distance should be finite.
(c) Intensity $\propto 1/r$

Plane wavefront :

(a) Light source is at large distant.
(b) Effective distance should be at infinite.
(c) Intensity does not depends on distance.

HUYGEN'S WAVE THEORY

(1) Huygen proposed the wave theory of light. Light travels in form of wavefront in medium.
(2) According to this principal, energy is emitted in form of waves from light source.
(3) It need medium for propagation of light that's why a universal hypothetical medium called ether is proposed.
(4) Each point on the wavefront acts as a centre of new disturbance and emits its own set of spherical waves called secondary wavelets.
(5) The envelope or the locus of these wavelets in the forward direction gives the position of new wavefront at any subsequent time.
(6) Direction of wave propagation and wave front are mutually perpendicular to each other.
(7) At large distances from the source, all wavefronts appear to be plane.
(8) The theory explained successfully the reflection, refraction, interference, diffraction.
(9) Huygens wave theory can't distinguish between longitudinal and transverse waves. Hence, the theory could not explain polarisation. However, later on it could interpret the phenomenon on the basis of light being assumed to be transverse.
(10) This principal is valid for all types of wave. e.g. light waves, sound waves.

Fails to explain :

(a) This theory cannot explain photo-electric effect, compton, & Raman effect.
(b) Hypothetical medium in vacuum is not true imagination.
(c) The theory predicted the presence of back wave, which proved to be failure.

QUANTUM NATURE OF LIGHT

(a) To explain the spectral energy distribution curve of black body radiation Plank Theory was used.

(b) According to this principle the light is emitted by the source in the form of energy bundles, called photons.

(c) Energy of photon (E) is proportional to frequency (ν)

$E \propto \nu \Rightarrow E = h\nu$; h is planck constant.

(d) Energy of photon of various frequency or wavelengths has different energy. $E = \frac{hc}{\lambda}$

(e) Rest mass of photon is zero, but its effective mass is

$$m = \frac{E}{c^2} = \frac{h\nu}{c^2}$$

(f) Momentum of photon, $P = \frac{h}{\lambda} = \frac{h\nu}{c} = \frac{E}{c}$

(g) Intensity I = nhν

n = number of photons incident on unit area in one second; hν = Energy of single photon

N (Total number of photon incident on the surface)

$$= \frac{\text{Total energy emitted}}{\text{Energy of one photon}},\ N = \frac{E}{hc/\lambda}$$

E = Total energy incident on the surface.

(h) On the basis of this theory photo electric effect, Compton effect & Raman effect can be explained.

(i) By this theory diffraction, Interference, Polarisation cannot be explained.

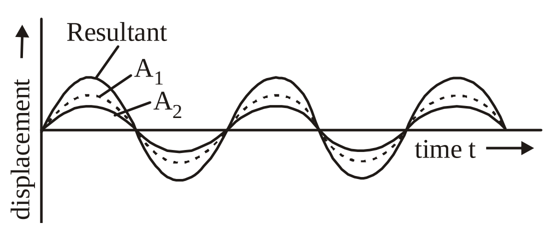
Dual Nature of Light :

* According to this light has dual nature, one wave nature (E.M. wave) & second corpuscles nature (Energy particle of planck).
* In microscopic description, when we talk about propagation of light in medium then wave nature of light is considered.
* In microscopic description, when light mutually interacts with matter, then particle nature of light is considered.
* Both particle & wave nature exist together but we can't see both nature in single experiment.
* All phenomenon of light can be explained by this.

INTERFERENCE

PRINCIPLE OF SUPERPOSITION

Two, or move Progressive waves can travel simultaneously in a medium without affecting the motion of one another, Therefore, the resultant displacement of each particle of the medium at any instant is equal to the vector sum of the displacements produced by the two waves separately. This principle is called principle of superposition.



Resultant displacement : $\vec{y} = \vec{y}_1 + \vec{y}_2$

Meaning of principle of superposition :

The principle of superposition means that if a number of waves are travelling in a medium, then each one travels independently as if the other waves were not present at all; the shape and other characteristics of any wave not changed.

INTERFERENCE OF TWO WAVES

When two waves of same frequency travel in a medium simultaneously in the same direction then, due to their superposition, the resultant intensity at any point of the medium is different from the sum of intensities of the two waves. At some points the intensity of the resultant wave is very large while at some other points it is very small or zero.

Mathematical interpretation of interference of two waves:

Let us consider two simple harmonic progressive waves of the same frequency travelling in the same direction, Let a_1 and a_2 be the amplitudes of the waves at that point be y_1 and y_2 then. $y_1 = a_1 \sin \omega t$............. (i)

and $y_2 = a \sin (\omega t + \phi)$ ...... (ii)

$\omega/2\pi$ is the frequency of each wave. By the principle of superposition, the resultant displacement at the point is given by $y = y_1 + y_2$

$= a_1 \sin \omega t + a_2 \sin (\omega t + \phi)$

$= a_1 \sin \omega t + a_2 \sin \omega t \cos \phi + a_2 \cos \omega t \sin \phi$

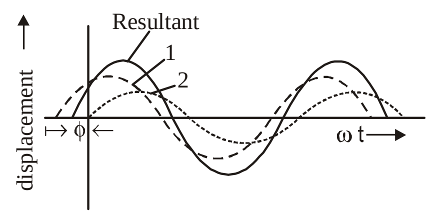
$= \sin \omega t (a_1 + a_2 \cos \phi) + \cos \omega t (a_2 \sin \phi)$

Let $a_1 + a_2 \cos \phi = R \cos \theta$............. (iii)

and $a_2 \sin \phi = R \sin \theta$ .... (iv)

where R and θ are new constants. Then

$y = R \sin \omega t \cos\theta + R \cos \omega t \sin \theta$ or $y = R \sin (\omega t + \theta)$



This equation is similar to eq. (i) and (ii) Hence the resultant displacement at that point is changing sinosudeally with amplitude R. To determine R, we square eq.(iii) and (iv) and then add:

$R^2 \cos^2 \theta + R^2 \sin^2\theta = (a_1 + a_2 \cos\phi)^2 + (a_2 \sin \phi)^2$

or $R^2 = a_1^2 + a_2^2 + 2a_1a_2 \cos\phi$

The intensity is directly proportional to the square of the amplitude. Hence the resultant intensity I is given by

$I \propto (a_1^2 + a_2^2 + 2a_1a_2 \cos\phi)$ and phase angle ϕ

$$= \tan^{-1} \frac{a_2 \sin \phi}{a_1 + a_2 \cos \phi}$$

The resultant intensity at any point depends upon the phase difference ϕ between the two waves at that point.

Comment : If ϕ phase diff is equivalent of x path difference or Δt time difference, then remember

$$\frac{\phi}{2\pi} = \frac{x}{\lambda} = \frac{\Delta t}{T}$$

TWO TYPES OF INTERFERENCE

(i) Constructive **(ii) Destructive**

Law of conservation of energy in constructive & Destructive interference :

Energy redistribution takes place in interference . Energy will shift from the position of destructive interference to position of contructive interference, total energy remain constant.

CONSTRUCTIVE $\{I > (I_1 + I_2)\}$

The phase difference between two waves an even multiple of π i.e.

$\delta = 2n\pi$ where n = 0,1, 2

The path difference between two waves is an even multiple of $\lambda/2$.

$\Delta = 2n(\lambda/2)$ where n = 0, 1, 2

The time interval between two waves is even multiple of T/2

$\theta = (2n)\,T/2$, n = 0, 1, 2

The resultant amplitude of wave is equal to the sum of amplitudes of individual waves

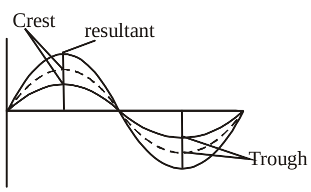
$A = a_1 + a_2$

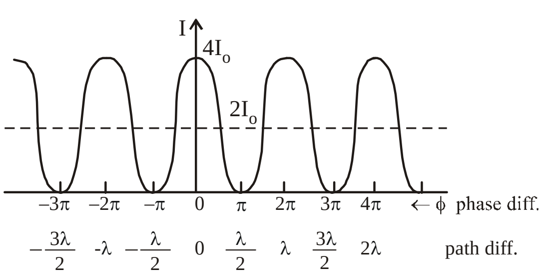
If $\phi = 0, 2\pi, 4\pi, \ldots 2n\pi$

The resultant intensity is more than the sum of intensities of individual waves.

$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \Rightarrow (\sqrt{I_1} + \sqrt{I_2})^2$

Both waves reach at any point in same phase





Intensity of resultant wave (interference) pattern when the waves have equal

DESTRUCTIVE $\{I < (I_1 + I_2)\}$

The phase difference between two waves is an is odd multiple of π.

$\delta = (2n - 1)\pi$ where n = 0,1, 2

The path difference between two waves is an odd multiple of $\lambda/2$.

$\Delta = (2n - 1)\lambda/2$, where n = 1, 2

The time interval between two waves is an odd an multiple of T/2

$\theta = (2n - 1)T/2$, n = 1, 2, 3

The resultant amplitude of wave is equal to the difference of amplitudes of two waves

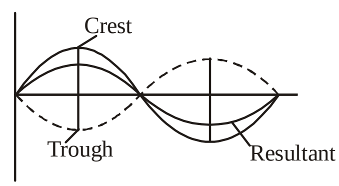
$A = a_1 - a_2$

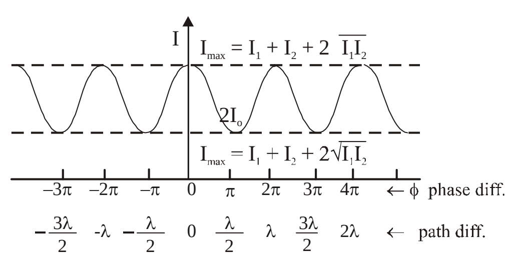
If $\phi = \pi, 3\pi, 5\pi, \ldots (2n - 1)\pi$

The resultant intensity is less than the sum of intensities due individual waves

$I = I_1 + I_2 - 2\sqrt{I_1 I_2} \Rightarrow (\sqrt{I_1} - \sqrt{I_2})^2$

Both waves reach at any point in opposite phase





Intensity of resultant wave (interference pattern) when the intensity of the two waves are not equal intensities note that the average intensity is

$$I = \frac{I_{max} + I_{min}}{2} = I_1 + I_2$$

Example 1 :

The two coherent sources of intensity that ratio 2 : 8 produce an interference pattern. The values of maximum and minimum intensities will be respectively.

(1) I_1 and $9I_1$ (2) $9I_1$ and I_1

(3) $2I_1$ and $8I_1$ (4) $8I_1$ and $2I_1$

Where I_1 is the intensity of first source

Sol. **(2).** $I_{max} = I_1 + I_2 + 2\sqrt{I_1 I_2}$ ....(1)

According to question

$$\frac{I_1}{I_2} = \frac{2}{8} = \frac{1}{4} \qquad \therefore I_2 = 4I_1 \qquad \text{.........(2)}$$

From eqs. (1) and (2)

$$I_{max} = I_1 + 4I_1 + 2\sqrt{4I_1^2} = 5I_1 + 4I_1$$

$$I_{max} = 9I_1 \qquad \text{.........(3)}$$

$$I_{min} = I_1 + I_2 - 2\sqrt{4I_1 I_2} \qquad \text{.........(4)}$$

From eqs. (2) and (4), $I_{min} = I_1 + 4I_1 - 2\sqrt{4I_1 I_2}$; $I_{min} = I_1$

COHERENT SOURCE

The two sources of light, whose frequencies are same and the phase difference between the waves emitted by which remains constant with respect to time are defined as coherent sources.

There are two independent concepts of coherence namely (i) temporal coherence (ii) spatial coherence

Temporal coherence: In a typical light source (like sodium lamp) a light wave (photon) is produced when an excited atom goes to the ground state and emits light the duration of this 10^{-9} to 10^{-10} sec. Thus the electromagnetic (light) wave remains sinusoidal for this much time. This time known as coherence time it is denoted by τ_c.

Spatial coherence: Two waves at different point in space are said to be space coherent if they preserve a constant phase difference over any time t .

Note: Laser is a source of monochromatic light waves of high degree of coherence. The entire wave front of the laser beam is spatially coherent.

Main points :

1. They are obtained from the same single source.

2. Their state of polarization is the same

NOTE

1. Laser light is highly coherent & monochromatic

2. The light emitted by two independent sources (candles, bulbs, etc.) is non coherent and interference phenomenon can not be produced by such two sources.

Method of obtain coherent light source :

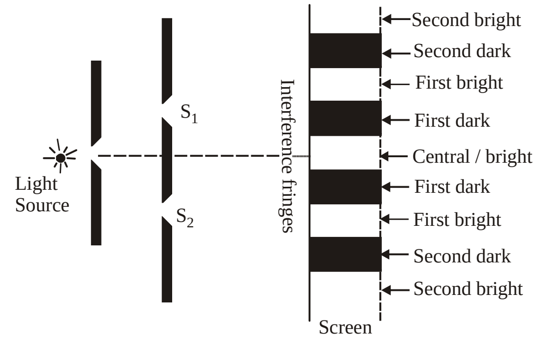
(i) Division of wavefront (ii) Division of Amplitude

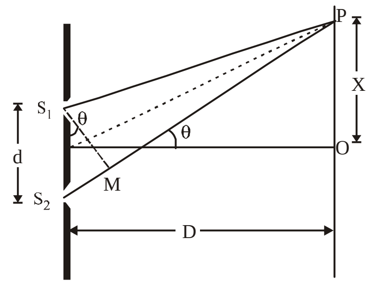
CONDITIONS FOR SUSTAINED INTERFERENCE PATTERN

* The source of light must the monochromatic.
* Two sources of light must be coherent.
* Frequencies of two waves must be same.
* The amplitudes of two waves must be nearly equal.
* The distance between two light sources must be small narrow.
* The two coherent sources must be narrow.
* If the two light waves are polarized then their state of polarizations must be same.
* The two light waves must travel in the same direction .
* The vibrations of two waves must be in the same direction
* The distance between the source & the screen must be large.

EXPERIMENT OF YOUNG'S DOUBLE SLIT

* This experiment shows interference of light
* S_1 & S_2 slit behaves like two coherent source.
* On Screen, Bright & Dark portion are alternatively found.
* Bright portion is called Bright fringe & dark portion is called dark fringe.
* Central fringe is always bright.
* Energy conserves in interference of light.
* It is explained on the basis of huygen principal .
* This experiment verifies the wave nature of light.





(a) At a point on screen to find dark or bright fringe, it depends upon path difference between S_1P & S_2P light waves.

(b) Two types of path difference between light waves :

(i) Geometrical path difference.

(ii) Optical path difference.

(c) In above experiment optical difference S_1P & S_2P has geometrical path difference so,

Total path difference = Geometrical difference

$$S_1P - S_2P = \frac{xd}{D} \quad (\text{note - } \sin\theta \approx \tan\theta \approx Q)$$

Bright Fringes: If n^{th} bright fringe forms at point P, then

$$\text{for Bright fringe : } S_2P - S_1P = \frac{X_n d}{D} = n\lambda \Rightarrow X_n = \frac{n\lambda D}{d}$$

So distance between central fringe & n^{th} bright fringe :

$$X_n = \frac{n\lambda D}{d} \quad n = 1 \text{ first bright fringe}$$

$\Rightarrow$ n = 2 Second bright fringe

Dark Fringe : If n^{th} dark fringe forms at a point P, then for

$$\text{dark fringe. } \frac{X_n d}{D} = \frac{(2n-1)}{2}\lambda$$

$\Rightarrow$ distance between central fringe & n^{th} fringe.

$$X_n = \frac{(2n-1)\lambda D}{2d}$$

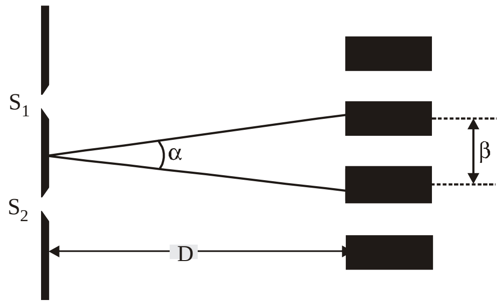
n = 1 First bright fringe.

n = 2 Second bright fringe.

Distance between dark & bright fringe which are in coming order is called fringe width.

In Interference Fringe width of dark & bright fringes are same $\beta = \frac{\lambda D}{d}$

Angular width of fringe : $\alpha D = \beta$; $\alpha = \beta/D = \dfrac{\lambda}{d}$



Comments on Young's interference experiment :

(1) Energy is conserved in interference. This indicated that energy is redistributed from destructive interference region to the constructive interference region .

(2) If the entire arrangement of young's double slit experiment is immersed in water then fringe width decreases

$$\frac{\beta_{water}}{\beta_{air}} = \frac{\lambda_{water}}{\lambda_{air}} = \frac{1}{{}_a\mu_w} = \frac{1}{(4/3)}$$

(3) If white light is used in placed of monochromatic light in young's double slit experiment.

(a) Central fringe is white

(b) Coloured fringe around the central white fringe

(c) Inner edge of the dark fringe is red. While the outer edge is violet (or blue)

(d) Inner edge of bright fringe is violet (or blue) and the outer edge is red.

(4) If a filter allowing only λ_{red} (of λ_1) is placed in front of slit s_1 and filter allowing only λ_{blue} (or λ_1) is placed is fornt of slit s_2. then there is no interference pattern.

(5) If a thin glass plate or mica sheet is placed in front of one of the slit, then central fringe shifts towards that slit, refractive index of glass is μ and the thickness of sheet t, then the optical path = μt so extra path difference $(\mu - 1)t$ If the central fringe now appears at the location of previously formed nth bright fringe then $(\mu - 1)t = n\lambda$ if the central fringe appears at the position of previously formed nth dark fringe then $(\mu - 1)t = (2n-1)\dfrac{\lambda}{2}$

(6) If the width of the slit S increased then degree of spatial coherence decreases. As a result the interference pattern gradually disappears similar occurs if distance between S_1 and S_2 is increased.

(7) The fringe visibility : $V = \dfrac{I_{max} - I_{min}}{I_{max} + I_{min}}$

V_{max} : if $I_1 = I_2 = I_0$ or $I_{min} = 0$

If widths of slits S_1 and S_2 are unequal the brightness of the bright fringe and the darkness of the dark fringe decreases.

if $I_1 >> I_2$ then $I_{max} = I_{min}$

(8) When waves from two coherent sources S_1 are S_2 interfere in space the shape of the fringe is hyperbolic with foci at S_1 and S_2 .

NOTE

* The fringe width increases with increase of distance between the source & the screen
* Fringe width decreases by increasing distance between two slits S_1 & S_2
* If the experiment is repeated in water instead of air then β decreases .
* When one of the slits of S_1 & S_2 is close then interference does not take place
* When the two slits are illuminated by two independent sources then interference fringes are not obtained.
* When one of the slit is closed & width of another is made of the order of λ, then diffraction fringes are observed
* When slit is illuminated with different colours then fringes are obtained of the same colour but their fringes width is different.
* In young's double slit experiment light waves undergo diffraction at both the slits and the diffracted waves superimpose to produce interference.
* The wavelength undergoing destructive interference, the colour of that wavelength will be absent.
* The wavelength for which the condition of constructive interference is fulfilled that colour will be visible maximum consequently the fringes will be coloured.

Example 2 :

In Young's slit experiment 10th order maximum is obtained at the point of observation in the interference pattern for λ = 7000 Å. If the source is replaced by another one of wavelength 5000 Å then the order of maximum at the same point will be -

(1) 12 th (2) 14 th

(3) 16 th (4) 18 th

Sol. **(2).** $n_1\lambda_1 = n_2\lambda_2$; $10 \times 7000 = n_2 \times 5000$; $n_2 = 14$

Example 3 :

In Young's double slit experiment the two slits are illuminated by light of wavelength 5890 Å and the distance between the fringes obtained on the screen is 0.2°. If the whole apparatus is immersed in water then the angular fringe width will be, it the refractive index of water is 4/3.

(1) 0.30° (2) 0.15°

(3) 15° (4) 30°

Sol. **(2).** $\omega_a = \lambda/d$

$$\therefore \quad \omega_a \propto \lambda \Rightarrow \frac{(\omega_0)_{water}}{\omega_a} = \frac{\lambda_{water}}{\lambda}$$

$$\Rightarrow \frac{(\omega_0)_{water}}{\omega_a} = \frac{\lambda}{\mu_{water}\lambda} \Rightarrow (\omega_0)_{water} = 0.15^\circ$$

Example 4 :

The intensities of two sources are I and 9 I respectively. If the phase difference between the waves emitted by them is π then the resultant intensity at the point of observation will be -

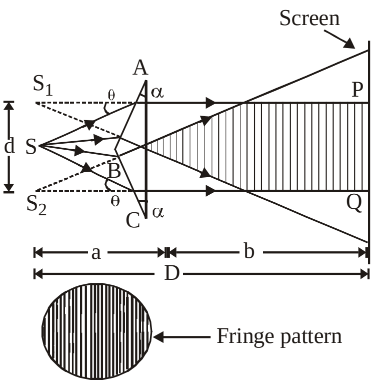
(1) 3I (2) 4 I
(3) 10 I (4) 82 I

Sol. (2). $I' = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$; $I_1 = I, I_2 = 9\,I, \phi = \pi$

$$I' = I + 9I + 2\sqrt{9I^2}\cos\pi = 10\,I - 6\,I = 4\,I$$

FRESNEL'S BIRPISM EXPERIMENT

(1) It is optical device to obtain two coherent sources by refraction of lights.
(2) The angle of biprism is 179º & refracting angle is α = 1/2º.
(3) Distance between source & screen D = a + b.

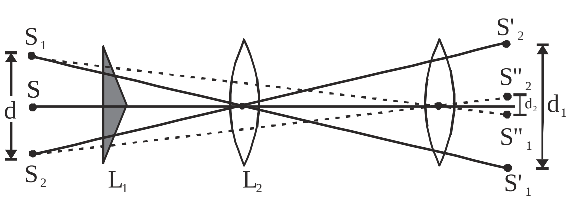


Distance between two coherent source = d = 2a (μ –1)α
Where a = distance between source & Biprism
b = distance between screen & Biprism
μ = refractive index of the material of prism.

$$\lambda = \frac{d\beta}{D} = \frac{2a(\mu-1)\alpha\beta}{(a+b)} = \frac{\sqrt{d_1 d_2}\,.\beta}{(a+b)}$$

Note- α is in radian $\alpha^\circ = \alpha \times \frac{3.14}{180}$.

Suppose refracting angle & refractive index is not known then d can be calculate by convex lens.



One convex lens whose focal length (f) and 4f < D.
First convex lens is kept near biprism & d_1 is calculated then it is kept near eyepiece & d_2 is calculated.

$$d = \sqrt{d_1 d_2}$$

Application : With the help of this experiment the wavelength of monochromatic light, thickness of thin films and their refractive index & distance between apparent coherent sources can be determined.

When Fresnel's arrangement is immersed in water :

(i) Effect on d : $d_{water} < d_{air}$. Thus when the Fresnel's biprism experiment is immersed in water, then the separation between the two virtual sources decreases but in young's double slit experiment it does not change.

(ii) In young's double slit experiment β decrease and in fresnel's biprism experiment β increases.

Example 5 :

In Fresnel's biprism experiment the width of 10 fringes is 2cm which are formed at a distance of two 2 meter from the slit. If the wavelength of light is 5100 Å then the distance between two coherent sources will be

(1) 5.1 × 10^{-4} m (2) 5.1 × 10^{4} cm.
(3) 5.1 × 10^{-4} mm (4) 10.1 × 10^{-4} cm

Sol. (1). $d = \frac{D\lambda}{\beta}$ ....(1)

According to question, $\lambda = 5100 \times 10^{-10}$ m

$\beta = \frac{2}{10} \times 10^{-2}$ m ....(2) ; D = 2m , d = ?

From eqs. (1) and (2), $d = \frac{2 \times 51 \times 10^{-8}}{2 \times 10^{-3}} = 5.1 \times 10^{-4}$ m

TO DETERMINE THICKNESS OF THIN FILM

On placing the film, the whole interference pattern gets shifted on that side where the film is placed. When a thin film of thickness t & refractive index μ is placed in the path of one of the waves then the fringe pattern gets shifted by a distance x and if the shift is equivalent to n fringes, then

$$n = \frac{(\mu-1)t}{\lambda} \quad \& \quad x = \frac{(\mu-1)tD}{d}$$

the path difference increases by (μ –1)t on placing the plate.

Example 6 :

When a mica sheet of thickness 7 microns and μ = 1.6 is placed in the path of one of interfering beams in the biprism experiment then the central fringe gets at the position of seventh bright fringe. Wavelength of light used will be

(1) 4000 Å (2) 5000 Å
(3) 6000 Å (4) 7000 Å

Sol. (3). $\lambda = \frac{(\mu-1)t}{n}$ .....(1)

According to question, n = 7 . μ = 1.6, $t = 7 \times 10^{-6}$ m ..(2)

From eqs. (1) and (2), $\lambda = 6 \times 10^{-7}$ meter

Example 7 :

When a plastic thin film of refractive index 1.45 is placed in the path of one of the interfering waves then the central fringe is displaced through width of five fringes. The thickness of the film will be, if wavelength of light is 5890Å.

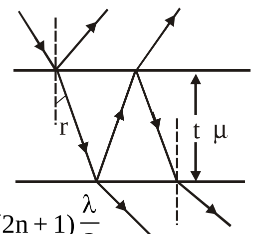
(1) 6.544 × 10^{-4} cm (2) 6.544 × 10^{-4} m
(3) 6.54 × 10^{-4} cm (4) 6.5 × 10^{-4} cm

Sol. **(2).** $\therefore X_0 = \frac{\beta}{\lambda}(\mu - 1)t \Rightarrow 5\beta = \frac{\beta(0.45)t}{5890 \times 10^{-10}}$

$$\therefore t = \frac{5 \times 5890 \times 10^{-10}}{0.45} = 6.544 \times 10^{-4} \text{ cm}$$

INTERFERENCE BY THIN FILMS

The interference cause by thin films is due to the interference between the waves reflected from the upper and lower surfaces. These two reflected coherent waves are obtained from the same incident wave by division of amplitude. A film of thickness t and refractive index μ produces a path difference of $2\mu t \cos r$ between the two reflected waves and an additional path difference $\frac{\lambda}{2}$ or phase difference of π is produced due to reflection of one wave from a denser medium. Thus the total path difference in reflected waves is



For maxima $2\mu t \cos r + \frac{\lambda}{2} = n\lambda$

or $2\mu t \cos r = (2n - 1)\frac{\lambda}{2}$

and for minima $2\mu t \cos r + \frac{\lambda}{2} = (2n + 1)\frac{\lambda}{2}$

or $2\mu t \cos r = (2n - 1)\frac{\lambda}{2}$

Here r is angle of refraction. For normal incidence or near normal incidence $r \approx 0$,so that

for maxima $2\mu t = (2n \pm 1)\frac{\lambda}{2}$; for minima $2\mu t = n\lambda$

If a film is very thin $t \approx 0$, then the condition of minima is satisfied and the film appears dark in reflected light.

In transmitted waves similar interference is observed but now the additional path difference of $\frac{\lambda}{2}$ is absent.

So in transmitted waves.

$2\mu t \cos r = n\lambda$ for maxima

and $2\mu t \cos r = (2n \pm 1)\frac{\lambda}{2}$ for minima.

TRY IT YOURSELF - 1

Q.1 Two beams of light having intensities I and 4I interfere to produce a fringe pattern on the screen. Phase difference between the beams is $\pi/2$ at point A and π at point B. Then the difference between resultant intensities at A and B is

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

Q.2 Waves from two slits are in phase at the slits and travel to a distant screen to produce the second minimum of the interference pattern. The difference in the distance traveled by the waves is:

(A) half a wavelength
(B) a wavelength
(C) three halves of a wavelength
(D) two wavelengths

Q.3 Intensities of light due to the two slits of YDSE are I and 4I. How far from the central maxima will the intensity be equal to the average intensity on the screen? (β is the fringe width).

(A) $\beta/2$ (B) $\beta/3$
(C) $\beta/6$ (D) $\beta/4$

Q.4 In a Young's double slit interference pattern, the intensity of the central fringe at P = I_o when one slit width is reduced to one forth the intensity at P will be

(A) $I_o/2$ (B) $I_o/4$
(C) $(9/16)\, I_o$ (D) $(3/4)\, I_o$

Q.5 Interference fringes are obtained in Young's double-slit experiment on a screen. Which of the following statements will be incorrect about the effect of introducing a thin transparent plate in the path of one of the two interfering beams.

(A) The separation between fringes remain unaffected.
(B) The entire fringe system shifts towards the side on which plate is placed
(C) The conditions for maxima and minima are reversed i.e., maxima for odd multiple of $\lambda/2$ and minima for even multiple of $\lambda/2$.
(D) Shape of the fringe also remains unaffected.

Q.6 In a Young's double–slit experiment, the central bright fringe can be identified

(A) as it has greater intensity than the other bright fringes
(B) as it is wider than the other bright fringes
(C) as it is narrower than the other bright fringes
(D) by using white light instead of monochromatic light

Q.7 In a Young's double–slit experiment, if the slits are of unequal width,

(A) fringes will not be formed
(B) the positions of minimum intensity will not be completely dark
(C) bright fringe will not be formed at the centre of the screen
(D) distance between two consecutive bright fringes will not be equal to the distance between two consecutive dark fringes

Q.8 In a YDSE, if the incident light consists of two wavelengths λ_1 and λ_2, the slit separation is d, and the distance between the slit and the screen is D, the maxima due to each wavelength will coincide at a distance from the central maxima, given by

(A) $\frac{\lambda_1 + \lambda_2}{2Dd}$ (B) LCM of $\frac{\lambda_1 D}{d}$ and $\frac{\lambda_2 D}{d}$

(C) $(\lambda_1 - \lambda_2)\frac{2d}{D}$ (D) HCF of $\frac{\lambda_1 D}{d}$ and $\frac{\lambda_2 D}{d}$

Q.9 The contrast in the fringes in any interference pattern depends on

(A) fringe width (B) ratio of width of slits
(C) distance between the slits (D) wavelength

Q.10 In Young's double slit experiment the distance between slits is 2×10^{-4} m. The adjacent maxima of interference pattern subtends an angle of 10.8 minutes at the midpoint between slits. The value of λ of light used in the experiment is nearly

(A) 5890 Å (B) 6280 Å
(C) 4850 Å (D) 6500 Å

ANSWERS

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

DIFFRACTION

* It is the spreading of waves round the corners of an obstacle, of the order of wave length.
* The phenomenon of bending of light waves around the sharp edges of opaque obstacles or aperture and their encroachment in the geometrical shadow of obstacle or aperture is defined as diffraction of light.
* **Necessary Conditions of Diffraction of Waves :**
The size of the obstacle (a) must be of the order of the wavelength of the waves (λ).

$$\frac{a}{\lambda} \approx 1$$

Note : Greater the wave length of wave higher will be its degree of diffraction. This is the reason that diffraction of sound & radio waves is easily observed but for diffraction of light, additional arrangement have to be arrange.

$\lambda_{sound} > \lambda_{light}$

Wave length of sound is nearly equal to size of obstacle. If size of obstacle is a & wavelength of light is λ then,

S.No.	a V/S a	Diffraction
(1)	$a << \lambda$	Not possible
(2)	$a >> \lambda$	Not possible
(3)	$a \simeq \lambda$	Possible

INTERPRETATION OF DIFFRACTION

As a result of diffraction, maxima & minima of light intensities are found which has unequal intensities. Diffraction is the result of superposing of waves from infinite number of coherent sources on the same wavefront after the wavefront has been distorted by the obstacle.

Example of Diffraction :

* When an intense source of light is views with the partially opened eye, colours are observed in the light.
* Sound produced in one room can be heard in the nearby room.
* Appearance of a shining circle around the section of sun just before sun rise.
* Coloured spectrum is observed if a light source at far distance is seen through a thin cloth.

TWO TYPE OF DIFFRACTION

Fresnel Diffraction : Fresnel diffraction which involves non-plane (spherical) wavefronts, so that the sources and the point p (where diffraction effect is to be observed) are to be at a finite distance from the diffracting obstacle.

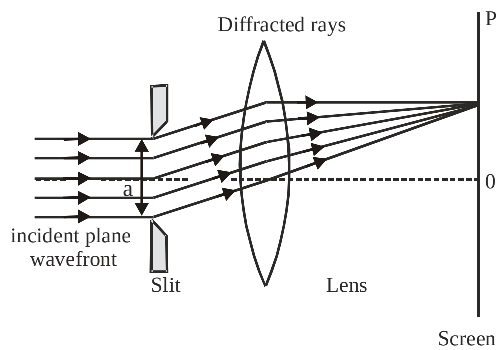
Fraunhoffer Diffraction : Fraunhoffer diffraction deals with wavefronts that are plane on arrival and an effective viewing distance of infinity. If follows that fraunhoffer diffraction is an important special case of fresnel diffraction. In Youngs double slit experiment, we assume the screen to be relatively distance, that we have fraunhoffer conditions.

FRAUNHOFFER DIFFRACTION FOR SINGLE SLIT

In this diffraction pattern central maxima is bright on the both side of it, maxima & minima occurs symmetrically

For Diffraction Maxima :

$a \sin \theta = (2n + 1) \lambda/2$

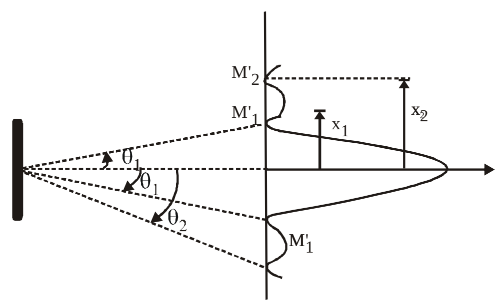


For Diffraction Minima :

$a \sin \theta = n\lambda$

The maxima or minima is observed due to the superposition of waves emerging from infinite secondary sources between A & B points of slit.

Fringe width :



The distance between two secondary minima formed on two sides of central maximum is known as the width of central maximum. $W = \frac{2f\lambda}{a}$

f = focal distance of convex lens, a = width of slit

Angular width = $W_{\theta} = \frac{2\lambda}{a}$

Example 8:

A monochromatic light with a wavelength of λ = 600 nm passes through a single slit which has a width of 0.800mm.
(a) What is the distance between the slit and the screen be located if the first minimum in the diffraction pattern is at a distance 1.00 mm from the center of the screen?
(b) Calculate the width of the central maximum.

Sol. (a) The general condition for destructive interference is

$$\sin\theta = m\frac{\lambda}{a},\ m = \pm 1, \pm 2, \pm 3, ...$$

For small θ, we employ the approximation

$$\sin\theta \approx \tan\theta = y/L, \text{ which yields } \frac{y}{L} \approx m\frac{\lambda}{a}$$

The first minimum corresponds to m = 1.
If $y_1 = 1.00m$, then

$$L = \frac{ay_1}{m\lambda} = \frac{(8.00\times10^{-4}\,m)\,(1.00\times10^{-3}\,m)}{1\,(600\times10^{-9}\,m)} = 1.33m$$

(b) The width of the central maximum is
$w = 2y_1 = 2\,(1.00\times10^{-3}\,m) = 2.00m.$

RESOLVING POWER OF OPTICAL INSTRUMENTS

A large number of images are formed as a consequence of light diffraction from a source. If two sources are separated such that their central maxima do not overlap, their images can be distinguished and are said to be resolved R.P. of an optical instrument is its ability to distinguish two neighbouring points.

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.

$$\text{Resolving power} = \frac{1}{d} = \frac{2\mu\sin\theta}{\lambda}$$

Resolving power of a telescope :

The resolving power of telescope is the reciprocal of the smallest angular separation between two distant objects whose imagesare 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.

Prism : R.P. = t (dμ/dλ) = λ/dλ.

Diffraction Grating :

R.P. = λ/dλ = N × n

(N is total number of lines & n is the order of spectrum)

Eye : The limit of resolution of human eye is 1' of arc (One minute of arc)

Example 9 :

In an electron microscope the accelerating voltage is increased from 20kV to 80 kV. The resolving power of the microscope will become ....

Sol. Resolving power of a microscope $\propto 1/\lambda \propto \sqrt{V}$

i.e., Resolving power will become two times.

Example 10 :

The diameter of the objective lens of a telescope is 5m and wavelength of light is 6000 Å. Find the limit of resolution of this telescope.

Sol. Angular limit of resolution $= \frac{1.22\lambda}{a}$ radian.

$$= \frac{1.22\times6000\times10^{-10}}{5}\times\frac{180^\circ}{\pi}\times3600s = 0.03\,s$$

DIFFRACTION OF LIGHT & SOUND

Sound travels in form of waves, that's why it is also diffracted. Generally diffraction of sound waves is easily observed rather than light because wavelength of sound waves is the order of obstacle, but wavelength of light is very small in comparison to obstacle.

(a) Ordinary audible sound has wavelength of the order of 1m & size of ordinary obstacle has same order that's why diffraction is easily observed.

(b) Ordinary light has wavelength of 10^{-7} m & ordinary obstacle has greater size in comparison to its wavelength that's why diffraction pattern is not observed.
Generally diffraction of ultrasonic waves are not observed because its wavelength has order of 1 cm.

RECTILINEAR MOTION OF LIGHT

* Rectilinear motion of light can be explained by diffraction of light.
* If size of obstacle is the order of wavelength of light, then diffraction of light takes place & its rectilinear motion of light is not possible.
* If size of obstacle is much greater than wave length of light, then rectilinear motion of light is observed.

THE VALIDITY OF RAY OPTICS

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. $D = z_F = \frac{d^2}{\lambda}$

For distances much smaller than z_F, the spreading due to diffraction is smaller compared to the size of the beam. It becomes comparable when the distance is approximately z_F. For distances much greater than z_F, the spreading due to diffraction dominates over that due to ray optics (i.e., the size a of the aperture). Ray optics is valid in the limit of wavelength tending to zero.

Example 11 :

Estimate the distance for which ray optics is good approximation for an aperture of 4 mm and wavelength 400nm.

Sol. Here, $a = 4mm = 4 \times 10^{-3}$ m

$\lambda = 400nm = 400 \times 10^{-9}$ m $= 4 \times 10^{-7}$ m

Ray optics is good approximation upto distances equal to Fresnel's distance (Z_F).

$$Z_F = \frac{a^2}{\lambda} = \frac{(4 \times 10^{-3})^2}{4 \times 10^{-7}} = 40m$$

POLARISATION

Experiments on interference and diffraction have shown that light is a form of wave motion. These effects do not tell us about the type of wave motion i.e., whether the light waves are longitudinal or transverse.

The phenomenon of polarization has helped to establish beyond doubt that light waves are transverse waves.

UNPOLARISED LIGHT

An ordinary beam of light consists of a large number of waves emitted by the atoms of the light source.

Each atom produces a wave with its own orientation of electric vector $\vec{E}$ so all direction of vibration of $\vec{E}$ are equally probable.

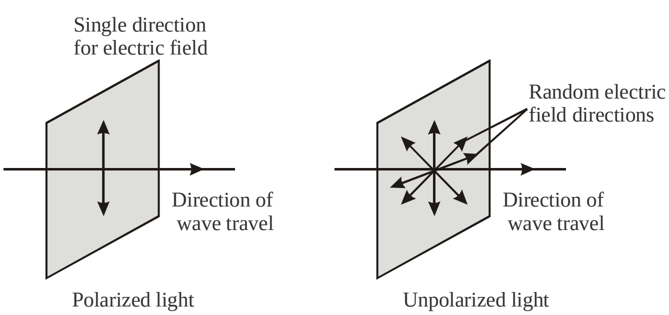
The resultant electromagnetic wave is a super position of waves produced by the individual atomic sources and it is called unpolarised light. In ordinary or unpolarised light, the vibrations of the electric vector occur symmetrically in all possible directions in a plane perpendicular to the direction of propagation of light.

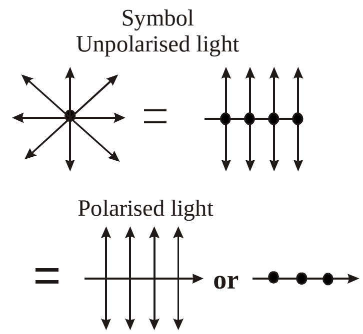
POLARISATION

The phenomenon of restricting the vibration of light (electric vector) in a particular direction perpendicular to the direction of propagation of wave is called polarisation of light.

In polarised light, the vibration of the electric vector occur in a plane perpendicular to the direction of propagation of light and are confined to a single direction in the plane (do not occur symmetrically in all possible directions).

After polarisation the vibrations become asymmetrical about the direction of propagation of light.





POLARISER

Tourmaline crystal : When light is passed through a tomaline crystal cut parallel to its optic axis, the vibrations of the light carrying out of the tourmaline crystal are confined only to one direction in a plane perpendicular to the direction of propagation of light. The emergent light from the crystal is said to be plane polarised light.

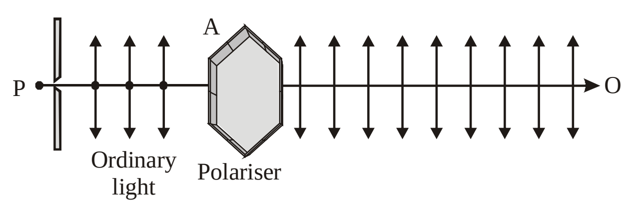
Nicol Prism : A nicol prism is an optical device which can be used for the production and detection of plane polarised light. It was invented by William Nicol in 1828.

Polaroid : A polaroid is a thin commercial sheet in the form of circular disc which makes use of the property of selective absorption to produce an intense beam of plane polarised light.

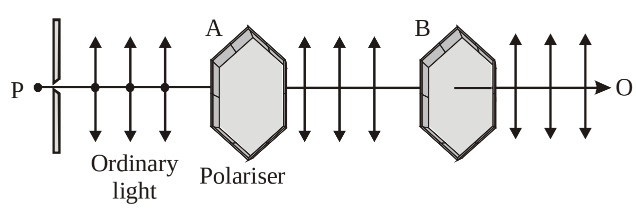
EXPERIMENTAL DEMONSTRATION OF POLARISATION OF LIGHT

Take two tourmaline crystals cut parallel to their crystallographic axis (optic axis).

First hold the crystal A normally to the path of a beam of colour light. The emergent beam will be slightly coloured.

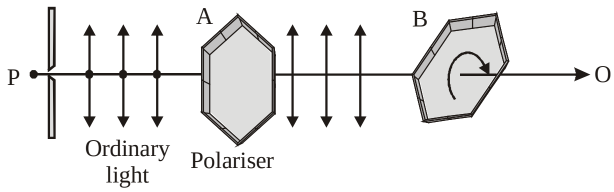


Rotate the crystal A about PO. No change in the intensity or the colour of the emergent beam of light. Take another crystal B and hold it in the path of the emergent beam of so that its axis is parallel to the axis of the crystal A. The beam of light passes through both the crystals and outcoming light appears coloured.



Now, rotate the crystal B about the axis PO.

It will be seen that the intensity of the emergent beam decreases and when the axes of both the crystals are at right angles to each other no light comes out of the crystal B.

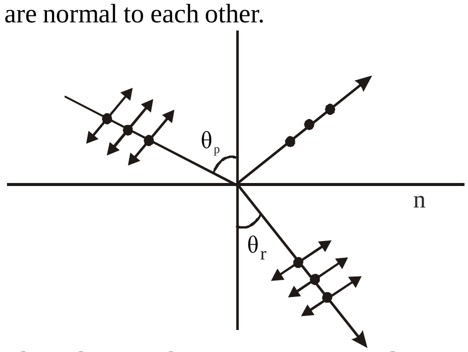


If the crystal B is further rotated light reappears and intensity becomes maximum again when their axes are parallel. This occurs after a further rotation of B through 90°. This experiment confirms that the light waves are transverse in nature.
The vibrations in light waves are perpendicular to the direction of propagation of the wave.
First crystal A polarises the light so it is called polariser.
Second crystal B, analyses the light whether it is polarised or not, so it is called analyser.

METHODS OF OBTAINING PLANE POLARISED LIGHT

Polarisation by reflection : The simplest method to produce plane polarised light is by reflection. This method was discovered by Malus in 1808. When a beam of ordinary light is reflected from a surface, the reflected light is partially polarised. The degree of polarisation of the polarised light in the reflected beam is greatest when it is incident at an angle called polarising angle or Brewster's angle.

Polarising angle : Polarising angle is that angle of incidence at which the reflected light is completely plane polarisation.
Brewster's Law : When unpolarised light strikes at polarising angle θ_p on an interface separating a rare medium from a denser medium of refractive index μ, such that $\mu = \tan\theta_p$ then the reflected light (light in rare medium) is completely polarised. Also reflected and refracted rays are normal to each other.



This relation is known as Brewster's law.
The law state that the tangent of the polarising angle of incidence of a transparent medium is equal to its refractive index $\mu = \tan\theta_p$
In case of polarisation by reflection :
(i) For $i = \theta_p$ refracted light is partially polarised.
(ii) For $i = \theta_p$ reflected and refracted rays are perpendicular to each other.
(iii) For $i < \theta_p$ or $i > \theta_p$ both reflected and refracted light become partially polarised.

According to snell's law, $\mu = \dfrac{\sin\theta_p}{\sin\theta_r}$ .... (i)

But according to Brewster's law

$$\mu = \tan\theta_p = \frac{\sin\theta_p}{\cos\theta_p} \quad \text{........ (ii)}$$

From equation (i) and (ii)

$$\frac{\sin\theta_p}{\sin\theta_r} = \frac{\sin\theta_p}{\cos\theta_p} \Rightarrow \sin\theta_r = \cos\theta_p$$

$\because \sin\theta_r = \sin(90° - \theta_r)$
$\Rightarrow \theta_r = 90° - \theta_p$ or $\theta_p + \theta_r = 90°$
Thus reflected & refracted rays are mutually perpendicular.

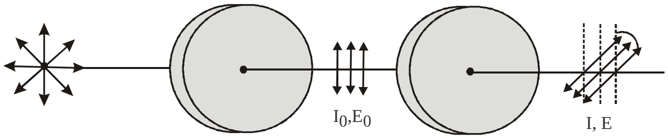
By Refraction : In this method, a pile of glass plates is formed by taking 20 to 30 microscope slides and light is made to be incident at polarising angle 57°. According Brewster law, the reflected light will be plane polarised with vibrations perpendicular to the plane of incidence and the transmitted light will be partially polarised.
Since in one reflection about 15% of the light with vibration perpendicular to plane of paper is reflected therefore after passing through a number of plates emerging light will become plane polarised with vibrations in the plane of paper.
By Dichroism : Some crystals such as tourmaline and sheets of iodosulphate of quinone have the property of strongly absorbing the light with vibrations perpendicular to the specific direction (called transmission axis) and transmitting the light with vibration parallel to it. This selective absorption of light is called dichroism. So if unpolarised light passes through proper thickness of these, the transmitted light will plane polarised with vibrations parallel to transmission axis. Polaroids work on this principle.
By scattering : When light is incident on small particles of dust, air molecule etc. (having smaller size as compared to the wavelength of light), it is absorbed by the electrons and is re-radiated in all directions. The phenomenon is called as scattering. Light scattered in a direction at right angles to the incident light is always plane-polarised.

LAW OF MALUS

When a completely plane polarised light beam is incident analyser, then intensity of emergent light varies as the square of cosine of the angle between the planes of transmission of the analyser and the polarizer.

$$I \propto \cos^2\theta \Rightarrow I = I_0 \cos^2\theta$$

(i) If $\theta = 0°$ then $I = I_0$ maximum value (Parallel arrangement)
(ii) If $\theta = 90°$ then $I = 0$ minimum value (Crossed arrangement)
If plane polarised light of intensity $I_0 (= KA^2)$ is incident on a polaroid and its vibrations of amplitude A make angle θ with transmission axis, then the component of vibrations parallel to transmission axis will be $A\cos\theta$ while perpendicular to it will be $A\sin\theta$.



Polaroid will pass only those vibrations which are parallel to transmission axis i.e. A cos θ $\because\ I_0 \propto A^2$

So the intensity of emergent light

$I = K(A\cos\theta)^2 = KA^2\cos^2\theta$

If an unpolarised light is converted into plane polarised light its intensity becomes half.

If light of intensity I_1, emerging from one polaroid called polariser is incident on a second polaroid (called analyser) the intensity of light emerging from the second polaroid is

$I_2 = I_1 \cos^2\theta$

θ= angle between the transmission axis of the two polaroids.

Optical activity : When plane polarised light passes through certain substances, the plane of polarisation of the emergent light is rotated about the direction of propagation of light through a certain angle. This phenomenon is optical rotation.

The substance which rotate the plane of polarision rotates the plane of polarisation is known as optical active substance. Ex. Sugar solution, sugar crystal, sodium chlorate etc.

Optical activity of a substance is measured with the help of polarimeter in terms of specific rotation which is defined as the rotation produced by a solution of length 10 cm (l dm) and of unit concentration (1g/cc) for a given wave length of light at a given temp.

Specific rotation

$$[\alpha]^{\lambda}_{t°C} = \frac{\theta}{L \times C}$$ θ = rotation in length L at concentration

Types of optically active substances

(a) Dextro rotatory substances : Those substances which rotate the plane of polarisation in clockwise direction are called dextro rotatory of right handed substances.

(b) Laveo rotatory substances : These substances which rotate the plane of polarisation in the anticlockwise direction are called laveo rotatory or left handed substances.

The amount of optical rotation depends upon the thickness and density of the crystal or concentration in case of solutions, the temperature and the wavelength of light used.

Rotation varies inversely as the square of the wavelength of light.

APPLICATIONS AND USES OF POLARISATION

* By determining the polarising angle and using Brewster's Law $\mu = \tan\theta_p$ refractive index of dark transparent substance can be determined.
* In calculators and watches, numbers and letters are formed by liquid crystals through polarisation of light called liquid crystal display (L.C.D.)
* In CD player polarised laser beam acts as needle for producing sound from compact disc.
* It has also been used in recording and reproducing three dimensional pictures.
* Polarised light is used in optical stress analysis known as photoelasticity.
* Polarisation is also used to study asymmetries in molecules and crystals through the phenomenon of optical activity.

Example 12 :

Two polaroids are crossed to each other. When one of them is rotated through 60°, then what percentage of the incident unpolarised light will be transmitted by the polaroids ?

Sol. Initially the polaroids are crossed to each other, that is the angle between their polarising directions is 90°. When one is rotated through 60°, then the angle between their polarising directions will become 30°.

Let the intensity of the incident unpolarised light = I_0

Then the intensity of light emerging from the first polaroid is $I_1 = \frac{1}{2}I_0$

This light is plane polarised and passes through the second polaroid. The intensity of light emerging from the second polaroid is $I_2 = I_1\cos^2\theta$

θ = the angle between the polarising directions of the two polaroids. $I_1 = \frac{1}{2}I_0$ and θ = 30°

So, $I_2 = I_1\cos^2 30° = \frac{1}{2}I_0\cos^2 30° \Rightarrow \frac{I_2}{I_0} = \frac{3}{8}$

$\Rightarrow$ Transmission % = $\frac{I_2}{I_0}\times 100 = \frac{3}{8}\times 100 = 37.5\%$

Example 13 :

At what angle of incidence will the light reflected from water (μ = 1.3) be completely polarised ?

Sol. From Brewster's law, $\tan\theta_p = \mu = 1.3 \Rightarrow \theta = \tan^{-1} 1.3 = 53°$

Example 14 :

If light beam is incident at polarising angle (56.3°) on air-glass interface, then what is the angle of refraction in glass?

Sol. $\because\ i_p + r_p = 90°$

$\therefore\ r = 90° - i_p = 90° - 56.3° = 33.7°$

TRY IT YOURSELF - 2

Q.1 A parallel beam of light of wavelength 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1 m away. It is observed that the first minimum is at a distance of 2.5 mm from the centre of the screen. Find the width of the slit.

Q.2 Two towers on top of two hills are 40 km apart. The line joining them passes 50 m above a hill halfway between the towers. What is the longest wavelength of radio waves, which can be sent between the towers without appreciable diffraction effects?

Q.3 Red light of wavelength 6500 Å from a distant source falls on a slit 0.5 mm wide. What is the distance between two dark bands on each side of central bright band of diffraction pattern observed on a screen placed 1.8 m from slit ?

Q.4 Calculate the distance of a beam of wavelength 500 nm can travel without significant broadening if the diffraction aperture is 3mm wide.

Q.5 A slit of width d is illuminated by light of wavelength 5500Å. What will be the value of d when (i) the first minimum falls at an angle of diffraction of 30°? (ii) The first maximum falls at an angle of diffraction of 30° ?

Q.6 The refractive index of denser medium is 1.732. Calculate (i) polarising angle (ii) the angle of refraction.

Q.7 Two polaroids 'A' and 'B' are kept in crossed position. How should a third polaroid 'C' be placed between them so that the intensity of polarized light transmitted by polaroid B reduces to 1/8th of the intensity of unpolarized light incident on A ?

ANSWERS

(1) 0.2 mm **(2)** 12.5cm. **(3)** 4.68×10^{-3} m
(4) 18 m **(5)** (i) 11000 Å, (ii) 16500 Å
(6) (i) 60°, (ii) 30° **(7)** 45°

ADDITIONAL EXAMPLES

Example 1 :

Consider interference between waves from two sources of intensities I & 4I. Find intensities at points where the phase difference is π.

(1) I (2) 5I
(3) 4I (4) 3I

Sol. **(1).** $I = R^2 = a_1^2 + a_2^2 + 2a_1 a_2 \cos\delta = I + 4I + 4I \cos\pi$
$I = 5I - 4I = I$

Example 2 :

The width of one of the two slits in a Young's double slits experiment is double of the other slit. Assuming that the amplitude of the light coming from a slit is proportion to slit-width. Find the ratio of the maximum to the minimum intensity in the interference pattern.

(1) 34 : 1 (2) 9 : 1
(3) 4: 1 (4) 16 : 1

Sol. **(2).** Suppose the amplitude of the light wave coming from the narrow slit is A and that coming from the wider slit is 2A. The maximum intensity occurs at a place where constructive interference takes place. Then the resultant amplitude is the sum of the individual amplitudes. Thus, $A_{max} = 2A + A = 3A$

The minimum intensity occurs at a place where destructive interference takes place. The resultant amplitude is then difference of the individual amplitudes.

Thus, $A_{min} = 2A - A = A$.

$$\therefore \frac{I_{max}}{I_{min}} = \frac{(A_{max})^2}{(A_{min})^2} = \frac{(3A)^2}{(A)^2} = 9$$

Example 3 :

The intensity of the light coming from one of the slits in a young's double slit experiment is double the intensity from the other slit. Find the ratio of the maximum intensity to the minimum intensity in the interference fringe pattern observed.

(1) 9 : 1 (2) 34 : 1
(3) 4 : 1 (4) 16 : 1

Sol. **(2).** $\frac{I_1}{I_2} = \frac{2}{1}$; $\frac{a_1}{a_2} = \sqrt{\frac{I_1}{I_2}} = \frac{\sqrt{2}}{1}$

At the point of constructive interference, the resultant amplitude becomes $(a_1 + a_2) = \sqrt{2} + 1$ at the point of destructive interference, the resultant amplitude is $(a_1 - a_2) = \sqrt{2} - 1$

$$\therefore \frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2} = \frac{(\sqrt{2}+1)^2}{(\sqrt{2}-1)^2} = 34$$

Example 4 :

Two waves originating from source S_1 and S_2 having zero phase difference and common wavelength λ will show completely destructive interference at a point P if $(S_1P - S_2P)$ is

(1) 5λ (2) 3λ/4
(2) 2λ (4) 11λ/2

Sol. **(4).** For destructive interference :

Path difference $= S_1P - S_2P = (2n - 1)\lambda/2$
For n = 1, $S_1P - S_2P = (2 \times 1 - 1)\lambda/2 = \lambda/2$
n = 2, $S_1P - S_2P = (2 \times 2 - 1)\lambda/2 = 3\lambda/2$
n = 3, $S_1P - S_2P = (2 \times 3 - 1)\lambda/2 = 5\lambda/2$
n = 4, $S_1P - S_2P = (2 \times 4 - 1)\lambda/2 = 7\lambda/2$
n = 5, $S_1P - S_2P = (2 \times 5 - 1)\lambda/2 = 9\lambda/2$
n = 6, $S_1P - S_2P = (2 \times 6 - 1)\lambda/2 = 11\lambda/2$

So, destructive pattern is possible only for path difference = 11λ/2.

Example 5 :

In an interference pattern, at a point we observe the 16th order maximum for $\lambda_1 = 6000$Å. What order will be visible here if the source is replaced by light of wavelength $\lambda_2 = 4800$Å .

(1) 40 (2) 20
(3) 10 (4) 80

Sol. **(2).** The distance of a bright fringe from zero order fringe is given by $X_n = \frac{n\lambda D}{d}$

D & d is constant
$n_1 \lambda_1 = n_2 \lambda_2$
$n_1 = 16, \lambda_1 = 6000$Å, $\lambda_2 = 4800$Å ; $n_2 = 20$

Example 6 :

In Young's experiment the wavelength of red light is 7.5×10^{-5} cm. and that of blue light 5.0×10^{-5} cm. The value of n for which $(n+1)^{th}$ the blue bright band coincides with n^{th} red band is -

(1) 8 (2) 4
(3) 2 (4) 1

Sol. **(3).** $n_1\lambda_1 = n_2\lambda_2$ for bright fringe

$$n(7.5\times10^{-5}) = (n+1)(5\times10^{-5})$$

$$n = \frac{5.0\times10^{-5}}{2.5\times10^{-5}} = 2.$$

Example 7 :

In Young's slit experiment, carried out with lights of wavelength λ = 5000 Å, the distance between the slit is 0.2mm and the screen is at 200 cm from the slits. The central maximum is at x = 0. The third maximum will be at x equal to.

(1) 1.67 cm (2) 1.5 cm
(3) 0.5 cm (4) 5.0 cm

Sol. **(2).** $X_n = \frac{n\lambda D}{d}$ or $X_3 = \frac{3\lambda D}{d}$

$$X_3 = \frac{3x\ (5000\times10^{-8})\times200}{0.02} = 1.5\text{ cm}$$

Example 8 :

Interference fringes were produced in young's double slit experiment using light of wave length 5000 A°. When a film of material 2.5×10^{-3} cm thick was placed over one of the slits, the fringe pattern shifted by a distance equal to 20 fringe width. The refractive index of the material of the film is

(1) 1.25 (2) 1.33
(3) 1.4 (4) 1.5

Sol. **(3).** $n = \frac{(\mu-1)tD}{d}$ but $\beta = \frac{\lambda D}{d} \Rightarrow \frac{D}{d} = \frac{\beta}{\lambda}$

$$n = (\mu-1)t\beta/\lambda$$

$$20\beta = (\mu-1)\,2.5\times10^{-3}\,(\beta/5000\times10^{-8})$$

$$\mu-1 = \frac{20\times5000\times x10^{-8}}{2.5\times10^{-3}} \Rightarrow \mu = 1.4$$

Example 9 :

The path difference between two interfering waves at a point on screen is 171.5 times the wavelength. If the path difference is 0.01029 cm. Find the wavelength.

(1) 6000×10^{-10} cm (2) 6000 Å
(3) 6000×10^{-8} mm (4) None

Sol. **(2).** Path difference = $171.5\,\lambda = \frac{343}{2}\lambda$

= odd multiple of half wavelength .

It means dark fringe is observed

According to question,

$$0.01029 = \frac{343}{2}\lambda \Rightarrow \lambda = \frac{0.01029\times2}{343} = 6\times10^{-5}\text{cm}$$

$\Rightarrow \lambda$ = 6000 Å

Example 10 :

A polariser and an analyser are oriented so that maximum light is transmitted, what will be the intensity of outcoming light when analyer is rotated through 60°.

Sol. According to Malus Law

$$I = I_0\cos^2\theta = I_0\cos^2 60° = I_0\left[\frac{1}{2}\right]^2 = \frac{I_0}{4}$$

Example 11 :

In young's double slit interference experiment, the distance between two sources is $0.1/\pi$ mm. The distance of the screen from the source is 25 cm. Wavelength of light used is 5000Å. Then the angular position of the first dark fringe is -

(1) 0.10° (2) 0.15°
(3) 0.30° (4) 0.45°

Sol. **(4).** The angular position $\theta = \frac{\beta}{D} = \frac{\lambda}{d}$ $(\because \beta = \frac{\lambda D}{d})$

The first dark fringe will be at half the fringe width from the mid point of central maximum. Thus the angular position of first dark fringe will be-

$$\alpha = \frac{\theta}{2} = \frac{1}{2}\left[\frac{\lambda}{d}\right];\ \alpha = \frac{1}{2}\left[\frac{5000\times\pi}{.1\times10^{-3}}\times10^{-10}\right]\frac{180}{\pi} = 0.45°.$$

Example 12 :

When wave of wavelength 0.2 cm is made incident normally on a slit of width 0.004m, then the semi-angular width of central maximum of diffraction pattern will be-

(1) 60° (2) 30°
(3) 90° (4) 0°

Sol. **(2).** $\theta = \sin^{-1}\left(\frac{\lambda}{a}\right)$ .... (1)

According to question, $\lambda = 2\times10^{-3}$ m

$a = 4\times10^{-3}$ m .... (2)

From equation (1) and (2) $\theta = \sin^{-1}\left(\frac{1}{2}\right) \Rightarrow \theta = 30°$

QUESTION BANK

CHAPTER 6 : OPTICS

EXERCISE - 1 [LEVEL-1]

Choose one correct response for each question.

PART 1 : REFLECTION BY PLANE MIRROR

Q.1 A ray is reflected in turn by two plane mirrors mutually at right angles to each other. The angle between the incident and the reflected rays is –

(A) 90° (B) 60°
(C) 180° (D) None

Q.2 Two plane mirrors are at right angles to each other. A man stands between them and combs his hair with his right hand. In how many of the images will he be seen using his right hand

(A) None (B) 1
(C) 2 (D) 3

Q.3 A man runs towards a mirror at a speed 15 m/s. The speed of the image relative to the man is

(A) 15 m/s (B) 30 m/s
(C) 35 m/s (D) 20 m/s

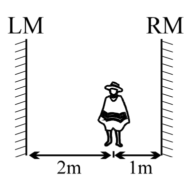
Q.4 Focal length of a plane mirror is

(A) Zero (B) Infinite
(C) Very less (D) Indefinite

Q.5 A clock hung on a wall has marks instead of numbers on its dial. On the opposite wall there is a mirror, and the image of the clock in the mirror if read, indicates the time as 8:20. What is the time in the clock.

(A) 3:40 (B) 4:40
(C) 5:20 (D) 4:20

Q.6 Two mirrors, labeled LM for left mirror and RM for right mirror in the adjacent figure, are parallel to each other and 3.0 m apart. A person standing 1.0 m from the right mirror (RM) looks into this mirror and sees a series of images. How far from the person is the second closest image seen in the right mirror (RM)?



(A) 10.0 m (B) 4.0 m
(C) 6.0 m (D) 8.0 m

Q.7 A plane mirror approaches a stationary person with some acceleration 'a'. The acceleration of his image, as seen by the person, will be

(A) a (B) 2a
(C) a/2 (D) none

PART 2 : REFLECTION BY SPHERICAL MIRROR

Q.8 The focal length of a concave mirror is 50cm. Where an object be placed so that its image is two times and inverted

(A) 75 cm (B) 72 cm
(C) 63 cm (D) 50 cm

Q.9 The minimum distance between the object and its real image for concave mirror is

(A) f (B) 2f
(C) 4f (D) Zero

Q.10 An object 2.5 cm high is placed at a distance of 10 cm from a concave mirror of radius of curvature 30 cm The size of the image is

(A) 9.2 cm (B) 10.5 cm
(C) 5.6 cm (D) 7.5 cm

Q.11 Image formed by a concave mirror of focal length 6 cm, is 3 times of the object, then the distance of object from mirror is –

(A) – 4 cm (B) 9 cm
(C) 6 cm (D) 12 cm

Q.12 A concave mirror of focal length f (in air) is immersed in water (μ = 4/3). The focal length of the mirror in water will be

(A) f (B) (4/3) f
(C) (3/4) f (D) (7/3) f

Q.13 Radius of curvature of concave mirror is 40cm & the size of image is twice as that of object, then the object distance is

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

Q.14 A concave mirror gives an image three times as large as the object placed at a distance of 20cm from it. For the image to be real, the focal length should be

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

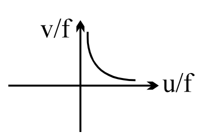
Q.15 The distance of an object from a spherical mirror is equal to the focal length of the mirror. Then the image:

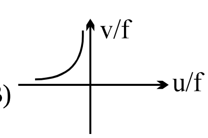
(A) must be at infinity (B) may be at infinity
(C) may be at the focus (D) none

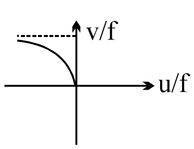
Q.16 Find the incorrect statement/s for a concave mirror producing a virtual image of the object.

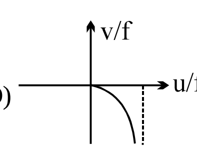
(A) The linear magnification is always greater than one, except at the pole.
(B) The linear magnification is always less than one.
(C) The magnification tends to one as the object move nearer to the pole of the mirror.
(D) The distance of the object from the pole of the mirror is less than the focal length of mirror.

Q.17 A virtual erect image in a concave mirror is represented, in the given figure, by

(A) 

(B) 

(C) 

(D) 

PART 3 : REFRACTION AT PLANE SURFACE

Q.18 Velocity of light in a medium is 1.5×10^8 m/s. Its refractive index will be –
(A) 8 (B) 6
(C) 4 (D) 2

Q.19 Light travels through a glass plate of thickness t and having refractive index n. If c is the velocity of light in vacuum, the time taken by the light to travel this thickness of glass is
(A) t/nc (B) tnc
(C) nt/c (D) tc/n

Q.20 When a light wave goes from air into water, the quantity that remains unchanged is its
(A) Speed (B) Amplitude
(C) Frequency (D) Wavelength

Q.21 The refractive indices of glass and water w.r.t. air are 3/2 and 4/3 respectively. The refractive index of glass w.r.t. water will be
(A) 8/9 (B) 9/8
(C) 7/6 (D) None of these

Q.22 For a colour of light the wavelength for air is 6000 Å and in water the wavelength is 4500 Å. Then the speed of light in water will be
(A) 5.0×10^{14} m/s (B) 2.25×10^8 m/s
(C) 4.0×10^8 m/s (D) Zero

Q.23 The speed of light in air is 3×10^8 m/s. What will be its speed in diamond whose refractive index is 2.4
(A) 3×10^8 m/s (B) 332 m/s
(C) 1.25×10^8 m/s (D) 7.2×10^8 m/s

Q.24 The refractive index of a piece of transparent quartz is the greatest for
(A) Red light (B) Violet light
(C) Green light (D) Yellow light

Q.25 The wavelength of sodium light in air is 5890 Å. The velocity of light in air is 3×10^8 m/s. The wavelength of light in a glass of refractive index 1.6 would be close to
(A) 5890 Å (B) 3681 Å
(C) 9424 Å (D) 15078 Å

Q.26 Speed of light is maximum in
(A) Water (B) Air
(C) Glass (D) Diamond

Q.27 Which one of the following statements is correct
(A) In vacuum, the speed of light depends upon frequency.
(B) In vacuum, the speed of light does not depend upon frequency but depends on wavelength.
(C) In vacuum, the speed of light is independent of frequency and wavelength.
(D) In vacuum, the speed of light depends upon wavelength.

Q.28 The distance travelled by light in glass (refractive index = 1.5) in a nanosecond will be
(A) 45 cm (B) 40 cm
(C) 30 cm (D) 20 cm

Q.29 The apparent depth of a swimming pool is 1.2m. What is its real depth ? (Take $\mu_g = 4/3$)
(A) 1.6m (B) 2.5m
(C) 3.2m (D) 1m

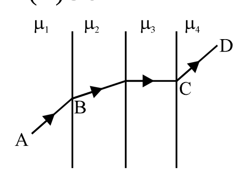
Q.30 A ray of light passes from vacuum into a medium of refractive index n. If the angle of incidence is twice the angle of refraction , then the angle of incidence is :
(A) $\cos^{-1}$ (n/2) (B) $\sin^{-1}$ (n/2)
(C) $2\cos^{-1}$ (n/2) (D) $2\sin^{-1}$(n/2)

Q.31 A parallel beam of light, travelling in air, is incident at an angle of 60° on a plane boundary of refractive index $\sqrt{3}$. The angle between incident and refracted wavefronts, is
(A) 0° (B) 30°
(C) 60° (D) 150°

Q.32 A glass slab of thickness 3 cm and refractive index 3/2 is placed on ink mark on a piece of paper. For a person looking at the mark at a distance 5.0 cm above it, the distance of the mark will appear to be –
(A) 3.0 cm (B) 4.0 cm
(C) 4.5 cm (D) 5.0 cm

Q.33 A fish at a depth of 12 cm in water is viewed by an observer on the bank of a lake. To what height the image of the fish is raised.
(A) 9 cm (B) 12 cm
(C) 3.8 cm (D) 3 cm

Q.34 A ray of light passes through four transparent media with refractive indices μ_1, μ_2, μ_3 and μ_4 as shown in the figure.



The surfaces of all media are parallel. If the emergent ray CD is parallel to the incident ray AB, we must have :
(A) $\mu_1 = \mu_2$ (B) $\mu_2 = \mu_3$
(C) $\mu_3 = \mu_4$ (D) $\mu_4 = \mu_1$

PART 4 : TOTAL INTERNAL REFLECTION

Q.35 Critical angle of light passing from glass to air is minimum for –
(A) Red (B) Green
(C) Yellow (D) Violet

Q.36 The wavelength of light in two liquids 'x' and 'y' is 3500Å and 7000 Å, then the critical angle of x relative to y will be
(A) 60° (B) 45°
(C) 30° (D) 15°

Q.37 For total internal reflection to take place, the angle of incidence i and the refractive index μ of the medium must satisfy the inequality
(A) $\frac{1}{\sin i} < \mu$ (B) $\frac{1}{\sin i} > \mu$
(C) $\sin i < \mu$ (D) $\sin i > \mu$

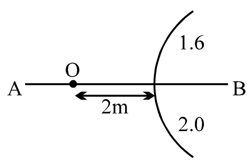
Q.38 Total internal reflection of light is possible when light enters from
(A) Air to glass (B) Vacuum to air
(C) Air to water (D) Water to air

Q.39 A cut diamond sparkles because of its
(A) Hardness
(B) High refractive index
(C) Emission of light by the diamond
(D) Absorption of light by the diamond

Q.40 If the critical angle for total internal reflection from a medium to vacuum is 30°, the velocity of light in the medium is
(A) 3×10^8 m/s (B) 1.5×10^8 m/s
(C) 6×10^8 m/s (D) $\sqrt{3} \times 10^8$ m/s

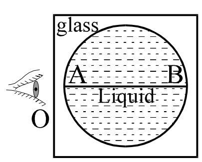
PART 5 : REFRACTION AT SPHERICAL SURFACES

Q.41 In the figure shown a point object O is placed in air. A spherical boundary separates various media of radius of curvature 1.0 m. AB is principal axis. The refractive index above AB is 1.6 and below AB is 2.0. The separation between the images formed due to refraction at spherical surface is:



(A) 12 m (B) 20 m
(C) 14 m (D) 10 m

Q.42 The observer 'O' sees the distance AB as infinitely large. If refractive index of liquid is μ_1 and that of glass is μ_2, then μ_1/μ_2 is:



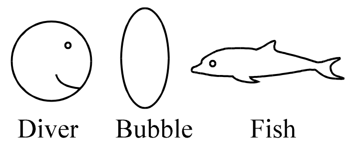
(A) 2 (B) 1/2
(C) 4 (D) None of these

Q.43 A solid transparent sphere ($\mu = 1.5$) has a small dot at its center. When observed from outside, the apparent position of the dot will be
(A) closer to the eye than its actual position.
(B) same as its actual position.
(C) farther away from the eye than its actual position.
(D) at infinity.

PART 6 : LENS

Q.44 Which of the following is not the case with the image formed by concave lens ?
(A) It may be erect or inverted.
(B) It may be magnified or diminished.
(C) It may be real or virtual.
(D) Real image may be between the pole and focus or beyond focus.

Q.45 A fish sees the smiling face of a scuba diver through a bubble of air between them, as shown. Compared to the face of the diver, the image seen by the fish will be –

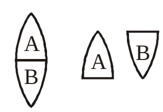


(A) smaller and erect
(B) smaller and inverted
(C) larger and erect
(D) Can be either of above depending on the distance of the diver.

Q.46 A bi-convex lens is made from glass of refractive index 1.5 and radius of curvature of both surfaces of the lens is 20cm. The incident ray parallel to principal axis will be focussed at a distance Lcm from lens on principal axis where :
(A) L = 10 (B) L = 20
(C) L = 40 (D) L = 20/3

Q.47 A convex lens of power 4D is kept in contact with a concave lens of power 3D, the effective power of combination will be :
(A) 7D (B) 4D/3
(C) 1D (D) 3D/4

Q.48 The power of a plano-convex lens is P. If this lens is cut longitudinally along its principal axis into two equal parts and then they are joined as given in the figure. The power of combination will be :

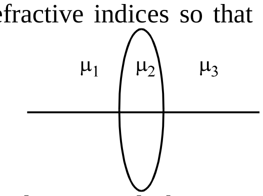


(A) P (B) 2P
(C) P/2 (D) zero

Q.49 If the focal length of a magnifier is 5 cm calculate the power of the lens.
(A) 20 D (B) 10 D
(C) 5 D (D) 15 D

Q.50 A concave lens with unequal radii of curvature made of glass ($\mu_g = 1.5$) has a focal length of 40 cm. In air if it is immersed in a liquid of refractive index $\mu_l = 2$, then
(A) it behaves like convex lens of 80 cm focal length.
(B) it behave like a convex lens of 20 cm focal length.
(C) its focal length becomes 60 cm.
(D) nothing can be said.

Q.51 The diagram shows an equiconvex lens. What should be the condition on the refractive indices so that the lens become diverging?



(A) $2\mu_2 > \mu_1 - \mu_3$
(B) $2\mu_2 < \mu_1 + \mu_3$
(C) $2\mu_2 > 2\mu_1 - \mu_3$
(D) $2\mu_2 > \mu_1 + \mu_3$

Q.52 In the case of a converging lens, a real object is at a finite distance L from the lens. It is moving with speed 5m/s. The image is formed at one of the focus of the lens. What is the speed of the image?
(A) 5 m/s (B) infinite
(C) 10 m/s (D) 20 m/s

Q.53 A converging lens is used to produce an image on a screen of an object. What change is needed for the real image to be formed nearer to the lens ?
(A) increase the focal length of the lens (lens and position of object is fixed).
(B) insert a diverging lens between the lens and the screen(converging lens & position of object is fixed).
(C) increase the distance of the object from the lens.
(D) move the object closer to the lens.

PART 7 : REFRACTION IN A PRISM

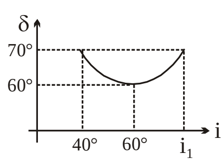
Q.54 A thin prism of angle A = 6° produces a deviation δ = 3°. Find the refractive index of the material of prism.
(A) 1.5 (B) 1.0
(C) 2.5 (D) 0.5

Q.55 Dispersion occurs when
(A) some material bend light more that other material.
(B) a material changes some frequencies more than other.
(C) light has different speeds in different materials.
(D) a material slows down some wavelengths more than others.

Q.56 White light is dispersed by the prism, and falls on a screen to form a visible spectrum. Which of the following is/are true?
(A) The frequency changes for each colour, but the speed stays the same.
(B) Red wavelengths are deviated through larger angles than green wavelengths.
(C) Violet light propagates at a higher speed than green light while in the prism.
(D) The speed of all colours is reduced in the prism, with maximum reduction for violet light.

Q.57 For a prism kept in air it is found that for an angle of incidence 60°, the angle of refraction 'A', angle of deviation 'δ' and angle of emergence 'e' become equal. Then the refractive index of the prism is
(A) 1.73 (B) 1.15
(C) 1.5 (D) 1.33

Q.58 The curve of angle of incidence versus angle of deviation shown has been plotted for prism. The value of refractive index of the prism used is



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

Q.59 In the given curve of **above question**. Find the value of angle i_1 in degrees is
(A) 40° (B) 60°
(C) 70° (D) 90°

PART 8 : SCATTERING OF LIGHT

Q.60 When light rays undergoes two internal reflection inside a raindrop, which of the rainbow is formed?
(A) Primary rainbow (B) Secondary rainbow
(C) Both (A) & (B) (D) Can't say

Q.61 At sunset or sunrise, the Sun's rays have to pass through a larger distance as
(A) shorter wavelengths are removed by scattering.
(B) longer wavelengths are removed by scattering.
(C) less frequency of scattering wavelength.
(D) Both (A) and (B).

Q.62 A passenger in an aeroplane shall
(A) never see a rainbow.
(B) may see a primary and a secondary rainbow as concentric circles.
(C) may see a primary and a secondary rainbow as concentric arcs.
(D) shall never see a secondary rainbow.

Q.63 The amount of scattering is inversely proportional to the fourth power of the wavelength. This is known as –
(A) rayleigh scattering (B) maxwell scattering
(C) oserted scattering (D) reynold scattering

Q.64 Which of the following statement is correct?
(A) At sunset or sunrise, the sun's rays have to pass through a small distance in the atmosphere.
(B) Rayleigh scattering which is proportional to $(1/\lambda)^2$.
(C) At sunset or sunrise the sun's rays have to pass through a larger distance in the atmosphere.
(D) Most of the blue and other shorter wavelengths are not removed by scattering.

Q.65 Red colour is used for danger signals because
(A) it causes fear.
(B) it undergoes least scattering.
(C) it undergoes maximum scattering.
(D) None of the above

PART 9 : HUMAN EYE

Q.66 A person cannot see distinctly at the distance less than one metre. Calculate the power of the lens that he should use to read a book at a distance of 25 cm
(A) + 3.0 D (B) + 0.125 D
(C) – 3.0 D (D) + 4.0 D

Q.67 A man can see upto 100 cm of the distant object. The power of the lens required to see far objects will be
(A) + 0.5 D (B) + 1.0 D
(C) + 2.0 D (D) – 1.0 D

Q.68 For the myopic eye, the defect is cured by
(A) Convex lens (B) Concave lens
(C) Cylindrical lens (D) Toric lens

Q.69 A person can not see the objects beyond 50cm. The power of a lens to correct this vision will be
(A) + 2 D (B) – 2 D
(C) + 5 D (D) 0.5 D

PART 10 : MICROSCOPE

Q.70 The focal length of the objective lens of a compound microscope is –
(A) Equal to the focal length of its eye piece
(B) Less than the focal length of eye piece
(C) Greater than the focal length of eye piece
(D) Any of the above three

Q.71 Least distance of distinct vision is 25 cm. Magnifying power of simple microscope of focal length 5 cm is
(A) 1 / 5 (B) 5
(C) 1 / 6 (D) 6

Q.72 The magnify power of the objective of a compound microscope is 7 if the magnifying power of the microscope is 35, then the magnifying power is eyepiece will be
(A) 245 (B) 5
(C) 28 (D) 42

Q.73 In a compound microscope, the focal lengths of two lenses are 1.5 cm and 6.25 cm. If an object is placed at 2cm from objective and the final image is formed at 25cm from eye lens, the distance between the two lenses is
(A) 6.00 cm (B) 7.75 cm
(C) 9.25 cm (D) 11.0 cm

PART 11 : TELESCOPE

Q.74 An astronomical telescope has an angular magnification of magnitude 5 for distant objects. The separation between the objective and eye- piece is 36 cm and the final image is formed at infinity. Determine the focal length of objective and eye-piece.
(A) 30cm, 6cm, (B) 15cm, 12cm
(C) 25cm, 12cm (D) 8cm, 12cm

Q.75 The focal length of achromatic combination of a telescope is 90cm. The dispersive powers of lenses are 0.024 and 0.036 respectively. Their focal lengths will be -
(A) 30 cm and 60 cm (B) 45 cm and 90 cm
(C) 15 cm and 45 cm (D) 30 cm and – 45 cm

Q.76 A reflecting telescope has a large mirror for its objective with radius of curvature equal to 80 cm. The magnifying power of this telescope if eye piece used has a focal length of 1.6 cm is
(A) 100 (B) 50
(C) 25 (D) 5

Q.77 A small telescope has an objective lens of focal length 144 cm and an eye piece of focal length 6.0cm. What is the separation between the objective and the eye piece?
(A) 0.75 m (B) 1.38 m
(C) 1.0 m (D) 1.5 m

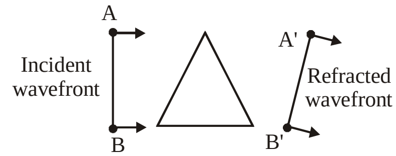
PART - 12 : HUYGEN'S PRINCIPLE

Q.78 The idea of secondary wavelets for the propagation of a wave was first given by
(A) Newton (B) Huygen
(C) Maxwell (D) Fresnel

Q.79 By a monochromatic wave, we mean
(A) A single ray
(B) A single ray of a single colour
(C) Wave having a single wavelength
(D) Many rays of a single colour

Q.80 A shortcoming of Huygen model could not
(A) explain the absence of the backwave.
(B) determine the shape of the wavefront for a plane wave.
(C) explain the point source emitting waves uniformly in all directions.
(D) All of the above

Q.81 Figure shows behaviour of a wavefront when it passes through a prism.



Which of the following statement{s) is/are correct?
I. Lower portion of wavefront (B') is delayed resulting in a tilt.
II. Time taken by light to reach A' from A is equal to the time taken to reach B' from B.
III. Speed of wavefront is same everywhere.
IV. A particle on wavefront A' B' is in phase with a particle on wavefront AB.
(A) I and II (B) II and III
(C) III and IV (D) I and III

Q.82 Ray diverging from a point source form a wavefront that is
(A) cylindrical (B) spherical
(C) plane (D) cubical

PART - 13 : INTERFERENCE OF LIGHT

Q.83 Two identical light sources S_1 and S_2 emit light of same wavelength λ. These light rays will exhibit interference if
(A) Their phase differences remain constant
(B) Their phases are distributed randomly
(C) Their light intensities remain constant
(D) Their light intensities change randomly

Q.84 The ratio of intensities of two waves are given by 4 : 1. The ratio of the amplitudes of the two waves is
(A) 2 : 1 (B) 1 : 2
(C) 4 : 1 (D) 1 : 4

Q.85 As a result of interference of two coherent sources of light, energy is
(A) Increased
(B) Redistributed and the distribution does not vary with time
(C) Decreased
(D) Redistributed and the distribution changes with time

Q.86 What causes changes in the colours of the soap or oil films for the given beam of light
(A) Angle of incidence (B) Angle of reflection
(C) Thickness of film (D) None of these

Q.87 The intensity ratio of two waves is 9 : 1. These waves produce the event of interference. The ratio of maximum to minimum intensity will be
(A) 1 : 9 (B) 9 : 1
(C) 1 : 4 (D) 4 : 1

Q.88 If the ratio of intensities of two waves is 1 : 25, then the ratio of their amplitudes will be
(A) 1 : 25 (B) 5 : 1
(C) 26 : 24 (D) 1 : 5

Q.89 If the amplitude ratio of two sources producing

interference is 3 : 5, the ratio of intensities at maxima and minima is
(A) 25 : 16 (B) 5 : 3
(C) 16 : 1 (D) 25 : 9

Q.90 Two light sources are said to be coherent if they are obtained from –
(A) Two independent point sources emitting light of the same wavelength.
(B) A single point source.
(C) A wide source.
(D) Two ordinary bulbs emitting light of different wavelengths.

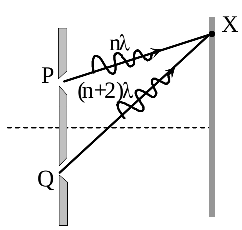
Q.91 Two waves of intensity I undergo Interference. The maximum intensity obtained is
(A) I / 2 (B) I
(C) 2I (D) 4I

Q.92 Two beams of light having intensities I and 4I interfere to produce a fringe pattern on a screen. The phase difference between the beams is $\pi/2$ at point A and π at point B. Then the difference between the resultant intensities at A and B is
(A) 2I (B) 4I
(C) 5I (D) 7I

PART - 14 : YOUNG'S DOUBLE SLIT EXPERIMENT

Q.93 Two coherent light sources S_1 and S_2 (λ= 6000 Å) are 1mm apart from each other. The screen is placed at a distance of 25 cm from the sources. The width of the fringes on the screen should be
(A) 0.015 cm (B) 0.025 cm
(C) 0.010 cm (D) 0.030 cm

Q.94 The figure shows a double slit experiment P and Q are the slits. The path lengths PX and QX are $n\lambda$ and $(n+2)\lambda$ respectively, where n is a whole number and λ is the wavelength. Taking the central fringe as zero, what is formed at X



(A) First bright (B) First dark
(C) Second bright (D) Second dark

Q.95 In the Young's double slit experiment, the spacing between two slits is 0.1 mm. If the screen is kept at a distance of 1.0m from the slits and the wavelength of light is 5000 Å, then the fringe width is
(A) 1.0 cm (B) 1.5 cm
(C) 0.5 cm (D) 2.0 cm

Q.96 In Young's double slit experiment, if L is the distance between the slits and the screen upon which interference pattern is observed, x is the average distance between the adjacent fringes and d being the slit separation. The wavelength of light is given by
(A) xd/L (B) xL/d
(C) Ld/x (D) 1/Ldx

Q.97 If yellow light in the Young's double slit experiment is replaced by red light, the fringe width will
(A) Decrease
(B) Remain unaffected
(C) Increase
(D) First increase and then decrease

Q.98 In Young's experiment, the ratio of maximum to minimum intensities of the fringe system is 4 : 1. Ratio of amplitudes of the coherent sources –
(A) 4 : 1 (B) 3 : 1
(C) 2 : 1 (D) 1 : 1

Q.99 In a Young double slit experiment, two films of thickness t_1 and t_2 having refractive indices μ_1 and μ_2 are placed in front of slits A and B respectively. If $\mu_1 t_1 = \mu_2 t_2$ the central max. will
(A) not shift
(B) shift towards A if $t_1 < t_2$
(C) shift towards B if $t_1 < t_2$
(D) shift towards A if $t_1 > t_2$

Q.100 In young's double slit experiment, the distance between two slits is made three times then the fringe width will become –
(A) 9 times (B) 1/9 times
(C) 3 times (D) 1/3 times

Q.101 A double slit experiment is performed with light of wavelength 500 nm. A thin film of thickness 2μm and refractive index 1.5 is introduced in the path of the upper beam. The location of the central maximum will –
(A) Remain unshifted
(B) Shift downward by nearly two fringes
(C) Shift upward by nearly two fringes
(D) Shift downward by 10 fringes

Q.102 Waves from two slits are in phase at the slits and travel to a distant screen to produce the second minimum of the interference pattern. The difference in the distance traveled by the waves
(A) half a wavelength
(B) a wavelength
(C) three halves of a wavelength
(D) two wavelengths

PART - 15 : DIFFRACTION

Q.103 The penetration of light into the region of geometrical shadow is called
(A) Polarisation (B) Interference
(C) Diffraction (D) Refraction

Q.104 A slit of size 0.15 cm is placed at 2.1 m from a screen. On illuminating it by a light of wavelength 5×10^{-5}cm, the width of central maxima will be
(A) 70 mm (B) 0.14 mm
(C) 1.4 mm (D) 0.14 cm

Q.105 Red light is generally used to observe diffraction pattern

from single slit. If blue light is used instead of red light, then diffraction pattern
(A) Will be more clear (B) Will contract
(C) Will expanded (D) Will not be visualized

Q.106 A beam of light of wavelength 600 nm from a distant source falls on a single slit 1 mm wide and the resulting diffraction pattern is observed on a screen 2 m away. The distance between the first dark fringes on either side of the central bright fringe is
(A) 1.2 mm (B) 1.2 cm
(C) 2.4 cm (D) 2.4 mm

Q.107 In order to see diffraction the thickness of the film is
(A) 100 Å (B) 6,000 Å
(C) 1 mm (D) 1 cm

Q.108 Fraunhoffer diffraction pattern is observed at a distance of 2m on screen, when a plane-wavefront of 6000Å is incident perpendicularly on 0.2 mm wide slit. Width of central maxima is:
(A) 10 mm (B) 6mm
(C) 12 mm (D) None

Q.109 The first diffraction minima due to a single slit diffraction is at $\theta = 30°$ for a light of wavelength 5000Å. The width of the slit is-
(A) 5×10^{-5} cm (B) 1.0×10^{-4} cm
(C) 2.5×10^{-5} cm (D) 1.25×10^{-5} cm

PART - 16 : RESOLVING POWER

Q.110 The diameter of objective lens of a telescope is 6cm and wavelength of light used is 540nm. The resolving power of telescope is –
(A) 9.1×10^4 rad^{-1} (B) 10^5 rad^{-1}
(C) 3×10^4 rad^{-1} (D) None of the above

Q.111 For better resolution, a telescope must have a
(A) large diameter objective. (B) small diameter objective.
(C) may be large. (D) neither large nor small.

Q.112 The resolving power of a microscope is basically determined by the –
(A) speed of the light used.
(B) wavelength of the light used.
(C) both (A) and (B).
(D) neither (A) nor (B).

PART - 17 : POLARISATION

Q.113 Two Nicols are oriented with their principal planes making an angle of 60°. The percentage of incident unpolarized light which passes through the system is
(A) 50% (B) 100%
(C) 12.5% (D) 37.5%

Q.114 When light of a certain wavelength is incident on a plane surface of a material at a glancing angle 30°, the reflected light is found to be completely plane polarised. Determine refractive index of given material –
(A) $\sqrt{3}$ (B) $\sqrt{2}$
(C) $1/\sqrt{2}$ (D) 2

Q.115 The critical angle of a certain medium is $\sin^{-1}(3/5)$. The polarizing angle of the medium is –
(A) $\sin^{-1}(4/5)$ (B) $\tan^{-1}(5/3)$
(C) $\tan^{-1}(3/4)$ (D) $\tan^{-1}(4/3)$

EXERCISE - 2 (LEVEL-2)

Choose one correct response for each question.

Q.1 An object of length 6 cm is placed on the principle axis of a concave mirror of focal length f at a distance of 4f. The length of the image will be
(A) 2 cm (B) 12 cm
(C) 4 cm (D) 1.2 cm

Q.2 A ray of light travelling inside a rectangular glass block of refractive index $\sqrt{2}$ is incident on the glass–air surface at an angle of incidence of 45°. The refractive index of air is 1. Under these conditions the ray –
(A) Will emerge into the air without any deviation.
(B) Will be reflected back into the glass.
(C) Will be absorbed.
(D) Will emerge into the air with an angle of refraction equal to 90°.

Q.3 What is the time taken by light to cross a glass of thickness 4 mm and $\mu = 3$
(A) 4×10^{-11} sec (B) 2×10^{-11} sec
(C) 16×10^{-11} sec (D) 8×10^{-10} sec

Q.4 An under water swimmer is at a depth of 12 m below the surface of water. A bird is at a height of 18 m from the surface of water, directly above his eyes. For the swimmer the bird appears to be at a distance from the surface of water equal to (Refractive Index of water is 4/3)
(A) 24 m (B) 12 m
(C) 18 m (D) 9 m

Q.5 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

Q.6 A plane sound wave travels from air to water. The angle of incidence is α_1 and the angle of refraction is α_2. Assuming Snell's law to be valid
(A) $\alpha_2 < \alpha_1$ (B) $\alpha_2 > \alpha_1$
(C) $\alpha_2 = \alpha_1$ (D) $\alpha_2 = 90°$

Q.7 Light passes from air into flint glass with index of refraction μ. What angle of incidence must the light have so that the component of its velocity perpendicular to the interface remains same in both medium?
(A) $\tan^{-1}(1/\mu)$ (B) $\sin^{-1}(1/\mu)$
(C) $\cos^{-1}(1/\mu)$ (D) $\tan^{-1}\mu$

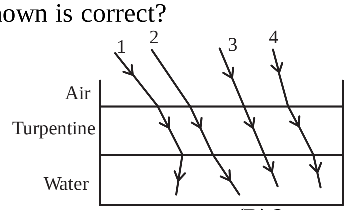
Q.8 If an observer is walking away from the plane mirror with 6m/sec. Then the velocity of the image with respect to observer will be
(A) 6m/sec (B) – 6m/sec
(C) 12 m/sec (D) 3m/sec

Q.9 An object of size 7.5cm is placed in front of a convex mirror of radius of curvature 25cm at a distance of 40cm. The size of the image should be
(A) 2.3 cm (B) 1.78 cm
(C) 1 cm (D) 0.8 cm

Q.10 The image formed by a convex mirror of focal length 30cm is a quarter of the size of the object. The distance of the object from the mirror is
(A) 30cm (B) 90cm
(C) 120cm (D) 60cm

Q.11 A concave mirror is used to focus the image of a flower on a nearby well 120cm from the flower. If a lateral magnification of 16 is desired, the distance of the flower from the mirror should be
(A) 8cm (B) 12cm
(C) 80cm (D) 120cm

Q.12 The optical density of turpentine is higher than that of water while its mass density is lower. Fig shows a layer of turpentine floating over water in a container. For which one of the four rays incident on turpentine in Fig, the path shown is correct?



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

Q.13 A light wave has a frequency of 4×10^{14} Hz and a wavelength of 5×10^{-7} meters in a medium. The refractive index of the medium is
(A) 1.5 (B) 1.33
(C) 1.0 (D) 0.66

Q.14 A concave lens of glass, refractive index 1.5 has both surfaces of same radius of curvature R. On immersion in a medium of refractive index 1.75, it will behave as a :
(A) convergent lens of focal length 3.5 R.
(B) convergent lens of focal length 3 R.
(C) divergent lens of focal length 3.5 R.
(D) divergent lens of focal length 3 R.

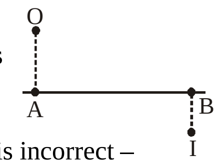
Q.15 The ratio of thickness of plates of two transparent mediums A and B is 6 : 4. If light takes equal time in passing through them, then refractive index of B with respect to A will be
(A) 1.4 (B) 1.5
(C) 1.75 (D) 1.33

Q.16 Refractive index of air is 1.0003. The correct thickness of air column which will have one more wavelength of yellow light (6000 Å) then in the same thickness in vacuum is
(A) 2 mm (B) 2 cm
(C) 2 m (D) 2 km

Q.17 A diver at a depth of 12m in water (μ = 4/3) sees the sky in a cone of semi-vertical angle
(A) $\sin^{-1}$ (4/3) (B) $\tan^{-1}$ (4/3)
(C) $\sin^{-1}$ (3/4) (D) 90°

Q.18 A person wears glasses of power – 2.5 D. The defect of the eye and the far point of the person without the glasses are respectively
(A) Farsightedness, 40 cm
(B) Nearsightedness, 40 cm
(C) Astigmatism, 40 cm
(D) Nearsightedness, 250 cm

Q.19 A luminous point object is placed at O, whose image is formed at I as shown in figure. Line AB is the optical axis.



Which of the following statement is incorrect –
(A) If a lens is used to obtain the image, then it must be a converging lens and its optical centre will be the intersection point of line AB and OI.
(B) If a lens is used to obtain the image, then it must be a diverging lens and its optical centre will be the intersection point of line AB and OI.
(C) If a mirror is used to obtain the image, then the mirror must be concave and object and image subtend equal angles at the pole of the mirror.
(D) I is real image

Q.20 A student can distinctly see the object upto a distance 15cm. He wants to see the black board at a distance of 3m. Focal length and power of lens used respectively will be
(A) – 4.8cm, –3.3D (B) – 5.8cm, –4.3D
(C) – 7.5cm, –6.3D (D) – 15.8cm, –6.3D

Q.21 If the focal length of objective and eye lens are 1.2 cm and 3 cm respectively and the object is put 1.25 cm away from the objective lens and the final image is formed at infinity. The magnifying power of the microscope is
(A) 150 (B) 200
(C) 250 (D) 400

Q.22 A telescope of diameter 2m uses light of wavelength 5000Å for viewing stars. The minimum angular separation between two stars whose image is just resolved by this telescope is
(A) 4×10^{-4} rad (B) 0.25×10^{-6} rad
(C) 0.31×10^{-6} rad (D) 5.0×10^{-3} rad

Q.23 A man can see the object between 15 cm and 30 cm. He uses the lens to see the far objects. Then due to the lens used, the near point will be
(A) (10/3) cm (B) 30 cm
(C) 15 cm (D) (100/3) cm

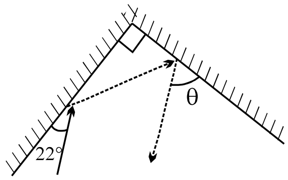
Q.24 An eye specialist prescribes spectacles having a combination of convex lens of focal length 40cm in contact with a concave lens of focal length 25 cm. The power of this lens combination in diopters is –
(A) + 1.5 (B) – 1.5
(C) + 6.67 (D) – 6.67

Q.25 The maximum magnification that can be obtained with a convex lens of focal length 2.5 cm is (the least distance of distinct vision is 25 cm)
(A) 10 (B) 0.1
(C) 62.5 (D) 11

Q.26 A simple magnifying lens is used in such a way that an image is formed at 25 cm away from the eye. In order to have 10 times magnification, the focal length of the lens should be –

(A) 5 cm (B) 2 cm
(C) 25 mm (D) 0.1 mm

Q.27 A ray of light is reflected by two mirrors placed normal to each other. The incident ray makes an angle of 22° with one of the mirrors. At what angle θ does the ray emerge?

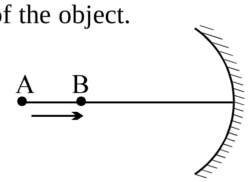


(A) 22° (B) 68°
(C) 44° (D) None

Q.28 An object of height h = 5cm is located at a distance a = 12 cm from a concave mirror with focal length 10 cm. Find the height of the image.

(A) 10 cm (B) 15 cm
(C) 20 cm (D) 25 cm

Q.29 A linear object AB is placed along the axis of a concave mirror. The object is moving towards the mirror with speed U. The speed of the image of the point A is 4U and the speed of the image of B is also 4U. If the center of the line AB is at a distance L from the mirror then find out the length of the object.



(A) 3L/2 (B) 5L/3
(C) L (D) None

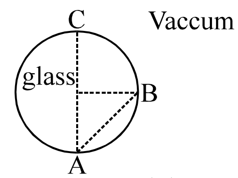
Q.30 A concave mirror of radius of curvature 40 cm forms an image of an object placed on the principal axis at a distance 45cm in front of it. Now if the system is completely immersed in water (μ = 1.33) then

(A) the image will shift towards the mirror.
(B) the magnification will reduce.
(C) the image will shift away from the mirror and magnification will increase.
(D) the position of the image and magnification will not change.

Q.31 A pin 10 mm tall is used as an object in front of a mirror and the image formed is erect and 2mm tall.

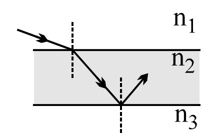
(A) Moving the pin closer to the mirror will make the image larger.
(B) The image must be real.
(C) The mirror must be converging.
(D) Both (B) and (C) are correct.

Q.32 It is found that electromagnetic signals sent inside glass sphere from A towards B reach diametrically opposite point C. The speed of electromagnetic signals in glass cannot be:



(A) 1.0×10^8 m/s (B) 2.1×10^8 m/s
(C) 2×10^7 m/s (D) 4×10^7 m/s

Q.33 Light traveling through three transparent substances follows the path shown in figure. Arrange the indices of refraction in order from smallest to largest. Note that total internal reflection does occur on the bottom surface of medium 2.



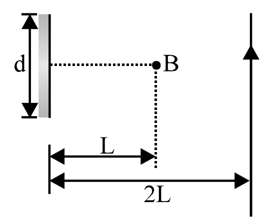
(A) $n_1 < n_2 < n_3$
(B) $n_2 < n_1 < n_3$
(C) $n_1 < n_3 < n_2$
(D) $n_3 < n_1 < n_2$

Q.34 A ray of light travelling in a medium of refractive index μ is incident at an angle θ on a composite transparent plate consisting of 50 plates of refractive indices 1.01μ, 1.02μ, 1.03μ.....1.50μ. They ray emerges from the composite plate into a medium of refractive index 1.6μ at angle x. Then

(A) $\sin x = \left(\frac{1.01}{1.5}\right)^{50} \sin\theta$ (B) $\sin x = (5/8) \sin\theta$

(C) $\sin x = (8/5) \sin\theta$ (D) $\sin x = \left(\frac{1.5}{1.01}\right)^{50} \sin\theta$

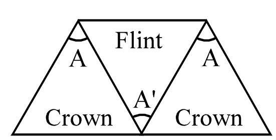
Q.35 A point source of light B, placed at a distance L in front of the centre of a plane mirror of width d, hangs vertically on a wall.



A man walks in front of the mirror along a line parallel to the mirror at a distance 2L from it as shown. The greatest distance over which he can see the image of the light source in the mirror is

(A) d/2 (B) d
(C) 2d (D) 3d

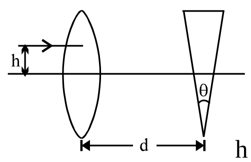
Q.36 Three thin prisms are combined as shown in figure. The refractive indices of the crown glass for red & violet rays are μ_r and μ_v respectively & those for the flint glass are μ'_r and μ'_v respectively. The ratio (A'/A) for which there is no net angular dispersion



(A) $\dfrac{\mu_V - \mu_r}{2(\mu'_V - \mu'_r)}$ (B) $\dfrac{2(\mu_V - \mu_r)}{\mu'_V - \mu'_r}$

(C) $\dfrac{\mu_V - \mu_r}{\mu'_V - \mu'_r}$ (D) None of these

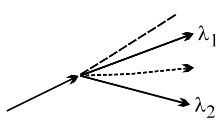
Q.37 A ray of light parallel to the axis of a converging lens (having focal length f) strikes it at a small distance 'h' from its optical centre. A thin prism having angle θ and refractive index μ is placed normal to the axis of lens at a distance 'd' from it. What should be the value of μ so that the ray emerges parallel to the lens axis.

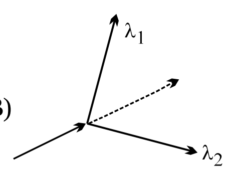


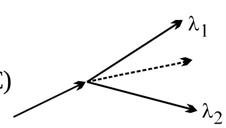
(A) $\dfrac{h}{f\,\theta}$ (B) $\dfrac{h}{f\,\theta}+1$

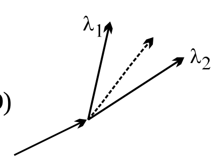
(C) $\dfrac{h}{(d+f)\theta}$ (D) $\dfrac{h}{(d+f)\theta}+1$

Q.38 Consider the four different cases of dispersion of light ray which has all the wave lengths from λ_1 to λ_2 ($\lambda_1 > \lambda_2$). The dotted represents the light ray of wave length λ_{avg}. Which ray diagram is showing maximum dispersive power?

(A) 

(B) 

(C) 

(D) 

Q.39 In Young's double slit experiment, the distance between the two slits is 0.1 mm and the wavelength of light used is 4×10^{-7}m. If the width of the fringe on the screen is 4mm, the distance between screen and slit is
(A) 0.1 mm (B) 1 cm
(C) 0.1 cm (D) 1 m

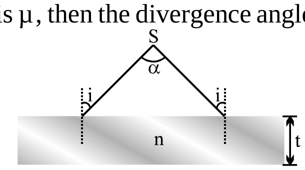
Q.40 In Young's double slit experiment, the distance between sources is 1 mm and distance between the screen and source is 1 m. If the fringe width on the screen is 0.06 cm, then λ =
(A) 6000 Å (B) 4000 Å
(C) 1200 Å (D) 2400 Å

Q.41 Two slits are separated by a distance of 0.5 mm and illuminated with light of λ = 6000Å. If the screen is placed 2.5m from the slits. The distance of the third bright image from the centre will be
(A) 1.5 mm (B) 3 mm
(C) 6 mm (D) 9 mm

Q.42 The equation of two light waves are $y_1 = 6\cos\omega t$, $y_2 = 8\cos(\omega t + \phi)$. The ratio of maximum to minimum intensities produced by the superposition of these waves will be
(A) 49 : 1 (B) 1 : 49
(C) 1 : 7 (D) 7 : 1

Q.43 In a Young's experiment , two coherent sources are placed 0.90 mm apart and the fringes are observed one metre away. f it produces the second dark fringe at a distance of 1mm from the central fringe, the wavelength of monochromatic light used would be.
(A) 60×10^{-4} cm (B) 10×10^{-4} cm
(C) 10×10^{-5} cm (D) 6×10^{-5} cm

Q.44 A diverging beam of light from a point source S having divergence angle α falls symmetrically on a glass slab as shown. The angles of incidence of the two extreme rays are equal. If the thickness of the glass slab is t and its refractive index is μ, then the divergence angle of the emergent beam is :



(A) zero (B) α
(C) $\sin^{-1}(1/\mu)$ (D) $2\sin^{-1}(1/\mu)$

Q.45 In a certain double slit experimental arrangement interference fringes of width 1.0 mm each are observed when light of wavelength 5000Å is used. Keeping the set up unaltered, if the source is replaced by another source of wavelength 6000 Å, the fringe width will be
(A) 0.5 mm (B) 1.0 mm
(C) 1.2 mm (D) 1.5 mm

Q.46 Two parallel slits 0.6 mm apart are illuminated by light source of wavelength 6000Å. The distance between two consecutive dark fringes on a screen 1 m away from the slits is
(A) 1 mm (B) 0.01 mm
(C) 0.1 m (D) 10 m

Q.47 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 1 m. What is the distance between the consecutive bright or dark fringes
(A) 1.5 mm (B) 1.0 mm
(C) 0.5 mm (D) None of these

Q.48 In a Young's double slit experiment, the slit separation is 1mm and the screen is 1 m from the slit. For a monochromatic light of wavelength 500 nm, the distance of 3rd minima from the central maxima is –
(A) 0.50 mm (B) 1.25 mm
(C) 1.50 mm (D) 1.75 mm

Q.49 The light of wavelength 6328 Å is incident on a slit of width 0.2 mm perpendicularly, the angular width of central maxima will be
(A) 0.36° (B) 0.18°
(C) 0.72° (D) 0.09°

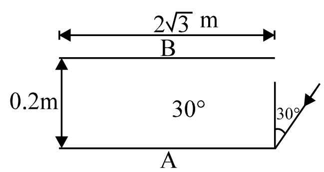
Q.50 When wave of wavelength 0.2 cm is made incident normally on a slit of width 0.004m, then the semi-angular width of central maximum of diffraction pattern will be-
(A) 60° (B) 30°
(C) 90° (D) 0°

Q.51 A screen is placed 2m away from the single narrow slit. Calculate the slit width if the first minimum lies 5mm on either side of the central maximum. Incident plane waves have a wavelength of 5000Å.
(A) 2×10^{-4} m (B) 2×10^{-3} cm
(C) 2×10^{-4} m (D) None

Q.52 In young's double slit experiment, 12 fringes are observed to be formed in a certain segment of the screen when light of wavelength 600 nm is used. If the wavelength of light is changed to 400 nm, number of fringes observed in the same segment of the screen is given by
(A) 12 (B) 18
(C) 24 (D) 30

Q.53 A beam of light of wavelength 600nm from a distant source falls on a single slit 1.00mm wide and the resulting diffraction pattern is observed on a screen 2m away. The width of the central max. is –
(A) 1.2 cm. (B) 1.2 mm.
(C) 2.4 cm. (D) 2.4 mm.

Q.54 Two plane mirrors A and B are aligned parallel to each other, as shown in the figure. A light ray is incident at an angle 30° at a point just inside one end of A. The plane of incidence coincides with the plane of the figure. The maximum number of times the ray undergoes reflections (including the first one) before it emerges out is



(A) 28 (B) 30
(C) 32 (D) 34

Q.55 In a Young's double slit interference pattern, the intensity of the central fringe at P = I_o when one slit width is reduced to one fourth the intensity at P will be
(A) $I_o/2$ (B) $I_o/4$
(C) $(9/16)\, I_o$ (D) $(3/4)\, I_o$

Q.56 Interference fringes are obtained in Young's double-slit experiment on a screen. Which of the following statements will be incorrect about the effect of introducing a thin transparent plate in the path of one of the two interfering beams.
(A) The separation between fringes remain unaffected.
(B) The entire fringe system shifts towards the side on which plate is placed
(C) The conditions for maxima and minima are reversed i.e., maxima for odd multiple of $\lambda/2$ and minima for even multiple of $\lambda/2$.
(D) Shape of the fringe also remains unaffected.

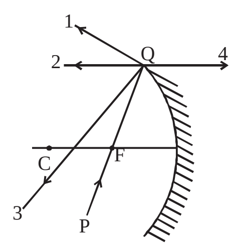
Q.57 In a Young's double–slit experiment, the central bright fringe can be identified
(A) as it has greater intensity than the other bright fringes.
(B) as it is wider than the other bright fringes.
(C) as it is narrower than the other bright fringes.
(D) by using white light instead of monochromatic light.

Q.58 A ray of light incident at an angle θ on a refracting face of a prism emerges from the other face normally. If the angle of the prism is 5° and the prism is made of a material of refractive index 1.5, the angle of incidence is
(A) 7.5° (B) 5°
(C) 15° (D) 2.5°

Q.59 Consider sunlight incident on a slit of width 10^4 Å. The image seen through the slit shall
(A) be a fine sharp slit white in colour at the center.
(B) a bright slit white at the center diffusing to zero intensities at the edges.
(C) a bright slit white at the center diffusing to regions of different colours.
(D) only be a diffused slit white in colour.

Q.60 Which one of the following phenomena is not explained by Huygens construction of wavefront?
(A) Refraction (B) Reflection
(C) Diffraction (D) Origin of spectra

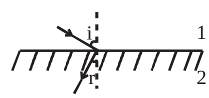
Q.61 The direction of ray of light incident on a concave mirror is shown by PQ while directions in which the ray would travel after reflection is shown by four rays marked 1, 2, 3 and 4 (Fig). Which of the four rays correctly shows the direction of reflected ray?

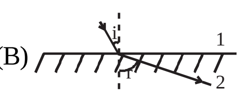


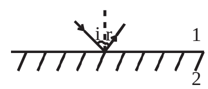
(A) 1 (B) 2
(C) 3 (D) 4

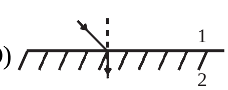
Q.62 When the angle of incidence is 60° on the surface of a glass slab, it is found that the reflected ray is completely polarized. Velocity of light in glass is
(A) $\sqrt{2} \times 10^8$ m/s (B) $\sqrt{3} \times 10^8$ m/s
(C) 2×10^8 m/s (D) 3×10^8 m/s

Q.63 There are certain material developed in laboratories which have a negative refractive index (Fig.). A ray incident from air (medium 1) into such a medium (medium 2) shall follow a path given by –

(A) 

(B) 

(C) 

(D) 

Q.64 The sky would appear red instead of blue, if –

(A) atmospheric particles scatter blue light more than red light.
(B) atmospheric particles scatter all colours equally.
(C) atmospheric particles scatter red light more than the blue light.
(D) the sun was much hotter.

Q.65 Unpolarised light is incident on a plane glass surface. What should be the angle of incidence so that the reflected and refracted rays are perpendicular to each other? [μ for glass = 1.5]

(A) 60° (B) 90°
(C) 0° (D) 57°

Q.66 If the ratio of amount of scattering of two light waves is 1 : 4, then the ratio of their wavelengths

(A) $\sqrt{2}:1$ (B) $2:1$
(C) $3:1$ (D) $2\sqrt{2}:1$

Q.67 An object approaches a convergent lens from the left of the lens with a uniform speed 5 m/s and stops at the focus. The image

(A) moves away from the lens with an uniform speed 5 m/s.
(B) moves away from the lens with an uniform acceleration.
(C) moves away from the lens with a non-uniform acceleration.
(D) moves towards the lens with a non-uniform acceleration.

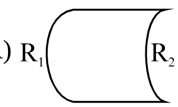
Q.68 A light of wavelength 6000Å is coming from a star. What is the limit of resolution of a telescope whose objective lens has a diameter of 100 inch?

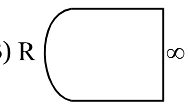
(A) 4.2×10^{-5} rad (B) 2.9×10^{-7} rad
(C) 1.5×10^{-4} rad (D) 4.0×10^{-7} rad

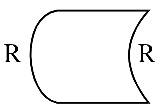
Q.69 In a Young's double slit experiment, the source is white light. One of the holes is covered by a red filter and another by a blue filter. In this case

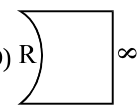
(A) there shall be alternate interference patterns of red and blue.
(B) there shall be an interference pattern for red distinct from that for blue.
(C) there shall be no interference fringes.
(D) there shall be an interference pattern for red mixing with one for blue.

Q.70 Which one of the following spherical lenses does not exhibit dispersion? The radii of curvature of the surfaces of the lenses are as given in the diagrams :

(A) 

(B) 

(C) 

(D) 

EXERCISE - 3 (NUMERICAL VALUE BASED QUESTIONS)

PART - A : RAY OPTICS

NOTE : The answer to each question is a NUMERICAL VALUE.

Q.1 The refracting angle of the prism is 60^o. What is the angle (in degree) of incidence for minimum deviation ? The refractive index of material of prism is $\sqrt{2}$.

Q.2 A plane mirror of circular shape with radius r = 20 cm is fixed to the ceiling. A bulb is to be placed on the axis of the mirror. A circular area of radius R = 1 m on the floor is to be illuminated after reflection of light from the mirror. The height of the room is 3 m. What is the maximum distance(in cm.) from the centre of the mirror and the bulb so that the required area is illuminated ?

Q.3 Figure I given below shows a glass vessel, partially filled with water. A narrow beam of light is incident vertically down into the water and passes straight through. Figure II shows the vessel glass tilted until the angle θ, such that the light is refracted along the lower surface of the glass. If refractive indices of air, water and glass are 1, 4/3 and 1.5 respectively and $\sin\theta = \frac{3}{A}$ then find the value of A.

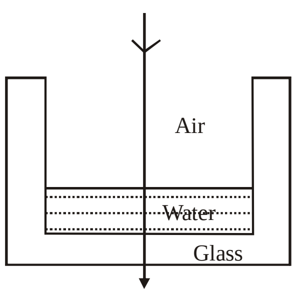


Figure-I

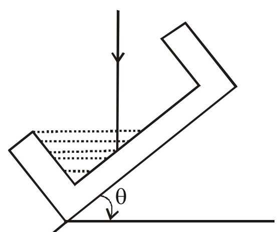
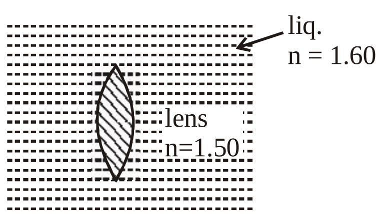


Figure-II

Q.4 Shown in the figure here is a equi-convex lens placed in liquid medium. The lens has focal length +20cm. when in air, and its material has refractive index 1.50. If the liquid has refractive index 1.60. Find the value of focal length (in cm.) of the lens in liquid.

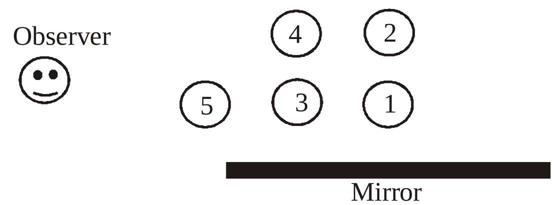


Q.5 A light ray parallel to the x-axis strikes the outer reflecting surface of a sphere at a point (2, 2, 0). Its centre is at the point (0, 0, –1). The unit vector along the direction of the reflected ray is $x\hat{i} + y\hat{j} + z\hat{k}$. Find the value of $\frac{yz}{x^2}$.

Q.6 A parallel beam of light falls normally on the first face of a prism of small angle. At the second face it is partly transmitted and partly reflected, the reflected beam striking at the first face again and emerging from it in a direction making an angle 6º 30′ with the reversed direction of the incident beam. The refracted beam is found to have undergone a deviation of 1º15′ from the original direction. The refractive index of the glass is 13/A. Find the value of A.

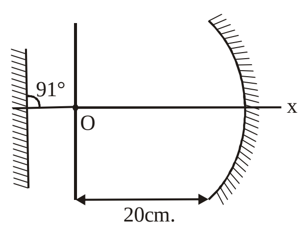
Q.7 In the above question, find the angle of the prism (in degree)

Q.8 Five spheres are lined up in front of a plane mirror as shown. Number on the sphere of which the observer will be able to see the reflection.



Q.9 A plane mirror is placed 25cm. away from a concave spherical mirror perpendicularly to the principal axis of the concave mirror. What should be the distance (in cm) infront of concave mirror, where we place a candle if its images formed by the two mirror independently are at the same distances from the candle ? The radius of the concave mirror is 40 cm. (Consider images formed by single reflection only.)

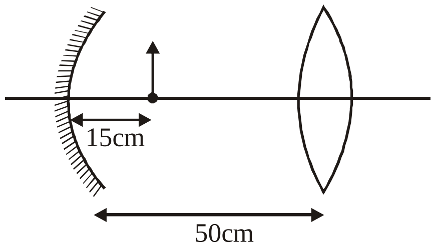
Q.10 A point object is placed at the centre of curvature of a concave mirror (taken as origin). A plane mirror is also placed at a distance of 10cm. from the object as shown. Consider two reflection first at plane mirror and then at concave mirror (x_0, y_0). Find $\frac{\pi x_0}{y_0}$ the coordinates of the image thus formed.



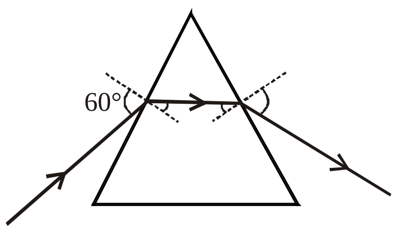
Q.11 A large glass slab (μ = 5/3) of thickness 8 cm is placed over a point source of light on a plane surface. It is seen that light emerges out of the top surface of the slab from a circular area of radius R cm. What is the value of R ?

Q.12 Image of an object approaching a convex mirror of radius of curvature 20 m along its optical axis is observed to move from 25/3m to 50/7m in 30 seconds. What is the speed of the object in km per hour ?

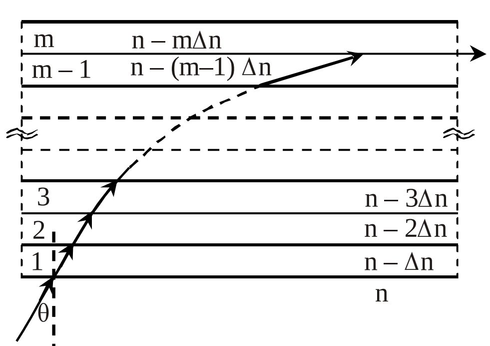
Q.13 Consider a concave mirror and a convex lens (refractive index = 1.5) of focal length 10 cm each, separated by a distance of 50 cm in air (refractive index = 1) as shown in the figure. An object is placed at a distance of 15 cm from the mirror. Its erect image formed by this combination has magnification M_1. When the set-up is kept in a medium of refractive index 7/6, the magnification becomes M_2. The magnitude $|M_2/M_1|$.



Q.14 A monochromatic beam of light is incident at 60° on one face of an equilateral prism of refractive index n and emerges from the opposite face making an angle (n) with the normal (see the figure). For n = $\sqrt{3}$ the value of θ is 60° and $\frac{d\theta}{dn} = m$. The value of m is –



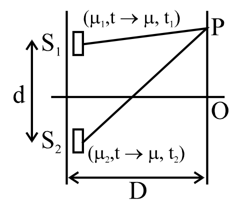
Q.15 A monochromatic light is travelling in a medium of refractive index n = 1.6. It enters a stack of glass layers from the bottom side at an angle θ = 30°. The interfaces of the glass layers are parallel to each other. The refractive indices of different glass layers are monotonically decreasing as $n_m = n - m\,\Delta n$, where n_m is the refractive index of the mth slab and Δn = 0.1 (see the figure). The ray is refracted out parallel to the interface between the $(m-1)^{th}$ and m^{th} slabs from the right side of the stack. What is the value of m?



PART - B : WAVE OPTICS

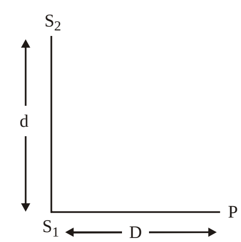
Q.1 In a YDSE two thin transparent sheets are used in front of the slits S_1 and S_2. $\mu_1 = 1.6$ and $\mu_2 = 1.4$. If both sheets have thickness 't', the central maximum is observed at a distance of 5 mm from centre O. Now the sheets are replaced by two sheets of same material of refractive index $\frac{\mu_1 + \mu_2}{2}$ but having thickness t_1 and t_2 such that 't' = $\frac{t_1 + t_2}{2}$.

Now central maximum is observed at distance of 8 mm from centre O on the same side as before. Find the thickness t_1 (in μm). [Given d = 1 mm, D = 1 m]



Q.2 Visible light of variable wavelength is incident normally on a thin sheet of plastic in air. The reflected light has a minima only for λ = 512 nm and λ = 640 nm in the visible spectrum. What is the minimum thickness (in μm) of the film (μ = 1.28)

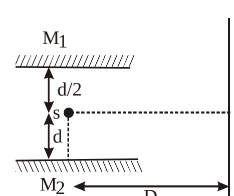
Q.3 Two coherent sources S_1 and S_2 are emitting light of wavelength 5000Å are placed at 0.1mm apart, as shown in the figure. A detector is moved along a line perpendicular to S_1S_2 and passing through S_1. Find the distance (in cm.) of farthest maxima from S_1.



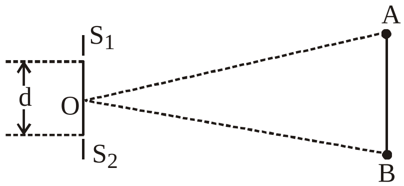
Q.4 In Young's double slit experiment, the introduction of a thin transparent film reduces the intensity at centre of screen by 75%. Then μ = refractive index of film = x/y if λ = t where t = thickness of film and λ = wavelength of light. Find the value of x+y.

Q.5 In a standard Young's double slit setup, we get 60 fringes on a section of screen with monochromatic light of wavelength 4000 Å. If we use monochromatic light of wavelength 6000 Å, then the number of fringes that would be obtained in the same section is –

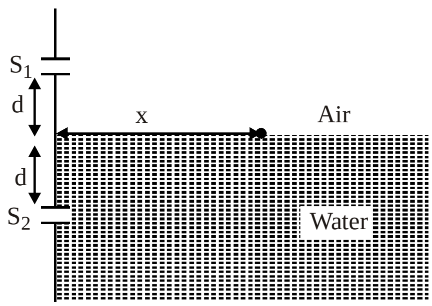
Q.6 M_1 and M_2 are plane mirrors and kept parallel to each other. At point O there will be a maxima for wavelength. Light from monochromatic source S of wavelength λ is not reaching directly on the screen if λ is $\frac{Xd^2}{2D}$ then find the value of X.[D >> d, d >> λ]



Q.7 Figure shows two coherent sources $S_1 - S_2$ vibrating in same phase. AB is an irregular wire lying at a far distance from the sources S_1 and S_2. Let $\frac{\lambda}{d} = 10^{-3}$. $\angle BOA = 0.12°$. How many bright spots will be seen on the wire, including points A and B.



Q.8 A Young's double slit interference arrangement with slits S_1 and S_2 is immersed in water (refractive index = 4/3) as shown in the figure.



The positions of maxima on the surface of water are given by $x^2 = p^2m^2\lambda^2 - d^2$, where λ is the wavelength of light in air (refractive index = 1), 2d is the separation between the slits and m is an integer. The value of p is –

Q.9 A parallel monochromatic beam of light is incident normally on a narrow slit. A diffraction pattern is formed on a screen placed perpendicular to the direction of the incident beam. At the first minimum of the diffraction pattern, the phase difference between the rays coming from the two edges of the slit is (X π). Find the value of X.

Q.10 Two beams of light having intensities I and 4I interfere to produce a fringe pattern on a screen. The phase difference between the beams is $\pi/2$ at point A and π at point B. Then the difference between resultant intensities at A and B is (X) I. Find the value of x.

EXERCISE - 4 [PREVIOUS YEARS JEE MAIN QUESTIONS]

PART - A : RAY OPTICS

Q.1 Two plane mirrors are inclined at 60^o to each other. The [illegible] **[AIEEE-2002]**
(A) 5 (B) 6
(C) 8 (D) None

Q.2 Which of the following is used in optical fibres – **[AIEEE-2002]**
(A) Total internal relection (B) Scattering
(C) Difraction (D) Refraction

Q.3 An astronomical telescope has a large aperture to – **[AIEEE-2002]**
(A) Reduce spherical aberration
(B) Have high resolution
(C) Increase span of observation
(D) Have low dispersion

Q.4 Wavelength of light used in an optical instument are $\lambda_1 = 4000Å$ and $\lambda_2 = 5000Å$, then ratio of their respective resolving powers (corresponding to λ_1 and λ_2) is– **[AIEEE-2002]**
(A) 16 : 25 (B) 9 : 1
(C) 4 : 5 (D) 5 : 4

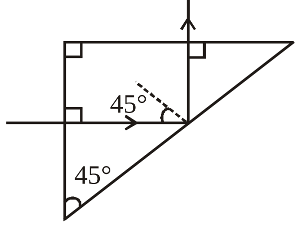
Q.5 The image formed by an objective of a compound microscope is – **[AIEEE-2003]**
(A) Real and diminished (B) Real and enlarged
(C) Virtual and enlarged (D) Virtual and diminished

Q.6 To get three images of a single object, one should have two plane mirrors at an angle of – **[AIEEE-2003]**
(A) 90^o (B) 120^o
(C) 30^o (D) 60^o

Q.7 A light ray is incident perpendicularly to one face of a 90° prism and is totally internally reflected at the glass-air interface. If the angle of reflexion is 45°, we conclud that the refractive index n – **[AIEEE-2004]**

(A) $n < \frac{1}{\sqrt{2}}$ (B) $n > \sqrt{2}$

(C) $n > \frac{1}{\sqrt{2}}$ (D) $n < \sqrt{2}$



Q.8 A plano convex lens of refractive index 1.5 and radius of curvature 30 cm is silvered at the curved surface. Now this lens has been used to form the image of an object. At what distance from this lens an object be placed in order to have a real image of the size of the object – **[AIEEE-2004]**
(A) 20 cm (B) 30 cm
(C) 60 cm (D) 80 cm

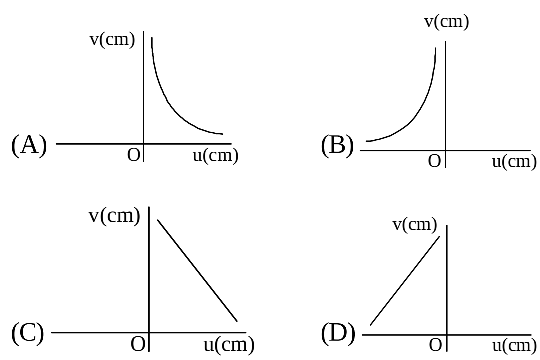
Q.9 A fish looking up through the water sees the outside world contained in a circular horizon. If the refractive index of water is 4/3 and the fish is 12 cm below the surface, the radius of this circle in cm is **[AIEEE-2005]**
(A) $36\sqrt{7}$ (B) $36/\sqrt{7}$
(C) $36\sqrt{5}$ (D) $4\sqrt{5}$

Q.10 Two point white dots are 1 mm apart on a black paper. They are viewed by eye of pupil diameter 3 mm. Approximately, what is the maximum distance at which these dots can be resolved by the eye ?
[Take wavelength of light = 500 nm] **[AIEEE-2005]**
(A) 5 m (B) 1 m
(C) 6 m (D) 3 m

Q.11 The refractive index of glass is 1.520 for red light and 1.525 for blue light. Let D_1 and D_2 be angles of minimum deviation for red and blue light respectively in a prism of this glass. Then – **[AIEEE 2006]**
(A) D_1 can be less than or greater than D_2 depending upon the angle of prism.
(B) $D_1 > D_2$ (C) $D_1 < D_2$ (D) $D_1 = D_2$

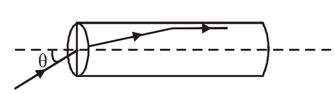
Q.12 Two lenses of power -15D and +5D are in contact with each other. The focal length of the combination is
(A) – 20 cm (B) –10 cm **[AIEEE 2007]**
(C) +20cm (D) +10 cm

Q.13 A student measures the focal length of a convex lens by putting an object pin at a distance 'u' from the lens and measuring the distance 'v' of the image pin. The graph between 'u' and 'v' plotted by the student should look like **[AIEEE 2008]**



Q.14 An experiment is performed to find the refractive index of glass using a travelling microscope. In this experiment distances are measured by - **[AIEEE-2008]**
(A) a standard laboratory scale
(B) a meter scale provided on the microscope
(C) a screw gauge provided on the microscope
(D) a vernier scale provided on the microscope

Q.15 A transparent solid cylindrical rod has a refractive index of $2/\sqrt{3}$. It is surrounded by air. A light ray is incident at the midpoint of one end of the rod as shown in the figure.



The incident angle θ for which the light ray grazes along the wall of the rod is - **[AIEEE-2009]**

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

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

Directions: Q.16 – 18 are based on the following paragraph.

An initially parallel cylindrical beam travels in a medium of refractive index $\mu(I) = \mu_0 + \mu_2 I$, where μ_0 and μ_2 are positive constants and I is the intensity of the light beam. The intensity of the beam is decreasing with increasing radius.

Q.16 As the beam enters the medium, it will – **[AIEEE 2010]**
(A) diverge
(B) converge
(C) diverge near the axis and converge near the periphery
(D) travel as a cylindrical beam

Q.17 The initial shape of the wave front of the beam is –
(A) convex **[AIEEE 2010]**
(B) concave
(C) convex near the axis and concave near the periphery
(D) planar

Q.18 The speed of light in the medium is – **[AIEEE 2010]**
(A) minimum on the axis of the beam
(B) the same everywhere in the beam
(C) directly proportional to the intensity I
(D) maximum on the axis of the beam

Q.19 Acar is fitted with a convex side view mirror of focal length 20 cm. A second car 2.8 m behind the first car is overtaking the first car at a relative speed of 15m/s. The speed of the image of the second car as seen in the mirror of the first one is – **[AIEEE 2011]**

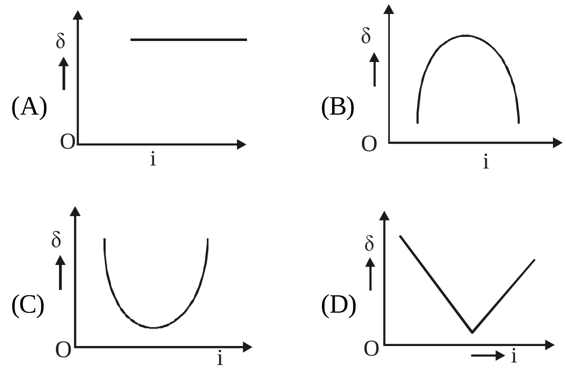
(A) $\frac{1}{10}$ m/s (B) $\frac{1}{15}$ m/s
(C) 10 m/s (D) 15 m/s

Q.20 Let the x - z plane be the boundary between two transparent media. Medium 1 in $z \geq 0$ has refractive index of $\sqrt{2}$ and medium 2 with $z < 0$ has a refractive index of $\sqrt{3}$. A ray of light in medium 1 given by the vector $\vec{A} = 6\sqrt{3}\,\hat{i} + 8\sqrt{3}\,\hat{j} - 10\,\hat{k}$ in incident on the plane of separation. The angle of refraction in medium 2 is
(A) 30° (B) 45° **[AIEEE 2011]**
(C) 60° (D) 75°

Q.21 An object 2.4 m in front of a lens forms a sharp image on a film 12 cm behind the lens. A glass plate 1 cm thick, of refractive index 1.50 is interposed between lens and film with its plane faces parallel to film. At what distance (from lens) should object shifted to be in sharp focus on film ?
(A) 7.2 m (B) 2.4 m **[AIEEE 2012]**
(C) 3.2 m (D) 5.6 m

Q.22 Diameter of a plano-convex lens is 6cm and thickness at the centre is 3mm. If speed of light in material of lens is 2×10^8 m/s, the focal length of the lens is –
[JEE MAIN 2013]
(A) 15 cm (B) 20 cm
(C) 30 cm (D) 10 cm

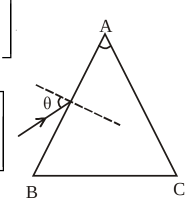
Q.23 The graph between angle of deviation (δ) and angle of incidence (i) for a triangular prismis represented by –
[JEE MAIN 2013]



Q.24 A thin convex lens made from crown glass ($\mu = 3/2$) has focal length f. When it is measured in two different liquids having refractive indices 4/3 and 5/3, it has the focal lengths f_1 and f_2 respectively. The correct relation between the focal lengths is – **[JEE MAIN 2014]**
(A) $f_2 > f$ and f_1 becomes negative
(B) f_1 and f_2 both become negative
(C) $f_1 = f_2 < f$
(D) $f_1 > f$ and f_2 becomes negative

Q.25 A green light is incident from the water to the air-water interface at the critical angle (θ). Select the correct statement **[JEE MAIN 2014]**
(A) The spectrum of visible light whose frequency is more than that of green light will come out to the air medium.
(B) The entire spectrum of visible light will come out of the water at various angles to the normal.
(C) The entire spectrum of visible light will come out of the water at an angle of 90° to the normal.
(D) The spectrum of visible light whose frequency is less than that of green light will come out to the air medium.

Q.26 Monochromatic light is incident on a glass prism of angle A. If the refractive index of the material of the prism is μ, a ray, incident at an angle θ, on the face AB would get transmitted through the face AC of the prism provided.
[JEE MAIN 2015]



(A) $\theta < \sin^{-1}\left[\mu \sin\left(A - \sin^{-1}\left(\frac{1}{\mu}\right)\right)\right]$

(B) $\theta > \cos^{-1}\left[\mu \sin\left(A + \sin^{-1}\left(\frac{1}{\mu}\right)\right)\right]$

(C) $\theta < \cos^{-1}\left[\mu \sin\left(A + \sin^{-1}\left(\frac{1}{\mu}\right)\right)\right]$

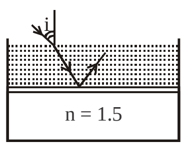
(D) $\theta > \sin^{-1}\left[\mu \sin\left(A - \sin^{-1}\left(\frac{1}{\mu}\right)\right)\right]$

Q.27 An observer looks at a distant tree of height 10 m with a telescope of magnifying power of 20. To the observer the tree appears: **[JEE MAIN 2016]**
(A) 10 times nearer (B) 20 times taller
(C) 20 times nearer (D) 10 times taller.

Q.28 In an experiment for determination of refractive index of glass of a prism by $i - \delta$, plot, it was found that a ray incident at angle 35°, suffers a deviation of 40° and that it emerges at angle 79°. In that case which of the following is closest to the maximum possible value of the refractive index? **[JEE MAIN 2016]**
(A) 1.6 (B) 1.7
(C) 1.8 (D) 1.5

Q.29 A diverging lens with magnitude of focal length 25 cm is placed at a distance of 15 cm from a converging lens of magnitude of focal length 20 cm. A beam of parallel light falls on the diverging lens. The final image formed is:
(A) Virtual and at a distance of 40 cm from convergent lens. **[JEE MAIN 2017]**
(B) Real & at a distance of 40 cm from the divergent lens.
(C) Real & at a distance of 6 cm from the convergent lens.
(D) Real & at a distance of 40 cm from convergent lens.

Q.30 Consider a tank made of glass(refractive index 1.5) with a thick bottom. It is filled with a liquid of refractive index μ. A student finds that, irrespective of what the incident angle i (see figure) is for a beam of light entering the liquid, the light reflected from the liquid glass interface is never completely polarized. For this to happen, the minimum value of μ is : **[JEE MAIN 2019(JAN)]**



(A) $3/\sqrt{5}$ (B) $5/\sqrt{3}$
(C) $\sqrt{5/3}$ (D) 4/3

Q.31 A convex lens is put 10 cm from a light source and it makes a sharp image on a screen, kept 10 cm from the lens. Now a glass block (refractive index 1.5) of 1.5 cm thickness is placed in contact with the light source. To get the sharp image again, the screen is shifted by a distance d. Then d is : **[JEE MAIN 2019(JAN)]**
(A) 0.55 cm away from the lens
(B) 1.1cm away from thelens
(C) 0.55 cm towards the lens
(D) 0

Q.32 An upright object is placed at a distance of 40 cm in front of a convergent lens of focal length 20 cm. A convergent mirror of focal length 10 cm is placed at a distance of 60 cm on the other side of the lens. The position and size of the final image will be : **[JEE MAIN 2019 (APRIL)]**
(A) 40 cm from the convergent lens, same size as the object.
(B) 20 cm from the convergent mirror, same size as the object.
(C) 20 cm from the convergent mirror, twice the size of the object.
(D) 40 cm from the convergent lens, twice the size of the object.

Q.33 A convex lens (of focal length 20 cm) and a concave mirror, having their principal axes along the same lines, are kept 80 cm apart from each other. The concave mirror is to the right of the convex lens. When an object is kept at a distance of 30 cm to the left of the convex lens, its image remains at the same position even if the concave mirror is removed. The maximum distance of the object for which this concave mirror, by itself would produce a virtual image would be : **[JEE MAIN 2019 (APRIL)]**
(A) 20 cm (B) 10 cm
(C) 25 cm (D) 30 cm

Q.34 Magnification of compound microscope is 375. Length of tube is 150mm. Given that focal length of objective lens is 5mm, then value of focal length of eyepiece is: **[JEE MAIN 2020 (JAN)]**
(A) 2 mm (B) 22 mm
(C) 12 mm (D) 33 mm

Q.35 Focal length of convex lens in air is 16 cm ($\mu_{glass} = 1.5$). Now the lens is submerged in liquid of refractive index 1.42. Find the ratio of focal length in medium to focal length in air has closest value **[JEE MAIN 2020 (JAN)]**
(A) 9 (B) 17
(C) 1 (D) 5

Q.36 The magnifying power of a telescope with tube 60cm is 5. What is the focal length of its eye piece? **[JEE MAIN 2020 (JAN)]**
(A) 30 cm (B) 40 cm
(C) 20 cm (D) 10 cm

Q.37 The critical angle of a medium for a specific wavelength, if the medium has relative permittivity 3 and relative permeability 4/3 for this wavelength, will be : **[JEE MAIN 2020 (JAN)]**
(A) 60° (B) 15°
(C) 45° (D) 30°

Q.38 A point object in air is in front of the curved surface of a plano-convex lens. The radius of curvature of the curved surface is 30 cm and the refractive index of the lens material is 1.5, then the focal length of the lens (in cm) is ———. **[JEE MAIN 2020 (JAN)]**

Q.39 A vessel of depth 2h is half filled with a liquid of refractive index $2\sqrt{2}$ and the upper half with another liquid of refractive index $\sqrt{2}$. The liquids are immiscible. The apparent depth of the inner surface of the bottom of vessel will be : **[JEE MAIN 2020 (JAN)]**
(A) $\frac{h}{\sqrt{2}}$ (B) $\frac{3}{4}h\sqrt{2}$ (C) $\frac{h}{2(\sqrt{2}+1)}$ (D) $\frac{h}{3\sqrt{2}}$

PART - B : WAVE OPTICS

Q.1 To demonstrate the phenomenon of interference, we require two sources which emit radiation – **[AIEEE-2003]**
(A) of the same frequency
(B) of different wavelengths
(C) of the same frequency and having a definite phase relationship.
(D) of nearly the same frequency

Q.2 The maximum number of possible interference maxima for slit-separation equal to twice the wavelength in Young's double-slit experiment is – **[AIEEE-2004]**
(A) Infinite (B) Five
(C) Three (D) Zero

Q.3 The angle of incidence at which reflected light in totally polarized for reflection from air to glass(refractive index n), is – **[AIEEE-2004]**
(A) $\sin^{-1}$ (n) (B) $\sin^{-1}$ (1/n)
(C) $\tan^{-1}$ (1/n) (D) $\tan^{-1}$ (n)

Q.4 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 - **[AIEEE-2005]**
(A) $\frac{1}{2}I_0$ (B) $\frac{1}{4}I_0$
(C) 0 (D) I_0

Q.5 If I_0 is the intensity of the principle maximum in the single slit diffraction pattern, then what will be its intensity when the slit width is doubled ? **[AIEEE-2005]**
(A) $2I_0$ (B) $4I_0$
(C) I_0 (D) $I_0/2$

Q.6 A Young's double slit experiment uses a monochromatic source. The shape of the interference fringes formed on a screen is - **[AIEEE-2005]**
(A) hyperbola (B) circle
(C) straight line (D) parabola

Q.7 In a Young's double slit experiment the intensity at a point where the path-difference is $\lambda/6$ (λ being the wavelength of the light used) is I. If I_0 denotes the maximum intensity, I/I_0 is equal to - **[AIEEE-2007]**
(A) $\frac{1}{\sqrt{2}}$ (B) $\frac{\sqrt{3}}{2}$
(C) 1/2 (D) 3/4

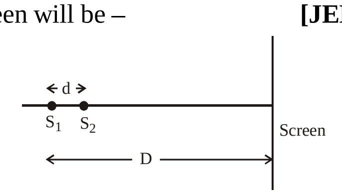
Q.8 A mixture of light, consisting of wavelength 590 nm and an unknown wavelength, illuminates Young's double slit and gives rise to two overlapping interference patterns on the screen. The central maximum of both lights coincide. Further, it is observed that the third bright fringe of known light coincides with the 4^{th} bright fringe of the unknown light. From this data, the wavelength of the unknown light is – **[AIEEE-2009]**
(A) 393.4 nm (B) 885.0 nm
(C) 442.5 nm (D) 776.8 nm

Q.9 A thin air film is formed by putting the convex surface of a plane-convex lens over a plane glass plate.With monochromatic light, this film gives an interference pattern due to light reflected from the top (convex) surface and the bottom (glass plate) surface of the film.
Statement-1 : When light reflects from the air-glass plate interface, the reflected wave suffers a phase change of π. **[AIEEE 2011]**
Statement-2 : The centre of the interference pattern is dark.
(A) Statement-1 is true, statement-2 is false.
(B) Statement-1 is true, Statement-2 is true, Statement-2 is the correct explanation of Statement-1.
(C) Statement-1 is true, Statement-2 is true, Statement-2 is not the correct explanation of Statement-1.
(D) Statement-1 is false, Statement-2 is true.

Q.10 In Young's double slit experiment, one of the slit is wider than other, so that amplitude of the light from one slit is double of that from other slit. If I_m be the maximum intensity, the resultant intensity I when they interfere at phase difference ϕ is given by : **[AIEEE-2012]**
(A) $\frac{I_m}{9}(4+5\cos\phi)$ (B) $\frac{I_m}{3}\left(1+2\cos^2\frac{\phi}{2}\right)$
(C) $\frac{I_m}{5}\left(1+4\cos^2\frac{\phi}{2}\right)$ (D) $\frac{I_m}{9}\left(1+8\cos^2\frac{\phi}{2}\right)$

Q.11 Abeam of unpolarised light of intensity I_0 is passed through a polaroidAand then through another polaroid B which is oriented so that its principal plane makes an angle of 45º relative to that of A. The intensity of the emergent light is – **[JEE MAIN 2013]**
(A) I_0 (B) $I_0/2$
(C) $I_0/4$ (D) $I_0/8$

Q.12 Two coherent point sources S_1 and S_2 are separated by a small distance 'd' as shown. The fringes obtained on the screen will be – **[JEE MAIN 2013]**



(A) points (B) straight lines
(C) semi-circles (D) concentric circles

Q.13 Two beams, A and B, of plane polarized light with mutually perpendicular planes of polarization are seen through a polaroid. From the position when the beam A has maximum intensity (and beam B has zero intensity), a rotation of Polaroid through 30° makes the two beams appear equally bright. If the initial intensities of the two beams are I_A and I_B respectively, then I_A/I_B equals :
(A) 1 (B) 1/3 **[JEE MAIN 2014]**
(C) 3 (D) 3/2

Q.14 Assuming human pupil to have a radius of 0.25 cm and a comfortable viewing distance of 25 cm, the minimum separation between two objects that human eye can resolve at 500 nm wavelength is **[JEE MAIN 2015]**
(A) 30 μm (B) 100 μm
(C) 300 μm (D) 1 μm

Q.15 On a hot summer night, the refractive index of air is smallest near the ground and increases with height form the ground. When a light beam is directed horizontally, the Huygen's principle leads us to conclude that as it travels, the light beam **[JEE MAIN 2016]**

(A) Goes horizontally without any deflection
(B) Bends downwards
(C) Bends upwards
(D) Becomes narrower

Q.16 The box of a pin hole camera, of length L, has a hole of radius a, It is assumed that when the hole is illuminated by a parallel beam of light of wavelength λ the spread of the spot (obtained on the opposite wall of the camera) is the sum of its geometrical spread and the spread due to diffraction. The spot would then have its minimum size (say b_{min}) when – **[JEE MAIN 2016]**

(A) $a = \sqrt{\lambda L}$ and $b_{min} = \frac{2\lambda^2}{L}$

(B) $a = \sqrt{\lambda L}$ and $b_{min} = \sqrt{4\lambda L}$

(C) $a = \frac{\lambda^2}{L}$ and $b_{min} = \sqrt{4\lambda L}$

(D) None of these

Q.17 In a Young's double slit experiment, slits are separated by 0.5 mm, and the screen is placed 150 cm away. A beam of light consisting of two wavelengths, 650 nm and 520nm, is used to obtain interference fringes on the screen. The least distance from the common central maximum to the point where the bright fringes due to both the wavelengths coincide is: **[JEE MAIN 2017]**

(A) 7.8 mm (B) 9.75 mm
(C) 15.6 mm (D) 1.56 mm

Q.18 Unpolarized light of intensity I passes through an ideal polarizer A. Another identical polarizer B is placed behind A. The intensity of light beyond B is found to be I / 2. Now another identical polarizer C is placed between A and B. The intensity beyond B is now found to be I / 8. The angle between polarizer A and C is **[JEE MAIN 2018]**

(A) 45° (B) 60°
(C) 0° (D) 30°

Q.19 The angular width of the central maximum in a single slit diffraction pattern is 60°. The width of the slit is 1µm. The slit is illuminated by monochromatic plane waves. If another slit of same width is made near it, Young's fringes can be observed on a screen placed at a distance 50 cm from the slits. If the observed fringe width is 1 cm, what is slit separation distance? (i.e., distance between the centres of each slit.) **[JEE MAIN 2018]**

(A) 75 µm (B) 100 µm
(C) 25 µm (D) 50 µm

Q.20 In a Young's double slit experiment, the slits are placed 0.320 mm apart. Light of wavelength $\lambda = 500$ nm is incident on the slits. The total number of bright fringes that are observed in the angular range $-30° \le \theta \le 30°$ is: **[JEE MAIN 2019(JAN)]**

(A) 320 (B) 641
(C) 321 (D) 640

Q.21 Calculate the limit of resolution of a telescope objective having a diameter of 200 cm, if it has to detect light of wavelength 500 nm coming from a star : **[JEE MAIN 2019 (APRIL)]**

(A) 305×10^{-9} radian (B) 152.5×10^{-9} radian
(C) 610×10^{-9} radian (D) 457.5×10^{-9} radian

Q.22 In a Young's doubble slit experiment, the ratio of the slit's width is 4 : 1. The ratio of the intensity of maxima to minima, close to the central fringe on the screen, will be **[JEE MAIN 2019 (APRIL)]**

(A) $(\sqrt{3}+1)^4 : 16$ (B) 9 : 1
(C) 4 : 1 (D) 25 : 9

Q.23 Visible light of wavelength 6000×10^{-8} cm falls normally on a single slit and produces a diffraction pattern. It is found that the second diffraction minimum is at 60° from the central maximum. If the first minimum is produced at θ_1, then θ_1 is close to **[JEE MAIN 2020 (JAN)]**

(A) 25° (B) 20°
(C) 30° (D) 45°

Q.24 A polarizer - analyser set is adjusted such that the intensity of light coming out of the analyser is just 10% of the original intensity. Assuming that the polarizer - analyser set does not absorb any light, the angle by which the analyser need to be rotated further to reduce the output intensity to be zero, is **[JEE MAIN 2020 (JAN)]**

(A) 60° (B) 18.4°
(C) 45° (D) 71.6°

Q.25 In a Young's double slit experiment, the separation between the slits is 0.15 mm. In the experiment, a source of light of wavelength 589 nm is used and the interference pattern is observed on a screen kept 1.5 m away. The separation between the successive bright fringes on the screen is: **[JEE MAIN 2020 (JAN)]**

(A) 5.9 mm (B) 3.9 mm
(C) 1.9 mm (D) 2.3 mm

Q.26 In a double slit experiment, at a certain point on the screen the path difference between the two interfering waves is $(1/8)^{th}$ of a wavelength. The ratio of the intensity of light at that point to that at the centre of a bright fringe is : **[JEE MAIN 2020 (JAN)]**

(A) 0.568 (B) 0.672
(C) 0.760 (D) 0.853

Q.27 In a Young's double slit experiment 15 fringes are observed on a small portion of the screen when light of wavelength 500 nm is used. Ten fringes are observed on the same section of the screen when another light source of wavelength λ is used. Then the value of λ is (in nm) ___________. **[JEE MAIN 2020 (JAN)]**

EXERCISE - 5 [PREVIOUS YEARS AIPMT / NEET QUESTIONS]

PART - A : RAY OPTICS

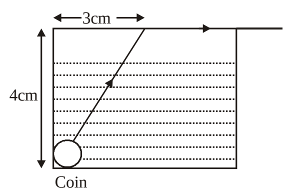
Q.1 The angular resolution of a 10cm. diameter telescope at a wavelength of 5000Å is of the order of – **[AIPMT 2005]**
(A) 10^6 rad (B) 10^{-2} rad
(C) 10^{-4} rad (D) 10^{-6} rad

Q.2 A convex lens and a concave lens, each having same focal length of 25cm. are put in contact to form a combination of lenses. The power in diopters of the combination is – **[AIPMT 2006]**
(A) 50 (B) infinite
(C) zero (D) 25

Q.3 A microscope is focussed on a mark on a piece of paper and then a slab of glass of thickness 3cm and refractive index 1.5 is placed over the mark. How should the microscope be moved to get the mark in focus again – **[AIPMT 2006]**
(A) 4.5cm. downward (B) 1 cm. downward
(C) 2cm upward (D) 1cm. upward

Q.4 The frequency of a light wave in a material is 2×10^{14} Hz and wavelength is 5000Å. The refractive index of material will be – **[AIPMT 2007]**
(A) 1.50 (B) 3.00
(C) 1.33 (D) 1.40

Q.5 A small coin is resting on the bottom of a beaker filled with liquid. A ray of light from the coin travels upto the surface of the liquid and moves along its surface. How fast is the light travelling in the liquid – **[AIPMT 2007]**



(A) 2.4×10^8 m/s (B) 3.0×10^8 m/s
(C) 1.2×10^8 m/s (D) 1.8×10^8 m/s

Q.6 Two thin lenses of focal lengths f_1 and f_2 are in contact and coaxial. Power of the combination is **[AIPMT 2008]**
(A) $\frac{f_1+f_2}{f_1f_2}$ (B) $\sqrt{\frac{f_1}{f_2}}$ (C) $\sqrt{\frac{f_2}{f_1}}$ (D) $\frac{f_1+f_2}{2}$

Q.7 A boy is trying to start a fire by focusing sunlight on a piece of paper using an equiconvex lens of focal length 10cm. The diameter of the sun is 1.39×10^9 m and its mean distance from the earth is 1.5×10^{11} m. What is the diameter of the sun's image on the paper ? **[AIPMT 2008]**
(A) 12.4×10^{-4} m (B) 9.2×10^{-4} m
(C) 6.5×10^{-4} m (D) 6.5×10^{-5} m

Q.8 A ray of light travelling in a transparent medium of refractive index μ, falls on a surface separating the medium from air at an angle of incidence of 45°. For which of the following value of μ the ray can undergo total internal reflection? **[AIPMT (PRE) 2010]**
(A) μ = 1.33 (B) μ = 1.40
(C) μ = 1.50 (D) μ = 1.25

Q.9 A lens having focal length f and aperture of diameter d forms an image of intensity I. Aperture of diameter d/2 in central region of lens is covered by a black paper. Focal length of lens and intensity of image now will be respectively **[AIPMT (PRE) 2010]**
(A) f & I/4 (B) 3f/4 & I/2
(C) f & 3I/4 (D) f/2 & I/2

Q.10 The speed of light in media M_1 and M_2 are 1.5×10^8 m/s and 2.0×10^8 m/s respectively. A ray of light enters from medium M_1 to M_2 at an incidence angle i. If the ray suffers total internal reflection, the value of i is **[AIPMT (MAINS) 2010]**
(A) Equal to $\sin^{-1}(2/3)$
(B) Equal to or less than $\sin^{-1}(3/5)$
(C) Equal to or greater than $\sin^{-1}(3/4)$
(D) Less than $\sin^{-1}(2/3)$

Q.11 A ray of light is incident on a 60° prism at the minimum deviation position. The angle of refraction at the first face (i.e., incident face) of the prism is – **[AIPMT (MAINS) 2010]**
(A) zero (B) 30°
(C) 45° (D) 60°

Q.12 Which of the following is not due to total internal reflection? **[AIPMT (PRE) 2011]**
(A) Brilliance of diamond
(B) Working of optical fibre
(C) Difference between apparent and real depth of a pond
(D) Mirage on hot summer days

Q.13 A biconvex lens has a radius of curvature of magnitude 20cm. Which one of the following options describe best the image formed of an object of height 2 cm placed 30cm from the lens? **[AIPMT (PRE) 2011]**
(A) Real, inverted, height = 1 cm
(B) Virtual, upright, height = 1 cm
(C) Virtual, upright, height = 0.5 cm
(D) Real, inverted, height = 4 cm

Q.14 A converging beam of rays is incident on a diverging lens. Having passed though the lens the rays intersect at a point 15 cm from the lens on the opposite side. If the lens is removed the point where the rays meets will move 5 cm closer to the lens. The focal length of the lens is : **[AIPMT (MAINS) 2011]**
(A) –10 cm (B) 20 cm
(C) – 30 cm (D) 5 cm

Q.15 A thin prism of angle 15° made of glass of refractive index $\mu_1 = 1.5$ is combined with another prism of glass of refractive index $\mu_2 = 1.75$, the combination of the prism produces dispersion without deviation . The angle of the second prism should be: **[AIPMT (MAINS) 2011]**
(A) 7° (B) 10° (C) 12° (D) 5°

Q.16 When a biconvex lens of glass having refractive index 1.47 is dipped in a liquid, it acts as a plane sheet of glass. This implies that the liquid must have refractive index. **[AIPMT (PRE) 2012]**
(A) equal to that of glass (B) less than one
(C) greater than that of glass (D) less than that of glass

Q.17 A ray of light is incident at an angle of incidence, i, on one face of prism of angle A (assumed to be small) and emerges normally from the opposite face. If the refractive index of the prism is μ, the angle of incidence i, is nearly equal to **[AIPMT (PRE) 2012]**

(A) μA (B) $\mu A/2$
(C) A/μ (D) $A/2\mu$

Q.18 A concave mirror of focal length f_1 is placed at a distance of d from a convex lens of focal length f_2. A beam of light coming from infinity and falling on this convex lens-concave mirror combination returns to infinity. The distance d must equal : **[AIPMT (PRE) 2012]**

(A) $f_1 + f_2$ (B) $-f_1 + f_2$
(C) $f_1 + 2f_2$ (D) $-2f_1 + f_2$

Q.19 The magnifying power of a telescope is 9. When it is adjusted for parallel rays the distance between the objective and eyepiece is 20 cm. The focal length of lenses are : **[AIPMT (PRE) 2012]**

(A) 10 cm, 10 cm (B) 15 cm, 5 cm
(C) 18 cm, 2 cm (D) 11 cm, 9 cm

Q.20 For the angle of minimum deviation of a prism to be equal to its refracting angle, the prism must be made of a material whose refractive index : **[AIPMT (MAINS) 2012]**

(A) lies between $\sqrt{2}$ & 1 (B) lies between 2 & $\sqrt{2}$
(C) is less than 1 (D) is greater than 2

Q.21 A rod of length 10 cm lies along the principal axis of a concave mirror of focal length 10 cm in such a way that its end closer to the pole is 20cm away from the mirror. The length of the image is **[AIPMT (MAINS) 2012]**

(A) 10 cm (B) 15 cm
(C) 2.5 cm (D) 5 cm

Q.22 A plano convex lens fits exactly into a plano concave lens. Their plane surfaces are parallel to each other. If lenses are made of different materials of refractive indices μ_1 and μ_2 and R is the radius of curvature of the curved surface of the lenses, then the focal length of combination **[NEET 2013]**

(A) $\frac{2R}{(\mu_2 - \mu_1)}$ (B) $\frac{R}{2(\mu_1 + \mu_2)}$ (C) $\frac{R}{2(\mu_1 - \mu_2)}$ (D) $\frac{R}{(\mu_1 - \mu_2)}$

Q.23 For a normal eye, the cornea of eye provides a converging power of 40 D and the least converging power of the eye lens behind the cornea is 20 D. Using this information, the distance between the retina and the cornea-eye lens can be estimated to be – **[NEET 2013]**

(A) 1.5 cm (B) 5 cm
(C) 2.5 cm (D) 1.67 cm

Q.24 If the focal length of objective lens is increased then magnifying power of – **[AIPMT 2014]**

(A) Microscope will increase but that of telescope decrease.
(B) Microscope and telescope both will increase.
(C) Microscope and telescope both will decrease.
(D) Microscope will decrease but that of telescope will increase.

Q.25 The angle of a prism is A. One of its refracting surfaces is silvered. Light rays falling at an angle of incidence 2A on the first surface returns back through the same path after suffering reflection at the silvered surface. The refractive index μ, of the prism is – **[AIPMT 2014]**

(A) 2sin A (B) 2 cos A
(C) (1/2) cos A (D) tan A

Q.26 The refracting angle of a prism 'A', and refractive index of the material of the prism is cot (A/2). The angle of minimum deviation is : **[AIPMT 2015]**

(A) $180° - 2A$ (B) $90° - A$
(C) $180° + 2A$ (D) $180° - 3A$

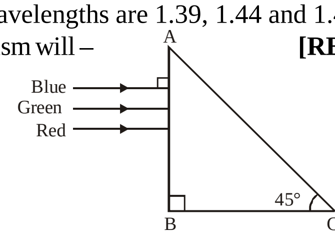
Q.27 Two identical thin plano-convex glass lenses (refractive index × 1.5) each having radius of curvature of 20 cm are placed with their convex surfaces in contact at the center. The intervening space is filled with oil of refractive index 1.7. The focal length of the combination is **[AIPMT 2015]**

(A) –25 cm (B) –50 cm
(C) 50 cm (D) –20 cm

Q.28 In an astronomical telescope in normal adjustment a straight black line of length L is drawn on inside part of objective lens. The eye-piece forms a real image of this line. The length of this image is I. The magnification of the telescope is : **[RE-AIPMT 2015]**

(A) $\frac{L}{I}$ (B) $\frac{L}{I}+1$ (C) $\frac{L}{I}-1$ (D) $\frac{L+1}{L-1}$

Q.29 A beam of light consisting of red, green and blue colours is incident on a right angled prism. The refractive index of the material of the prism for the above red, green and blue wavelengths are 1.39, 1.44 and 1.47, respectively. The prism will – **[RE-AIPMT 2015]**



(A) separate the red colour part from the green and blue colours.
(B) separate the blue colour part from the red and green colours.
(C) separate all the three colours from one another.
(D) not separate the three colours at all.

Q.30 The angle of incidence for a ray of light at a refracting surface of a prism is 45°. The angle of prism is 60°. If the ray suffers minimum deviation through the prism, the angle of minimum deviation and refractive index of the material of the prism respectively, are **[NEET 2016 PHASE 1]**

(A) $45°\,;\,1/\sqrt{2}$ (B) $30°\,;\,\sqrt{2}$
(C) $45°\,;\,\sqrt{2}$ (D) $30°\,;\,1/\sqrt{2}$

Q.31 A astronomical telescope has objective and eyepiece of focal length 40 cm and 4 cm respectively. To view an object 200 cm away from the objective, the lenses must be separated by a distance **[NEET 2016 PHASE 1]**
(A) 37.3 cm (B) 46.0 cm
(C) 50.0 cm (D) 54.0 cm

Q.32 Match the corresponding entries of column-1 with column-2. [Where m is the magnification produced by the mirror] **[NEET 2016 PHASE 1]**

Column-1	**Column-2**
(A) m = –2	(a) Convex mirror
(B) m = –1/2	(b) Concave mirror
(C) m = +2	(c) Real image
(D) m = +1/2	(d) Virtual image

(A) A → b and c; B → b and c; C → b & d; D → a & d
(B) A → a and c; B → a and d; C → a & b; D → c and d
(C) A → a and d; B → b and c; C → b & d; D → b & c
(D) A → c and d; B → b and d; C → b & c ; D → a & d

Q.33 Two identical glass ($\mu_g = 3/2$) equiconvex lenses of focal length f each 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 **[NEET 2016 PHASE 2]**
(A) f / 3 (B) f
(C) 4f / 3 (D) 3f / 4

Q.34 An air bubble in a glass slab with refractive index 1.5 (near normal incidence) is 5 cm deep when viewed from one surface and 3 cm deep when viewed from the opposite face. The thickness (in cm) of the slab is – **[NEET 2016 PHASE 2]**
(A) 8 (B) 10
(C) 12 (D) 16

Q.35 A person can see clearly objects only when they lie between 50 cm and 400 cm from his eyes. In order to increase the maximum distance of distinct vision to infinity, the type and power of the correcting lens, the person has to use, will be **[NEET 2016 PHASE 2]**
(A) Convex, +2.25 diopter
(B) Concave, –0.25 diopter
(C) Concave, –0.2 diopter
(D) Convex, +0.15 diopter

Q.36 The ratio of resolving powers of an optical microscope for two wavelengths λ_1 = 4000 Å and λ_2 = 6000 Å is – **[NEET 2017]**
(A) 9 : 4 (B) 3 : 2
(C) 16 : 81 (D) 8 : 27

Q.37 A beam of light from a source L is incident normally on a plane mirror fixed at a certain distance x from the source. The beam is reflected back as a spot on a scale placed just above the source I. When the mirror is rotated through a small angle θ, the spot of the light is found to move through a distance y on the scale. The angle θ is given by **[NEET 2017]**
(A) y / x (B) x / 2y
(C) x / y (D) y / 2x

Q.38 A thin prism having refracting angle 10° is made of glass of refractive index 1.42. This prism is combined with another thin prism of glass of refractive index 1.7. This combination produces dispersion without deviation. The refracting angle of second prism should be **[NEET 2017]**
(A) 6° (B) 8°
(C) 10° (D) 4°

Q.39 An astronomical refracting telescope will have large angular magnification and high angular resolution, when it has an objective lens of **[NEET 2018]**
(A) Large focal length and large diameter.
(B) Large focal length and small diameter.
(C) Small focal length and large diameter.
(D) Small focal length and small diameter.

Q.40 The refractive index of the material of a prism is $\sqrt{2}$ and the angle of the prism is 30°. One of the two refracting surfaces of the prism is made a mirror inwards, by silver coating. A beam of monochromatic light entering the prism from the other face will retrace its path (after reflection from the silvered surface) if its angle of incidence on the prism is **[NEET 2018]**
(A) 30° (B) 45°
(C) 60° (D) Zero

Q.41 An object is placed at a distance of 40 cm from a concave mirror of focal length 15 cm. If the object is displaced through a distance of 20 cm towards the mirror, the displacement of the image will be **[NEET 2018]**
(A) 30 cm towards the mirror
(B) 36 cm away from the mirror
(C) 30 cm away from the mirror
(D) 36 cm towards the mirror

Q.42 Two similar thin equi-convex lenses, of focal length f each, are kept coaxially in contact with each other such that the focal length of the combination is F_1. When the space between the two lenses is filled with glycerine (which has the same refractive index (μ = 1.5) as that of glass) then the equivalent focal length is F_2. The ratio $F_1 : F_2$ will be : **[NEET 2019]**
(A) 2 : 1 (B) 1 : 2
(C) 2 : 3 (D) 3 : 4

Q.43 Pick the wrong answer in the context with rainbow. **[NEET 2019]**
(A) When the light rays undergo two internal reflections in a water drop, a secondary rainbow is formed.
(B) The order of colours is reversed in the secondary rainbow.
(C) An observer can see a rainbow when his front is towards the sun.
(D) Rainbow is a combined effect of dispersion refraction and reflection of sunlight.

Q.44 In total internal reflection when the angle of incidence is equal to the critical angle for the pair of media in contact, what will be angle of refraction? **[NEET 2019]**
(A) 180°
(B) 0°
(C) Equal to angle of incidence
(D) 90°

PART - B : WAVE OPTICS

Q.1 In Young's double slit experiment, the slits are 2mm apart and are illuminated by photons of two wavelengths λ_1 = 12000Å & λ_2=10000Å. At what minimum distance from the common central bright fringe on the screen 2m from the slit will a bright fringe from one interference pattern coincide with a bright fringe from the other ?
(A) 3 mm (B) 8 mm **[NEET 2013]**
(C) 6 mm (D) 4 mm

Q.2 A parallel beam of fast moving electrons is incident normally on a narrow slit. A fluorescent screen is placed at a large distance from the slit. If the speed of the electrons is increased, which of the following statements is correct
(A) The angular width of central maximum will be unaffected. **[NEET 2013]**
(B) Diffraction pattern is not observed on the screen in the case of electrons.
(C) The angular width of the central maximum of the diffraction pattern will increase.
(D) The angular width of the central maximum will decrease.

Q.3 A beam of light of λ = 600 nm from a distant source falls on a single slit 1 mm wide and the resulting diffraction pattern is observed on a screen 2m away. The distance between first dark fringes on either side of the central bright fringe is **[AIPMT 2014]**
(A) 1.2 cm (B) 1.2 mm
(C) 2.4 cm (D) 2.4 mm

Q.4 In the Young's double-slit experiment, the intensity of light is K at a point on the screen where the path difference is λ. (λ being the wavelength of light used). The intensity at a point where the path difference is λ/4, will be –
(A) K (B) K/4 **[AIPMT 2014]**
(C) K/2 (D) Zero

Q.5 In a double slit experiment, the two slits are 1mm apart and the screen is placed 1 m away. A monochromatic light wavelength 500 nm is used. What will be the width of each slit for obtaining ten maxima of double slit within the central maxima of single slit pattern ? **[AIPMT 2015]**
(A) 0.1 mm (B) 0.5 mm
(C) 0.02mm (D) 0.2 mm

Q.6 For a parallel beam of monochromatic light of wavelength 'λ', diffraction is produced by a single slit whose width 'a' is of the wavelength of the light. If 'D' is the distance of the screen from the slit, the width of the central maxima will be **[AIPMT 2015]**
(A) $\frac{D\lambda}{a}$ (B) $\frac{Da}{\lambda}$ (C) $\frac{2Da}{\lambda}$ (D) $\frac{2D\lambda}{a}$

Q.7 At the first minimum adjacent to the central maximum of a single-slit diffraction pattern the phase difference between the Huygen's wavelet from the edge of the slit and the wavelet from the mid point of the slit is **[RE-AIPMT 2015]**
(A) (π/8) radian (B) (π/4) radian
(C) (π/2) radian (D) π radian

Q.8 Two slits in Young's experiment have widths in the ratio 1 : 25. The ratio of intensity at the maxima and minima in the interference pattern, (I_{max} / I_{min}) is
(A) 4/9 (B) 9/4 **[RE-AIPMT 2015]**
(C) 121/49 (D) 49/121

Q.9 In a diffraction pattern due to a single slit of width a, the first minimum is observed at an angle 30° when light of wavelength 5000 Å is incident on the slit. The first secondary maximum is observed at an angle of – **[NEET 2016 PHASE 1]**
(A) $\sin^{-1}$ (1/4) (B) $\sin^{-1}$ (2/3)
(C) $\sin^{-1}$ (1/2) (D) $\sin^{-1}$ (3/4)

Q.10 The intensity at the maximum in a Young's double slit experiment is I_0. Distance between two slits is d = 5λ, where λ is the wavelength of light used in the experiment. What will be the intensity in front of one of the slits on the screen placed at a distance D=10 d **[NEET 2016 PHASE 1]**
(A) I_0 (B) I_0/4
(C) (3/4) I_0 (D) I_0/2

Q.11 The interference pattern is obtained with two coherent light sources of intensity ratio n. In the interference .... $\frac{I_{max}-I_{min}}{I_{max}+I_{min}}$ will be **[NEET 2016 PHASE 2]**
(A) $\frac{\sqrt{n}}{n+1}$ (B) $\frac{2\sqrt{n}}{n+1}$ (C) $\frac{\sqrt{n}}{(n+1)^2}$ (D) $\frac{2\sqrt{n}}{(n+1)^2}$

Q.12 A linear aperture whose width is 0.02 cm is placed immediately in front of a lens of focal length 60 cm. The aperture is illuminated normally by a parallel beam of wavelength 5 × 10^{-5} cm. The distance of the first dark band of the diffraction pattern from the centre of the screen is **[NEET 2016 PHASE 2]**
(A) 0.10 cm (B) 0.25 cm
(C) 0.20 cm (D) 0.15 cm

Q.13 Young's double slit experment is first performed in air and then in a medium other than air. It is found that 8^{th} bright fringe in the medium lies where 5^{th} dark fringe lies in air. The refractive index of the medium is nearly
(A) 1.59 (B) 1.69 **[NEET 2017]**
(C) 1.78 (D) 1.25

Q.14 Two Polaroids P_1 and P_2 are placed with their axis perpendicular to each other. Unpolarised light I_0 is incident on P_1 . A third polaroid P_3 is kept in between P_1 and P_2 such that its axis makes an angle 45° with t hat of P_1 . The intensity of transmitted light through P_2 is
(A) I_0/4 (B) I_0/8 **[NEET 2017]**
(C) I_0/16 (D) I_0/2

Q.15 Unpolarised light is incident from air on a plane surface of a material of refractive index 'μ'. At a particular angle of incidence 'i', it is found that the reflected and refracted rays are perpendicular to each other. Which of the following options is correct for this situation?

(A) $i = \sin^{-1}(1/\mu)$ **[NEET 2018]**

(B) Reflected light is polarised with its electric vector perpendicular to the plane of incidence.

(C) Reflected light is polarised with its electric vector parallel to the plane of incidence.

(D) $i = \tan^{-1}(1/\mu)$

Q.16 In Young's double slit experiment the separation d between the slits is 2 mm, the wavelength λ of the light used is 5896 Å and distance D between the screen and slits is 100 cm. It is found that the angular width of the fringes is 0.20°. To increase the fringe angular width to 0.21° (with same λ and D) the separation between the slits needs to be changed to **[NEET 2018]**

(A) 2.1 mm (B) 1.9 mm

(C) 1.8 mm (D) 1.7 mm

Q.17 In a double slit experiment, when light of wavelength 400 nm was used, the angular width of the first minima formed on a screen placed 1 m away, was found to be 0.2°. What will be the angular width of the first minima, if the entire experimental apparatus is immersed in water?

$(\mu_{water} = 4/3)$ **[NEET 2019]**

(A) 0.266° (B) 0.15°

(C) 0.05° (D) 0.1°

ANSWER KEY

EXERCISE - 1

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	C	B	B	B	A	C	B	A	D	D	A	A	D	B	B	B	D	D	C	C	B	B	C	B	B
Q	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
A	B	C	D	A	C	B	B	D	D	D	C	A	D	B	B	A	A	B	A	A	B	C	D	A	A
Q	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
A	B	D	C	A	D	D	A	A	D	B	A	B	A	C	B	A	D	B	B	B	D	B	D	A	D
Q	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
A	C	D	B	C	A	A	B	A	A	B	C	D	D	C	B	D	B	A	C	C	A	C	B	B	D
Q	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115										
A	C	C	C	C	B	D	B	C	B	A	A	B	C	A	B										

EXERCISE - 2

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	A	D	A	A	C	B	D	C	B	B	A	B	A	A	B	A	C	B	B	D	B	C	B	B	D
Q	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
A	C	B	D	C	D	A	B	D	B	D	B	B	B	D	A	D	A	D	B	C	A	C	B	A	B
Q	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70					
A	A	B	D	B	C	C	D	A	A	D	B	B	A	C	D	A	C	B	C	C					

EXERCISE - 3 (PART-A)

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A	45	75	4	160	32	8	2	1	10	180	6	3	7	2	8

EXERCISE - 3 (PART-B)

Q	1	2	3	4	5	6	7	8	9	10
A	33	1	1	7	40	3	3	3	2	4

EXERCISE - 4 (PART-A)

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	A	A	B	D	C	A	B	A	B	A	C	B	B	D	D	B	D	A	B	B
Q	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	
A	D	C	C	D	D	D	B	D	D	A	A	A	B	B	A	D	D	6	B	

EXERCISE - 4 (PART-B)

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	C	B	D	A	B	A	D	C	A	D	C	D	B	A	C	D	A	A	C	B
Q	21	22	23	24	25	26	27													
A	A	B	A	B	A	D	750													

EXERCISE - 5 (PART-A)

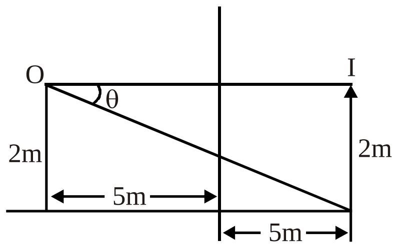
Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	D	C	D	B	D	A	B	C	C	C	B	C	D	C	B	A	A	C	C	B	D	D	D	D	B
Q	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44						
A	A	B	A	A	B	D	A	D	C	B	B	D	A	A	B	B	B	C	D						

EXERCISE - 5 (PART-B)

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A	C	D	D	C	D	D	D	B	D	D	B	D	C	B	B	B	B

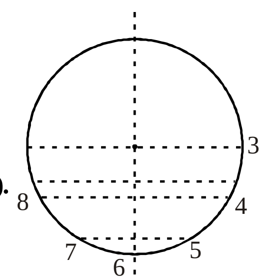
SOLUTIONS
RAY OPTICS
TRY IT YOURSELF - 1

(1) **(B).**



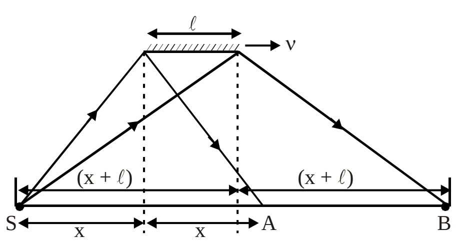
$\tan\theta = \frac{2}{10}$, $\tan\theta = \theta$

(2) **(A).**

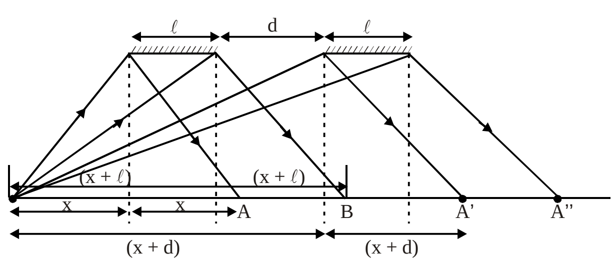


$$\begin{array}{r} 12:00 \\ -8:20 \\ \hline 3:40 \end{array}$$

(3) **(C).**



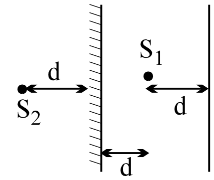
$SA = 2x$, $SB = 2(x + \ell)$
$AB = SB - SA = 2\ell$
Length of the patch will be $= 2\ell$



$SA = 2x$
$SA' = 2(x + d)$
$SA' - SA = 2(x + d) - 2x = 2d$
So if plane mirror is moved then patch will move 2d in same time so velocity of patel will be 2ν if velocity of mirror is ν.

(4) **(B).** $I_1 = I_0 = \frac{P}{4\pi d^2}$

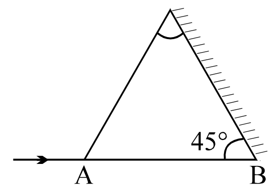
$I_2 = \frac{P}{4\pi(3d)^2}$



$I = I_1 + I_2 = \frac{P}{4\pi d^2}\left[1 + \frac{1}{9}\right] = \frac{10}{9} I_0$

(5) **(D).** Insect can see it's image from A to B.

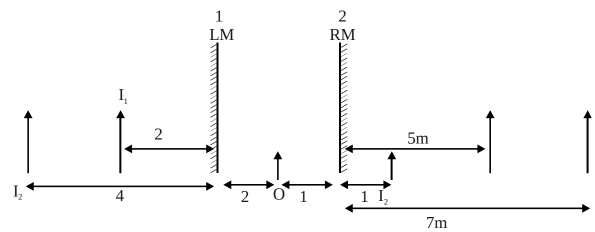
$AB = \frac{l}{\cos 45} = 2\sqrt{2}$



$\text{Time} = \frac{2\sqrt{2}}{4 \times 10^{-2}}$

$= 50\sqrt{2}$ sec

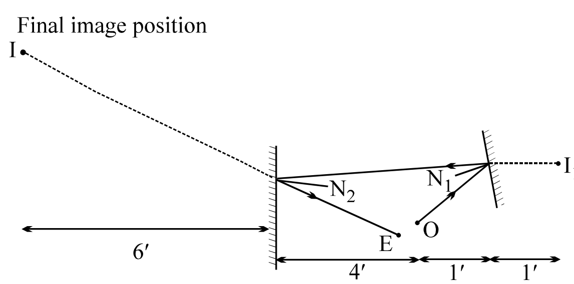
(6) **(C).**



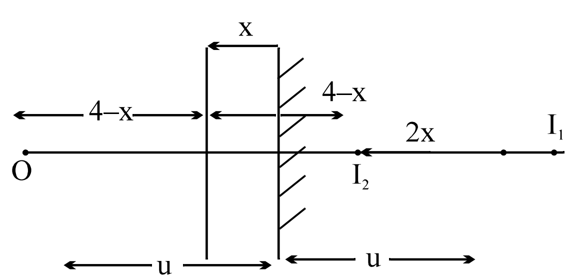
Distance between I_{12} and $0 \Rightarrow 6$m

(7) **(B).** In direction parallel to mirror
$V_I - V_M = -[V_O - V_M]$
$V_I = 2V_M - V_0 = 2 \times 1 - 2 = 0$
In direction parallel to mirror, $V_I = V_0$

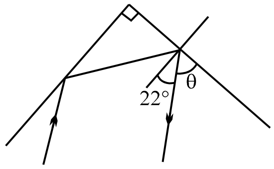
(8) **(A).**



(9) **(B).** Since in the same time in which mirror moves by x, the image moves by 2x. so same relation will carry in velocity as well as acceleration.



(10) **(B).**



From a corner reflector, reflected ray is antiparallel to incident ray.

TRY IT YOURSELF - 2

(1) **(D).** $v = \frac{uf}{uf} = -60$ cm

$\frac{h_I}{5} = \frac{-v}{u} \Rightarrow h_I = -25$ cm

(2) **(B).**

(3) **(B).**

(4) **(D).**

(5) **(C).** For concave mirror if x & y are object distance image distance respectively, we have $-\frac{1}{x} - \frac{1}{y} = -\frac{1}{|f|}$

$\Rightarrow \frac{1}{x} + \frac{1}{y} = \frac{1}{|f|} \Rightarrow -\frac{1}{x^2}\frac{dx}{dt} - \frac{1}{y^2}\frac{dy}{dt} = 0$

$\Rightarrow \left|\frac{V_x}{V_y}\right| = \frac{x^2}{y^2}$ For $\left|\frac{V_x}{V_y}\right| = \frac{1}{4}, \frac{x}{y} = \pm 2$

For, $\frac{x}{y} = 2$, we get $x = \frac{3|f|}{2}$ [for point A]

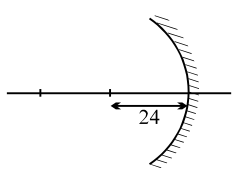
For, $\frac{x}{y} = -2$, we get $x = \frac{|f|}{2}$ [for point B]

As the middle point happens to be focus of mirror, we get $|f| = L$

(6) **(D).** In mirrors focal length is independent of surrounding medium.

(7) **(AB).** $f = -24; |v| = 48, u = ?$

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



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

$\frac{1}{u} = \frac{1}{-24} \pm \frac{1}{48} = \frac{-2 \pm 1}{48} = -\frac{-1}{48}, \frac{-3}{48}$

$\Rightarrow u = -48$ cm or -16 cm

(8) **(C).** $f = 10$ cm l $\quad m = \frac{f}{f-u}$

$m = \frac{1}{2}$; $\frac{1}{2} = \frac{10}{10-u}$; $10 - u = 20$; $u = -10$

(9) **(CD).** As long as object moves towards the mirror image moves away from the mirror (for $u > f$) and $m = -v/u$ $v > u$ so image size increases.

(10) **(A).** Mirror is convex because image of a real object is small, erect and virtual as the object pin moves towards the mirror size of image increase but m is always $m \le 1$, $m = 1$ when object is at pole.

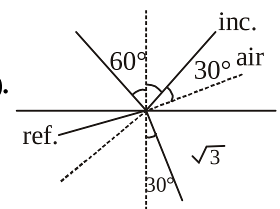
TRY IT YOURSELF - 3

(1) **(C).** Let angle of refraction is θ

$\frac{\sin 2\theta}{\sin\theta} = n \Rightarrow \frac{2\sin\theta\cos\theta}{\sin\theta} = n$

$\theta = \cos^{-1}(n/2)$

(2) **(B).**

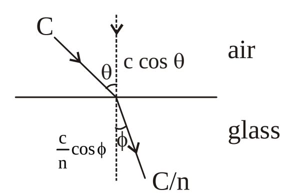


$1 \sin 60° = \sqrt{3} \sin\phi$

$\phi = 30°$

(3) **(B).** In water, speed of sound is higher so water is rarer medium hence bending away from normal.

(4) **(D).** $c\cos\theta = \frac{c}{n}\cos\phi$



$n\cos\theta = \cos\phi$

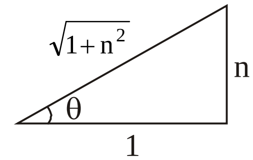
$1\sin\theta = n\sin\phi$

$\therefore n^2\cos^2\theta + \frac{\sin^2\theta}{n^2} = 1$

$n^2 - n^2\sin^2\theta + \frac{\sin^2\theta}{n^2} = 1$

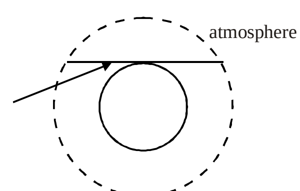
$\sin^2\theta\left[\frac{1}{n^2} - n^2\right] = 1 - n^2$

$\sin^2\theta = \frac{n^2}{1+n^2}$



$\sin\theta = \frac{n}{\sqrt{1+n^2}}$; $\tan\theta = n$

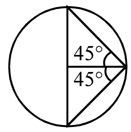
(5) **(A).** .



As distance from earth decreases μ of air increases. Hence even if sun is below horizon, its rays reach the earth hence increasing the period of day.

(6) **(B).** $45° > \theta_C$

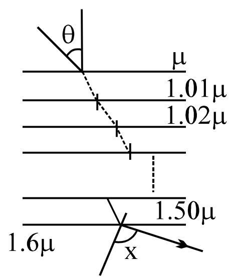
$\sin 45 > \frac{1}{\mu} \Rightarrow \sqrt{2} < \mu$



or $v < \frac{3\times10^8}{\sqrt{2}}$

(7) **(D).** As the ray moves towards the normal while entering medium 2 from 1, we have $n_2 > n_1$
For total internal reflection at interface of 2 & 3, $n_2 > n_3$
Besides, n_3 should also be less than n_1 or else ray would have emerged in medium 3, parallel to its path in medium 1. Hence, $n_3 < n_1 < n_2$ is the correct order.

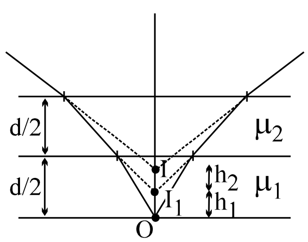
(8) **(B).**



Snell's law : $\mu \sin\theta = 1.6\,\mu \sin x$

$\sin x = \frac{5}{8}\sin\theta$

(9) **(A).**



$h_2 = d/(2\mu_2)$; $h_1 = d/(2\mu_1)$
O — Initial object position
I — Final image position.

(10) **(D).** $\Delta t = t\left(1 - \frac{1}{\mu_{rel}}\right)$

$\Delta t = t(\mu - 1)$
Hence, $0.4 + 0.2[\mu - 1] = 0.5$

$\mu - 1 = \frac{1}{2}$

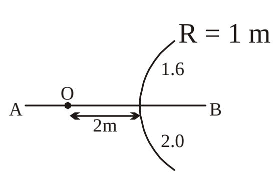
TRY IT YOURSELF - 4

(1) **(A).** $I_1 \Rightarrow \frac{1.6}{v} - \frac{1}{-2} = \frac{1.6-1}{+1}$

$\Rightarrow v_1 = 16$

$I_2 \Rightarrow \frac{2.0}{v} - \frac{1}{-2} = \frac{2-1}{1}$

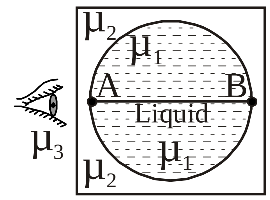
$\Rightarrow v_2 = 4$; $|v_1 - v_2| = 12$ m



(2) **(A).** The bubble acts as a diverging lens.
$\Rightarrow$ Image is virtua, erect and diminished.

(3) **(C).**

(4) **(A).** Image of B must be at infinity



$$\frac{\mu_3}{v} - \frac{\mu_1}{u} = \frac{\mu_2-\mu_1}{R_1} + \frac{\mu_3-\mu_2}{R_2}$$

$$\frac{\mu_3}{\infty} - \frac{\mu_1}{(-2R)} = \frac{\mu_2-\mu_1}{(-R)} + \frac{\mu_3-\mu_2}{\infty}$$

$$\frac{\mu_1}{2R} = \frac{\mu_2-\mu_1}{-R} \;;\; -\mu_1 = 2\mu_2 - 2\mu_1$$

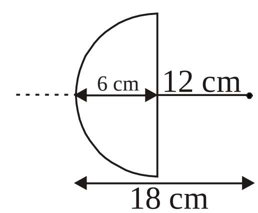
$$\mu_1 = 2\mu_2 \;;\; \frac{\mu_1}{\mu_2} = 2$$

(5) **(D).** $\frac{1.5}{v} - \frac{1}{\infty} = \frac{1.5-1}{6}$

$\frac{1.5}{v} = \frac{0.5}{6}$

$v = 18$ cm

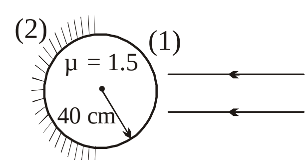
$\frac{1}{v} - \frac{1.5}{12} = \frac{1-1.5}{\infty}$; $n = \frac{12}{3/2} = 8$ cm.



(6) **(D).** R = 40 cm
For refracting surface

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

n = 120 cm



for mirror (2), $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$; $\frac{1}{v} + \frac{1}{40} = \frac{1}{(-20)}$

$v = -40/3$ .... (1)
for refracting surface

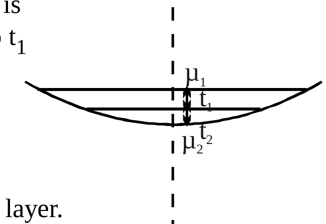
$u = 80 - \frac{40}{3} = \frac{200}{3}$

$\frac{1}{v} - \frac{1.5}{-(200/3)} = \frac{1-1.5}{-40}$

$\frac{1}{v} + \frac{4.5}{200} = \frac{0.5}{40} \Rightarrow \frac{1}{v} = \frac{1}{80} - \frac{4.5}{200}$

$v = -100$ cm
So distance of image from centre will be
100 – 40 = 60 cm (left of the centre)

(7) **(D).** As thickness of liquid is negligible, shift due to t_1 is negligible.



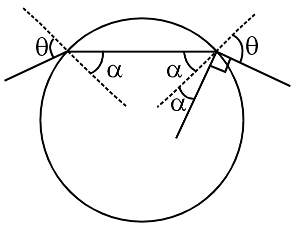
$\left(t_1 \left(1 - \frac{1}{\mu_1} \right) \right)$.

So we can remove this layer.
Now apparent ht. of object for mirror = $d\mu_2$
So for this to form image on the object, object should be at centre of curvature of mirror.

$\therefore$ $R = d\mu_2$

(8) **(B).** No effect of refraction on light coming from centre, because it is along normal.

(9) **(A).** $\alpha + 90° + \theta = 180° \Rightarrow \quad \alpha = 90 - \theta$



$\Rightarrow \; 1 \sin\theta = \sqrt{3} \sin(90 - \theta)\,;\; \theta = 60°$

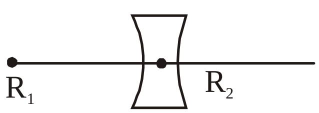
(10) **(D).**

TRY IT YOURSELF - 5

(1) **(A).** $\frac{1}{f_a} = ({}_a\mu_g - 1)\left[\frac{1}{(-R_1)} - \frac{1}{R_2}\right]$

$\frac{1}{f_i} = ({}_i\mu_g - 1)\left[\frac{1}{(-R_1)} - \frac{1}{R_2}\right]$

$\frac{f_i}{f_a} = \frac{{}_a\mu_g - 1}{{}_i\mu_g - 1}$



$\frac{f_i}{-40} = \frac{1.5 - 1}{\frac{1.5}{2} - 1}$; $f_i - 40 \times \frac{(0.5)}{-0.25} = 80$ cm

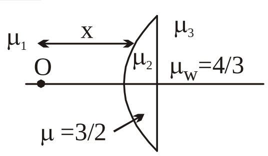
$f_i = +80$ cm (convex nature)

(2) **(C).** $\frac{\mu_3}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R_1} + \frac{\mu_3 - \mu_2}{R_2}$

$\frac{\mu_3}{\infty} - \frac{1}{x} = \frac{1.5 - 1}{10} + \frac{4/3 - 3/2}{\infty}$

$\frac{-1}{x} = \frac{0.5}{10}$

$x = -20$ cm

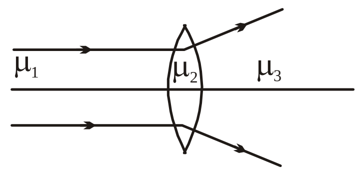


(3) **(B).** $\frac{\mu_3}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R_1} + \frac{\mu_3 - \mu_2}{R_2}$

$\frac{\mu_3}{v} - \frac{\mu_1}{\infty} = \frac{\mu_2 - \mu_1}{R} + \frac{\mu_3 - \mu_2}{(-R)}$

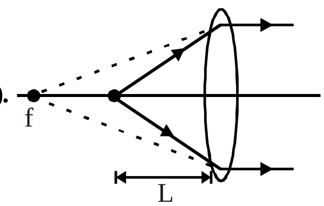
$\frac{\mu_3}{v} = \frac{\mu_2 - \mu_1}{R} - \frac{(\mu_3 - \mu_2)}{R} < 0$

For diverging nature $v < 0$



$\frac{\mu_2 - \mu_1}{R} < \frac{\mu_3 - \mu_2}{R}$; $2\mu_2 < \mu_1 + \mu_3$

(4) **(D).**



$u = -L\,;\, v = -f$

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \Rightarrow \quad \frac{1}{f} + \frac{1}{L} = \frac{1}{f} \Rightarrow \; L = \frac{F}{2}$

$\Rightarrow \; v = -f \;;\; u = -f/2$

$\Rightarrow \; v_I = \frac{v^2}{u^2} v_0 \Rightarrow v_1 = \frac{f^2}{f^2} \times 4v_0 = 4 \times 5 \Rightarrow 20$ m/s

(5) **(C).** $\frac{1}{v} - \frac{1}{-x} = \frac{1}{f}$; $\frac{1}{v} + \frac{1}{x} = \frac{1}{f}$; $\frac{1}{v} + \frac{1}{f} - \frac{1}{x}$

(a) $v\downarrow \Rightarrow f\downarrow$
(b) diverging lens will diverge rays further.
(c) $v\downarrow \;\Rightarrow x\uparrow$

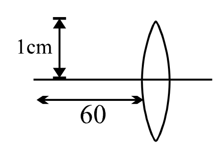
(6) **(A).** If image of ∞ is formed at 250 cm lens works will

$\frac{1}{-250} - \frac{1}{\infty} = \frac{1}{f} \Rightarrow f = -250$ cm ; $f = -2.5$ m

$P = \frac{1}{-2.5} = -0.4$ D

(7) **(C).** $h_I = mh_0 = \frac{f\,h_0}{u + f}$

$= \frac{40h_0}{-60 + 40} \;\; -2\,h_0$



$\frac{dh_I}{dt} = -2\,\frac{dh_0}{dt} = -2 \times 10 = -20$ cm/s

(8) **(ABC).**

(9) **(C).** $\frac{1}{f_1} = (\mu_1 - 1)\left(\frac{1}{\infty} + \frac{1}{R}\right) = \frac{\mu_1 - 1}{R}$

$\frac{1}{f_2} = (\mu_3 - 1)\left(-\frac{1}{R} + \frac{1}{R}\right) = 0$

$\frac{1}{f_3} = (\mu_2 - 1)\left(-\frac{1}{R} - \frac{1}{\infty}\right) = -\frac{(\mu_2 - 1)}{R}$

$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} = \frac{(\mu_1 - 1)}{R} - \frac{(\mu_2 - 1)}{R} = \frac{1}{R}(\mu_1 - \mu_2)$

$f = \frac{R}{(\mu_1 - \mu_2)}$

(10) **(C).** $m = \frac{-2.4}{160} = \frac{v}{u}$; $v = \frac{2.4}{168}$

$-\frac{70}{u} - \frac{1}{u} = \frac{1}{5.5}$

$u = -71 \times 5.5 \text{ cm} = -3.9 \text{ m}$

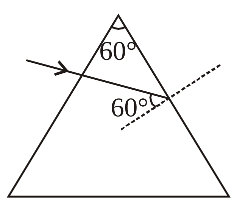
(11) **(B).** $\frac{f}{f'} = -\frac{\omega}{\omega'}$

but $\frac{\omega}{\omega'} = \frac{5}{3}$ and $f = -15$ cm

$\therefore f' = -f\left(\frac{\omega'}{\omega}\right) = +15 \times \frac{3}{5} = 9$ cm

TRY IT YOURSELF - 6

(1) **(AB).** $\delta_{min} \le 30°$



$$\mu = \frac{\sin\left(\frac{60 + \delta_{min}}{2}\right)}{\sin\frac{60}{2}} \le \frac{\sin\left(\frac{60 + 30°}{2}\right)}{\sin\left(\frac{60}{2}\right)} = \sqrt{2}$$

$\mu \le \sqrt{2}$

$\delta_{max} \ge 30°$

$i + 90 - 60 \ge 30° \Rightarrow i \ge 0°$

$\mu \ge \frac{2}{\sqrt{3}}$; $\mu \sin 60° \ge 1 \sin 90°$

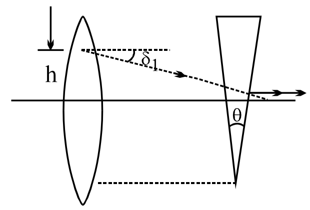
(2) **(B).** $\theta_T = 2A(\mu_v' - \mu_r) - (\mu_v' - \mu_r')$ $A' = 0$

$\therefore \frac{A'}{A} = \frac{2(\mu_v - \mu_r)}{\mu_v' - \mu_r'}$

(3) **(D).**

(4) **(D).**

(5) **(B).** $\tan\delta_1 = h/f$



$\delta_{Net} = 0 = -\delta_L + \delta_P = 0$

$\frac{h}{f} = (\mu - 1)\theta \Rightarrow \frac{h}{f\theta} + 1 = \mu$

(6) **(B).** $\omega = \frac{\delta_V - \delta_R}{\delta_\gamma - 1}$

$\because$ $\delta_\gamma - 1 = 0$ for B, so B is showing maximum dispersive power.

(7) **(A).** $\delta = i + e - A$

for $i = 60°$ given $A = \delta = e$

$\therefore$ $A = \delta = e = 60°$

Applying Snell's law on first surface

$1 \times \sin 60° = \mu \sin 30° \Rightarrow \mu = \sqrt{3} = 1.73$

(8) **(A).** $\delta = i + e - A$

$d_{min} = 60°$ when i = e

$\therefore$ $60° = 2i - A = 2(60°) - A$

$\therefore$ $A = 60°$

$$\therefore \quad \mu = \frac{\sin\left(\frac{A + \delta_{min}}{2}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{\sin\left(\frac{60 + 60}{2}\right)}{\sin\left(\frac{60}{2}\right)} = \sqrt{3}$$

(9) **(D).** When angle of incidence is i_1, e = 40°

(from reversibility of ray)

also $\delta = 70°$

$\therefore$ $70° = i_1 + 40° - A$ $\quad\therefore$ $i_1 = 90°$

(10) **(C).**

(11) **(B).**

TRY IT YOURSELF - 7

(1) **24, 150cm**

Here, focal length of objective lens, $f_0 = 144$ cm

Focal length of eye-piece, $f_e = 6.0$ cm

Therefore, using $m = \frac{f_0}{f_e} \Rightarrow m = \frac{144}{6.0} = 24$

Also, the distance between objective and eye piece is

$= f_0 + f_e = 144 + 6 = 150$ cm

(2) **1500.**

Angular magnification $= \frac{f_0}{f_e} = \frac{1500}{1} = 1500$

(3) 13.7 cm

Let D be the diameter of moon's image

Then $\frac{D}{1500} = \frac{\text{Diameter of moon}}{\text{Radius of lunar orbit}}$

$$= \frac{3.48 \times 10^6 \times 100}{3.8 \times 10^8 \times 100}$$

$$\Rightarrow D = 1500 \times \frac{3.48}{380} = 13.7\text{ cm}$$

(4) 9.47cm, 88

Here $f_0 = 0.8$ cm ; $f_e = 2.5$ cm

$D = 25$ cm, $v_e = -D = -25$ cm

$u_0 = -9.0$ mm $= -0.90$ cm

Linear magnification of the eye lens is given by

$$m_e = \frac{v_e}{u_e} = 1 + \frac{D}{f_e} \Rightarrow \frac{-25}{u_e} = 1 + \frac{25}{2.5} = 11$$

$$\therefore u_e = -\frac{25}{11}\text{ cm}$$

Using $-\frac{1}{u_0} + \frac{1}{v_0} = \frac{1}{f_0}$ for objective lens we get

$$-\frac{1}{-0.90} + \frac{1}{v_0} = \frac{1}{0.80}$$

or $\frac{1}{v_0} = \frac{1}{0.8} - \frac{1}{0.9} = \frac{0.9 - 0.8}{0.72}$

$$\therefore v_0 = \frac{0.72}{0.1}\text{ cm} = 7.2\text{ cm}$$

$\therefore$ Separation between two lenses

$$= |u_e| + |v_0| = \frac{25}{11} + 7.2 = 2.27 + 7.2 = 9.47\text{ cm}$$

Magnifying power

$$M = \frac{v_0}{-u_0}\left(1 + \frac{D}{f_0}\right) = \frac{7.2}{0.9}\left(1 + \frac{25}{2.5}\right) = 88$$

(5) 20 to 24 dioptre

When the object is placed at infinity, the eye makes use of the least converging power, Therefore, total converging power of cornea and the eye lens = 40 + 20 = 60 dioptre.

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

$$u = -\infty, f = \frac{1}{P} = \frac{1}{60}\text{ m}$$

$$\therefore \frac{-1}{-\infty} + \frac{1}{v} = 60 \Rightarrow v = \frac{1}{60}\text{ m} = \frac{100}{60}\text{ cm i.e., } v = \frac{5}{3}\text{ cm}$$

To focus the object at the near point,

$$u = -25\text{ cm} ; v = \frac{5}{3}\text{ cm}$$

$$\therefore -\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \Rightarrow \frac{1}{f} = \frac{-1}{-25} + \frac{1}{5/3} = \frac{1}{25} + \frac{3}{5}$$

or $\frac{1}{f} = \frac{1+15}{25} = \frac{16}{25}$

$$\therefore \text{Power } P = \frac{100}{f\text{ (cm)}}\text{ dioptre} = \frac{100}{25} \times 16 = 64\text{ dioptre}$$

$\Rightarrow$ Power of eye lens = 64 – 40 = 24 dioptre.

Therefore, the rough range of eye lens is 20 to 24 dioptre.

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

$$\therefore P = \frac{1}{-2} + \frac{1}{\infty} = -0.5\text{ dioptre lens}$$

(7) Here $\ell = 20$cm, $D = 25$cm. $f_0 = 1$cm and $f_e = 2$

$$m_0 = \frac{\ell}{f_0} = \frac{20}{1} = 20 ; \quad m_e = \frac{D}{f_0} = \frac{25}{2}$$

$$m = m_0 m_e = 20 \times \frac{25}{2} = 250$$

(8) $m = \frac{f_0}{f_e} = 100$

or, $f_0 = 100 f_e$

Since, $f_0 + f_e = 101$

Then, $100 f_e + f_e = 101$

$\therefore$ $f_e = 1$cm. and $f_0 = 100$cm.

(9) Since the aperture of lens L_1 is largest, it is used as objective for a telescope.

The lens L_3 is used as eyepiece since its focal length is smaller.

WAVE OPTICS

TRY IT YOURSELF - 1

(1) **(D).** $I_A = I + 4I + 2\sqrt{4I^2}\cos\frac{\pi}{2} = 5I$

$I_B = I + 4I + 2\sqrt{4I^2}\cos\pi = I$

$I_A - I_B = 4I$

(2) **(C).**

(3) **(D).**

(4) **(C).**

(5) **(C).**

(6) **(D).**

(7) **(B).**

(8) **(B).** $\frac{n_1 D\lambda_1}{d} = \frac{n_2 D\lambda_2}{d}$; $\frac{n_1}{n_2} = \left(\frac{D\lambda_2}{d}\right) / \left(\frac{D\lambda_1}{d}\right)$

$$\Rightarrow \quad \text{LCM of } \frac{D\lambda_1}{d} \,\&\, \frac{D\lambda_2}{d}$$

(9) **(B).**

(10) **(B).** $d = 2 \times 10^{-4}$

$$\theta = \lambda/d \Rightarrow \lambda = \left(\frac{10.8}{60}\right) \times \frac{\pi}{180} \times 2 \times 10^{-4} = 6280\ \text{Å}$$

TRY IT YOURSELF - 2

(1) Given, $D = 1\text{m}, n = 1$

$x = 2.5\text{mm} = 2.5 \times 10^{-3}\ \text{m}$

$\lambda = 500\text{nm} = 500 \times 10^{-9}\ \text{m} = 5 \times 10^{-7}\ \text{m}$

Using formula, $x = n\dfrac{\lambda D}{d} \Rightarrow d = \dfrac{n\lambda D}{x}$

or $d = \dfrac{1 \times 5 \times 10^{-7} \times 1}{2.5 \times 10^{-3}} = 2 \times 10^{-4}\ \text{m} = 0.2\ \text{mm}$

(2) Size of aperture, $a = 50\text{m}$

Distance of aperture from tower,

$$Z_F = \frac{40}{2} = 20\ \text{km} = 20 \times 10^3\ \text{m}$$

Fresnel distance, $Z_F = \dfrac{a^2}{\lambda} \Rightarrow \lambda = \dfrac{a^2}{Z_F} = \dfrac{(50)^2}{20 \times 10^3}$

or $\lambda = 125 \times 10^{-3}\ \text{m} = 12.5\text{cm}.$

(3) Width of the central maximum

$$y = \frac{2D\lambda}{d} = \frac{2 \times 1.8 \times (6500 \times 10^{-10})}{(0.5 \times 10^{-3})} = 4.68 \times 10^{-3}\ \text{m}$$

(4) Fresnel's distance, $D_F = \dfrac{d^2}{\lambda} = \dfrac{(3 \times 10^{-3})^2}{5 \times 10^{-7}} = 18\ \text{m}$

(5) (i) $\sin\theta = \dfrac{n\lambda}{d}$

For first minimum

Using, $\sin\theta = \dfrac{n\lambda}{\sin 30°} = \dfrac{1 \times 5500}{0.5} = 11000\ \text{Å}$

(ii) Using $\sin\theta = \dfrac{(2n+1)\lambda}{2\quad d}$

For 1 maximum, we get $\sin\theta = \dfrac{3\lambda}{2d}$

$\therefore\ d = \dfrac{3}{2}\dfrac{\lambda}{\sin 30°} = \dfrac{3}{2} \times \dfrac{5500}{0.5} = 16500\ \text{Å}$

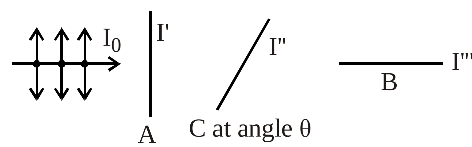
(6) (i) Using $\mu = \tan i_p$

We get $\tan i_p = \mu = 1.732 \Rightarrow i_p = 60°$

(ii) $\mu = \dfrac{\sin i_p}{\sin r}$ or $\sin r = \dfrac{\sin i_p}{\mu} = \dfrac{\sin 60^0}{1.732}$

or $\sin r = \dfrac{\sqrt{3/4}}{1.732} = \dfrac{1.732/2}{1.732} = \dfrac{1}{2} \Rightarrow r = 30°$

(7)



Let I_0 be the intensity of unpolarised light incident on polaroid A so using Malus law $[I = I_0\cos^2\theta]$

$$I' = \frac{I_0}{2}\cos^2\theta \text{ then } I'' = \frac{I_0}{2}\cos^2\theta$$

and $I''' = \dfrac{I_0}{2}\cos^2\theta\cos^2\left(\dfrac{\pi}{2} - \theta\right)$

$$= \frac{I_0}{2}\cos^2\theta\sin^2\theta = \frac{I_0}{8}\sin^2 2\theta \text{ But } I''' = \frac{I_0}{8}$$

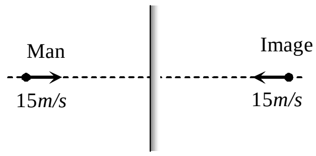
thus $\sin^2 2\theta = 1$ or $\theta = 45°$ or $\pi/4$ radian.

CHAPTER- 6 : OPTICS
EXERCISE-1

(1) **(C).** Ray after reflection from two mutually perpendicular mirrors becomes anti-parallel.

(2) **(B).** In two images man will see himself using left hand.

(3) **(B).**

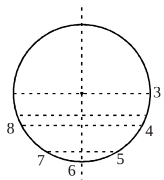


Relative velocity of image w.r.t man

$= 15 - (-15) = 30$ m/s

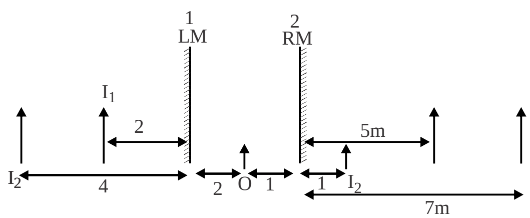
(4) **(B).** f = R/2, and R = ∞ for plane mirror.

(5) **(A).**



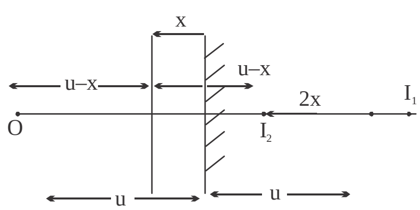
$$\begin{array}{r} 12:00 \\ \underline{-8:20} \\ 3:40 \end{array}$$

(6) **(C).**



Distance between I_{12} and O ⇒ 6m

(7) **(B).** Since in the same time in which mirror moves by x, the image moves by 2x. So same relation will carry in velocity as well as acceleration.



(8) **(A).** For real image m = – 2, so by using $m = \frac{f}{f-u}$

$$\Rightarrow -2 = \frac{-50}{-50-u} \Rightarrow u = -75 \text{ cm}$$

(9) **(D).** When object is kept at centre of curvature. It's real image is also formed at centre of curvature.

(10) **(D).** $R = -30\,\text{cm} \Rightarrow f = -15\,\text{cm}$; $O = +2.5\text{cm}, u = -10\text{cm}$

By mirror formula $\frac{1}{-15} = \frac{1}{v} + \frac{1}{(-10)} \Rightarrow v = 30\,\text{cm}.$

$$\frac{I}{O} = -\frac{v}{u} \Rightarrow \frac{I}{(+2.5)} = -\frac{30}{(-10)} \text{ ; } I = +7.5\text{cm}.$$

(11) **(A).** m = ± 3 and f = – 6 cm

Now $m = \frac{f}{f-u} \Rightarrow \pm 3 = \frac{-6}{-6-u}$

For real image $-3 = \frac{-6}{-6-u} \Rightarrow u = -8$ cm

For virtual image $3 = \frac{-6}{-6-u} \Rightarrow u = -4$cm

(12) **(A).** Focal length of the mirror remains unchanged.

(13) **(D).** $f = \frac{R}{2} = 20\,\text{cm},\ m = 2$

For real image; m = –2,

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

For virtual image; m = +2

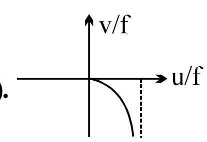
So, $+2 = \frac{-20}{-20-u} \Rightarrow u = -10\,\text{cm}$

(14) **(B).** $m = \frac{f}{f-u}$; $-3 = \frac{f}{f-(-20)} \Rightarrow f = -15\text{cm}$

(15) **(B).** The distance of an object from a spherical mirror is equal to the focal length of the mirror then the image may be at infinity.

(16) **(B).** The linear magnification is less than one.

(17) **(D).**



(18) **(D).** $\mu = \frac{c}{v} = \frac{3\times 10^8}{1.5\times 10^8} = 2$

(19) **(C).** $\text{time} = \frac{\text{distance}}{\text{speed}} = \frac{t}{c/n} = \frac{nt}{c}$

(20) **(C).** Let ν ' and λ' represents frequency and wavelength of light in medium respectively.

so $\nu' = \frac{v}{\lambda'} = \frac{c/\mu}{\lambda/\mu} = \frac{c}{\lambda} = \nu$

(21) **(B).** ${}_a\mu_g = \frac{3}{2}, {}_a\mu_w = \frac{4}{3}$ ∴ ${}_w\mu_g = \frac{{}_a\mu_g}{{}_a\mu_w} = \frac{3/2}{4/3} = \frac{9}{8}$

(22) **(B).** $v \propto \lambda \Rightarrow \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$

$$\therefore\ v_2 = \frac{v_1}{\lambda_1}\times\lambda_2 = 3\times 10^8 \times \frac{4500}{6000} = 2.25\times 10^8\,\text{m/s}$$

(23) **(C).** $v = \frac{c}{\mu} = \frac{3\times 10^8}{2.4} = 1.25\times 10^8\,\text{m/s}$

(24) **(B).** $\mu \propto \frac{1}{\lambda}, \lambda_r > \lambda_v$

(25) **(B).** $\lambda_g = \frac{\lambda_a}{\mu_g} = \frac{5890}{1.6} = 3681\text{Å}$.

(26) **(B).** $v \propto \frac{1}{\mu}$, μ is smaller for air than water, glass and diamond.

(27) **(C).** In vacuum speed of light is constant and it is equal to 3×10^8 m/sec

(28) **(D).** Distance $= v \times t = \frac{c}{\mu} \times t = \frac{3 \times 10^8}{1.5} \times 10^{-9}$

$= 0.2 \text{ m} = 20 \text{ cm}.$

(29) **(A).** Swimming pool means $\mu_{water} = 4/3$

So that the real depth R = a $\mu = 1.2 \times \frac{4}{3} = 1.6$ m

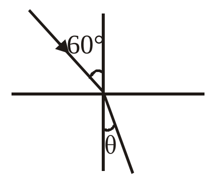
(30) **(C).** Let angle of refraction is θ

$$\frac{\sin 2\theta}{\sin\theta} = n \Rightarrow \frac{2\sin\theta\cos\theta}{\sin\theta} = n$$

$\theta = \cos^{-1}(n/2)$

Angle of incidence $= 2\theta = 2\cos^{-1}(n/2)$

(31) **(B).** $\frac{\sin 60}{\sin\theta} = \sqrt{3}$; $\theta = 30°$



Angle between incident ray and refracted ray $= 60 - 30 = 30°$

(32) **(B).** The apparent depth of ink mark

$$= \frac{\text{real depth}}{\mu} = \frac{3}{3/2} = 2 \text{ cm}$$

Thus person views mark at a distance = 2 + 2 = 4cm.

(33) **(D).** Apparent rise $= d\left(1 - \frac{1}{{}_a\mu_w}\right) = 12 \times \left(1 - \frac{3}{4}\right) = 3$ cm.

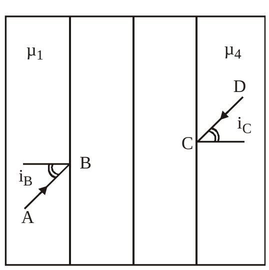
(34) **(D).** Applying Snell's law at B and C,

$\mu \sin i$ = constant or

$\mu_1 \sin i_B = \mu_4 \sin i_C$

But $AB \parallel CD$

$\therefore\ i_B = i_C$ or $\mu_1 = \mu_4$



(35) **(D).** ${}_a\mu_g = \frac{1}{\sin C} \Rightarrow \sin C = \frac{1}{{}_a\mu_g}$

As μ for violet colour is maximum, so sin C is minimum and hence critical angle C is minimum for violet colour.

(36) **(C).** The critical angle C is given by

$$\sin C = \frac{n_2}{n_1} = \frac{\lambda_1}{\lambda_2} = \frac{3500}{7000} = \frac{1}{2} \Rightarrow C = 30°$$

(37) **(A).** For total internal reflection i > C

$$\Rightarrow \sin i > \sin C \Rightarrow \sin i > \frac{1}{\mu} \Rightarrow \frac{1}{\sin i} < \mu.$$

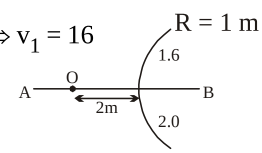
(38) **(D).** For total internal reflection light must travel from denser medium to rarer medium.

(39) **(B).** Due to high refractive index its critical angle is very small so that most of the light incident on the diamond is total internally reflected repeatedly and diamond sparkles.

(40) **(B).** $\mu = \frac{1}{\sin C} = \frac{1}{\sin 30} = 2$

$$\therefore v = \frac{3 \times 10^8}{2} = 1.5 \times 10^8 \text{ m/s}$$

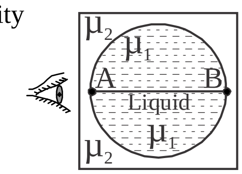
(41) **(A).** $I_1 \Rightarrow \frac{1.6}{v} - \frac{1}{-2} = \frac{1.6 - 1}{+1} \Rightarrow v_1 = 16$



$I_2 \Rightarrow \frac{2.0}{v} - \frac{1}{-2} = \frac{2-1}{1}$

$\Rightarrow v_2 = 4$; $|v_1 - v_2| = 12$ m

(42) **(A).** Image of B must be at infinity



$$\frac{\mu_2}{\infty} - \frac{\mu_1}{-2R} = \frac{\mu_2 - \mu_1}{-R}$$

$$\frac{\mu_1}{2} = \mu_1 - \mu_2 \ ; \ \frac{\mu_1}{\mu_2} = 2$$

(43) **(B).** No effect of refraction on light coming from centre, because it is along normal.

(44) **(A).** For a real object in concave lens, the image is always virtual, erect, diminished and on the other side of the lens as object.

(45) **(A).** The bubble acts as a diverging lens.

$\Rightarrow$ Image is virtual, erect and diminished.

(46) **(B).** From lens formula

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = 0.5\left[\frac{1}{R} - \left(\frac{1}{-R}\right)\right] = \frac{0.5 \times 2}{20}$$

f = 20 cm. Therefore rays coming parallel to axis will form image at 20cm.

(47) **(C).** Effective power $P = P_1 + P_2 = 4 - 3 = 1D$

(48) **(D).** One part of combination will behave as converging lens and the other as diverging lens of same focal length. As such total power will be zero.

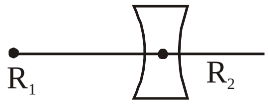
(49) **(A).** As power of a lens is reciprocal of focal length in m,

$$P = \frac{1}{5 \times 10^{-2} \text{ m}} = \frac{1}{0.05} \text{ diopter} = 20 \text{ D}$$

(50) **(A).** $\frac{1}{f_a} = ({}_a\mu_g - 1)\left[\frac{1}{(-R_1)} - \frac{1}{R_2}\right]$

$$\frac{1}{f_i} = ({}_i\mu_g - 1)\left[\frac{1}{(-R_1)} - \frac{1}{R_2}\right]$$

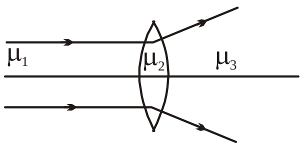
$$\frac{f_i}{f_a} = \frac{{}_a\mu_g - 1}{{}_i\mu_g - 1}$$



$$\frac{f_i}{-40} = \frac{1.5-1}{\frac{1.5}{2}-1} \; ; \; f_i = -40 \times \frac{(0.5)}{-0.25} = 80 \text{ cm}$$

$f_i = +80$ cm (convex nature)

(51) **(B).**



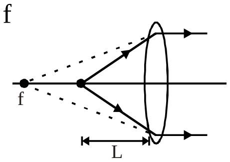
Assume $\mu_1 = \mu_3 = \mu$

Convex lens become diverging if $\mu_2 < \mu$ check option which satisfy above relation.

(52) **(D).** $u = -L$; $v = -f$; $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$\Rightarrow \frac{1}{f} + \frac{1}{L} = \frac{1}{f} \Rightarrow L = \frac{F}{2}$

$\Rightarrow v = -f$; $u = -f/2$



$\Rightarrow v_I = \frac{v^2}{u^2} v_0 \Rightarrow v_1 = \frac{f^2}{f^2} \times 4v_0 = 4 \times 5 \Rightarrow$ 20 m/s

(53) **(C).** $\frac{1}{v} - \frac{1}{-x} = \frac{1}{f}$; $\frac{1}{v} + \frac{1}{x} = \frac{1}{f}$

(a) $f\uparrow \rightarrow v\uparrow$

(b) diverging lens will diverge rays further.

(c) $x\uparrow \Rightarrow v\downarrow$

(54) **(A).** We know that $\delta = A(\mu - 1)$ or $\mu = 1 + \frac{\delta}{A}$

Here $A = 6°$, $\delta = 3°$, therefore $\mu = 1 + \frac{3}{6} = 1.5$

(55) **(D).** Dispersion occurs when a material slows down some wavelengths more than others.

(56) **(D).** The speed of all colours is reduced in the prism, with maximum reduction for violet light.

(57) **(A).** $\delta = i + e - A$

for $i = 60°$ given $A = \delta = e$

$\therefore$ $A = \delta = e = 60°$

Applying Snell's law on first surface

$1 \times \sin 60° = \mu \sin 30° \Rightarrow \mu = \sqrt{3} = 1.73$

(58) **(A).** $\delta = i + e - A$

$d_{min} = 60°$ when $i = e$

$\therefore$ $60° = 2i - A = 2(60°) - A$ $\therefore$ $A = 60°$

$$\therefore \quad \mu = \frac{\sin\left(\frac{A+\delta_{min}}{2}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{\sin\left(\frac{60+60}{2}\right)}{\sin\left(\frac{60}{2}\right)} = \sqrt{3}$$

(59) **(D).** When angle of incidence is i_1, $e = 40°$ (from reversibility of ray)

also $\delta = 70°$ $\therefore$ $70° = i_1 + 40° - A$ $\therefore$ $i_1 = 90°$

(60) **(B).** Secondary rainbow is formed by rays undergoing internal reflection twice inside the drop.

(61) **(A).** At sunset or sunrise, the Sun's rays have to pass through a larger distance in the atmosphere. Most of the blue and other shorter wavelengths are removed by scattering. The least scattered light reaching our eyes, therefore, the Sun looks reddish. This explains the reddish appearance of the Sun and full Moon near the horizon.

(62) **(B).** A passenger in an aeroplane may see a primary and a secondary rainbow as concentric circles.

(63) **(A).** As sunlight travels through the Earth's atmosphere, it gets scattered (changes its direction) by the atmospheric particles. Light of shorter wavelengths is scattered much more than light of longer wavelengths. The amount of scattering is inversely proportional of the fourth power of the wavelength. This is known as Rayleigh scattering. Hence, the bluish colour predominates in a clear sky, since, blue has a shorter wavelength, than red and is scattered much more strongly. In fact violet gets scattered even more than blue, having a shorter wavelength. But since, our eyes are more sensitive to blue than violet, we see the sky blue.

(64) **(C).** At sunset or sunrise the sun's rays have to pass through a larger distance in the atmosphere and most of the blue and other shorter wavelengths are removed by scattering.

(65) **(B).** From Rayleigh's scattering,

Amount of scattering $\propto \frac{1}{\lambda^4}$

Since, λ_{red} is more, it is least scattered and hence, suitable for indication signals.

(66) **(A).** $P = \frac{1}{f} = -\frac{1}{v} + \frac{1}{u} = -\frac{1}{100} + \frac{1}{25} = \frac{3}{100} = +3$ D

(67) **(D).** The image of object at infinity should be formed at 100cm from the eye $\frac{1}{f} = \frac{1}{\infty} - \frac{1}{100} = -\frac{1}{100}$

So the power $= \frac{-100}{100} = -1$D

(Distance is given in cm but $P = \frac{1}{f}$ in metres)

(68) **(B).** In myopia, $u = \infty$, $v = d$ = distance of far point.

By $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ we get $f = -d$

Since f is negative, hence the lens used is concave.

(69) **(B).** As the person can see objects upto 50 cm. it means that the image of an object situated at infinity must be formed at 50 cm. i.e. $u = \infty$, $v = -50$ cm. therefore

from $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ or $f = v = -50$ cm

$\because P = \frac{1}{f}$ meter or $P = -\frac{1}{0.50} = -2D$

(70) **(B).** For a compound microscope

$f_{objective} < f_{eye\,piece}$

(71) **(D).** In general, the simple microscope is used with image at D, hence $m = 1 + \frac{D}{f} = 1 + \frac{25}{5} = 6$

(72) **(B).** $m = m_0 m_e$; $35 = 7 m_e$ $\therefore m_e = 5$

(73) **(D).** Here, $f_0 = 1.5$ cm, $f_e = 6.25$ cm, $u_0 = -2$ cm, $v_e = -25$ cm

For objective, $\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0}$ $\therefore \frac{1}{v_0} - \frac{1}{-2} = \frac{1}{1.5}$

$\frac{1}{v_0} = \frac{1}{1.5} - \frac{1}{2}$ or $v_0 = 6$cm

For eye piece, $\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e}$

$\frac{1}{-25} - \frac{1}{u_e} = \frac{1}{6.25}$; $-\frac{1}{u_e} = \frac{1}{6.25} + \frac{1}{25}$ or $u_e = -5$cm.

Distance between two lenses

$= |v_0| + |u_e| = 6\text{ cm} + 5\text{ cm} = 11\text{ cm}$

(74) **(A).** In case of astronomical telescope if object and final image both are at infinity.

MP = $-(f_0/f_e)$ and $L = f_0 + f_e$

So here $-(f_0/f_e) = -5$ and $f_0 + f_e = 36$

Solving these for f_0 and f_e, we get

$f_0 = 30$ cm and $f_e = 6$ cm

(75) **(D).** $\because \frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} = 0$; $\frac{1}{f_2} = -\frac{0.024}{0.036 f_1}$

$\frac{1}{f_2} = -\frac{2}{3f_1}$ $\because \frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$ $\because F = 90$ cm

$\therefore \frac{1}{90} = \frac{1}{f_1} - \frac{2}{3f_1}$; $f_1 = 30$ cm or $f_2 = -\frac{3 \times 30}{2} = -45$ cm

(76) **(C).** The focal length of objective mirror

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

and focal length of eye piece = 1.6 cm

$\therefore$ Magnifying power, $m = \frac{f_0}{f_e} = \frac{40}{1.6} = 25$

(77) **(D).** The separation between the objective and the eye piece = Length of the telescope tube $f = f_0 + f_e$

Here, $f_0 = 144$ cm $= 1.44$ m

$f_e = 6.0$ cm $= 0.06$ m

$\therefore f = 1.44 + 0.06 = 1.5$ m

(78) **(B).** The idea of secondary wavelets is given by Huygen.

(79) **(C).** Monochromatic wave means of single wavelength not the single colour

(80) **(A).** Huygen's argued that the amplitude of the secondary wavelets is maximum in the forward direction and zero in the backward direction, by making this adhoc assumption. He could explain the absence of the backwave. However, this adhoc assumption is not satisfactory and the absence of the backwave is really justified from more rigorous wave theory.

(81) **(A).** When incident wave fronts passes through a prism, then lower portion of wavefront (B) is delayed resulting in a tilt. So, time taken by light to reach A' from A is equal to the time taken to reach B' from B.

(82) **(B).** Wavefronts eminating from a point source are spherical wavefronts.

(83) **(A).** For interference phase difference must be constant.

(84) **(A).** $I \propto a^2 \Rightarrow \frac{a_1}{a_2} = \left(\frac{4}{1}\right)^{1/2} = \frac{2}{1}$

(85) **(B).** In interference energy is redistributed.

(86) **(C).** For viewing interference in oil films or soap bubble, thickness of film is of the order of wavelength of light.

(87) **(D).** $\frac{I_1}{I_2} = \frac{9}{1}$; $\frac{I_{max}}{I_{min}} = \left[\frac{\sqrt{\frac{I_1}{I_2}} + 1}{\sqrt{\frac{I_1}{I_2}} - 1}\right]^2 = \left[\frac{\sqrt{9}+1}{\sqrt{9}-1}\right]^2 = \frac{4^2}{2^2} = \frac{4}{1}$

(88) **(D).** $\frac{I_1}{I_2} = \frac{1}{25}$ $\therefore \frac{a_1^2}{a_2^2} = \frac{1}{25} \Rightarrow \frac{a_1}{a_2} = \frac{1}{5}$

(89) **(C).** $\frac{a_1}{a_2} = \frac{3}{5}$ $\therefore \frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2} = \frac{(3+5)^2}{(3-5)^2} = \frac{16}{1}$

(90) **(B).** When two sources are obtained from a single source, the wavefront is divided into two parts. These two wavefronts acts as if they emanated from two sources having a fixed phase relationship.

(91) **(D).** For maximum intensity $\phi = 0°$

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

$= I + I + 2\sqrt{I\,I} \cos 0° = 4I$

(92) **(B).** At point A, resultant intensity

$I_A = I_1 + I_2 = 5I$; and at point B

$$I_B = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\pi = 5I + 4I$$

$I_B = 9I$ so $I_B - I_A = 4I$

(93) (A). $\beta = \dfrac{6000\times10^{-10}\times25\times10^{-2}}{10^{-3}}$

$= 150000\times10^{-9} = 0.15\times10^{-3}\text{m} = 0.015\text{cm}.$

(94) (C). For brightness, path difference = $n\lambda = 2\lambda$
So second is bright.

(95) (C). $\beta = \dfrac{\lambda D}{d} = \dfrac{5000\times10^{-10}\times1}{0.1\times10^{-3}}\text{m} = 5\times10^{-3}\text{m} = 0.5\text{ cm}.$

(96) (A). We know that fringe width

$$\beta = \frac{D\lambda}{d} \quad \therefore x = \frac{L\lambda}{d} \Rightarrow \lambda = \frac{xd}{L}$$

(97) (C). Fringe width $(\beta) = \dfrac{D\lambda}{d} \Rightarrow \beta \propto \lambda$

As $\lambda_{red} > \lambda_{yellow}$, hence fringe width will increase.

(98) (B). $\dfrac{I_{max}}{I_{min}} = \dfrac{\left(\dfrac{a_1}{a_2}+1\right)^2}{\left(\dfrac{a_1}{a_2}-1\right)^2} = \dfrac{4}{1} \Rightarrow \dfrac{a_1}{a_2} = \dfrac{3}{1}$

(99) (B). Optical path difference

$= (\mu_1 - 1)\,t_1 - (\mu_2 - 1)\,t_2 = t_2 - t_1$

If $t_1 < t_2 = (+)$ so it should shift towards A.

(100) (D). $\beta \propto 1/d$ $\therefore$ On increasing d three times
β will become 1/3 times.

(101) (C). If shift is equal to n fringes width, then

$$n = \frac{(\mu-1)\,t}{\lambda} = \frac{(1.5-1)\times2\times10^{-6}}{500\times10^{-9}} = \frac{1}{500}\times10^{3} = 2$$

Since a thin film is introduced in upper beam.
So shift will be upward.

(102) (C). Waves from two slits are in phase at the slits and travel to a distant screen to produce the second minimum of the interference pattern. The difference in the distance traveled by the waves is three halves of a wavelength.

(103) (C). It is caused due to turning of light around corners.

(104) (C). Width of central maxima

$$= \frac{2\lambda D}{d} = \frac{2\times2.1\times5\times10^{-7}}{0.15\times10^{-2}} = 1.4\times10^{-3}\text{m} = 1.4\text{ mm}$$

(105) (B). $\lambda_{Blue} < \lambda_{Red}$. Therefore fringe pattern will contract because fringe width $\propto \lambda$

(106) (D). Distance between the first dark fringes on either side of central maxima = width of central maxima

$$= \frac{2\lambda D}{d} = \frac{2\times600\times10^{-9}\times2}{1\times10^{-3}} = 2.4\text{ mm.}$$

(107) (B). Thickness of the film must be of the order of wavelength of light falling on film (i.e. visible light)

(108) (C). Width of central maxima

$$= \frac{2f\lambda}{a} = \frac{2\times2\times6000\times10^{-10}}{0.2\times10^{-3}} = 12\text{ mm}$$

(109) (B). The distance of first diffraction minimum from the central principal maximum $x = \lambda D/d$

$$\therefore \sin\theta = \frac{x}{D} = \frac{\lambda}{d} \Rightarrow d = \frac{\lambda}{\sin\theta}$$

$$\Rightarrow d = \frac{5000\times10^{-8}}{\sin 30^\circ} = 2\times5\times10^{-5} = 1.0\times10^{-4}\text{ cm.}$$

(110) (A). Resolving power of telescope (RP) $= \dfrac{1}{\Delta\theta} = \dfrac{D}{1.22\lambda}$

where, D = diameter of objective
λ = wavelength of light
Given, $D = 6\text{ cm} = 6\times10^{-2}\text{ m}$
$\lambda = 540\text{ nm} = 540\times10^{-9}\text{ m}$

$$RP = \frac{6\times10^{-2}}{1.22\times540\times10^{-9}}\text{rad}^{-1} = \frac{6000\times10^{4}}{540\times1.22}\text{rad}^{-1}$$

$= 9.1\times10^{4}\text{ rad}^{-1}$

(111) (A). $\Delta\theta \approx \dfrac{0.61\lambda}{a}$

$\Delta\theta$ will be small if the diameter of the objective is large. This implies that the telescope will have better resolving power, if a is large. It is for this reason that for better resolution, a telescope must have a large diameter objective.

(112) (B). From equation, $d_{min} = \dfrac{1.22\lambda}{2n\sin\beta}$, it is to be noted that it is not possible to make sin β larger than unity. Thus, we see the resolving power of a microscope is basically determined by the wavelength of the light used.

(113) (C). Intensity of polarized light from first polarizer

$= 100/2 = 50$

$$I = 50\cos^2 60^\circ = \frac{50}{4} = 12.5$$

(114) (A). Angle of incident light with the surface is 30°. Hence angle of incidence = 90° – 30° = 60°.
Since reflected light is completely polarised, therefore, incidence takes place at polarising angle of incidence θ_p. $\therefore \theta_p = 60^\circ$
Using Brewster's law, $\mu = \tan\theta_p = \tan 60^\circ$ $\therefore$ $\mu = \sqrt{3}$

(115) (B). Here critical angle, $i_c = \sin^{-1}(3/5)$ $\therefore \sin i_c = 3/5$

As, $\mu = \dfrac{1}{\sin i_c} = \dfrac{5}{3}$

According to Brewster's law, $\tan i_p = \mu$
where i_p is the polarising angle

$\Rightarrow \tan i_p = \frac{5}{3} \Rightarrow i_p = \tan^{-1}\left(\frac{5}{3}\right)$

EXERCISE-2

(1) **(A).** $\frac{I}{O} = \frac{f}{f-u} \Rightarrow \frac{I}{+6} = \frac{-f}{-f-(-4f)} \Rightarrow I = -2\,\text{cm}.$

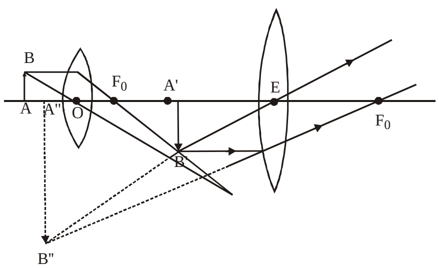
(2) **(D).** Since ${}_a\mu_g = \sqrt{2}$, so ${}_g\mu_a = \frac{\sin i}{\sin r} = \frac{1}{\sqrt{2}}$

$\therefore \sin r = 1 \Rightarrow r = 90^o$

(3) **(A).** $t = \frac{\mu x}{c} = \frac{3 \times 4 \times 10^{-3}}{3 \times 10^8} = 4 \times 10^{-11}\,\text{sec}$

(4) **(A).** $\mu = \frac{h'}{h} \Rightarrow h' = \mu h = \frac{4}{3} \times 18 = 24\text{m}$

(5) **(C).** The ray diagrams as follows :



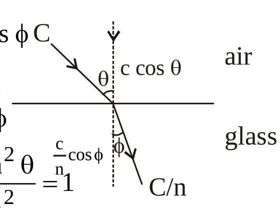
From the figure it is clear that image formed by objective (or the intermediate image) is real, inverted and magnified.

(6) **(B).** In water, speed of sound is higher so water is rarer medium hence bending away from normal.

(7) **(D).** $c \cos\theta = \frac{c}{n}\cos\phi$ C

$n \cos\theta = \cos\phi$

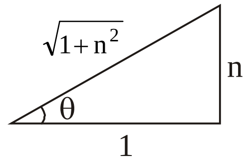
$1 \sin\theta = n \sin\phi$



$\therefore n^2\cos^2\theta + \frac{\sin^2\theta}{n^2} = 1$

$n^2 - n^2\sin^2\theta + \frac{\sin^2\theta}{n^2} = 1$

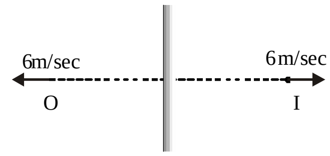
$\sin^2\theta\left[\frac{1}{n^2} - n^2\right] = 1 - n^2$



$\sin^2\theta = \frac{n^2}{1+n^2}$

$\sin\theta = \frac{n}{\sqrt{1+n^2}}$; $\tan\theta = n$

(8) **(C).** Relative velocity of image w.r.t. object
$= 6 - (-6) = 12$ m/sec



(9) **(B).** By using $\frac{I}{O} = \frac{f}{f-u}$

$\frac{I}{+(7.5)} = \frac{(25/2)}{\left(\frac{25}{2}\right) - (-40)} \Rightarrow I = 1.78\text{ cm}$

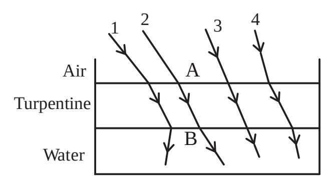
(10) **(B).** $m = \frac{f}{(f-u)} \Rightarrow \left(+\frac{1}{4}\right) = \frac{(+30)}{(+30) - u} \Rightarrow u = -90\text{ cm}$

(11) **(A).** Let distance = u.

Now $\frac{v}{u} = 16$ and $v = u + 120$

$\therefore \frac{120+u}{u} = 16 \Rightarrow 15u = 120 \Rightarrow u = 8\,\text{cm}$.

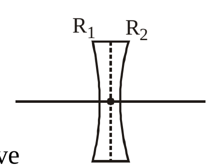
(12) **(B).** In the figure, the path shown for the ray 2 is correct. The ray suffers two refractions: At A, ray goes from air to turpentine, bending towards normal. At B, ray goes from turpentine to water (i.e., from denser to rarer medium), bending away from normal.



(13) **(A).** $\mu = \frac{c}{v} = \frac{v}{v\lambda} = \frac{3 \times 10^8}{4 \times 10^{14} \times 5 \times 10^{-7}} = 1.5$

(14) **(A).** $R_1 = -R$, $R_2 = +R$, $\mu_g = 1.5$ and $\mu_m = 1.75$

$\therefore \frac{1}{f} = \left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$



Substituting the values, we have

$\frac{1}{f} = \left(\frac{1.5}{1.75} - 1\right)\left(\frac{1}{-R} - \frac{1}{R}\right) = \frac{1}{3.5R}$ $\therefore f = +3.5\,R$

Therefore, in the medium it will behave like a convergent lens of focal length 3.5 R. It can be understood as, $\mu_m > \mu_g$, the lens will change its behaviour.

(15) **(B).** Time taken by light to travel distance x through a medium of refractive index μ is

$t = \frac{\mu x}{c} \Rightarrow \frac{\mu_B}{\mu_A} = \frac{x_A}{x_B} = \frac{6}{4} \Rightarrow {}_A\mu_B = \frac{3}{2} = 1.5$

(16) **(A).** For vacuum $t = n\lambda_0$ .....(i)

For air $t = (n+1)\lambda_a$ .....(ii)

From equation (i) and (ii)

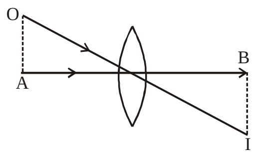
$$t=\frac{\lambda}{\mu-1}=\frac{6\times10^{-7}}{1.0003-1}=2\times10^{-3}\text{m}\quad\left(\mu=\frac{\lambda_o}{\lambda_a}\right)$$
$= 2\text{mm}.$

(17) (C). Semi vertical angle $=C=\sin^{-1}\left(\frac{1}{\mu}\right)=\sin^{-1}\left(\frac{3}{4}\right)$

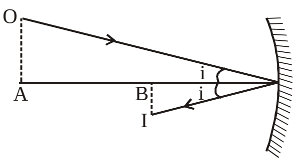
(18) (B). Negative power is given, so defect of eye is nearsigntedness. Also defected far point

$$=-f=-\frac{1}{p}=-\frac{100}{(-2.5)}=40\,\text{cm}$$

(19) (B). (A)



(C)



(D) Image is inverted $\Rightarrow$ It should be real

(20) (D). $v=-15\text{cm},\ u=-300\text{cm}$

From lens formula $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$

$$\frac{1}{f}=\frac{1}{-15}-\frac{1}{-300}=\frac{-19}{300};\quad f=\frac{-300}{19}=-15.8\,\text{cm}$$

Power $P=\frac{100}{f}\text{cm}=\frac{-100\times19}{300}=-6.33\text{ D}.$

(21) (B). $m_\infty=-\frac{v_o}{u_o}\times\frac{D}{f_e}$. From $\frac{1}{f_o}=\frac{1}{v_o}-\frac{1}{u_o}$

$$\Rightarrow\frac{1}{(+1.2)}=\frac{1}{v_o}-\frac{1}{(-1.25)}\ \Rightarrow v_o=30\text{ cm}$$

$$\therefore|m_\infty|=\frac{30}{1.25}\times\frac{25}{3}=200$$

(22) (C). Minimum angular separation

$$\Delta\theta=\frac{1}{\text{R.P.}}=\frac{1.22\,\lambda}{d}$$

$$=\frac{1.22\times5000\times10^{-10}}{2}=0.3\times10^{-6}\text{rad}$$

(23) (B). For improving far point, concave lens is required and for this concave lens $u=\infty,\ v=-30$ cm

So $\frac{1}{f}=\frac{1}{-30}-\frac{1}{\infty}\Rightarrow f=-30$ cm

for near point $\frac{1}{-30}=\frac{1}{-15}-\frac{1}{u}\Rightarrow u=-30$ cm

(24) (B). Power of convex lens $P_1=\frac{100}{40}=2.5$ D

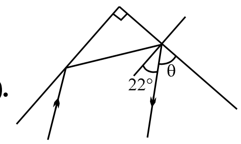
Power of concave lens $P_2=-\frac{100}{25}=-4$ D

$P=P_1+P_2=2.5\text{ D}-4\text{ D}=-1.5\text{ D}$

(25) (D). $m_{max}=1+\frac{D}{f}=1+\frac{25}{2.5}=11$

(26) (C). $m=1+\frac{D}{f_e}\Rightarrow10=1+\frac{25}{f_e}\Rightarrow f_e=\frac{25}{9}\simeq25\text{mm}$

(27) (B).



From a corner reflector, reflected ray is antiparallel to incident ray.

(28) (D). $\frac{1}{v}+\frac{1}{u}=\frac{1}{f};\ \frac{1}{v}+\frac{1}{-12}=\frac{1}{-10};\ v=-60$ cm

$\frac{h_I}{5}=\frac{-v}{u}\Rightarrow h_I=-25$ cm

(29) (C). For concave mirror if x & y are object and image distance respectively, we have $-\frac{1}{x}-\frac{1}{y}=-\frac{1}{|f|}$

$$\Rightarrow\frac{1}{x}+\frac{1}{y}=\frac{1}{|f|}\Rightarrow-\frac{1}{x^2}\frac{dx}{dt}-\frac{1}{y^2}\frac{dy}{dt}=0$$

$$\Rightarrow\left|\frac{V_x}{V_y}\right|=\frac{x^2}{y^2}\quad\text{For }\left|\frac{V_x}{V_y}\right|=\frac{1}{4},\ \frac{x}{y}=\pm2$$

For, $\frac{x}{y}=2$, we get $x=\frac{3|f|}{2}$ [for point A]

For, $\frac{x}{y}=-2$, we get $x=\frac{|f|}{2}$ [for point B]

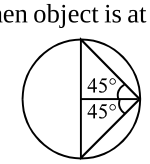
As the middle point happens to be focus of mirror, we get $|f|=L$

(30) (D). In mirrors focal length is independent of surrounding medium.

(31) (A). Mirror is convex because image of a real object is small, erect and virtual as the object pin moves towards the mirror size of image increase but m is always $m\le1$, $m=1$ when object is at pole.

(32) (B). $45°>\theta_C$

$\sin45>\frac{1}{\mu}\Rightarrow\sqrt{2}<\mu$

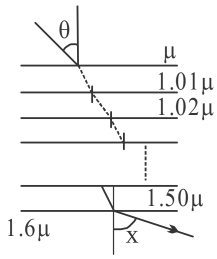


or $v<\frac{3\times10^8}{\sqrt{2}}$

(33) (D). As the ray moves towards the normal while entering medium 2 from 1, we have $n_2>n_1$

For total internal reflection at interface of 2 & 3, $n_2>n_3$ Besides, n_3 should also be less than n_1 or else ray would have emerged in medium 3, parallel to its path in medium 1. Hence, $n_3 < n_1 < n_2$ is the correct order.

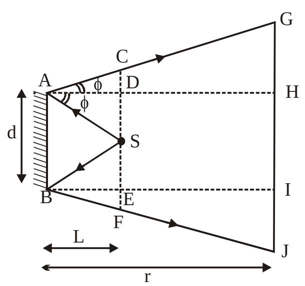
(34) **(B).**



Snell's law : $\mu \sin\theta = 1.6\,\mu \sin x$

$$\sin x = \frac{5}{8}\sin\theta$$

(35) **(D).** The ray diagram will be as follows :



HI = AB = d ; DS = CD = d/2

Since, AH = 2AD $\therefore$ $GH = 2CD = 2\frac{d}{2} = d$

Similarly, IJ = d $\therefore$ GJ = GH + HI + IJ = d + d + d = 3d

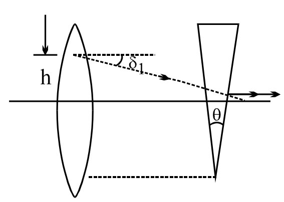
(36) **(B).** $\theta_T = 2A(\mu_v - \mu_r) - (\mu_v' - \mu_r')\ A' = 0$

$$\therefore \quad \frac{A'}{A} = \frac{2(\mu_v - \mu_r)}{\mu_v' - \mu_r'}$$

(37) **(B).** $\tan\delta_1 = h/f$

$\delta_{Net} = 0 = -\delta_L + \delta_P = 0$

$$\frac{h}{f} = (\mu - 1)\theta \Rightarrow \frac{h}{f\theta} + 1 = \mu$$



(38) **(B).** $\omega = \dfrac{\delta_V - \delta_R}{\delta_y - 1}$

$\because$ $\delta_y - 1 = 0$ for B, so B is showing maximum dispersive power.

(39) **(D).** $\beta = \dfrac{\lambda D}{d} \Rightarrow (4\times10^{-3}) = \dfrac{4\times10^{-7}\times D}{0.1\times10^{-3}} \Rightarrow D = 1\text{m}$

(40) **(A).** $\beta = \dfrac{\lambda D}{d} \Rightarrow (0.06\times10^{-2}) = \dfrac{\lambda\times1}{1\times10^{-3}} \Rightarrow \lambda = 6000\,\text{Å}$

(41) **(D).** Distance of the n^{th} bright fringe from the centre,

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

$$\Rightarrow \quad x_3 = \frac{3\times6000\times10^{-10}\times2.5}{0.5\times10^{-3}} = 9\times10^{-3}\text{m} = 9\,\text{mm}$$

(42) **(A).** $a_1 = 6$ units, $a_2 = 8$ units

$$\frac{I_{max}}{I_{min}} = \frac{\left[\frac{a_1}{a_2}+1\right]^2}{\left[\frac{a_1}{a_2}-1\right]^2} = \frac{\left[\frac{6}{8}+1\right]^2}{\left[\frac{6}{8}-1\right]^2} = \frac{49}{1}$$

(43) **(D).** D = 1m. , d = .90 mm = $.9\times10^{-3}$ m

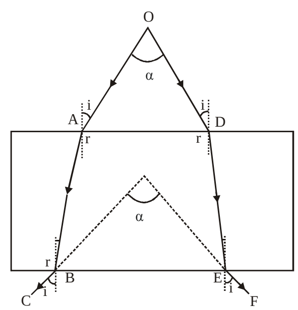
The distance of the second dark ring from centre $= 10^{-3}$ m

$$\therefore\ X_n = (2n-1)\frac{\lambda}{2}\frac{D}{d}. \quad \text{For } n = 2,\ X_n = \frac{3\lambda}{2}\frac{D}{d}$$

$$\Rightarrow \quad \lambda = \frac{2Xn\,d}{3D} = \frac{2\times10^{-3}\times.9\times10^{-3}}{3}$$

$\lambda = 6\times10^{-7}$ m. $= 6\times10^{-5}$ cm.

(44) **(B).** Divergence angle will remain unchanged because in case of a glass slab every emergent ray is parallel to the incident ray. However, the rays are displaced slightly towards outer side. (In the figure OA || BC and OD || EF)



(45) **(C).** $\dfrac{\beta_1}{\beta_2} = \dfrac{\lambda_1}{\lambda_2}$ or $\dfrac{1.0}{\beta_2} = \dfrac{5000}{6000}$ or $\beta_2 = \dfrac{6000}{5000} = 1.2$ mm

(46) **(A).** Distance between two consecutive

$$\text{Dark fringes} = \frac{\lambda D}{d} = \frac{6000\times10^{-10}\times1}{0.6\times10^{-3}}$$

$$= 1\times10^{-3}\text{m} = 1\text{ mm.}$$

(47) **(C).** Distance between consecutive bright fringes or dark fringes = β

$$\beta = \frac{\lambda D}{d} = \frac{550\times10^{-9}\times1}{1.1\times10^{-3}} = 500\times10^{-6} = 0.5\text{ mm}$$

(48) **(B).** Distance of n^{th} minima from central bright fringe

$$x_n = \frac{(2n-1)\lambda D}{2d}$$

For n = 3 i.e. 3^{rd} minima

$$x_3 = \frac{(2\times3-1)\times500\times10^{-9}\times1}{2\times1\times10^{-3}}$$

$$= \frac{5\times500\times10^{-6}}{2} = 1.25\times10^{-3}\text{m} = 1.25\text{ mm}$$

(49) **(A).** The angular half width of the central maxima is given by $\sin\theta = \frac{\lambda}{a} \Rightarrow \theta = \frac{6328\times10^{-10}}{0.2\times10^{-3}}$ rad

$$= \frac{6328\times10^{-10}\times180}{0.2\times10^{-3}\times\pi}\text{ degree} = 0.18^o$$

Total width of central maxima = $2\theta = 0.36°$

(50) **(B).** $\theta = \sin^{-1}(\lambda/a)$ .....(1)

According to question

$\lambda = 2\times10^{-3}$ m

$a = 4\times10^{-3}$ m .....(2)

From equation (1) and (2),

$\theta = \sin^{-1}(1/2)$; $\theta = 30°$

(51) **(A).** Here distance of the screen from the slit,

D = 2m, a = ?,

x = 5 mm = 5×10^{-3} m,

$\lambda = 5000Å = 5000\times10^{-10}$ m

For the first minima, $\sin\theta = \lambda/a = x/D$,

$$a = \frac{D\lambda}{x} = \frac{2\times5000\times10^{-10}}{5\times10^{-3}} = 2\times10^{-4}\text{ m}$$

(52) **(B).** Fringe width, $\omega = \frac{\lambda D}{d} \propto \lambda$

When the wavelength is decreased from 600nm to 400nm, fringe width will also decrease by a factor of 4/6 or 2/3 or the number of fringes in the same segment will increase by a factor of 3/2.

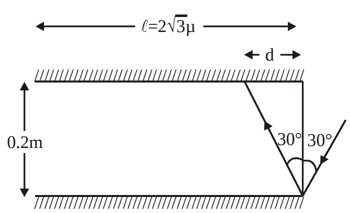
Therefore, number of fringes observed in the same segment = 12 × (3/2) = 18

(53) **(D).** Angular width of central maximum = $\frac{2\lambda}{d}$

$$\text{Width of central maximum} = \frac{2\lambda D}{d} = \frac{2\times600\times10^{-9}\times2}{1\times10^{-3}}$$

$$= 24\times10^{-4}\text{ m} = 2.4\text{ mm}$$

(54) **(B).** $d = 0.2\tan30° = \frac{0.2}{\sqrt{3}}$



$$\frac{\ell}{d} = \frac{2\sqrt{3}}{0.2/\sqrt{3}} = 30$$

Therefore, maximum number of reflections are 30.

(55) **(C).** $I = I + I + 2\sqrt{I}\sqrt{I} = 4I$

$$I' = I + \frac{I}{4} + 2\sqrt{I}\sqrt{\frac{I}{4}} = \frac{9}{4}I = \frac{9}{16}I_0$$

(56) **(C).** The conditions for maxima and minima depends on path difference.

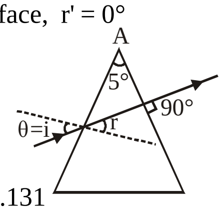
(57) **(D).** In a Young's double–slit experiment, the central bright fringe can be identified by using white light instead of monochromatic light.

(58) **(A).** According to the question, ray emerges from other surface of prism normally,

∴ Angle of incidence at second face, r' = 0°

Now, r + r' = A

⇒ r = A – r' = 5° – 0° = 5°



Using snell's law, $\mu = \frac{\sin i}{\sin r}$

sin i = μ sin r = 1.5 × sin 5° = 0.131

⇒ $\theta = i = \sin^{-1}(0.131) = 7.5$

(59) **(A).** The image seen through the slit shall be a fine sharp slit white in colour at the center.

(60) **(D).** Huygen's construction does not explain quantisation of energy and as it is not able to explain emission & absorption spectrum.

(61) **(B).** In spherical mirrors, the incident ray passing through the focus of mirror becomes parallel to principal axis after reflection, which is shown by ray 2.

(62) **(B).** As reflected light is completely polarized, therefore,

$i_p = 60°$, $u = \tan i_p = \tan 60° = \sqrt{3}$

$$\text{As } \mu = \frac{c}{v} \quad \therefore v = \frac{c}{\mu} = \frac{3\times10^8}{\sqrt{3}} = \sqrt{3}\times10^8\text{ m/s}$$

(63) **(A).** Using Snell's law, $\mu = \frac{\sin i}{\sin r} \Rightarrow \sin r = \frac{\sin i}{\mu}$

According to question, μ is negative

∴ sin r is negative.

Hence, r is negative, therefore graph (A) is correct.

(64) **(C).** Amount of scattering $\propto \frac{1}{\lambda^4}$ (Rayleigh's law)

Thus, sky appears blue as blue light (short wavelength) is scattered more than red and predominates. If red light will be scattered more, sky would appears red.

(65) **(D).** Given, $i + r = \pi/2$

According to Brewster's law, we get $\tan i_B = \mu = 1.5$

So, $i_B = \tan^{-1}(1.5) \Rightarrow i_B = 57°$

i.e., this is the Brewster's angle for air to glass interface.

(66) **(A).** We know, from Rayleigh's scattering.

Amount of scattering $\propto \frac{1}{\lambda^4}$

$$\Rightarrow \frac{(\text{Amount of scattering})_1}{(\text{Amount of scattering})_2} = \frac{\lambda_2^4}{\lambda_1^4}$$

$$\Rightarrow \frac{1}{4} = \left(\frac{\lambda_2}{\lambda_1}\right)^4 \Rightarrow \frac{\lambda_2}{\lambda_1} = \left(\frac{1}{4}\right)^{1/4} = \frac{1}{\sqrt{2}} \therefore \lambda_1 : \lambda_2 = \sqrt{2} : 1$$

(67) **(C).** When an object approaches a convergent lens from the left of the lens with a uniform speed of 5 m/s, the image moves away from the lens with a non–uniform acceleration.

(68) **(B).** A 100 inch telescope implies that
$2a = 100$ inch $= 254$ cm
Thus, if $\lambda = 6000$ Å $= 6 \times 10^{-5}$ cm
Then, limit of resolution of a telescope

$$\Delta\theta = \frac{0.61 \times 6 \times 10^{-5}}{127} = 2.9 \times 10^{-7} \text{ rad}$$

(69) **(C).** The light from two slits of Young's double slit experiment is of different colours/wavelengths/ frequencies. Hence, there shall be no interference fringes.

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

For no dispersion, $R_1 = R_2$

EXERCISE-3
PART - A : RAY OPTICS

(1) **45.** For minimum deviation, $r = A/2 = 60/2 = 30^o$

From snell's law $\frac{\sin i}{\sin r} = \mu$ or $\sqrt{2} = \frac{\sin i}{\sin 30^0}$

$\therefore \sin i = \frac{1}{2} \times \sqrt{2} = \frac{1}{\sqrt{2}} = \sin 45^o$ or $i = 45^o$

(2) **75.** From ΔABC

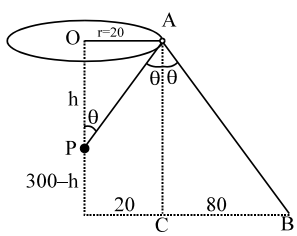
$\tan\theta = \frac{80}{300} = \frac{4}{15}$ ...(1)

From ΔAPO

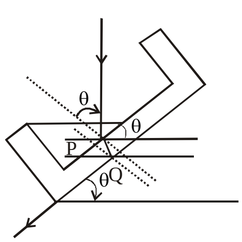
$\tan\theta = \frac{20}{h}$ ...(2)

From (1) and (2)

$\frac{4}{15} = \frac{20}{h} \Rightarrow h = \frac{20 \times 15}{4} = 75$ cm



(3) **4.**



For refraction at glass-air interface, ray passing through point Q, $\frac{\sin r}{\sin 90} = \frac{1}{1.5} \Rightarrow \sin r = \frac{1}{1.5}$

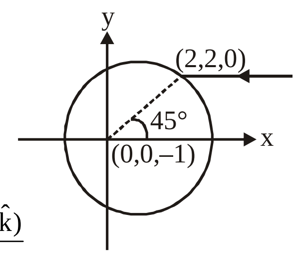
For refraction at water-glass interface, ray passing through point P, $\frac{\sin\theta}{\sin r} = \frac{1.5}{4/3} \Rightarrow \sin\theta = \frac{3}{4}$

(4) **160.** $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$; $f = 20,\ \mu = 1.5$

$\therefore \left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{10}$; $\frac{1}{f'} = \left(\frac{15}{16} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$f' = -160$cm.

(5) **32.**



$\hat{n} = \frac{2\hat{i} + 2\hat{j} + \hat{k}}{3}$; $\hat{e} = -\hat{i}$

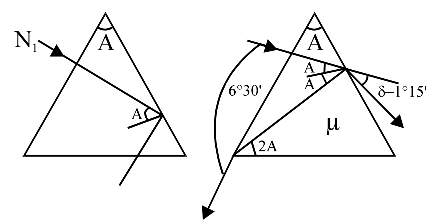
Using, $\hat{r} = \hat{e} - 2(\hat{e}.\hat{n})\hat{n}$

$$\hat{r} = -\hat{i} - \frac{2(-2)}{3}\frac{(2\hat{i} + 2\hat{j} + \hat{k})}{3}$$

$$= -\hat{i} + \frac{4}{9}(2\hat{i} + 2\hat{j} + \hat{k}) = \frac{-\hat{i} + 8\hat{j} + 4\hat{k}}{9}$$

(6) 8, (7) 2. $r_1 = 6°30'$; $\delta = (\mu - 1)A$

$$1.25 \times \frac{\pi}{180} = (\mu - 1)A \qquad .....(1)$$



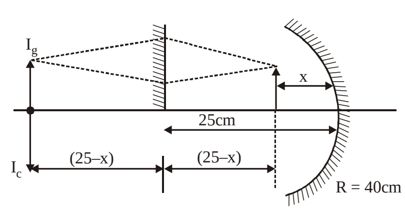
$$\frac{\sin 2A}{\sin 6.5°} = \frac{1}{\mu} \Rightarrow 2A\mu = 6.5 \times \frac{\pi}{180} \qquad ....(2)$$

Dividing $\frac{\mu - 1}{2\mu} = \frac{1.25}{6.5}$; $6.5(\mu - 1) = 2.5\mu$; $\mu = 13/8$

$$A = \frac{6.5°}{2\mu} = \frac{6.5}{2 \times 65} \times 40 = 2°$$

(8) **1.** Use the first law of reflection. Only sphere #1 is in a position such that light leaving it can reflect from the mirror to the observer.

(9) **10.**



Since, single reflection is taken.
The image formed by the plane mirror must lie at the centre of curvature of the concave mirror, so that the final image formed by the concave mirror must be formed at the same position (at the object position of the concave mirror.
Hence $x + 2(25 - x) = R$; $x = 10$ cm.

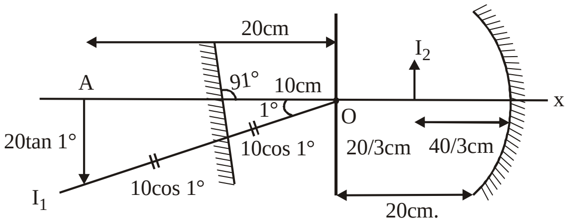
(10) **180.** Distance of I_1 from mirror = 40 cm

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow \frac{1}{-10} = \frac{1}{v} + \frac{1}{-140} \Rightarrow \frac{1}{v} = \frac{1}{40} - \frac{1}{10}$$

$$\frac{1}{v} = \frac{1-4}{10} \Rightarrow v = -\frac{40}{3}\text{cm}$$

Using magnification formula,

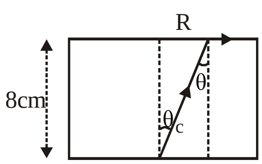
$$m = \frac{I}{0} = -\frac{v}{u} \Rightarrow \frac{I}{-20\tan 1^\circ} = \frac{-40/3}{-40}$$



$$\Rightarrow I = \frac{20\tan 1^\circ}{3} = \frac{20}{3}\tan\frac{\pi}{180} \simeq \frac{20}{3} \times \frac{\pi}{180} = \frac{\pi}{27}$$

$$\text{Coordinate of image} = \left(\frac{20}{3}, \frac{\pi}{27}\right)$$

(11) **6.**



$\sin\theta_c = 3/5$ $\therefore$ $R = 6$cm.

(12) **3.** For $v_1 = \frac{50}{7}$m, $u_1 = -25$cm.; $v_2 = \frac{25}{3}$m, $u_2 = -50$m

$$\text{Speed of object} = \frac{25}{30} \times \frac{18}{5} = 3 \text{ kmph}$$

(13) **7.** For mirror, $M = \frac{f}{f-u} = -\frac{V}{u}$

$$M = \frac{-10}{-10+15} = -\frac{V}{-15}$$

$M = -2$, $v = -30$cm.

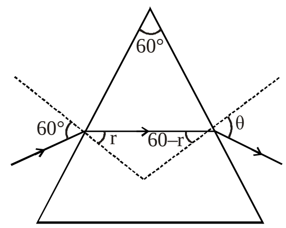
For lens, $M' = \frac{f}{f+u} = \frac{10}{10-20} = -1$; $M_1 = 2$

In liquid, $\frac{f'}{f} = \frac{\mu - 1}{\left(\frac{\mu}{\mu_0} - 1\right)} = \frac{7}{4} \Rightarrow f' = \frac{70}{4}$cm

(f ' is the focal length of lens in medium of refractive index $\mu_0 = 7/6$)

$$M' = \frac{f'}{f'+u} = \frac{\frac{70}{4}}{\frac{70}{4} - 20} = -7 \;;\; M_2 = 14 \;;\; \left|\frac{M_2}{M_1}\right| = 7$$

(14) **2.** $\sin 60 = n \sin r$ .... (1)
$\sin\theta = n\sin(60 - r)$ .... (2)



Differentiating eq. (2)

$$\cos\theta\frac{d\theta}{dn} = -n\cos(60-r)\frac{dr}{dn} + \sin(60-r)$$

Differentiating eq. (1)

$$n\cos r\frac{dr}{dn} + \sin r = 0$$

$$\cos\theta\frac{d\theta}{dn} = -n\cos(60-r)\left(\frac{-\tan r}{n}\right) + \sin(60-r)$$

$$\frac{d\theta}{dn} = \frac{1}{\cos\theta}(+\cos(60-r)\tan r + \sin(60-r))$$

$$\frac{d\theta}{dn} = \frac{1}{\cos 60}(\cos 30 \times \tan 30 + \sin 30) = 2\left(\frac{1}{2} + \frac{1}{2}\right) = 2$$

(15) **8.** We know that for the given case,
$\mu \sin\theta$ = constant
So, $1.6\sin(30^\circ) = (n - m\,\Delta n)\sin 90^\circ$
i.e. $0.8 = n - m\,\Delta n$
Solving, $m = 8$

PART - B : WAVE OPTICS

(1) **33.** Path difference ,

$$\Delta x = \{(S_2P - t_2) + \mu_2 t_2\} - \{(S_1P - t_1) + \mu_1 t_1\}$$

$$= (S_2P - S_1P) + \{(\mu_2 - 1)t_2 - (\mu_1 - 1)t_1\}$$

(i) In first case :

$$y_1 = \frac{D}{d}\{t(\mu_1 - 1) - t(\mu_2 - 1)\} = \frac{D}{d}\{t(\mu_1 - \mu_2)\}$$

or $t = \frac{5\times10^{-3} \times 1\times10^{-3}}{1\times(1.6-1.4)}$ $\therefore$ $t_1 + t_2 = 5 \times 10^{-5}$

(ii) When both sheets have same refractive index

$$\mu = \frac{1.6+1.4}{2} = 1.5$$

$$y_2 = \frac{D}{d}\{t_1(\mu-1) - t_2(\mu-1)\} = \frac{D}{d}\{(\mu-1)(t_1 - t_2)\}$$

$$\therefore\ t_1 - t_2 = \frac{8\times10^{-3}\times1\times10^{-3}}{1\times(1.5-1)} = \frac{8\times10^{-6}}{0.5} = 1.6\times10^{-5}$$

On solving, $t_1 = 33\ \mu m$

(2) **1.** Reflected ray from upper surface would shift by $\lambda/2$ only while reflected from lower surface would not have any shift. $2\mu t = n_1\lambda_1 = n_2\lambda_2 \Rightarrow (n_1 = n_2 + 1)$ as there is no minima in between these two wave-lengths

$(n+1)(512) = (n)(640)$
$n_2(640-512) = 512$
$n_2 = 4$
So $2\times1.28\,t = (4)(640)$

$$t = \frac{4\times640}{2\times1.28} = 1000\,nm = 1\mu m$$

(3) **1.** $\sqrt{d^2 + D^2} - D = \lambda$

$$d^2 + D^2 = D^2 + \lambda^2 + 2\lambda D$$

$$D = \frac{d^2}{2\lambda} = \frac{10^{-8}}{2\times5\times10^{-7}} = 10^{-2}\,m$$

$D = 1$ cm.

(4) **7.** As intensity becomes one-fourth

$$\therefore\ \cos\phi = -\frac{1}{2} \Rightarrow \phi = \frac{2\pi}{3}, \frac{4\pi}{3}.........$$

and $\phi = \frac{2\pi}{\lambda}\Delta x = \frac{2\pi}{\lambda}(\mu-1)\,t$

(5) **40.** $n_1 b_1 = n_2 b_2$ Þ $n_1 l_1 = n_2 l_2$ Þ $n_2 = n_1 \frac{l_1}{l_2}$

$$= 60\frac{4000Å}{6000Å} = 40$$

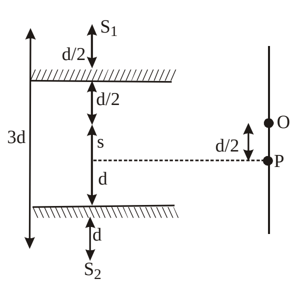
(6) **3.** The situation can be taken as if there are two sources S_1 and S_2 as shown in figure. Due to these S_1 and S_2, the central maxima will be at P at a distance d/2 from O.

For O to be a maxima :

Path difference $= \frac{3d.d}{2D} = n\lambda$

$\Rightarrow\ \lambda = \frac{3d^2}{2nD}$

i.e., $\lambda = \frac{3d^2}{2D}, \frac{3d^2}{4D}$



(7) **3.** Angular width $= \frac{\lambda}{d} = 10^{-3}$ (given)

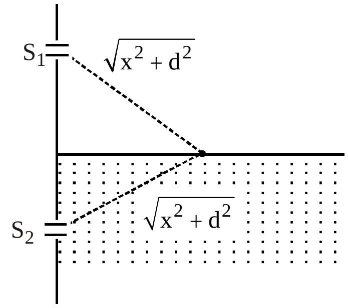
$\therefore$ No. of fringes within 0.12° will be

$$n = \frac{0.12\times2\pi}{360\times10^{-3}} \cong [2.09]$$

$\therefore$ The number of bright spots will be three.

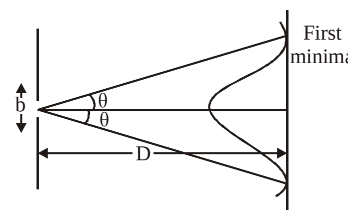
(8) **3.** For constructive interference $\Delta x = m\lambda$

$$\frac{4}{3}\sqrt{d^2+x^2} - \sqrt{d^2+x^2} = m\lambda$$



$\frac{1}{3}\sqrt{d^2+x^2} = m\lambda$; $x^2 = 9m^2\lambda^2 - d^2$; $p = 3$

(9) **2.** At first minima, $b\sin\theta = \lambda$



or $b\theta = \lambda$ or $b\,(y/D) = \lambda$ or $y = \frac{\lambda D}{b}$

or $\frac{\lambda b}{D} = \lambda \sin\theta \approx \theta$

Now, at P (First minima) path difference between the rays reaching from two edges (A and B) will be

$\Delta x = \frac{yb}{D}$ (compare with $\Delta x = \frac{yd}{D}$ in YDSE)

or $\Delta x = \lambda$ [From eq. (1)]

Corresponding phase difference (ϕ) will be

$$\phi = \left(\frac{2\pi}{\lambda}\right)\cdot\Delta x = \frac{2\pi}{\lambda}\cdot\lambda = 2\pi$$

(10) **4.** $I(\phi) = I_1 + I_2 + 2\sqrt{I_1I_2}\cos\phi$ .... (1)

Here, $I_1 = I$ and $I_2 = 4I$
At point, A, $\phi = \pi/2$
$\therefore\ I_A = I + 4I = 5I$
At point B, $\phi = \pi$
$\therefore\ I_B = I + 4I - 4I = I$
$\therefore\ I_A - I_B = 4I$

EXERCISE-4
PART - A : RAY OPTICS

(1) **(A).** $\theta = 60^\circ$; $n = \frac{360^\circ}{\theta} = \frac{360^\circ}{60^\circ} = 6$

as n is even no. of images is (n – 1).
so no. of images is (6 – 1) = 5.

(2) **(A).** Total internal reflection.

(3) **(B).** Have high resolution

(4) **(D).** Resolving power of an optical instruments is in-

. . . . λ i.e., $RP \propto \frac{1}{\lambda}$

$\therefore \frac{\text{Resolving power at } \lambda_1}{\text{Resolving power at } \lambda_2} = \frac{\lambda_2}{\lambda_1} = \frac{5000}{4000} = 5:4$

(5) **(C).** Virtual and enlarged.

(6) **(A).** $n = \frac{360^\circ}{\theta} - 1$; Given $n = 3$

$3 = \frac{360^\circ}{\theta} - 1$; $4 = \frac{360^\circ}{\theta}$; $\theta = 90^\circ$

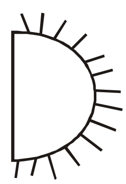
(7) **(B).** For total internal reflection at glass-air interface, the critical angle C must be less than 45°.

Now, $n = \frac{1}{\sin C}$ or $C = \sin^{-1}\left(\frac{1}{n}\right) < 45^\circ$

or $\left(\frac{1}{n}\right) < \sin 45^\circ$ or $n > \frac{1}{\sin 45^\circ}$ $\therefore$ $n > \sqrt{2}$

(8) **(A).** The effective focal length is given by

$\frac{1}{f} = \frac{2}{f_\ell} + \frac{1}{f_m}$



But $\frac{1}{f_\ell} = (1.5-1)\left(\frac{1}{\infty} + \frac{1}{30}\right) = \frac{1}{60}$

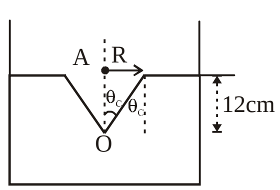
or $\frac{2}{f_\ell} = \frac{1}{30}$; Again, R = 30 cm ; $f_m = \frac{R}{2} = 15$ cm

Now, $\frac{1}{f} = \frac{1}{30} + \frac{1}{15}$ or $\frac{1}{f} = \frac{1+2}{30} = \frac{3}{30} = \frac{1}{10}$ or f=10 cm

To have a real image of the size of the object, the object must be placed at the centre of curvature of the equivalent mirror.

So, the required distance is 2 × 10 cm = 20 cm.

(9) **(B).** The situation is shown in figure.



$\sin\theta_C = \frac{1}{\mu}$; $\tan\theta_C = \frac{AB}{AO}$ $\therefore$ $AB = OA \tan\theta_C$

or $AB = \frac{OA}{\sqrt{\mu^2 - 1}} = \frac{12}{\sqrt{\left(\frac{4}{3}\right)^2 - 1}} = \frac{36}{\sqrt{7}}$

(10) **(A).** We know $\frac{Y}{D} \ge 1.22\frac{\lambda}{d}$

$\Rightarrow D \ge \frac{Yd}{1.22\lambda} = \frac{10^{-3} \times 3 \times 10^{-3}}{1.22 \times 5 \times 10^{-7}} = \frac{30}{6.1} = 5\text{m}$

$D_{max} = 5$m

(11) **(C).** $D = (\mu - 1)A$

For blue light μ is greater than that for red light.

So, $D_2 > D_1$

(12) **(B).** Power of a lens is reciprocal of its focal length.

Power of combined lens is

$P = P_1 + P_2 = -15 + 5 = -10D$

$\therefore f = \frac{1}{P} = \frac{100}{-10}$ cm = – 10 cm

(13) **(B).** The convex lens formula is, $\frac{1}{v} - \frac{1}{-u} = \frac{1}{f}$

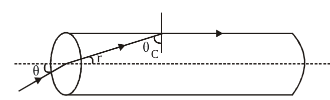
If u increase, on the negative side v decreases

So that $\frac{1}{v} + \frac{1}{u}$ = constant. Also, $v = \frac{fu}{u-f}$

i.e., v does not decrease linearly with increasing u.

(14) **(D).** A vernier scale provided on the microscope.

(15) **(D).** $\sin\theta_C = \frac{\sqrt{3}}{2}$



$1 \sin\theta = \mu \sin r = \frac{2}{\sqrt{3}}\sin(90 - \theta_C)$

$= \frac{2}{\sqrt{3}}\sqrt{1 - \frac{3}{4}} = \frac{2}{\sqrt{3}} \times \frac{1}{2}$; $\theta = \sin^{-1}\frac{1}{\sqrt{3}}$

(16) **(B).** As intensity is maximum at axis,

$\therefore$ μ will be maximum and speed will be minimum on the axis of the beam.

$\therefore$ beam will converge.

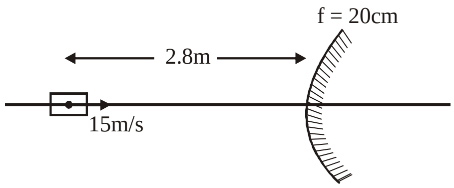
(17) **(D).** For a parallel cylinderical beam, wavefront will be planar.

(18) **(A).** The speed of light in the medium is minimum on the axis of the beam.

(19) **(B).** $\frac{1}{v} + \frac{1}{-280} = \frac{1}{20}$

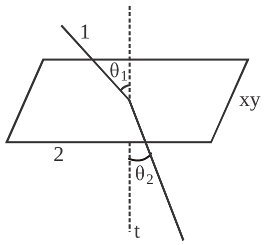
$\frac{1}{v} = \frac{1}{20} + \frac{1}{280}$; $\frac{1}{v} = \frac{14+1}{280}$; $v = \frac{280}{15}$

$v_1 = -\left(\frac{v}{u}\right)^2 .v_{om}$ $\therefore$ $v_1 = -\left(\frac{280}{15 \times 280}\right)^2 .15$



$\therefore\ v_1 = \frac{-15}{15\times 15}\ ;\ v_1 = -\frac{1}{15}\,m/s$

(20) **(B).**



X–Y plane, $\mu_1 \sin\theta_1 = \mu_2 \sin\theta_2$

$$\cos\theta_1 = \frac{10}{\sqrt{(6\sqrt{3})^2 + (8\sqrt{3})^2 + 100}} = \frac{10}{\sqrt{400}} = \frac{10}{20}$$

$$\cos\theta_1 = \frac{1}{2}\ ;\ \theta_1 = 60^\circ$$

$$\sqrt{2}\sin 60^\circ = \sqrt{3}\sin\theta_2\ ;\ \sqrt{2}\times\frac{\sqrt{3}}{2} = \sqrt{3}\sin\theta_2\ ;$$

$$\sin\theta_2 = \frac{1}{\sqrt{2}}\ ;\theta_2 = 45^\circ$$

(21) **(D).** $\frac{1}{f} = \frac{1}{12} + \frac{1}{240} = \frac{20+1}{240}\ ;\ f = \frac{240}{21}\,m$

Shift $= 1\left(1-\frac{2}{3}\right) = \frac{1}{3}$; Now, $v' = 12 - \frac{1}{3} = \frac{35}{3}$ cm.

$\therefore\ \frac{21}{240} = \frac{3}{35} - \frac{1}{u}\ ;\ \frac{1}{u} = \frac{3}{35} - \frac{21}{240} = \frac{1}{5}\left(\frac{3}{7} - \frac{21}{48}\right)$

$\frac{5}{u} = \left|\frac{144-147}{48\times 7}\right|$; u = 560 cm. = 5.6m

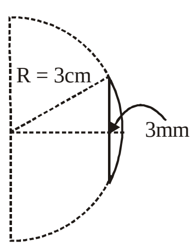
(22) **(C).** n = 3/2

$3^2 + (R - 3mm)^2 = R^2$

$\Rightarrow 3^2 + R^2 - 2R\,(3mm) + (3mm)^2 = R^2$

$\Rightarrow R \approx 15$ cm

$\frac{1}{f} = \left(\frac{3}{2} - 1\right)\left(\frac{1}{15}\right) \Rightarrow f = 30$cm



(23) **(C).**

(24) **(D).** $\frac{f_m}{f} = \frac{(\mu-1)}{\left(\frac{\mu}{\mu_m} - 1\right)}\ ;\ \frac{f_1}{f} = \frac{\left(\frac{3}{2}-1\right)}{\left(\frac{3/2}{4/3} - 1\right)} = 4 \Rightarrow f_1 = 4f$

$$\frac{f_2}{f} = \frac{\left(\frac{3}{2}-1\right)}{\left(\frac{3/2}{5/3} - 1\right)} = -5 \Rightarrow f_2 < 0$$

(25) **(D).** As frequency of visible light increases refractive index increases. With the increase of refractive index critical angle decreases. So that light having frequency greater than green will get total internal reflection and the light having frequency less than green will pass to air.

(26) **(D).** $\sin\theta = \mu \sin r_1$

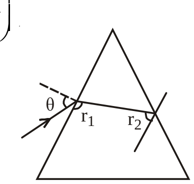
$$\Rightarrow\ \sin r_1 = \frac{\sin\theta}{\mu} \Rightarrow r_1 = \sin^{-1}\left(\frac{\sin\theta}{\mu}\right)$$

$$r_2 = A - \sin^{-1}\left(\frac{\sin\theta}{\mu}\right) \Rightarrow r_2 < \sin^{-1}\left(\frac{1}{\mu}\right)$$

$$\Rightarrow\ A - \sin^{-1}\left(\frac{\sin\theta}{\mu}\right) < \sin^{-1}\left(\frac{1}{\mu}\right)$$

$$\Rightarrow\ A - \sin^{-1}\left(\frac{1}{\mu}\right) < \sin^{-1}\left(\frac{\sin\theta}{\mu}\right)$$

$$\Rightarrow\ \sin\left(A - \sin^{-1}\left(\frac{1}{\mu}\right)\right) < \frac{\sin\theta}{\mu}$$



$$\Rightarrow\ \mu\left(\sin\left(A - \sin^{-1}\left(\frac{1}{\mu}\right)\right)\right) < \sin\theta$$

$$\Rightarrow\ \sin^{-1}\left(\mu\sin\left(A - \sin^{-1}\left(\frac{1}{\mu}\right)\right)\right) < \theta$$

(27) **(B).** 20 times taller as the angular magnification is 20 and we observe angular magnification.

Option (C) would not be very correct as the telescope can be adjusted to form image anywhere between infinity and least distance for distinct vision. Suppose that the image is formed at infinity. Then the observer will have to focus the eyes at infinity to observe the image. Hence it is incorrect to say that the image will appear nearer to the observer.

(28) **(D).** $\delta = i + e - A \Rightarrow 40 = 35 + 79 - A \Rightarrow A = 74°$

Let us put $\mu = 1.5$ and check.

$$1.5 = \frac{\sin\left(\frac{A+\delta_{min}}{2}\right)}{\sin\frac{A}{2}} \Rightarrow 1.5 = \frac{\sin\left(\frac{74+\delta_{min}}{2}\right)}{\sin(37°)}$$

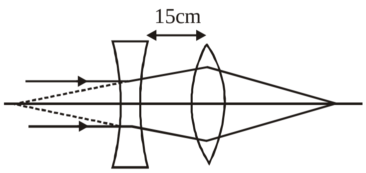
$$\Rightarrow \quad 0.9 = \sin\left(37 + \frac{\delta_m}{2}\right)$$

Solving, $37 + \frac{\delta_m}{2} = 64° \Rightarrow \delta_m = 54°$

This angle is greater than the 40° deviation angle already given. For greater μ, deviation will be even higher. Hence μ of the given prism should be less than 1.5. Hence the closest option will be 1.5.

Upon solving the given case we get $\mu = 1.31$.

(29) **(D).** $f_1 = -25cm, f_2 = 20cm$



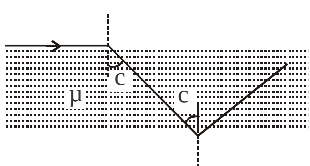
For diverging lens $V = -25cm$

For converging lens, $u = -(15 + 25) = -40$ cm

$$\frac{1}{v} - \frac{1}{-40} = \frac{1}{+20} \Rightarrow \frac{1}{v} = \frac{1}{20} - \frac{1}{40} = \frac{1}{40} \Rightarrow v = 40cm$$

$\Rightarrow$ Image is real

(30) **(A).** $C < i_b$, Here i_b is "brewester angle" and c is critical angle.

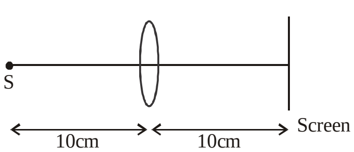


$\sin i_c < \sin i_b$ since $\tan i_b = \frac{1.5}{\mu}$

$$\frac{1}{\mu} < \frac{1.5}{\sqrt{\mu^2 + (1.5)^2}} ; \sin i_b = \frac{1.5}{\sqrt{\mu^2 + (1.5)^2}}$$

$$\sqrt{\mu^2 + (1.5)^2} < 1.5 \times \mu ; \ \mu^2 + (1.5)^2 < (\mu \times 1.5)^2 ; \mu < \frac{3}{\sqrt{5}}$$

(31) **(A).**



$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{10} - \frac{1}{-10} = \frac{1}{f} \Rightarrow f = 5 \text{ cm.}$$

Shift due to slab = $t\left(1 - \frac{1}{\mu}\right)$ in the direction of incident ray $= 1.5\left(1 - \frac{2}{3}\right) = 0.5$

$$\frac{1}{v} - \frac{1}{-9.5} = \frac{1}{5} \Rightarrow \frac{1}{v} = \frac{1}{5} - \frac{2}{19} = \frac{9}{95} \Rightarrow v = \frac{95}{9} = 10.55 \text{ cm.}$$

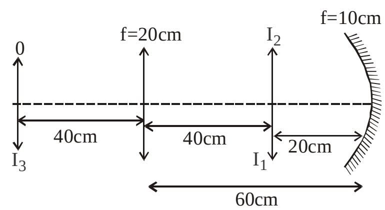
(32) **(A).** There will be 3 phenomenon

(i) Refraction from lens

(ii) Reflection from mirror

(iii) Refraction from lens

After these phenomena. Image will be on object and will have same size.



1st refraction $u = -40cm; f = +20cm$

$\Rightarrow$ $v = +40$ cm (image I_1) and $m_1 = -1$

For reflection

$u = -20cm; f = -10cm$

$\Rightarrow$ $v = -20cm$ (image I_2) and $m_2 = -1$

2nd refraction

$u = -40cm; f = +20cm$

$\Rightarrow$ $v = +40$ cm (image I_3) and $m_3 = -1$

Total magnification $= m_1 \times m_2 \times m_3 = -1$

and final image is formed at distance 40 cm from convergent lens and is of same size as the object.

(33) **(B).**

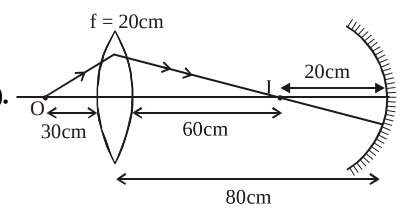


Image formed by lens

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \ ; \ \frac{1}{v} + \frac{1}{30} = \frac{1}{20} \ ; v = +60 \text{ cm}$$

If image position does not change even when mirror is removed it means image formed by lens is formed at centre of curvature of spherical mirror.

Radius of curvature of mirror $= 80 - 60 = 20$cm

$\Rightarrow$ Focal length of mirror f = 10 cm

For virtual image, object is to be kept between focus and pole.

$\Rightarrow$Maximum distance of object from spherical mirror for which virtual image is formed, is 10cm.

(34) **(B). Case-I :** If final image is at least distance of clear vision

$$M.P. = \frac{L}{f_0}\left(1+\frac{D}{f_e}\right); 375 = \frac{150}{5}\left(1+\frac{25}{f_e}\right)$$

$$\frac{375}{30} = 1+\frac{25}{f_e} \;;\; \frac{345}{30} = \frac{25}{f_e}$$

$$f_e = \frac{750}{345} = 2.17 \text{ cm} ;\; f_e \approx 22 \text{ mm}$$

Case-II : If final image is at infinity

$$M.P. = \frac{L}{f_0}\left(\frac{D}{f_e}\right) = 375 \;;\; f_e \approx 22 \text{ mm}$$

(35) **(A).** $\frac{1}{f_a} = \left(\frac{\mu_g}{\mu_a}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

$$\frac{1}{f_m} = \left(\frac{\mu_g}{\mu_m}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

$$\frac{f_a}{f_m} = \frac{\left(\frac{\mu_g}{\mu_m}-1\right)}{\left(\frac{\mu_g}{\mu_a}-1\right)} = \frac{\left(\frac{1.50}{1.42}-1\right)}{\left(\frac{1.50}{1}-1\right)} = \frac{0.08}{(1.92)\,(0.5)}$$

$$\frac{f_m}{f_a} = \frac{(1.42)\,(0.5)}{0.08} = 8.875 \approx 9$$

(36) **(D).** $L = f_0 + f_e = 60$ cm

$$M = \frac{f_0}{f_e} = 5 \Rightarrow f_0 = 5f_e \Rightarrow 6f_e = 60 \text{ cm} ;\; f_e = 10 \text{ cm}$$

(37) **(D).** $\sin\theta_C = \frac{1}{\mu} = \frac{1}{\sqrt{3\times(4/3)}}$; $\theta_C = 30°$

(38) **60.00**

Using Lens-Maker's formula :

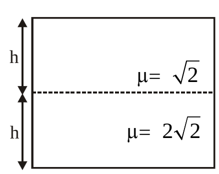
$$\frac{1}{f} = (\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

$$\frac{1}{f} = (1.5-1)\left(\frac{1}{30}-0\right)$$

f = 60 cm

(39) **(B).** For near normal incidence,

$$h_{app} = \frac{h_{actual}}{\left(\frac{\mu_{in}}{\mu_{ref}}\right)}$$



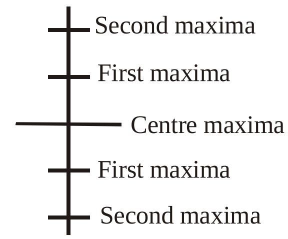
$$\therefore\; h_{apparent} = \frac{\frac{h}{\left(\frac{2\sqrt{2}}{\sqrt{2}}\right)}+h}{\frac{\sqrt{2}}{1}} = \frac{3h}{2\sqrt{2}} = \frac{3}{4}h\sqrt{2}$$

PART - B : WAVE OPTICS

(1) **(C).** Of the same frequency and having a definite phase relationship.

(2) **(B).** For maximum $d\sin\theta = n\lambda$

$$\therefore \sin\theta = \frac{n\lambda}{d}$$



$\sin\theta \le 1$

$$\therefore \frac{n\lambda}{d} \le 1$$

$$n \le \frac{d}{\lambda}$$

Given $d = 2\lambda$ $\quad\therefore n \le \frac{2\lambda}{\lambda}$

$n \le 2$ $\quad\therefore n_{max} = 2$

$\therefore$ Total possible max will be five.

(3) **(D).** According to Brewester's law, $n = \tan i_p$

Here, i_p = Polarized angle, n = refractive index

so, $i_p = \tan^{-1}(n)$

(4) **(A).** $I = I_0\cos^2\theta$

Intensity of polarized light = $I_0/2$

$\therefore$ Intensity of untransmitted light $= I_0 - \frac{I_0}{2} = \frac{I_0}{2}$

(5) **(B).** $I = I_0\left(\frac{\sin\theta}{\theta}\right)^2$ and $\theta = \frac{\pi}{\lambda}\left(\frac{ay}{D}\right)$

For principal maximum y = 0

$\therefore$ θ = 0. Hence, intensity will remain same.

(6) **(A).** Hyperbola

(7) **(D).** Phase difference $= \frac{2\pi}{\lambda}\times$ path difference

$$\text{i.e., } \phi = \frac{2\pi}{\lambda}\times\frac{\lambda}{6} = \frac{\pi}{3}$$

$$\text{As } I = I_{max}\cos^2\left(\frac{\phi}{2}\right) ;\; \frac{I}{I_{max}} = \cos^2\left(\frac{\phi}{2}\right)$$

(8) **(C).** $\frac{3\lambda_1 D}{d} = \frac{4\lambda_2 D}{d}$; $3\times 590 = 4\times\lambda_2$; $\lambda_2 = 442.5$ nm

(9) **(A).** S1 : When light reflects from denser med (Glass) a phase dift of π is generated.

S2 : Centre maxima or minima depends on thickness of the lens.

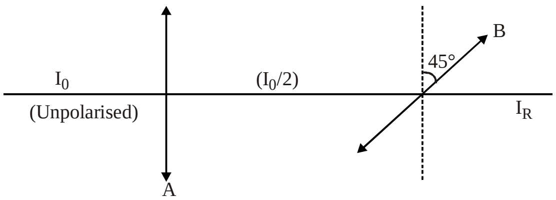
(10) **(D).** $I_m = I_0 + 4I_0 + 2\sqrt{I_0\times 4I_0}\cos\phi$

$$I_m = I_0 + 4I_0 + 4I_0\cos\phi = \frac{I_m}{9}(5+4\cos\phi)$$

$$= \frac{I_m}{9}(1+8\cos^2\phi/2)$$

(11) **(C).** Relation between intensities is

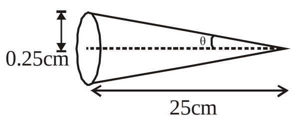
$$I_R = \left(\frac{I_0}{2}\right)\cos^2(45°) = \frac{I_0}{2}\times\frac{1}{2} = \frac{I_0}{4}$$



(12) **(D).** It will be concentric circles.

(13) **(B).** $I_A\cos^2 30 = I_B\cos^2 60$; $\frac{I_A}{I_B} = \frac{1}{3}$

(14) **(A).**

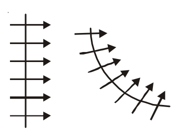


$$RP = \frac{1.22\lambda}{2\mu\sin\theta} = \frac{1.22\times(500\times10^{-9}\,m)}{2\times1\times\left(\frac{1}{100}\right)}$$

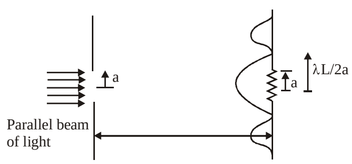
$= 3.05\times10^{-5}m = 30\,\mu m$

(15) **(C).** Consider a plane wavefront travelling horizontally. As it moves, its different parts move with different speeds. So, its shape will change as shown

$\Rightarrow$ Light bends upward



(16) **(D).** Geometrical spread = a



Diffraction spread $= \left(\frac{\lambda}{2a}\right)L = \frac{\lambda}{2a}L$; Sum (b) $= a + \frac{\lambda L}{2a}$

For b to be minimum

$$\frac{db}{da} = 0 \Rightarrow 1 - \frac{\lambda L}{2a^2} = 0 \Rightarrow a = \sqrt{\frac{\lambda L}{2}}$$

and $b_{min} = \sqrt{\frac{\lambda L}{2}} + \sqrt{\frac{\lambda L}{2}} = \sqrt{2\lambda L}$

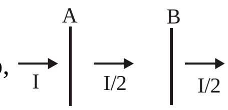
(17) **(A).** $y_1 = \frac{n_1\lambda_1 D}{d}$, $y_2 = \frac{n_2\lambda_2 D}{d}$. Given, $y_1 = y_2$

$n_1\lambda_1 = n_2\lambda_2$

$$\frac{n_1}{n_2} = \frac{\lambda_2}{\lambda_1} = \frac{4}{5}\ ;\ y_1 = \frac{4\times650\times10^{-9}\times1.5}{0.5\times10^{-3}} = 7.8\text{ mm}$$

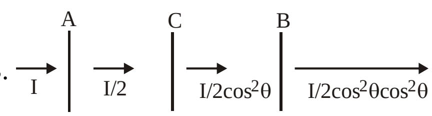
(18) **(A).** When an unpolarized light of intensity I passes through a polarizer for the 1st time, intensity of output is I/2 (irrespective of orientation of polarizer)

So,



i.e., polarizers A and B have axes parallel to each other.

Now let the axis of C make an angle θ with A, & (–θ) with B.



$\frac{I}{2}\cos^4\theta = \frac{I}{8}$; Solving, $\theta = 45°$

(19) **(C).** Angular width of central maxima $= \frac{2\lambda}{a}$

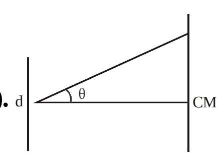
(where a is slit width and λ is wavelength)

$\frac{2\lambda}{a} = \frac{\pi}{3}$ .... (i) In YDSE, fringe width

$\beta = \frac{\lambda D}{d}$ [where d is slit separation and D is distance of screen from slits) $\beta = \frac{D}{d}\times\frac{\pi}{6}a \Rightarrow d = \frac{D\pi a}{6\beta}$

$$d = \frac{1}{2}\times\frac{3.14\times10^{-6}}{6\times10^{-2}} \approx \frac{100}{4}\times10^{-6} \approx 25\mu m$$

(20) **(B).**



Path difference $d\sin\theta = n\lambda$, where d = seperation of slits, λ = wave length, n = no. of maximas

$0.32\times10^{-3}\sin 30 = n\times500\times10^{-9}$; $n = 320$

Hence total no. of maximas observed in angular range $-30° \le \theta \le 30°$ is maximas $= 320 + 1 + 320 = 641$

(21) **(A).** Limit of resolution of telescope $= \frac{1.22\,\lambda}{D}$

$$\theta = \frac{1.22\times500\times10^{-9}}{200\times10^{-2}} = 305\times10^{-9}\text{ radian}$$

(22) **(B).** $I_1 = 4I_0$; $I_2 = I_0$

$$I_{max} = (\sqrt{I_1}+\sqrt{I_2})^2 = (2\sqrt{I_0}+\sqrt{I_0})^2 = 9I_0$$

$$I_{min} = (\sqrt{I_1}-\sqrt{I_2})^2 = (2\sqrt{I_0}-\sqrt{I_0})^2 = I_0 \quad\therefore\ \frac{I_{max}}{I_{min}} = \frac{9}{1}$$

(23) **(A).** For 2nd minima, $d \sin\theta = 2\lambda$

$\sin\theta = \frac{\sqrt{3}}{2}$ (given) ; $\frac{\lambda}{d} = \frac{\sqrt{3}}{4}$ ...... (i)

So for 1st minima is, $d \sin\theta = \lambda$

$\sin\theta = \frac{\lambda}{d} = \frac{\sqrt{3}}{4}$ (from equation (i))

$\theta = 25.65°$ (from sin table) ; $\theta \approx 25°$

(24) **(B).** $I = I_0 \cos^2\theta$; $\frac{I_0}{10} = I_0 \cos^2\theta$

$\cos\theta = \frac{1}{\sqrt{10}} = 0.31 < \frac{1}{\sqrt{2}}$ which is 0.707

So $\theta > 45°$ and $90 - \theta < 45°$ so only one option is correct i.e. 18.4°.

Angle rotated should be = 90° – 71.6° = 18.4°

(25) **(A).** $\beta = \frac{\lambda D}{d} = \frac{589 \times 10^{-9} \times 1.5}{0.15 \times 10^{-3}} = 5.9$ mm

(26) **(D).** $I = I_0 \cos^2\left(\frac{\Delta\phi}{2}\right)$

$$\frac{I}{I_0} = \cos^2\left(\frac{\Delta\phi}{2}\right) = \cos^2\left(\frac{\frac{2\pi}{\lambda} \times \frac{\lambda}{8}}{2}\right) = \cos^2\left(\frac{\pi}{8}\right) = 0.853$$

(27) **750.00.** The length of the screen used portion for 15 fringes, and also for ten fringes.

$15 \times 500 \times \frac{D}{\lambda} = 10 \times \frac{\lambda D}{\lambda}$; $15 \times 50 = \lambda$; $\lambda = 750$ nm

EXERCISE-5
PART - A : RAY OPTICS

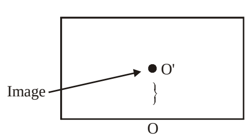
(1) **(D).** $\delta\phi = 1.22\frac{\lambda}{D} = 1.22 \times \frac{5000 \times 10^{-10}}{10 \times 10^{-2}}$

$= 6.1 \times 10^{-6}$ $\therefore$ Order $= 10^{-6}$

(2) **(C).** From the formula, $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{25} - \frac{1}{25} = 0$

Power of combination = 1/f = 0

(3) **(D).** In the later case microscope will be focussed for O'. So it is required to be lifted by distance OO'.



OO' = real depth of O – apparent depth of O.

$= 3 - \frac{3}{1.5}\left[\mu = \frac{\text{real depth}}{\text{apparent depth}}\right]$

$= 3\left[\frac{1.5 - 1}{1.5}\right] = \frac{3 \times 0.5}{1.5} = 1$cm.

(4) **(B).** By using $v = n\lambda$

Here, $n = 2 \times 10^{14}$ Hz

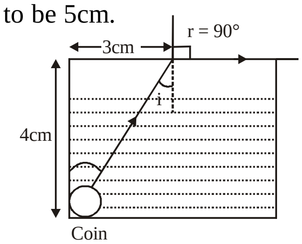
$\lambda = 5000$ Å $= 5000 \times 10^{-10}$ m

$v = 2 \times 10^{14} \times 5000 \times 10^{-10} = 10^8$ m/s

Refractive index of the material

$\mu = \frac{c}{v} = \frac{3 \times 10^8}{10^8} = 3$

(5) **(D).** Hypotenuse comes out to be 5cm.



Since, $\frac{1}{\mu} = \frac{\sin i}{\sin 90°}$

$\mu = \frac{1}{\sin i} = \frac{5}{3}$

Speed, $v = \frac{c}{\mu} = \frac{3 \times 10^8}{5/3} = 1.8 \times 10^8$ m/s

(6) **(A).** $\frac{1}{F_{eq}} = \frac{1}{f_1} + \frac{1}{f_2}$; $P_{eq} = \frac{f_1 + f_2}{f_1 f_2}$

(7) **(B).** $\frac{I}{O} = \frac{v}{u}$; $O = 1.39 \times 10^9$m, $v = 0.1$m,

$u = 1.5 \times 10^{11}$ m ; $I = 9.2 \times 10^{-4}$ m

(8) **(C).** For total internal reflection, $\sin i > \sin C$

where, i = angle of incidence,

C = critical angle But, $\sin C = 1/\mu$;

$\sin i > 1/\mu$ or $\mu > 1/\sin i$

$\mu > 1/\sin 45°$ ($i = \sin 45°$ (Given)) ; $\mu > \sqrt{2}$

(9) **(C).** Focal length of the lens remains same.

Intensity of image formed by lens is proportional to area exposed to incident light from object.

i.e., Intensity $\propto$ area i.e., $\frac{I_2}{I_1} = \frac{A_2}{A_1}$;

Initial area, $A_1 = \left(\frac{d}{2}\right)^2 = \frac{\pi d^2}{4}$

After blocking, exposed area,

$$A_2 = \frac{\pi d^2}{4} - \frac{\pi (d/2)^2}{4} = \frac{\pi d^2}{4} - \frac{\pi d^2}{16} = \frac{3\pi d^2}{16}$$

$$\frac{I_2}{I_1} = \frac{A_2}{A_1} = \frac{\frac{3\pi d^2}{16}}{\frac{\pi d^2}{16}} = \frac{3}{4} \text{ or } I_2 = \frac{3}{4}I_2 = \frac{3}{4}I \ (\because I_2 = I)$$

Hence focal length of a lens = f_1

Intensity of the image = 3I/4

(10) **(C).** For M_1 : $\mu_1 = \frac{c}{v_1} = \frac{3 \times 10^8}{1.5 \times 10^8} = 2$

For M_2 : $\mu_2 = \frac{c}{v_2} = \frac{3 \times 10^8}{2.0 \times 10^8} = \frac{3}{2}$

For total internal reflection

$\sin i \geq \sin C$, where i = angle of incidence,

C = critical angle. But $\sin C = \frac{\mu_2}{\mu_1}$

$\sin i \geq \frac{\mu_2}{\mu_1} \geq \frac{3/2}{2} \Rightarrow \sin^{-1}\left(\frac{3}{4}\right)$

(11) **(B).** Angle of prism, $A = r_1 + r_2$
For minimum deviation, $r_1 = r_2 = r$
$\therefore \quad A = 2r\ ;\ A = 60°\ ;\ r = \frac{A}{2} = \frac{60°}{2} = 30°$

(12) **(C).** Real & apparent depth are explained on the basis of refraction only. TIR not involved

(13) **(D).** Assume $\mu = 1.5$

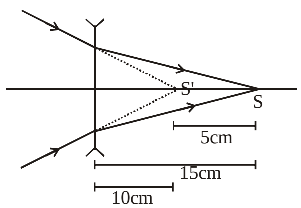
$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$; f = 20 cm.

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}\ ;\ \frac{1}{v} - \frac{1}{-30} = \frac{1}{20}\ ;\ v = 60$

Magnification is v/u = –2

$\frac{|h_i|}{|h_0|} = 2\ ;\ |h_i| = 2 \times |h_0|$

(14) **(C).** $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$



u = 10, v = 15, f = ?

$\frac{1}{15} - \frac{1}{10} = \frac{1}{f}$;

$\frac{10-15}{150} = \frac{1}{f} \quad \therefore\ f = -\frac{150}{5} = -30\text{cm}$

(15) **(B).** Deviation = zero. So, $\delta = \delta_1 + \delta_2 = 0$
$(\mu_1 - 1)A_1 + (\mu_2 - 1)A_2 = 0$
$A_2(1.75 - 1) = -(1.5 - 1)\,15°$

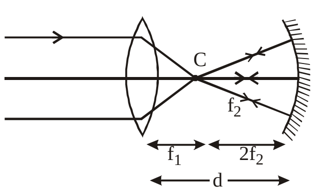
$A_2 = -\frac{0.5}{0.75} \times 15° = -10°$

(16) **(A).** $\frac{1}{f} = \left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$.

Here, $f = \infty$, so $1/f = 0$, so $\mu_g = \mu_m$

(17) **(A).** For normal emergence, e = 0.
Therefore $r_2 = 0$ and $r_1 = A$
Snell's Law for incident rays
$1 \sin i = \mu \sin r_1 = \mu \sin A$
For small angle, $i = \mu A$

(18) **(C).**



; $d = f_1 + 2f_2$

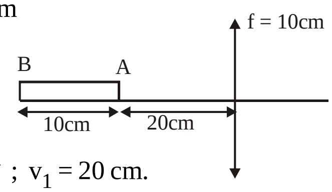
(19) **(C).** M.P = f_0/f_e ..... (1) $f_0 + f_e = 20$ ..... (2)
On solving, $f_0 = 18$ cm, $f_e = 2$ cm

(20) **(B).** $\delta_{min} = i + e - A$
$\delta_{min} = A$ then $2A = i + e$ in case of minimum deviatioin, i = e
$2A = 2i\ ;\ r_1 = r_2 = A/2$
Consider, $i = A = 90°$ then $1 \sin i = n \sin r_1$
$\sin A = n \sin (A/2)$

$2\sin\frac{A}{2}\cos\frac{A}{2} = n\sin\frac{A}{2}\ ;\quad 2\cos\frac{A}{2} = n$

When $A = 90° = i_{min}$ then $n_{min} = \sqrt{2}$
$i = A = 0\ ;\ n_{max} = 2$

(21) **(D).** When $u_1 = -20$ cm



$\frac{1}{v_1} + \frac{1}{20} = \frac{1}{10}$

$\frac{1}{v_1} = \frac{1}{10} - \frac{1}{20} = \frac{1}{20}\ ;\ v_1 = 20$ cm.

When $u_2 = -30$cm.

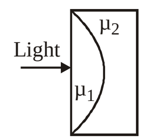
$\frac{1}{v_2} = \frac{1}{10} - \frac{1}{30} = \frac{1}{15}\ ;\ v_2 = 15$cm.

$L = v_1 - v_2 = 5$ cm.

(22) **(D).** Equivalent focal length : $\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2}$

$\frac{1}{f_{eq}} = (\mu_1 - 1)\left(\frac{1}{\infty} - \frac{1}{-R}\right) + (\mu_2 - 1)\left(\frac{1}{-R} - \frac{1}{\infty}\right)$

$\Rightarrow \quad f_{eq} = \frac{R}{\mu_1 - \mu_2}$

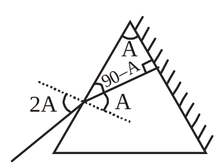


(23) **(D).** For a normal eye, rays coming from infinity should go to the retina without effort when we look at infinity, lens offers minimum power and hence combination gives 40D + 20D = 60D.
Distance between the retina and the cornea eye has must be equal to focal length.
f = (1/60) m = 1.67 cm

(24) **(D).** MP of microscope = $\frac{L}{f_0}\left[1 + \frac{P}{f_e}\right]$

MP of telescope = $\frac{f_0}{f_e}\left[1 + \frac{f_e}{D}\right]$

(25) **(B).** Normal incidence at silvered surface



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

$\mu = \frac{\sin 2A}{\sin A} = \frac{2\sin A\cos A}{\sin A} = 2\cos A$

(26) **(A).** $\mu = \frac{\sin\left(\frac{\delta_m + A}{2}\right)}{\sin(A/2)}$

$$\cot\frac{A}{2} = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin(A/2)} = \frac{\cos(A/2)}{\sin(A/2)}$$

$$\sin\left(\frac{A+\delta_m}{2}\right) = \sin(90 - A/2) \Rightarrow \delta_{min} = 180° - 2A$$

(27) **(B).** $\frac{1}{f_1} = \left(\frac{1.5}{1} - 1\right)\left(\frac{1}{\infty} - \frac{1}{-20}\right) \Rightarrow f_1 = 40\text{cm}$

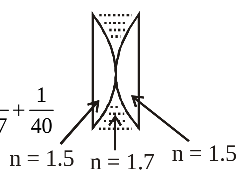
$$\frac{1}{f_2} = \left(\frac{1.7}{1} - 1\right)\left(\frac{1}{-20} - \frac{1}{+20}\right)$$

$$\Rightarrow f_2 = -\frac{100}{7}\text{cm}$$

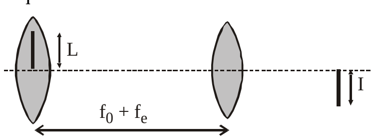
f_3 is also 40cm.

$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} = \frac{1}{40} + \frac{1}{-100/7} + \frac{1}{40}$$

$f_{eq} = -50\text{cm}$



(28) **(A).**



Magnification of telescope, $M = f_0/f_e$

$$\frac{f_e}{f_e + u} = -\frac{I}{L};\ \frac{f_e}{f_e - (f_0 + f_e)} = -\frac{I}{L} \Rightarrow \frac{f_e}{f_0} = \frac{I}{L}$$

$$M = \frac{L}{I}$$

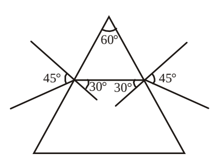
(29) **(A).** $\mu = \frac{1}{\sin i_c} = \frac{1}{\sin 45°} = \sqrt{2} = 1.414$

$(\mu_{red} = 1.39) < \mu,\ \mu_v > \mu\ ;\ \mu_g > \mu$

Only red colur do not suffer total internal reflection.

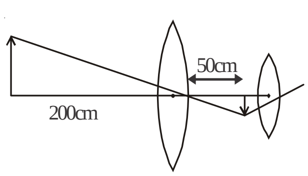
(30) **(B).** Ray pass symmetrically through prism

$\delta_{min} = (i + e) - A = 30°$



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

(31) **(D).**



Objective, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v} - \frac{1}{-200} = \frac{1}{40}$

$$\frac{1}{v} = \frac{1}{40} - \frac{1}{200} = \frac{5-1}{200} = \frac{1}{50}\ ;\ v = 50$$

For normal adjustment $L = u + f_e = 54$ cm.

(32) **(A).**

(A) m = –2, so image is magnified and inverted. Which is possible only for concave mirror. since image is i inverted so it will be real.

(B) m = –1/2, so image is inverted and diminished. since image is inverted, so it will be real, and the mirror will be concave.

(C) m = +2, image is magnified so the mirror will be concave. Image is erect so it will be virtual.

(D) m = +1/2 , image is erect so image will be virtual. Image is virtual and diminished, so the mirror should be convex.

(33) **(D).** $\frac{1}{f} = (\mu_g - 1)\frac{2}{R} = \frac{1}{R},\ \left(\mu_g = \frac{3}{2}\right)$, R = f

$$\frac{1}{f_1} = -(\mu_w - 1)\frac{2}{R} = \frac{-2}{3R} = \frac{-2}{3f}$$

$$\frac{1}{f_{eq}} = \frac{1}{f} + \frac{1}{f} + \frac{1}{f_1};\ \frac{1}{f_{eq}} = \frac{1}{f} + \frac{1}{f} - \frac{2}{3f}$$

$$\frac{1}{f_{eq}} = \frac{2}{f} - \frac{2}{3f} = \frac{4}{3f};\quad f_{eq} = \frac{3f}{4}$$

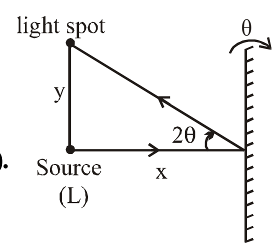
(34) **(C).** $d = (d_1 + d_2)\,\mu = 1.5\,(5 + 3) = 12$ cm

(35) **(B).** Maximum distance of distinct vision = 400cm. So image of object at infinity is to be formed at 400 cm.

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f};\ \frac{1}{-400} - \frac{1}{\infty} = \frac{1}{f};\ P = -0.25\text{ D}$$

(36) **(B).** Resolving power $\propto \frac{1}{\lambda}$; $\frac{RP_1}{RP_2} = \frac{\lambda_2}{\lambda_1} = \frac{6000\text{ Å}}{4000\text{ Å}} = \frac{3}{2}$

(37) **(D).**



$2\theta = \frac{y}{x}\ ;\ \theta = \frac{y}{2x}$

(38) **(A).** For dispersion without deviation, $\delta_1 = \delta_2$

$A_1(\mu_1 - 1) = A_2(\mu_2 - 1)$

$10\,(1.42 - 1) = A_2\,(1.7 - 1)\ ;\ A_2 = 6°$

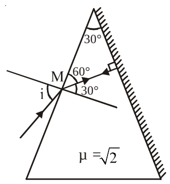
(39) **(A).** For telescope, angular magnification = $\frac{f_0}{f_E}$

So, focal length of objective lens should be large.

Angular resolution = $\frac{D}{1.22\,\lambda}$ should be large.

So, objective should have large focal length (f_0) and large diameter D.

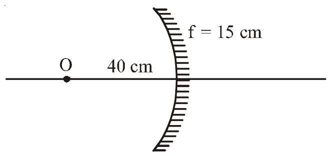
(40) **(B).** For retracing its path, light ray should be normally incident on silvered face.
Applying Snell's law at M,



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

$$\Rightarrow \sin i = \sqrt{2} \times \frac{1}{2} = \frac{1}{\sqrt{2}} \quad \text{i.e., } i = 45°$$

(41) **(B).**



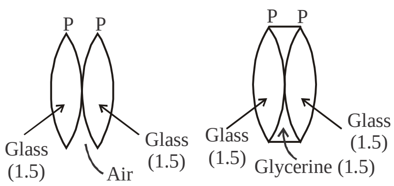
$$\frac{1}{f} = \frac{1}{v_1} + \frac{1}{u}\ ;\ -\frac{1}{15} = \frac{1}{v_1} - \frac{1}{40}\ ;\ \frac{1}{v_1} = -\frac{1}{15} + \frac{1}{40}$$

$v_1 = -24$ cm.
When object is displaced by 20 cm towards mirror.
Now, $u_2 = -20$

$$\frac{1}{f} = \frac{1}{v_2} + \frac{1}{u_2}\ ;\ \frac{1}{-15} = \frac{1}{v_2} - \frac{1}{20}\ ;\ \frac{1}{v_2} = \frac{1}{20} - \frac{1}{15}$$

$v_2 = -60$ cm.
Image shifts away from mirror by = 60 – 24 = 36 cm.

(42) **(B).**



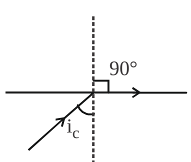
Equivalent focal length in air $\frac{1}{F_1} = \frac{1}{f} + \frac{1}{f} = \frac{2}{f}$

When glycerin is filled inside, glycerin lens behaves like a diverging lens of focal length (–f).

$$\frac{1}{F_2} = \frac{1}{f} + \frac{1}{f} - \frac{1}{f} = \frac{1}{f}\ ;\ \frac{F_1}{F_2} = \frac{1}{2}$$

(43) **(C).** Rainbow can't be observed when observer faces towards sun.

(44) **(D).**



At $i = i_c$, refracted ray grazes with the surface.
So angle of refraction is 90°.

PART - B : WAVE OPTICS

(1) **(C).** According to question $n_1\lambda_1 = n_2\lambda_2$

So, $\frac{n_1}{n_2} = \frac{\lambda_2}{\lambda_1} = \frac{10000}{12000} = \frac{5}{6}$

Minimum n_1 & n_2 are 5 and 6 respectively.

$$X_{min} = \frac{n_1\lambda_1 D}{d} = \frac{5\,(12000 \times 10^{-10})\,(2)}{2 \times 10^{-3}}$$

$= 6 \times 10^{-3}$ m = 6 mm

(2) **(D).** As speed of electrons is increased so wavelength of electrons will decreases. The angular width ($\propto\lambda$) of the central maximum of diffraction pattern will decrease.

(3) **(D).** Distance between 1st order dark fringes
= width of principal max

$$x = \frac{2\lambda D}{d} = \frac{2 \times 600 \times 10^{-9} \times 2}{10^{-3}}$$

$= 2400 \times 10^{-6} = 2.4 \times 10^{-3}$m = 2.4 mm

(4) **(C).** Path difference λ means maxima $I_{max} = K$

$$I = K\cos^2\frac{\phi}{2} = K\cos^2\left[\frac{2\pi}{\lambda} \times \frac{\lambda}{4} \times \frac{1}{2}\right] = K\cos^2\frac{\pi}{4} = \frac{K}{2}$$

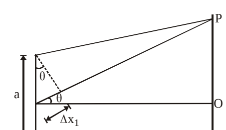
(5) **(D).** $d = 1\text{mm} = 10^{-3}$ m, D = 1 mm
$\lambda = 500\text{nm} = 500 \times 10^{-9}$ m
Width of central maxima in single slit = $2\lambda D/a$.
Fringe width in double slit exp., $\beta = \lambda D/d$

$$\frac{10\lambda D}{d} = \frac{2\lambda D}{a}\ ;\ a = \frac{d}{5} = \frac{1}{5} \times 10^{-3}\text{m} = 0.2 \text{ mm}$$

(6) **(D).** Width of central maxima = $\frac{2D\lambda}{a}$

(7) **(D).** For first minima at P, $a \sin\theta = \lambda$

Phase difference, $\Delta\phi_1 = \frac{\Delta x_1}{\lambda} \times 2\pi = \frac{(a/2)\sin\theta}{\lambda} \times 2\pi$



$$\Delta\phi_1 = \frac{\lambda}{2\lambda} \times 2\pi = \pi \text{ radian}$$

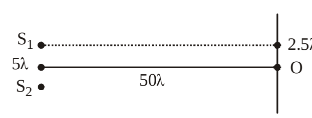
(8) **(B).** $\frac{I_1}{I_2} = \frac{W_1}{W_2} = \frac{1}{25} \Rightarrow \frac{I_2}{I_1} = \frac{25}{1}$

$$\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{(I_2/I_1)}+1}{\sqrt{(I_2/I_1)}-1}\right)^2 = \left(\frac{5+1}{5-1}\right)^2 = \frac{9}{4}$$

(9) **(D).** 1st minimum, $a\sin\theta = n\lambda$
$n = 1$, $a \sin 30° = \lambda \Rightarrow a = 2\lambda$
1st secondary maximum, $a\sin\theta_1 = 3\lambda/2$

$$\Rightarrow \sin\theta_1 = \frac{3\lambda}{2a} = \frac{3}{4} \Rightarrow \theta = \sin^{-1}\frac{3}{4}$$

(10) **(D).** $I_{max} = I_0$



$$\text{Path diff.} = \frac{dy_n}{D} = \frac{d \times \frac{d}{2}}{10d} = \frac{d}{20} = \frac{\lambda}{4}$$

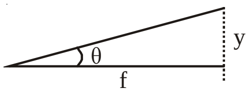
Phase diff = 90° ; $I = I_0\cos^2\frac{\phi}{2} = \frac{I_0}{2}$

(11) **(B).** $I_1/I_2 = n$

$$I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2 = (\sqrt{n}+1)^2 I_2$$

$$I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2 = (\sqrt{n}-1)^2 I_2$$

$$\frac{I_{max} - I_{min}}{I_{max} + I_{min}} = \frac{4\sqrt{n}}{2\,(n+1)} = \frac{2\sqrt{n}}{n+1}$$

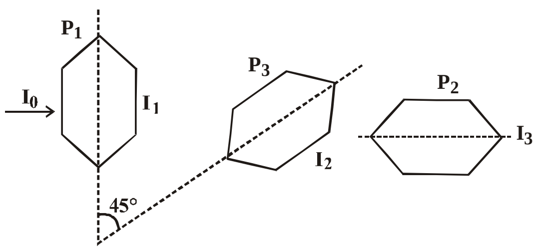
(12) **(D).** 

$$\theta = \frac{\lambda}{a} = \frac{y}{f}$$

$$y = \frac{f\lambda}{a} = \frac{60 \times 5 \times 10^{-5}}{0.02} = 0.15 \text{ cm.}$$

(13) **(C).** $(y_8)_{\text{Bright, medium}} = (y_5)_{\text{Dark, air}}$

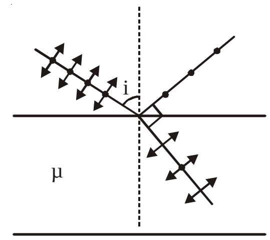
$$\frac{8\lambda_m D}{d} = \left(\frac{2\,(5)-1}{2}\right)\frac{\lambda D}{d}\ ;\ \frac{8\lambda}{\mu}\frac{D}{d} = \frac{9}{2}\frac{\lambda D}{d} \Rightarrow \mu = \frac{16}{9} = 1.78$$

(14) **(B).** 

$$I_1 = \frac{I_0}{2}\quad ;\quad I_2 = \frac{I_0}{2}\cos^2 45° = \frac{I_0}{4}$$

$$I_3 = \frac{I_0}{4}\cos^2 45° = \frac{I_0}{8}$$

(15) **(B).** When reflected light rays and refracted rays are perpendicular, reflected light is polarised with electric field vector perpendicular to the plane of incidence.



Also, $\tan i = \mu$ (Brewster angle)

(16) **(B).** Angular width $= \dfrac{\lambda}{d}$

$$0.20° = \frac{\lambda}{2\text{mm}} \quad \ldots\text{(i)};\quad 0.21° = \frac{\lambda}{d}\quad \ldots\text{(ii)}$$

Dividing we get, $\dfrac{0.20}{0.21} = \dfrac{d}{2\text{mm}}$ $\quad \therefore\ d = 1.9$ mm

(17) **(B).** In air angular fringe width $\theta_0 = \beta / D$
Angular fringe width in water

$$\theta_w = \frac{\beta}{\mu D} = \frac{\theta_0}{\mu} = \frac{0.2°}{4/3} = 0.15°$$