

Chapter 16

Optics

Topic 1 Ray Optics and Optical Instruments

Revision Notes

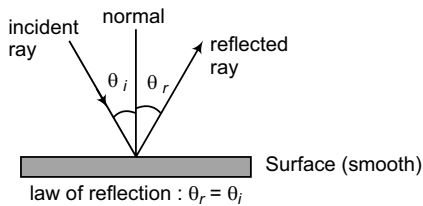
►► Reflection of light

When a ray of light impinges upon a polished, smooth, and shiny surface, the rebounding of the light within the same medium is referred to as the reflection of light.

►► Laws of Reflection

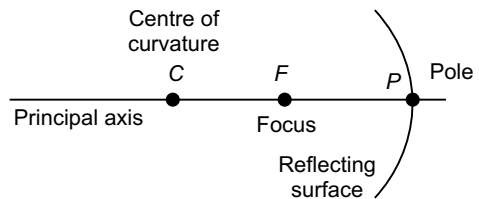
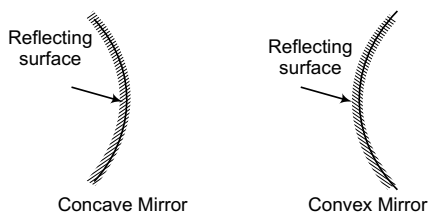
The angle of reflection is always equal to the angle of incidence.

Incident ray, reflected ray and normal to the surface at the point of incidence, all lie in the same plane.



►► Reflection of light through spherical mirrors

Spherical mirror is a piece cut out of a spherical surface which can be concave and convex.

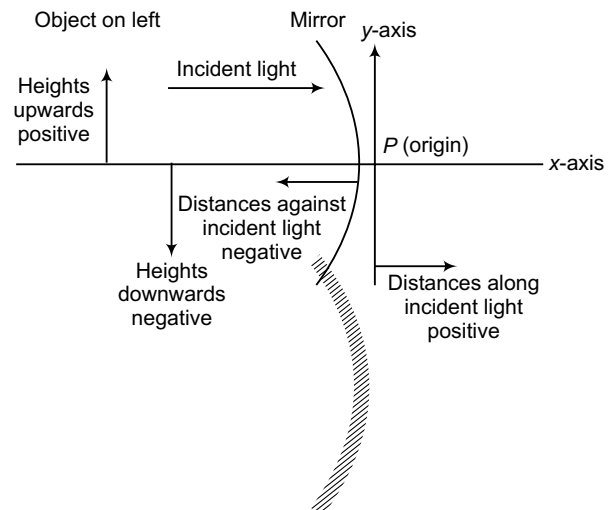


The centre of the sphere of which the mirror is a part, is center of curvature C and the distance of C from the pole is called radius of curvature.

The line joining the pole of mirror to the center of curvature is called the principal axis.

The midway point between the pole and center of curvature is focal point F and its distance from the pole is called focal length ' f '.

►► The Cartesian Sign Convention



►► Image formation in concave mirror for different positions of object

Position of the object	Position of the image	Size of the image	Nature of the Image
At infinity	At the focus F	Highly diminished, point sized	Real and inverted
Beyond C	Between F and C	Diminished	Real and inverted
At C	At C	Same size	Real and inverted
Between C and F	Beyond C	Enlarged	Real and inverted
At F	At infinity	Highly Enlarged	Real and inverted
Between P and F	Behind the mirror	Enlarged	Virtual and erect

►► Image formation in convex mirror for different positions of object

Position of the object	Position of the image	Size of the image	Nature of the Image
At infinity	At the focus F , behind the mirror	Highly diminished, point sized	Virtual and Erect
Between infinity and the pole P of the mirror	Between P and F , behind the mirror	Diminished	Virtual and Erect

►► Mirror formula

A mirror formula gives the relationship between the distance of image v , distance of object u , and the focal length of a mirror, $1/f = 1/u + 1/v$ where symbols have usual meanings.

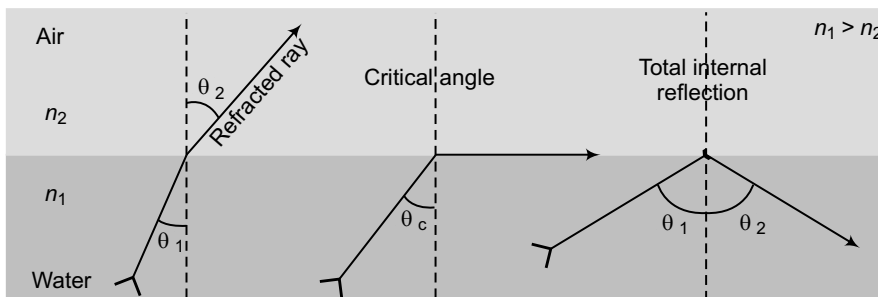
The mirror formula is applicable both in spherical mirrors and in plane mirrors.

►► Magnification by Mirror

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

Here, all alphabets are in their usual meanings.

The angle of incidence must be greater than critical angle.

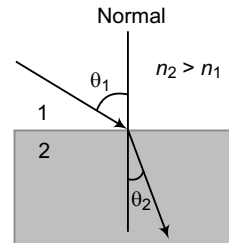


►► Refraction of light

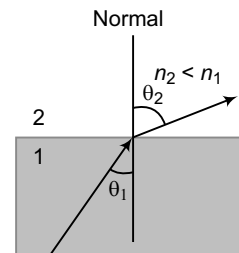
Refraction of light is the change in direction if it passes from one optically transparent medium to another.

The speed of light in given material is related to index of refraction n , which is the ratio of speed of light in vacuum to speed of light in medium, $n = c/v$. It has no unit.

If light travels from one medium to another, its speed and wavelength changes.



Snell's law : $n_1 \sin \theta_1 = n_2 \sin \theta_2$



or, equivalently, $\sin \theta_1 / \sin \theta_2 = \frac{v_1}{v_2} = \frac{n_2}{n_1}$

►► Laws of Refraction

First law of refraction shows that incident ray, refracted ray and normal to the interface lies on the same plane.

Second law of refraction shows that for two given media, ratio $\sin i/\sin r = \text{constant}$, where i is angle of incidence and r is angle of refraction, (Snell's law).

►► Total internal reflection and its applications

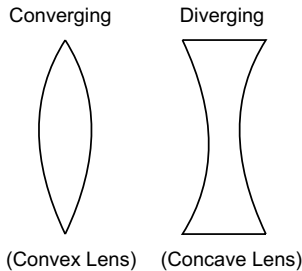
Total internal reflection is complete reflection of ray of light in optically denser medium from the surrounding surfaces of optically less dense media back into denser medium.

Light ray should travel from an optically denser medium to less dense medium.

If ray of light passes from optically denser to less dense medium, then critical angle θ_c is the angle of incidence in the denser medium at which the angle of refraction is 90° in the rarer medium.

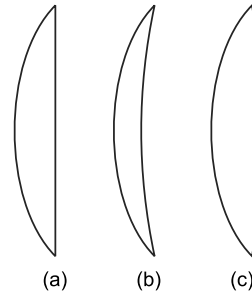
$$\theta_c = \sin^{-1}\left(\frac{1}{n}\right)$$

► Lenses

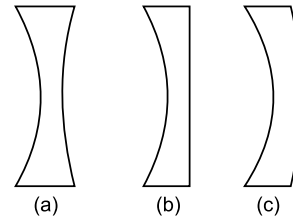


A lens is a transparent medium bounded by two curved surfaces.

The converging lenses can be plano-convex, and convex meniscus, biconvex.



Concave lens can be biconcave, plano-concave and concave meniscus



Nature, position and relative size of image formed by a convex lens for various positions of the object.

Position of the object	Position of the image	Relative size of the image	Nature of the Image
At infinity	At focus F_2	Highly diminished, point sized	Real and inverted
Beyond $2F_1$	Between F_2 and $2F_2$	Diminished	Real and inverted
At $2F_1$	At $2F_2$	Same size	Real and inverted
Between F_1 and $2F_1$	Beyond $2F_2$	Enlarged	Real and inverted
At focus F_1	At infinity	Infinitely large or highly enlarged	Real and inverted
Between focus F_1 and optical centre O	On the same side of the lens as the object	Enlarged	Virtual and erect

Nature, position and relative size of the image formed by a concave lens for various positions of the object

Position of the object	Position of the image	Relative size of the image	Nature of the Image
At infinity	At the focus F_1	Highly diminished, point-sized	Virtual and Erect
Between infinity and optical centre O of the lens	Between focus F_1 and optical centre O	Diminished	Virtual and Erect

► Lens formula

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

where v = image distance, u = object distance, f = focal length

► Lens maker's formula
$$\frac{1}{f} = (n - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

where f = focal length, n = Refractive Index

► Lens Magnification

Magnification (m) =
$$\frac{h_i}{h_o} = \frac{v}{u}$$

where h_i = height of image, h_o = height of object

► Power of lens

Power of a lens is the ability of the lens to converge or diverge a beam of light that falls on it.

$$P = \frac{1}{f}$$
 (measured in diopetre D)

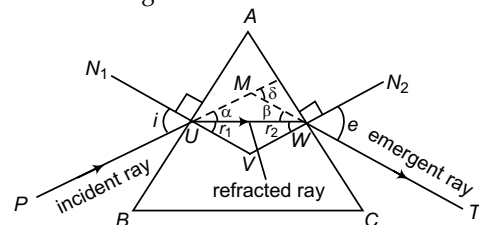
► Combination of thin lenses in contact

Thin lenses of focal lengths f_1, f_2, f_3, \dots will have effective focal length as $1/f = 1/f_1 + 1/f_2, \dots$ and power, $P = P_1 + P_2 + P_3 + \dots$, which is total powers of individual lenses.

► Refraction of light through a prism

A prism is a transparent, geometric, optical object with two polished plane faces inclined in relation to each other from where light gets reflected or refracted.

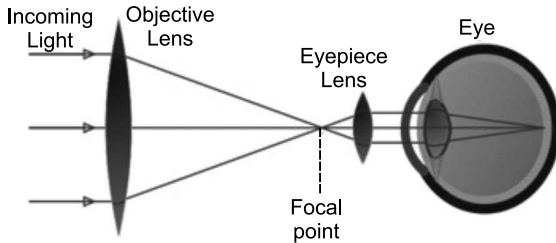
In a glass prism A is refracting angle of prism, ' i ' is angle of incidence, ' e ' is angle of emergence, r_1 and r_2 are refracting angles, δ is angle of deviation and μ is refractive index of glass.



In a quad AUVW in figure, where $A = r_1 + r_2$. In triangle MUW, δ exterior angle as sum of interior, angles α and β , $\delta = \alpha + \beta$ where $\alpha = i - r_1$ and $\beta = e - r_2$, $2i = A + \delta$ which shows that $\sin i / \sin r_1 = \mu$ and $\sin e / \sin r_2 = \mu$, $\mu = \sin(A + \delta/2) / \sin(A/2)$

► **Telescope :**

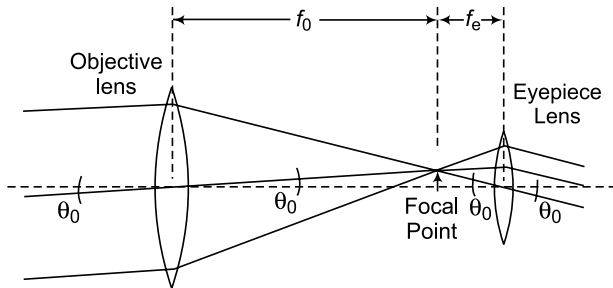
Telescope is an optical instrument with two optical elements; objective and eyepiece.



Objective is a large lens that collects light from distant object and forms an image in focal plane showing faithful representation of object while eyepiece is smooth magnifying glass by which an image can be seen.

► **Magnification of Telescope**

Magnification is the ratio of apparent size to actual size of an object.



► **Resolving Power of Telescope**

Resolving power of a telescope is ability of the instrument to produce images of two closely spaced objects/ sources where plane waves from each source after passing through an aperture from diffraction pattern results as characteristics of an aperture.

It is the inverse of the distance or angular separation among two objects that can be resolved when seen through optical instrument.

In telescopes, very close objects like binary stars or stars of galaxies subtend very small angles on the telescope.

To resolve, very large apertures are required and using Rayleigh's criterion for resolving power, angular separation between two objects as $\sin \theta = 1.22 \frac{\lambda}{d}$ (where θ is very small)

It depends on telescope focal length and eyepiece focal length.

A useful range of magnification for many telescopes is 50x to 250x.

If the image gets magnified for observer, the position of each feature in the image moves towards larger and larger angle off the centerline where magnification shows ratio of angle at eyepiece to angle by objective lens.

If θ_o is the angle seen at objective, θ_e is the angle at eyepiece, f_o is the focal length of objective, f_e is the focal

length of eyepiece, then light rays from a distant point arrives at objective in parallel and passes through center of lens, as ray is not bent and forms a straight line by the lens.

If angle of incoming ray with centerline is θ_o and same at front and back of the lens, then line passes from center of objective to focal point at a distance f_o from objective, so θ_o is h/f_o and other line from focal plane to center of eyepiece, the angle at eyepiece θ_e is h/f_e then telescope's magnification, $M = \theta_e / \theta_o = h/f_e / h/f_o$ or $m = f_o/f_e$

$$m = -\frac{f_o}{f_e} \left(1 + \frac{f_e}{D} \right) \quad \text{(for distinct vision)}$$

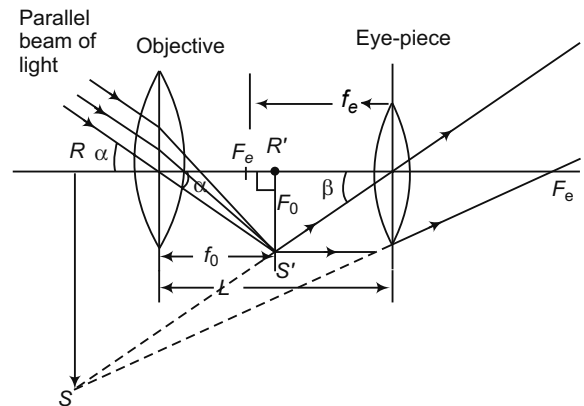
$$= -\frac{f_o}{f_e} \quad \text{(for relaxed eye)}$$

In telescope, there are lowest and highest magnification, where lowest magnification is the ratio of the telescope's aperture to eye's pupil which for 6'' or 15cm aperture is 6'' \times 25.4mm/inch / 7mm eye-pupil = 22x.

The highest magnification is magnification where eye's resolving power is fully utilized.

► **Types of Telescope**

Telescope are refractors and reflectors.



► **Refracting Telescope**

Refractor telescope is a tube with two lenses – one at the front end with little magnification, 'objective lens' while other at bottom end closest to user's eye, 'eyepiece'.

In Refractor telescopes, large objective lens collects lots of light from object far away and then refracts or 'bends' that light, bringing it to a point near the bottom end of the telescope.

The smaller eyepiece lens further magnifies that point and brings it in focus at user's eye.

In this, the tube holds the lenses at right distance from each other by keeping out light, dust and moisture that interferes with image.

The two convex lenses where objective is bigger in size with more focal length compared to eye-piece. The object being far away. Incident parallel beam of light form intermediate image R'S' in focal plane.

The intermediate image is allowed to be in focal length distance of eye-piece with final image RS being bigger in size. Magnification power of optical instrument is $M = \alpha/\beta = (R'S'/f_e)/(R'S'/f_o) = f_o/f_e$

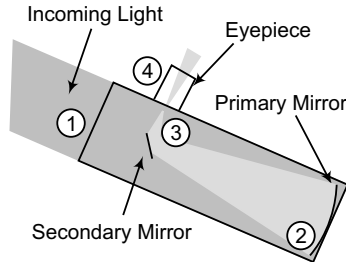
► Reflecting Telescopes

A reflecting telescope is similar to refracting telescope which uses mirrors to reflect the light internally.

In the telescope, light enters at one end (1) and is reflected by a concave mirror at other end (2) towards a smaller mirror known as secondary mirror.

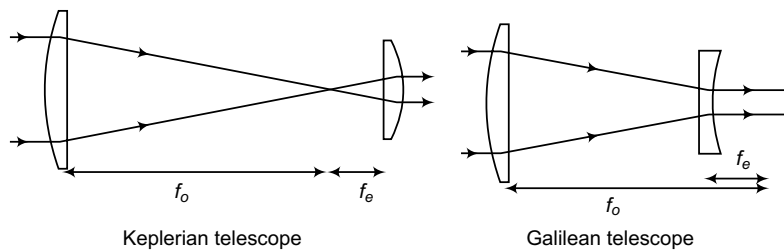
The mirror reflects (3) the light into the eyepiece, which is usually mounted on the side of the telescope (4).

Telescope can be Keplerian telescope, Galilean telescope, Terrestrial telescope.



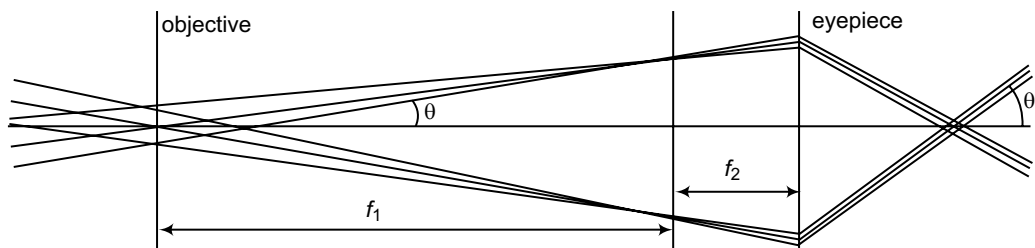
Keplerian telescope has a converging lens eyepiece while Galilean telescope has a diverging lens eyepiece.

The telescope by itself is not an image forming system where an eye of observer or camera is attached to telescope which forms an image.



Telescope is used for collecting light so as to increase the angle which a distant object subtends at the eye.

If an eye is relaxed for distant viewing, telescope produces an angular magnification and an incident, parallel beam from distant source point makes an angle θ with respect to optical axis that emerges as parallel beam making large angle θ' with respect to axis.

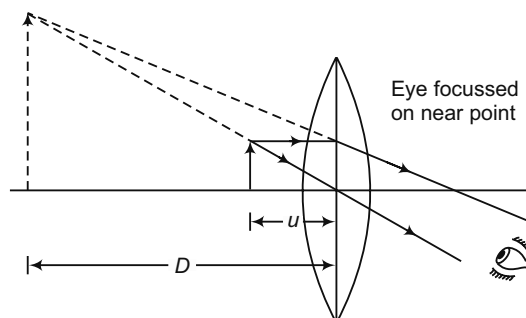


Simple Microscope : Convex lens behaves as simple microscope.

The magnifying power of the simple microscope :

(i) For least distance of distinct vision $m = 1 + \frac{D}{f}$

where, D is the least distance of distinct vision of the eye and f is focal length of the lens.



(ii) For relaxed eye :

$$m = \frac{D}{f}$$

From above formulae, it is clear that for larger magnifying power, the focal length of the convex lens should be small. Also note that angular magnification by optical instruments is the linear magnification by lenses only. It means magnification of an instrument is basically how many times it enlarges the image of object. So this is just as

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

where, h is size of object (in one dimension) and h' is the size of image.

Compound Microscope : For much larger magnification, compound microscope is used. It is a combination of two convex lenses, hence the magnification of each lens is compounded.

These two lenses are placed co-axially and the distance between them is adjustable.

The lens towards the object is called objective and that towards the eye is called eyepiece.

The final image formed by the compound microscope is magnified and inverted.

Total magnification by compound lens

$$m = m_o \times m_e$$

where, m_o is magnification by objective lens and m_e is magnification by eyepiece.

For least distance of distinct vision magnification by object lens is

$$m_o = \frac{v_o}{u_o} = \frac{L}{f_o}$$

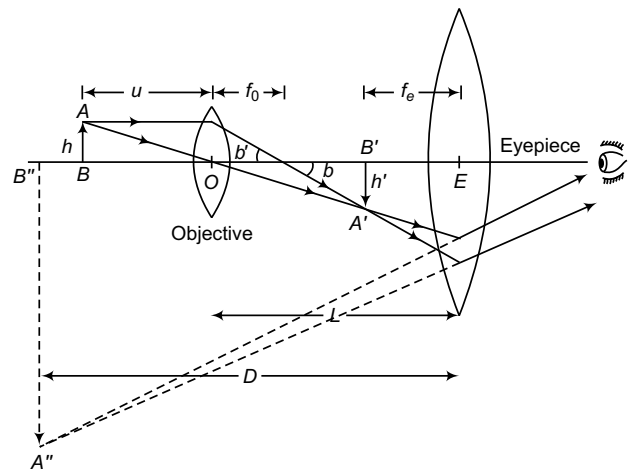
where, L is the distance between the second focal point of the objective and the first focal point of the eyepiece (focal length f_e). It is called the tube length of the compound microscope.

Eyepiece lens acts as a simple microscope.

Magnification by eyepiece lens is

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

Hence, Magnification by compound lens = $\frac{L}{f_o} \left(1 + \frac{D}{f_e} \right)$



►► For relaxed eye (normal adjustment)

For relaxed eye the magnification by objective lens

remains same, the magnification by eyepiece is $1 + \frac{D}{f_e}$.

Hence, the total magnification of compound microscope in relaxed eye condition is

$$m = \frac{L}{f_o} \times \frac{D}{f_e}$$

►► Properties of Compound Microscope :

For large magnification of a compound microscope, both f_o and f_e should be small.

If the length of the microscope tube increases, then its magnifying power increases.

Generally f_o is much smaller. So that objective is placed very near to principle focus.

The aperture of the eyepiece is generally small, so that whole of the light may enter the eye.

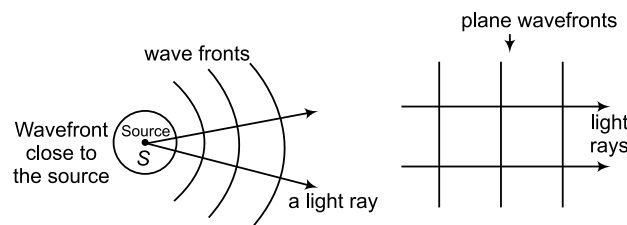
The aperture of the objective is also small so that the field of view may be restricted.

Topic 2 Wave Optics

Revision Notes

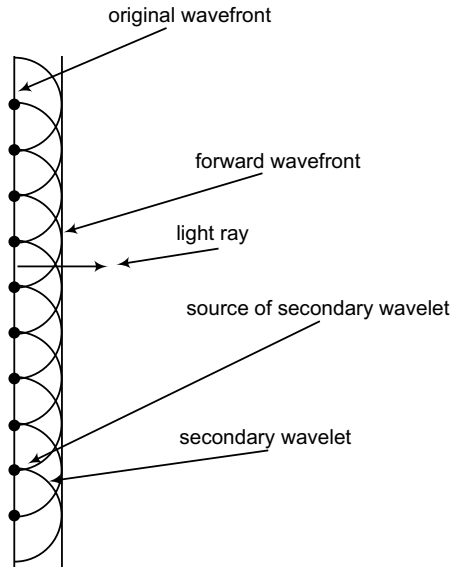
►► Wavefront

Wavefront is an imaginary surface where an optical wave has constant phase with its surface having maximum or minimum value.

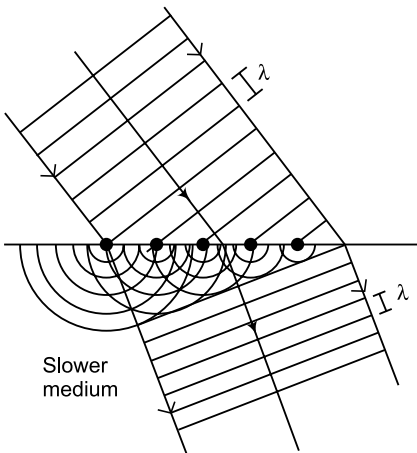


If similar waves with common origin travel through a homogeneous medium, the corresponding crests and troughs at that instant are in phase with similar fractions of cyclic motion.

The direction of propagation of wave is always be perpendicular to surface of wavefront at every point, so wavefront of a point source is a sphere and wave propagates radially outward where radius of a sphere is perpendicular to its circumference at every point.



► Huygen's principle



The principle shows that, every point on wavefront acts as a point source which emits spherical wavelets that travels with velocity of light in a medium.

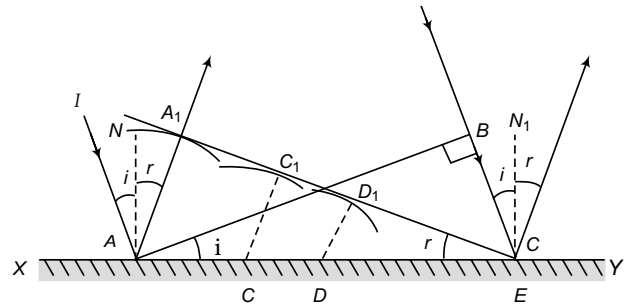
In this, each point on wavefront be considered as a source of secondary spherical wavelets that spread out in forward direction at speed of light.

The new wavefront is tangential to all the surface of secondary wavelets and a plane light wave propagates through free space at the speed of light, c .

The light rays get associated with wavefront which propagates in straight lines, so it is easy to visualize refraction where a point on wavefront at boundary of different media serves as source of light that propagates with change in direction.

In this, speed of light is smaller in second medium and waves do not travel as far in given time as new wavefront changes direction showing why a ray changes direction to become closer to perpendicular when it slows down.

► **Proof of laws of reflection using Huygen's principle :** Reflection is sudden change in direction of propagation of wave that strikes the boundary between two different media.



If light is incident on a surface, it gets re-emitted without any change in frequency known as Reflection of Light.

If incoming rays are incident on a surface where wavefront are plane waves with infinite parallel planes to each other with fixed amplitude, the wave AB falls on reflecting surface and is incident on wavefront perpendicular to incident ray at an angle i on the surface.

The Huygen's principle shows that each point on wave AB acts as source of secondary wavelets where A and B are new sources that emit secondary waves where velocity of propagation of waves is ' v ' and time taken is ' t '.

If ' vt ' is distance travelled by secondary wavelets, then AA_1 and BE are secondary waves.

As new wavefront needs to be a tangents line that joins two secondary waves, so reflected waves act perpendicular to new wavefront.

A_1E is new tangential line which connects the secondary wavelets, so in $\triangle ABE$ and $\triangle AA_1E$, AE is common, $\angle B = \angle A_1 = 90^\circ$.

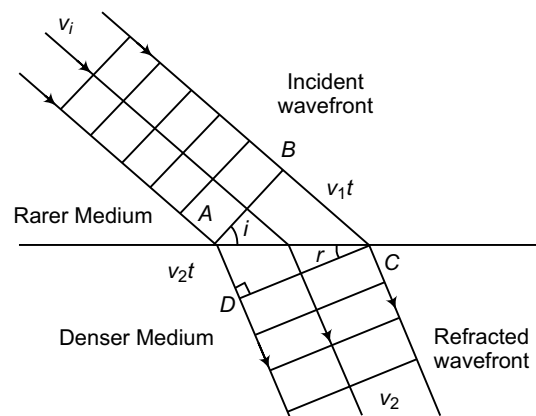
$AA_1 = BE$, so triangles are congruent triangles, hence $\angle i = \angle r$

► **Laws :**

First Law: Angle of Incidence = Angle of Reflection

Second law: The incident wavefront, reflected wavefront and normal lie in same plane perpendicular to reflecting surface.

► **Proof of laws of refraction using Huygen's principle :** Refraction is the change in velocity of light if it passes from one medium to another.



If a plane wavefront AB is incident on surface where v_1 and v_2 being velocities of incident ray and refracted ray of medium 1 and medium 2 ($v_1 > v_2$), velocity of waves depends on the medium.

The Huygen's principle shows that, A and C forms the source of secondary spherical wavelets, where t is time

taken from B to reach C, so $BC = v_1t$ in medium 1 and $AD = v_2t$ in medium 2.

If CD is tangent drawn from point C to sphere, then AD and CD will act as refracted wavefronts, so ΔABC and ΔADC gives $\sin i / \sin r = (BC/AC) / (AD/AC) = BC/AD = v_1t/v_2t = v_1/v_2 = \mu$, refractive index of the medium.

Refractive Index is ratio of velocity of light in vacuum to velocity of light in other medium.

Snell's Law of refraction, $\sin i / \sin r = v_1/v_2 = n$ (constant) is proved using Huygens's principle where incident wavefront, the refracted wavefront and the normal lie in the same plane.

► **Interference : (Young's double slit experiment)**

Thomas Young's experiment strongly inferred wave-like nature of light where light was made of waves and where certain type of interaction takes place if two light waves met together.

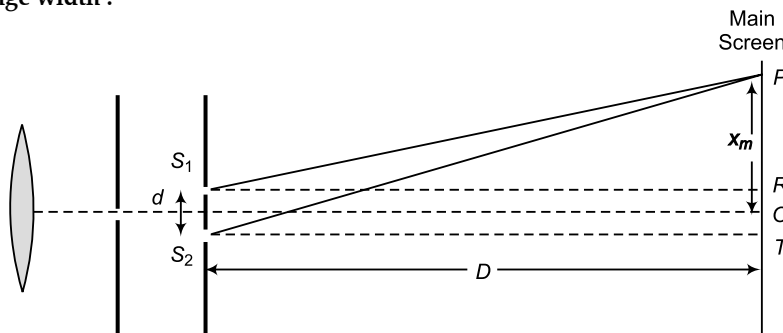
In this, light source is kept at certain distance behind the slit screen A that possesses pair of closely spaced narrow slits and light emerges from pinholes and spreads as spherical waves which overlaps resulting in interference pattern, projected on measurement screen B.

The simulation of pattern of light was observed on screen B where bright lines of light from two slits form constructive interferences along with dark lines giving destructive interferences.



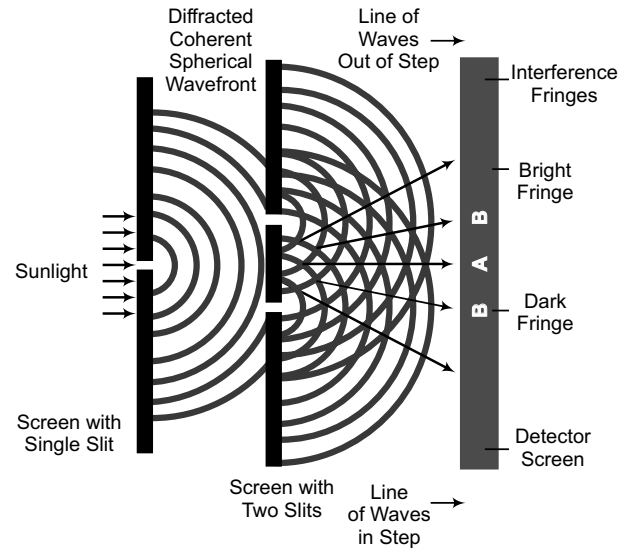
With sunlight diffracted through small slit as source of coherent illumination, Young's projected light rays from slit to other screen with two slits placed side by side.

► **Expression for fringe width :**



If two slits S_1 and S_2 separated by distance 'd' illuminated by monochromatic light of wavelength λ , where main screen is at a distance of D from the slits S_1, S_2 then waves from two slits superimpose on each other forming interference pattern on the screen and point O is equidistant from S_1 and S_2 , forming path difference between waves at O. So point O is of maximum intensity, central maximum while other point P at distance 'x' from O, path difference at $P = S_2P - S_1P$, or $S_1S_2 = RT = d$ or $S_1R = S_2T = D = xd/D$. In bright fringes, path difference is integral multiple of wavelength i.e., $n\lambda = xd/D$ or $x = n\lambda D/d$ where x is

If slits were large, then two overlapping patches of light appears on the screen and if size of slits are reduced and kept closer to slits, then light passes through the slits and screen shows distinct bands of light separated by dark regions in serial order.



The coherent wavefront of light that impinges on the twin slits undergoes division into two new wavefronts, each having distinct phases. Light waves emanating from each slit travel equal distances to reach point A on the screen. This satisfies the fundamental conditions for constructive interference, where the waves add together coherently, resulting in the formation of a bright interference fringe on the screen.

The wave coming from slit close to point B not far to travel to reach its destination, as compared to wave travelling from other slit and the wave from closer slit arrives at point B before wave from far slit.

The waves do not arrive at point B in phase and undergo destructive interference to produce a dark region.

distance of n^{th} bright fringe from point O where $x_1 = \lambda D/d$, distance of 1^{st} bright fringe, $x_n = n\lambda D/d$ as distance of n^{th} bright fringe from point. So separation between centers of two consecutive bright fringe is width of dark fringe, $\lambda_1 = x_n - x_{n-1} = \lambda D/d$ as dark fringes, $x_n = (2n - 1)\lambda D/2d$. The separation between centers of two consecutive dark interference fringes is the width of bright fringe, $\beta_2 = x_n - x_{n-1} = \lambda D/d$ while separation between the centers of two consecutive dark interference fringes shows width of a bright fringe where all bright and dark fringes result equal in width as $b_1 = b_2$.

Fringe width is the distance between two successive bright fringes or two successive dark fringes.

In interference pattern, the fringe width is constant for all fringes where all bright and dark fringes are equally spaced.

Fringe width is independent of order of fringe and is directly proportional to wavelength of the light used.

► Coherent sources

Coherent sources are those sources of light that give continuous light waves of similar wavelength and frequency and are in same phase or have a constant phase difference.

For light waves emitted by two sources of light to be coherent, the initial phase difference between the waves should be constant in time.

If phase difference changes continuously with time, then the sources are incoherent.

Two independent sources of light are not coherent and hence cannot produce interference as light beam is emitted by millions of atoms those radiate independently so that phase difference between waves fluctuates randomly many times per second.

Two coherent sources can be created either by utilizing a physical source and obtaining its virtual image or by generating two virtual images of the same source. Any change in phase occurring in the real source results in a simultaneous and equal change in the virtual images.

► Sustained interference of light

Interference is the phenomenon of redistribution of light energy in a medium on account of superposition of light waves from two coherent sources.

At the points, where resultant intensity of light is maximum, interference is constructive while at point where resultant intensity of light is minimum, interference is destructive.

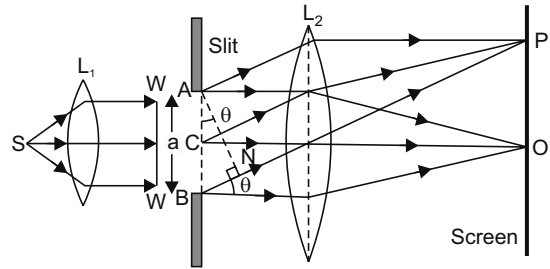
Interference pattern where positions of maximum and minimum intensity of light remain fixed with time is sustained or permanent interference pattern.

Sustained and observable interference pattern should have following conditions:

- The two sources should be coherent *i.e.*, the sources should emit light of similar frequency with constant phase difference.
- Two sources should be very narrow.
- The sources should lie very close to each other to form distinct and broad fringes.
- The interfering waves should have equal amplitude for making minimum intensity to be zero for general illumination.
- Two interfering waves must propagate along same line for making vibrations to be on common line.
- The separation between two sources must be very small for making satisfying fringes of maximum and minimum intensity to lie close together for clear visibility.

► Diffraction due to a single slit

As shown a source S of monochromatic light is placed at the focus of a convex lens L_1 . A parallel beam of light and hence a plane wavefront WW gets incident on a narrow rectangular slit AB of width a .



Central maximum: All the secondary wavelets going straight across the slit AB are focussed at the central point O of the screen. The wavelets from any two corresponding points of the two halves of the slit reach the point O in the same phase, they add constructively to produce a central bright fringe.

Suppose the secondary wavelets diffracted at an angle θ are focussed at point P . Then the path difference between the wavelets from A and B will be

$$p = BP - AP = BN = AB \sin \theta = a \sin \theta.$$

► Positions of minima

The condition for n th dark fringe can be written as

$$a \sin \theta_n = n\lambda, n = 1, 2, 3, \dots$$

The directions of various minima are given by

$$\theta_n = \sin \theta_n = n \frac{\lambda}{a}$$

[As $\lambda \ll a$, so $\sin \theta_n \approx \theta_n$]

► Positions of secondary maxima

The condition for n th secondary maximum can be written as

$$a \sin \theta'_n = (2n + 1) \frac{\lambda}{2}, n = 1, 2, 3, \dots$$

The directions of secondary maxima are given by

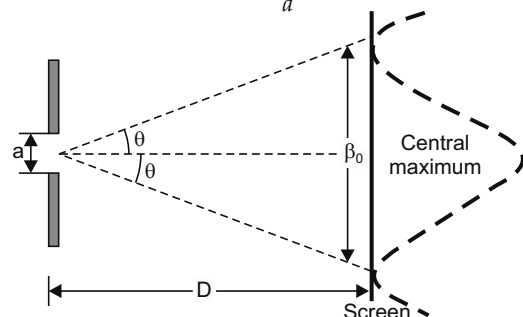
$$\theta'_n = \sin \theta'_n = (2n + 1) \frac{\lambda}{2a}$$

► Angular width of central maximum

$$\text{Angular width} = 2\theta = \frac{2\lambda}{a}$$

► Linear width of central maximum

$$\text{Linear width } \beta_0 = D \times 2\theta = \frac{2D\lambda}{a}$$



► Linear width of a secondary maximum

Angular width of n th secondary maximum

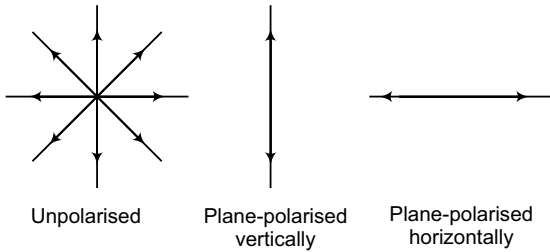
$$= \theta_{n+1} - \theta_n = (n + 1) \frac{\lambda}{a} - n \frac{\lambda}{a} = \frac{\lambda}{a}$$

Hence, the linear width of n th secondary maximum =

$$\text{Angular width} \times D \text{ Or } \beta = \frac{\lambda D}{a}.$$

► Polarisation

Polarisation is a phenomenon in which the vibrations are made to occur in one plane only.



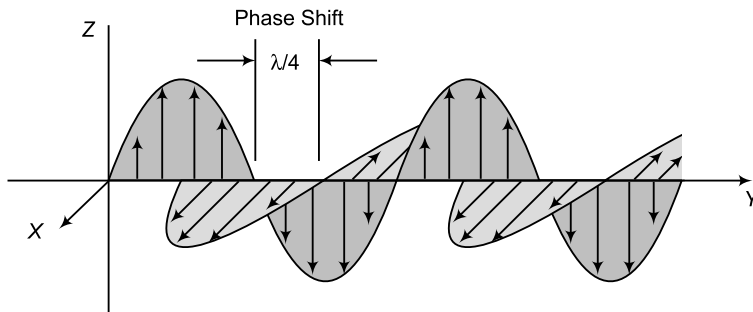
It is measured with polarimeter.

Transverse waves traveling perpendicular to their direction of oscillation can be polarised when their oscillation aligns with a specific plane perpendicular to the wave's direction of propagation.

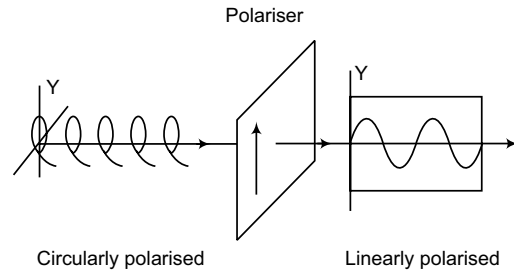
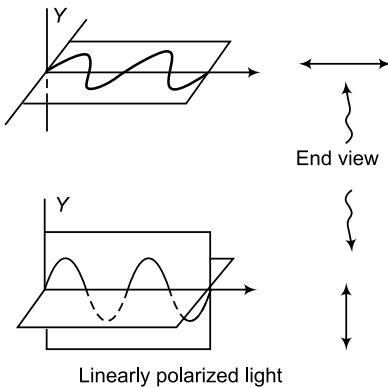
Longitudinal waves, such as sound waves, do not get polarised because their particles oscillate parallel to the direction of propagation, lacking a specific plane for polarization.

Light polarisation can manifest in various forms, including plane-polarised light, circularly polarised light, and elliptically polarised light.

Unpolarised light can be converted into single polarised beam using Nicol prism, a device that separates incident light into two rays by double refraction where unwanted ray is removed from the beam by reflection.



Vertically polarised light is that where there is no amplitude in x ($E_{0x} = 0$), but there is one component in y (vertical) direction.



The polarising material has long particles, rods or plates, aligned parallel to each other which transmits one plane of polarised light and absorbs the perpendicular light.

The polariser can transform circularly polarised light into linearly polarised light.

The direction of polarisation of X-ray photon can change as a result of scattering/diffraction where change is maximum or no change, as per initial polarisation in plane with pre and post scattered X-rays.

The component of polarisation resolved along new direction is reduced by cosine of scattering angle, so reduction in intensity results by $\cos^2 2\theta$ as intensity is proportional to square of amplitude.

The component of polarisation which is unaffected and remains unchanged, by diffraction process, so reduction factor is 1.

The mixture polarisation occurs with diffractometer as X-ray sources produce unpolarised X-rays, where X-rays polarised is equal in all directions and reduction factor shows mean of cases,

Circular polarisation has phase difference $\phi = 90^\circ$ and E_{0x}

$= E_{0y}$, where $\frac{E_x}{E_{0x}} = \cos \theta$, $\frac{E_y}{E_{0y}} = \sin \theta$ having equation of

$$\text{circle, } \left(\frac{E_x}{E_{0x}}\right)^2 + \left(\frac{E_y}{E_{0y}}\right)^2 = \cos^2 \theta + \sin^2 \theta = 1 .$$

Elliptical polarisation results from a combination of linear polarisation and circular polarisation.

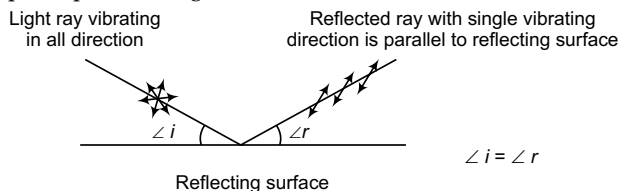
Linear polarisation occurs when light waves lie in a horizontal or vertical plane.

A Polaroid refers to a class of materials that selectively absorb light oscillations in one direction while allowing the passage of light with components oriented at right angles.

Case (1) : Polarisation in plane of scattering,	$P = \cos^2 2\theta$
Case (2) : Polarisation perpendicular to plane of scattering,	$P = 1$
Case (3) : Unpolarised X-rays,	$P = (1 + \cos^2 2\theta)/2$

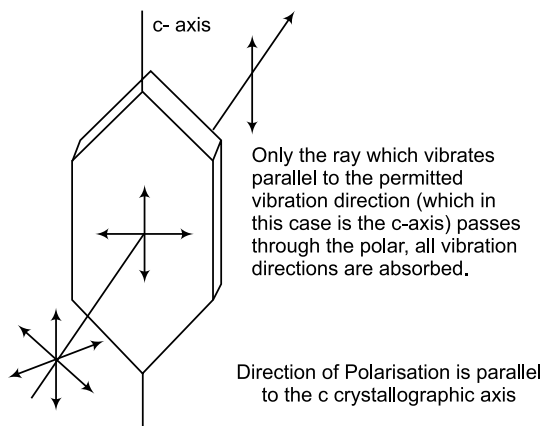
►► Plane Polarised Light

A polarised light which vibrates in single plane, perpendicular to direction of propagation is known as plane polarised light.



In plane-polarised light, the electric vectors of the majority of light waves are aligned parallel to each other. Plane polarised light is produced by reflection, selective absorption, double refraction and scattering.

►► Reflection

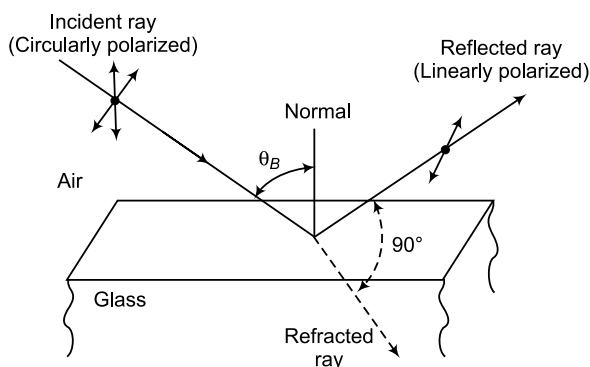


Unpolarised light on striking a smooth surface reflects and is polarised such that its direction of vibration is parallel to the reflecting surface.

The reflected light is completely polarised when angle between reflected and refracted ray is 90° .

►► Brewster's law

Polarized light is produced by transmission through polarizers or by reflection from the surface of transparent material.



Topic 1: Previous Year's Questions

- Assertion (A):** The resolving power of a telescope is more if the diameter of the objective lens is more.
Reason (R): Objective lens of large diameter collects more light.

(a) Both (A) and (R) are true and (R) is the correct explanation of (A).
 (b) Both (A) and (R) are true but (R) is not the correct explanation of (A).

The incident light, wave-oscillation vectors shows polarization of reflected light in plane of reflecting surface, where refracted beam have mixture of two orientations.

If incident light is incident at Brewster angle θ_B , reflected light gets fully polarized and at angles other than Brewster angle, reflected light gets partially polarized.

The Brewster angle is related to index of refraction n of the material by $\tan \theta_B = n(\text{material}) / n(\text{air}) = n(\text{material})$

For glass, $n = 1.5$ and $\theta_B = 56.3^\circ$ and for water, $n = 1.33$ and $\theta_B = 53^\circ$.

►► Uses of plane polarised light and Polaroids

Polarized light is produced by using tourmaline crystal which removes one of the polarized rays by absorption.

Applications of Polarized Light:

Polarized light is used in photo elastic stress analysis.

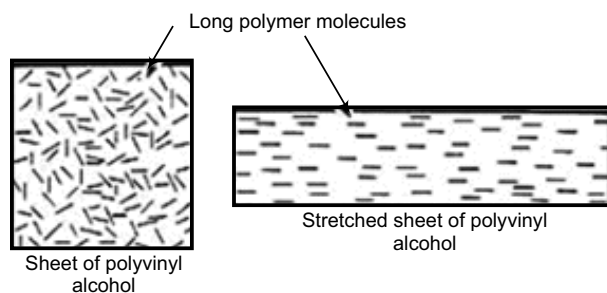
For 3-D view, special type of glasses, which have polaroids with perpendicular axes, are used.

Polarized light is useful to find size and shape of viruses.

Polarized light helps in many practical applications in industry and engineering.

►► Polaroids

Is made by heating and stretching a sheet of PVA laminated to support sheet of cellulose acetate treated with iodine solution.



►► Crystal polarisers

It is an anisotropic crystal, where electrons are bound with different springs as per orientation.

In this, different spring constants show different propagation speeds and different indices of refraction with two output beams.

Crystal polarisers used as beam displacers, beam splitters, polarizers, analysers.

Examples: Nicol prism, Glan-Thompson polariser, Glan or Glan-Foucault prism, Wollaston prism, Thin-film polarizer.

◇◇◇

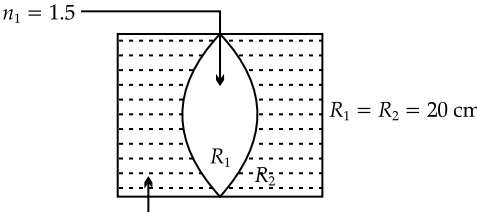
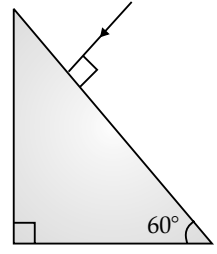
(c) (A) is true but (R) is false.

(d) Both (A) and (R) are false.

- Assertion (A):** Interference pattern is made by using yellow light instead of red light, the fringes become narrower.

Reason (R): In YDSE, fringe width is given by $\beta = \lambda D/d$.

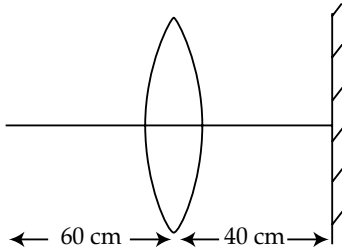
(a) Both (A) and (R) are true and (R) is the correct explanation of (A).

- (b) Both (A) and (R) are true but (R) is not the correct explanation of (A).
 (c) (A) is true but (R) is false.
 (d) Both (A) and (R) are false.
3. **Assertion (A):** All bright interference bands have same intensity.
Reason (R): Because all bands do not receive same light from two sources.
 (a) Both (A) and (R) are true and (R) is the correct explanation of (A).
 (b) Both (A) and (R) are true but (R) is not the correct explanation of (A).
 (c) (A) is true but (R) is false.
 (d) Both (A) and (R) are false.
4. **Statement I:** The formula connecting u , v and f for a spherical mirror is valid only for mirrors whose sizes are very small compared to their radii of curvature.
Statement II: Laws of reflection are strictly valid for plane surfaces, but not for large spherical surfaces.
 (a) Both statement I and statement II are true
 (b) Statement I is true but statement II is false
 (c) Statement I is false but statement II is true
 (d) Both statement I and statement II are false
5. **Statement I:** Sound waves cannot be polarised.
Statement II: Sound waves are longitudinal in nature.
 (a) Both statement I and statement II are true
 (b) Statement I is true but statement II is false
 (c) Statement I is false but statement II is true
 (d) Both statement I and statement II are false
6. Light travels a distance x in time t_1 in air and $10x$ in time t_2 in another denser medium. What is the critical angle for this medium?
 (a) $\sin^{-1}\left(\frac{10t_2}{t_1}\right)$ (b) $\sin^{-1}\left(\frac{t_1}{10t_2}\right)$
 (c) $\sin^{-1}\left(\frac{10t_1}{t_2}\right)$ (d) $\sin^{-1}\left(\frac{t_2}{t_1}\right)$ [NEET 2023]
7. In the figure shown here, what is the equivalent focal length of the combination of lenses (Assume that all layers are thin)?

 (a) -40 cm (b) -100 cm
 (c) -50 cm (d) 40 cm [NEET 2023]
8. Two thin lenses are of same focal lengths (f), but one is convex and the other one is concave. When they are placed in contact with each other, the equivalent focal length of the combination will be
 (a) $\frac{f}{4}$ (b) $\frac{f}{2}$
 (c) Infinite (d) Zero [NEET 2023]
9. During a cloudy day, a primary and a secondary rainbow may be created, then the:
 (a) primary rainbow is due to double internal reflection and is formed above the secondary one.
 (b) primary rainbow is due to double internal reflection and is formed below the secondary one.
 (c) secondary rainbow is due to double internal reflection and is formed above the primary one.
 (d) secondary rainbow is due to single internal reflection and is formed above the primary one. [NEET 2022]
10. An astronomical refracting telescope is being used by an observer to observe planets in normal adjustment. The focal lengths of the objective and eye piece used in the construction of the telescope are 20 m and 2 cm respectively. Consider the following statements about the telescope:
 (a) The distance between the objective and eye piece is 20.02 m
 (b) The magnification of the telescope is (-) 1000
 (c) The image of the planet is erect and diminished
 (d) The aperture of eye piece is smaller than that of objective
 The correct statements are:
 (a) (a), (b) and (c) (b) (b), (c) and (d)
 (c) (c), (d) and (a) (d) (a), (b) and (d) [NEET 2022]
11. A biconvex lens has radii of curvature, 20 cm each. If the refractive index of the material of the lens is 1.5, the power of the lens is :
 (a) +2 D (b) +20 D
 (c) +5 D (d) infinity [NEET 2022]
12. A light ray falls on a glass surface of refractive index $\sqrt{3}$, at an angle 60° . The angle between the refracted and reflected rays would be :
 (a) 30° (b) 60°
 (c) 90° (d) 120° [NEET 2022]
13. The transparent media A and B are separated by a plane boundary. The speed of light in those media are 1.5×10^8 m/s and 2.0×10^8 m/s, respectively. The critical angle for a ray of light for these two media is :
 (a) $\sin^{-1}(0.500)$ (b) $\sin^{-1}(0.750)$
 (c) $\tan^{-1}(0.500)$ (d) $\tan^{-1}(0.750)$ [NEET 2022]
14. A lens of large focal length and large aperture is best suited as an objective of an astronomical telescope since
 (a) a large aperture contributes to the quality and visibility of the images.
 (b) a large area of the objective ensures better light gathering power.
 (c) a large aperture provides a better resolution.
 (d) all of the above [NEET 2021]
15. Find the value of the angle of emergence from the prism. Refractive index of the glass is $\sqrt{3}$

 (a) 90° (b) 60°
 (c) 30° (d) 45° [NEET 2021]

16. A convex lens 'A' of focal length 20 cm and a concave lens 'B' of focal length 5 cm are kept along the same axis with a distance 'd' between them. If a parallel beam of light falling on 'A' leaves 'B' as a parallel beam, then the distance 'd' in cm will be:

- (a) 30 (b) 25
(c) 15 (d) 50 [NEET 2021]

17. A point object is placed at a distance of 60 cm from a convex lens of focal length 30 cm. If a plane mirror were put perpendicular to the principal axis of the lens and at a distance of 40 cm from it, the final image would be formed at a distance of:



- (a) 20 cm from the plane mirror, it would be a virtual image
(b) 20 cm from the lens, it would be a real image
(c) 30 cm from the lens, it would be a real image
(d) 30 cm from the plane mirror, it would be a virtual image [NEET 2021]

18. A ray is incident at an angle of incidence i on one surface of a small angle prism (with angle of prism A) and emerges normally from the opposite surface. If the refractive index of the material of the prism is μ , then the angle of incidence is nearly equal to:

- (a) $\frac{2A}{\mu}$ (b) μA
(c) $\frac{\mu A}{2}$ (d) $\frac{A}{2\mu}$ [NEET 2020 Phase I]

19. In Young's double slit experiment, if the separation between coherent sources is halved and the distance of the screen from the coherent sources is doubled, then the fringe width becomes:

- (a) half. (b) four times.
(c) one-fourth. (d) double.

[NEET 2020 Phase I]

20. The Brewsters angle i_b for an interface should be:

- (a) $30^\circ < i_b < 45^\circ$ (b) $45^\circ < i_b < 90^\circ$
(c) $i_b = 90^\circ$ (d) $0^\circ < i_b < 30^\circ$

[NEET 2020 Phase I]

21. Two coherent sources of light interfere and produce fringe pattern on a screen. For central maximum, the phase difference between the two waves will be:

- (a) zero (b) π
(c) $3\pi/2$ (d) $\pi/2$

[NEET 2020 Phase II]

22. An object is placed on the principal axis of a concave mirror at a distance of $1.5f$ (f is the focal length). The image will be at,

- (a) $-3f$ (b) $1.5f$
(c) $-1.5f$ (d) $3f$

[NEET 2020 Phase II]

23. If the critical angle for total internal reflection from a medium to vacuum is 45° , then velocity of light in the medium is,

- (a) 1.5×10^8 m/s (b) $\frac{3}{\sqrt{2}} \times 10^8$ m/s
(c) $\sqrt{2} \times 10^8$ m/s (d) 3×10^8 m/s

[NEET 2020 Phase II]

24. The power of a biconvex lens is 10 dioptre and the radius of curvature of each surface is 10 cm. Then the refractive index of the material of the lens is,

- (a) $\frac{4}{3}$ (b) $\frac{9}{8}$
(c) $\frac{5}{3}$ (d) $\frac{3}{2}$ [NEET 2020 Phase II]

25. Which colour of the light has the longest wavelength?

- (a) blue (b) green
(c) violet (d) red [NEET 2019]

26. 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 glycerin (which has the same refractive index ($\mu = 1.5$) as that of glass) then the equivalent focal length is F_2 . The ratio $F_1 : F_2$ will be:

- (a) 1 : 2 (b) 2 : 3
(c) 3 : 4 (d) 2 : 1 [NEET 2019]

27. 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?

- (a) 0°
(b) equal to angle of incidence
(c) 90°
(d) 180°

[NEET 2019]

28. Pick the wrong answer in the context with rainbow.

- (a) An observer can see a rainbow when his front is towards the sun.
(b) Rainbow is a combined effect of dispersion refraction and reflection of sunlight.
(c) When the light rays undergo two internal reflections in a water drop, a secondary rainbow is formed.
(c) The order of colours is reversed in the secondary rainbow. [NEET 2019]

29. An astronomical refracting telescope will have large angular magnification and high angular resolution, when it has an objective lens of

- (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

[NEET 2018]

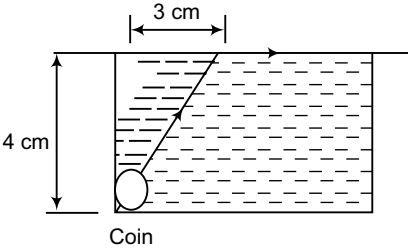
30. A thin prism having refracting angle 10° is made of glass of refractive index 1.42. This prism is combined with another thin prism of glass of refractive index 1.7. This combination produces dispersion without deviation. The refracting angle of second prism should be :

- (a) 6° (b) 8°
(c) 10° (d) 4° [NEET 2017]

31. 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 :

- (a) $f/3$ (b) f
(c) $4f/3$ (d) $3f/4$ [NEET 2016]

32. 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:

- (a) 8 (b) 10
(c) 12 (d) 16 [NEET 2016]
33. If the focal length of objective lens is increased then magnifying power of :
(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 [AIPMT 2014]
34. 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 is :
(a) $2R/(\mu_2 - \mu_1)$ (b) $R/2(\mu_1 + \mu_2)$
(c) $R/2(\mu_1 - \mu_2)$ (d) $R/(\mu_1 - \mu_2)$ [AIPMT 2013]
35. 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 :
(a) lies between 2 and $\sqrt{2}$
(b) is less than 1
(c) is greater than 2
(d) lies between $\sqrt{2}$ and 1 [AIPMT 2012]
36. A rod of length 10 cm lies along the principal axis of concave mirror of focal length 10 cm in such a way that its end closer to the pole is 20 cm away from the mirror. The length of the image is
(a) 15 cm (b) 2.5 cm
(c) 5 cm (d) 10 cm [AIPMT 2012]
37. 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 :
(a) 7° (b) 10°
(c) 12° (d) 5° [AIPMT 2011]
38. A converging beam of rays is incident on a diverging lens. Having passed through the lens the rays intersect at a point 15 cm from the lens on the opposite side. If the lens is removed the point where the rays meet will move 5 cm closer to the lens. The focal length of the lens is:
(a) -10 cm (b) 20 cm
(c) -30 cm (d) 5 cm [AIPMT 2011]
39. 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?
(a) $\mu = 1.33$ (b) $\mu = 1.40$
(c) $\mu = 1.50$ (d) $\mu = 1.25$ [AIPMT 2010]
40. A small coin is resting on the bottom of a beaker filled with a 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 ?
- 
- (a) 1.2×10^8 m/s (b) 1.8×10^8 m/s
(c) 2.4×10^8 m/s (d) 3.0×10^8 m/s [AIPMT 2007]
41. A transparent cube of 15 cm edge contains a small air bubble. Its apparent depth when viewed through one face is 6 cm and when viewed through the opposite face is 4 cm. Then the refractive index of the material of the cube is :
(a) 2.0 (b) 2.5
(c) 1.6 (d) 1.5 [CPMT 2004]
42. 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 [CBSE PMT 1996]
43. The refractive index of a certain glass is 1.5 for light whose wavelength in vacuum is 6000 \AA . The wavelength of this light when it passes through glass is :
(a) 4000 \AA (b) 6000 \AA
(c) 9000 \AA (d) 15000 \AA [CBSE PMT 1993]
44. Electromagnetic radiation of frequency n , wavelength λ , travelling with velocity v in air, enters a glass slab of refractive index μ . The frequency, wavelength and velocity of light in the glass slab will be respectively
(a) $n/\mu, \lambda/\mu, v/\mu$ (b) $n, \lambda/\mu, v/\mu$
(c) $n, \lambda, v/\mu$ (d) $n/\mu, \lambda/\mu, v$ [CBSE PMT 1997]
45. When light is refracted from air into glass :
(a) Its wavelength and frequency both increase
(b) Its wavelength increases but frequency remains unchanged
(c) Its wavelength decreases but frequency remains unchanged
(d) Its wavelength and frequency both decrease [CBSE PMT 1992]
46. If ${}_i\mu_j$ represents refractive index when a light ray goes from medium i to medium j , then the product ${}_2\mu_1 \times {}_3\mu_2 \times {}_4\mu_3$ is equal to :
(a) ${}_3\mu_1$ (b) ${}_3\mu_2$
(c) $1/{}_1\mu_4$ (d) ${}_4\mu_2$ [CBSE PMT 1990]

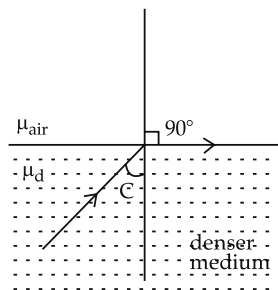
Answer Key

1.	(a)	2.	(a)	3.	(c)	4.	(b)	5.	(a)	6.	(c)
7.	(b)	8.	(c)	9.	(c)	10.	(d)	11.	(c)	12.	(c)
13.	(b)	14.	(d)	15.	(b)	16.	(c)	17.	(a)	18.	(b)
19.	(b)	20.	(b)	21.	(a)	22.	(a)	23.	(b)	24.	(d)
25.	(d)	26.	(a)	27.	(c)	28.	(a)	29.	(a)	30.	(a)

31.	(d)	32.	(c)	33.	(d)	34.	(d)	35.	(a)	36.	(c)
37.	(b)	38.	(c)	39.	(c)	40.	(b)	41.	(d)	42.	(c)
43.	(a)	44.	(b)	45.	(c)	46.	(c)				

Answers with Explanation

1. (b) Resolving Power of a telescope = $\frac{D}{d} = \frac{a}{1.22\lambda}$
 where, d = diameter of the objective lens, λ = wavelength).
 Hence, the objective lens of a large diameter collects more light but does not increase the resolving power of the telescope because resolving power increases when angular separation increases.
2. (a) Both Assertion and Reason are correct and Reason is the correct explanation for Assertion. Fringe width (β) is directly proportional to wavelength (λ), the wavelength of yellow light is less than that of the red light. So, for yellow light the fringe will be narrower.
3. (c) Assertion is true, but the reason is false. Bright bands have same intensity, because $I_{(\max)}$ is proportional to $(a + b)^2$, which is constant, where a and b are amplitudes of two waves.
4. (b) While deriving mirror formula for a spherical surface, we consider only paraxial rays as a spherical surface is perfectly focusing mirror only in such cases. Hence, we need to take the aperture of the mirror to be very small. Which implies that the size of the mirror should be very small as compared to their radii of curvature.
 So, statement I is correct, Laws of reflection can be applied to any type of surface. So, statement II is false.
5. (a) Sound waves are longitudinal waves, meaning the particles in the medium oscillate parallel to the direction of wave propagation. Since, polarization involves restricting the vibration of waves to a specific orientation, it is not applicable to sound waves because their oscillation is inherently parallel to the direction of propagation
6. (c)



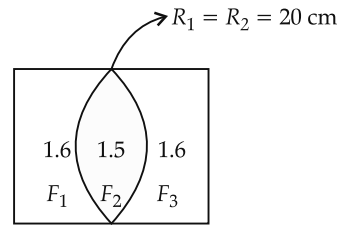
$$\mu_d \sin C = \mu_{\text{air}} \sin 90^\circ$$

$$\frac{e}{v_d} \sin C = \frac{C}{v_{\text{air}}} \quad \left[\because \mu_{\text{medium}} = \frac{C}{v_{\text{medium}}} \right]$$

$$\sin C = \frac{v_d}{v_{\text{air}}} = \frac{\frac{10x}{t_2}}{\frac{x}{t_1}} = \frac{10t_1}{t_2}$$

$$C = \sin^{-1} \left(\frac{10t_1}{t_2} \right)$$

7. (b)



$$\frac{1}{f_1} = (1.6 - 1) \left(\frac{1}{\infty} - \frac{1}{20} \right) = \frac{1}{f_3}$$

$$\Rightarrow \frac{1}{f_1} = \frac{1}{f_3} = \frac{-0.3}{10}$$

$$\frac{1}{f_2} = (1.5 - 1) \left[\frac{1}{20} + \frac{1}{20} \right]$$

$$= \frac{0.5}{10}$$

For combination of lens.

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

$$= \frac{-0.3}{10} + \frac{-0.3}{10} + \frac{0.5}{10}$$

$$= \frac{-1}{100}$$

$$\Rightarrow F = -100 \text{ cm.}$$

8. (c) $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$

$$= \frac{1}{f} - \frac{1}{f} = 0$$

$$\Rightarrow F = \infty$$

9. (c) Secondary rainbow is formed due to double internal reflection and is formed above the primary rainbow. The secondary rainbow is brighter than the primary rainbow.

10. (d) Given,

$$f_e = 2 \text{ cm, and}$$

$$f_o = 20 \text{ m} = 2000 \text{ cm}$$

For normal adjustment,

$$\text{Magnification power} = \frac{-f_o}{f_e} = \frac{-2000}{2}$$

$$= -1000$$

$$\text{Length of telescope} = f_o + f_e$$

$$= 2000 + 2$$

$$= 2002 \text{ cm}$$

$$= 20.02 \text{ m}$$

The image formed is inverted and magnified, and the aperture of objective is larger than eye piece of the telescope.

(f_o & f_e are focal lengths of objective & eye piece respectively.)

11. (c) Given: $R_1 = R_2 = 20 \text{ cm} = 0.2 \text{ m}$, $\mu = 1.5$

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

$$P = (1.5 - 1) \left\{ \frac{1}{0.2} - \left(\frac{1}{-0.2} \right) \right\}$$

$$\left[\begin{array}{l} \text{for biconvex lens,} \\ R_1 = +ve \\ R_2 = -ve \end{array} \right]$$

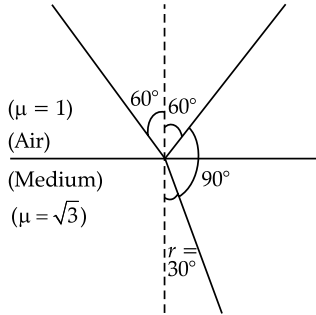
$$P = 0.5 \left(\frac{1}{0.2} + \frac{1}{0.2} \right)$$

$$P = 0.5 \times \frac{2}{0.2} = 5D$$

12. (c) Given:

$$\mu = \sqrt{3}$$

$$i = 60^\circ$$



By using Snell's law, we have;

$$\mu_1 \sin i = \mu_2 \sin r$$

$$1 \times \sin 60^\circ = \sqrt{3} \sin r$$

$$\sin r = \frac{\sqrt{3}/2}{\sqrt{3}} = \frac{1}{2}$$

$$r = 30^\circ$$

Hence, angle between reflected and refracted ray
 $= 60^\circ + 30^\circ = 90^\circ$

13. (b) As, $\mu = \frac{c}{v}$

Hence, $\mu \propto \frac{1}{v}$

Now, Critical angle,

$$\begin{aligned} \sin i_c &= \frac{\mu_2}{\mu_1} = \frac{v_1}{v_2} \\ &= \frac{1.5 \times 10^8}{2 \times 10^8} = \frac{3}{4} \end{aligned}$$

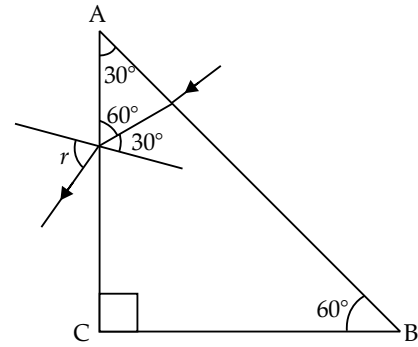
$$i_c = \sin^{-1} \left(\frac{3}{4} \right)$$

$$i_c = \sin^{-1} (0.750)$$

14. (d) In the astronomical telescope, the focal length of the objective lens and aperture is quite large. Due to which the light gathering power of telescope used to increase, and the resolving power or the ability to observe two object distinctly gets increase.

By using larger diameters, the fainter objects can be observed so, the larger focal length of the objective lens contributes in the better quality and visibility of images.

15. (b) Since, when any ray of light incident normally on any surface, then it will not face any deviation.



So, angle of incident on the surface AC (i) = 30°

Now, applying Snell's law,

$$\text{Refractive index } (\mu) = \frac{\sin i}{\sin r}$$

$$\Rightarrow \frac{\sin 30^\circ}{\sin r} = \sqrt{3}$$

$$\Rightarrow \sin r = \frac{1}{\sqrt{3}}$$

$$\Rightarrow \sin r = \frac{\sqrt{3}}{2} = \sin(60^\circ)$$

$$r = 60^\circ$$

Hence, the angle of emergence is 60°

16. (c) Given,

Focal length of the convex lens A,

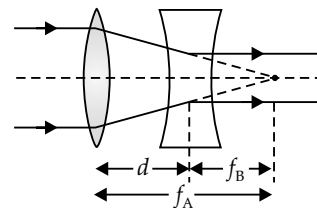
$$f_A = 20 \text{ cm}$$

Focal length of concave lens B is

$$f_B = 5 \text{ cm}$$

Distance between the lens = d

The emergent ray is parallel to X-axis.



When any parallel beam of light incident on convex lens, then it will meet at focal point.

If a beam of light gets parallel to principal axis after the refraction, then it means that object is at focal point of the concave lens.

Hence,

$$\begin{aligned} d &= f_A - f_B \\ &= 20 \text{ cm} - 5 \text{ cm} \\ &= 15 \text{ cm} \end{aligned}$$

Hence, the required distance between the lens is 15 cm.

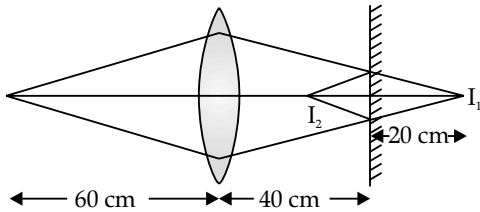
17. (a) Given,

Distance between object and convex lens

$$u = -60 \text{ cm}$$

Focal length of convex lens (f) = 30 cm

Distance between plane mirror and convex lens (d) = 40 cm



Applying lens law

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

$$\Rightarrow \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{30} + \frac{1}{(-60)}$$

$$\Rightarrow \frac{1}{v_1} = \frac{1}{60}$$

$$\Rightarrow v = 60 \text{ cm}$$

I_1 , will work as a object for plane mirror which will produce image at 20 cm in front of it.

Now, again this image will work as a object.

So, $u_1 = -20 \text{ cm}$

$$\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f}$$

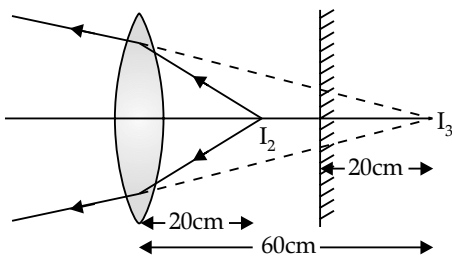
$$\Rightarrow \frac{1}{v_1} = \frac{1}{f} + \frac{1}{u_1}$$

$$\Rightarrow \frac{1}{v_1} = \frac{1}{30} + \frac{1}{(-20)} = \frac{2-3}{60}$$

$$\Rightarrow \frac{1}{v_1} = -\frac{1}{60}$$

$$v_1 = -60 \text{ cm}$$

Now, again I_2 will work as object



Hence, final virtual image will be formed at 60 cm from lens or we can say 20 cm behind mirror.

18. (b) Since the light emerges normally from the other surface, the angle of emergence

$$e = 0$$

For the triangular prism, we know

$$r_1 + r_2 = A$$

But, $e = r_2 = 0$

So, $r_1 = A$

For surface 1,

From Snell's law is $\sin i = \mu \sin r_1$

$$\sin i = \mu \sin A$$

For small angles $\sin \theta \approx \theta$

So, $i = \mu A$

19. (b) Given that the slit distance is made half and the screen distance made double than the original value, then,

$$\text{Frings width, } \beta = \frac{\lambda D}{d}$$

$$\text{Now, } d' = \frac{d}{2} \text{ and } D' = 2D$$

$$\text{So, } \beta' = \frac{\lambda(2D)}{d/2} = \frac{4\lambda D}{d}$$

$$\Rightarrow \beta' = 4\beta$$

20. (b) Refractive index μ is equal to tangent of Brewster's angle i_b

$$\mu = \tan i_b$$

$$1 < \mu < \infty$$

$$1 < \tan i_b < \infty$$

$$\tan^{-1}(1) < i_b < \tan^{-1}(\infty)$$

$$45^\circ < i_b < 90^\circ$$

21. (a) In YDSE,

$$\text{Path difference, } \Delta x = d \sin \theta \quad \dots(i)$$

$$\text{and phase difference, } \Delta \phi = \frac{2\pi}{\lambda} \Delta x \quad \dots(ii)$$

For central maxima $\theta = 0$

using equation (i) and (ii)

$$\Delta \phi = 0$$

22. (a) Applying mirror's formula

$$\frac{1}{V} + \frac{1}{(-1.5f)} = \frac{1}{(-f)}$$

$$\Rightarrow \frac{1}{V} = -\frac{1}{3f}$$

$$\Rightarrow V = -3f$$

23. (b) Relation between critical angle (C) and refractive index (μ) is

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

$$\Rightarrow \mu = \frac{1}{\sin 45^\circ} = \sqrt{2}$$

$$\text{Now, } \mu = \frac{c}{v}$$

$$\Rightarrow v = \frac{c}{\sqrt{2}} = \frac{3}{\sqrt{2}} \times 10^8 \text{ m/s}$$

24. (d) Power = $\frac{1}{f}$

$$\therefore f = 0.1 \text{ m} = 10 \text{ cm}$$

Now, by len's makers formula

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

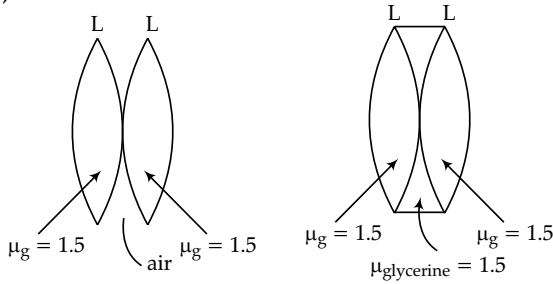
$$\frac{1}{10} = (\mu - 1) \left(\frac{1}{(+10)} - \frac{1}{(-10)} \right)$$

$$\Rightarrow \mu = \frac{3}{2}$$

25. (d) Since, Red colour has least frequency. So, red has the longest wavelength among the given colour.

$$\text{As, } v = \nu \lambda$$

26. (a)



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 $(-f)$

$$\frac{1}{F_2} = \frac{1}{f} + \frac{1}{f} - \frac{1}{f} = \frac{1}{f}$$

Now, $\frac{F_1}{F_2} = \frac{1}{2}$

27. (c) Let i_c be the critical angle,

Hence, at $i = i_c$, refracted ray grazes with the surface. So, angle of refraction is 90° .

28. (a) When observer faces in front of Sun, he will not observe rainbow.

29. (a) In telescope, angular magnification f_o/f_e , which shows that focal length of objective lens to be large. Angular resolution = $D/1.22\lambda$ which is large, hence objective should have large focal length and larger diameter.

30. (a) Now, $(\mu - 1)A + (\mu' - 1)A' = 0$

Condition for dispersion without deviation,

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

$$(1.42 - 1) \times 10^\circ = (1.7 - 1)A'$$

$$4.2 = 0.7A' \text{ or } A' = 6^\circ$$

31. (d) Now $1/f = (\mu_g - 1) \times 2/R = 1/R$, $(\mu_g = 3/2)$, $R = f$

$$1/f_1 = -(\mu_w - 1) \times 2/R = -2/3R = -2/3f$$

$$1/f_{eq} = 1/f + 1/f + 1/f_1 = 1/R + 1/R - 2/3R$$

$$1/f_{eq} = 1/f + 1/f - 2/3f = 2/f - 2/3f = 4/3f \text{ so, } f_{eq} = 3f/4$$

32. (c) Seeing from one end, $h_1 = \mu \times (h - b)$
 $= 3/2 \times 5 = 15/2 \text{ cm}$

From other end of the slab, $h_2 = \mu \times h$
 $= 3/2 \times 3 = 9/2 \text{ cm}$

Now, total height, $(15/2 + 9/2) = 24/2 = 12 \text{ cm}$

33. (d) In case of telescope, magnifying power = f_o/f_e . Now, on increasing focal length of objective f_o , magnifying power M.P will also increase

For microscope, magnifying power M.P.

$$\approx v_o/u_o (1 + D/f_e) \approx L/f_o (1 + D/f_e)$$

Now, on increasing focal length of objective f_o , magnifying power M.P will decrease.

34. (d)

Equivalent focal length is $1/f_{eq} = 1/f_1 + 1/f_2$
 $1/f_{eq} = (\mu_1 - 1)[1/(\infty) - 1/(-R)] + (\mu_2 - 1)[1/(-R) - 1/\infty]$
 Now, $f_{eq} = R/(\mu_1 - \mu_2)$



35. (a) Now, refractive index,

$$\mu = \sin [(\delta_m + A)/2] / \sin (A/2)$$

$$\mu = \sin [(A + A)/2] / \sin (A/2) = \sin A / \sin (A/2)$$

$$= 2 \sin (A/2) \cos (A/2) / \sin (A/2)$$

$$= 2 \cos (A/2)$$

When $\delta_m = A$, then the angle may vary for 0° to 90°

For 0° , $\mu = 2 \cos 60^\circ = 2$

For 90° , $\mu = 2 \cos 45^\circ = \sqrt{2}$

So, refractive index lies between 2 and $\sqrt{2}$.

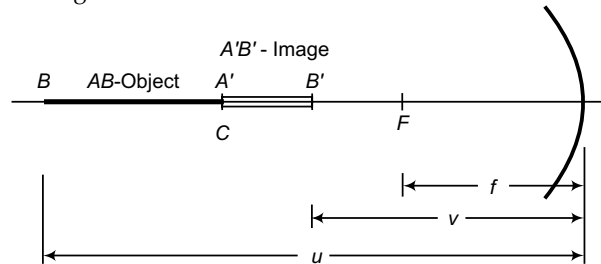
36. (c) Focal length (f) = -10 cm

Radius of Curvature (R) = $2f = -20 \text{ cm}$

Length of rod AB = 10 cm

Distance of end A = 20 cm

As distance of object 'A' is on centre of curvature, so image of 'A' will be at 'C'



Now distance of end 'B' = $10 + 20 = 30 \text{ cm}$

$$u = -30 \text{ cm}$$

As per mirror formula, $1/f = 1/u + 1/v$

$$1/(-10) = 1/(-30) + 1/v$$

$$1/v = 1/(-10) + 1/30 \text{ or } v = -15 \text{ cm}$$

Hence, the length of image $A'B'$ will now be $20 - 15 = 5 \text{ cm}$

37. (b) From the question, deviation is zero, so

$$\delta = \delta_1 + \delta_2 = 0$$

$$(\mu_1 - 1)A + (\mu_2 - 1)A' = 0$$

$$A'(1.75 - 1) = -1(1.5 - 1) 15^\circ$$

Now, $A' = (-0.5/0.75) \times 15^\circ$
 $A' = -10^\circ$

38. (c) $u = 10 \text{ cm}$, $v = 15 \text{ cm}$

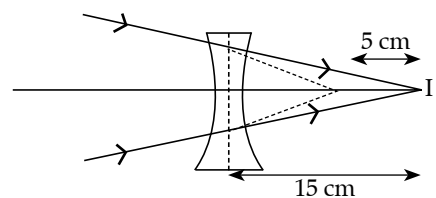
Since, the lens formula is

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

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

$$\frac{1}{f} = \frac{-1}{30}$$

$$f = -30 \text{ cm}$$



39. (c) In case of total internal reflection, $\sin i > \sin c$

$$\sin 45^\circ > 1/\mu$$

$$\mu > \sqrt{2}$$

40. (b) $\mu \sin \theta = \text{constant}$

$$\mu \times (3/5) = 1 \times \sin 90^\circ \text{ or } \mu = 5/3$$

$$v = c/\mu = 1.8 \times 10^8 \text{ m/s}$$

41. (d) Since, real depth/apparent depth = refractive index

$$h_1/6 \text{ cm} = \mu$$

$$h_1 = 6 \mu$$

Now, $h_2/4\text{cm} = \mu$

$$h_2 = 4\ \mu$$

Hence, $h_1 + h_2 = 15\text{ cm} = 10\ \mu$

On solving refractive index, $\mu = 1.5$

42. (c) Time = distance/speed = $t/(c/n) = nt/c$

43. (a) Since, $\mu = \frac{\lambda_0}{\lambda_m}$

Hence, $\lambda_m = 6000/1.5$

The wavelength of this light when it passes through glass is $4000\ \text{\AA}$.

44. (b) It is observed that frequency does not change with medium while wavelength and velocity decrease with increase in refractive index, so frequency, wavelength and velocity of light in glass slab will be $n, \lambda/\mu, v/\mu$

45. (c) Since, $\lambda \propto \frac{1}{\mu}$

As $\mu_{\text{air}} < \mu_g \Rightarrow \lambda_{\text{air}} > \lambda_g$

Hence, the wavelength decreases while frequency remains unchanged.

46. (c) Now ${}_2\mu_1 \times {}_3\mu_2 \times {}_4\mu_3 = \mu_1/\mu_2 \times \mu_2/\mu_3 \times \mu_3/\mu_4$
 $= \mu_1/\mu_4 = {}_4\mu_1 = 1/{}_1\mu_4$

Topic 2: Previous Year's Questions

- 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?
 - $i = \sin^{-1}(1/\mu)$
 - Reflected light is polarised with its electric vector perpendicular to the plane of incidence
 - Reflected light is polarised with its electric vector parallel to the plane of incidence
 - $i = \tan^{-1}(1/\mu)$ [NEE 2018]
- In Young's double slit experiment the separation d between the slits is 2 mm, the wavelength λ of the light used is $5896\ \text{\AA}$ 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 :
 - 2.1 mm
 - 1.9 mm
 - 1.8 mm
 - 1.7 mm [NEET 2018]
- 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 :
 - y/x
 - $x/2y$
 - x/y
 - $y/2x$ [NEET 2017]
- 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 that of P_1 . The intensity of transmitted light through P_2 is :
 - $I_0/4$
 - $I_0/8$
 - $I_0/16$
 - $I_0/2$ [NEET 2017]
- The interference pattern is obtained with two coherent light sources of intensity ratio n . In the interference pattern, the ratio $(I_{\text{max}} - I_{\text{min}}) / (I_{\text{max}} + I_{\text{min}})$ will be :
 - $\sqrt{n}/n+1$
 - $2\sqrt{n}/(n+1)$
 - $\sqrt{n}/(n+1)^2$
 - $2\sqrt{n}/(n+1)^2$ [NEET 2016]
- 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 $5 \times 10^{-5}\text{ cm}$. The distance of the first dark band of the diffraction pattern from the centre of the screen is :
 - 0.10 cm
 - 0.25 cm
 - 0.20 cm
 - 0.15 cm [NEET 2016]
- For a parallel beam of monochromatic light of wavelength ' λ ', diffraction is produced by a single slit whose width ' a ' is of the order 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 :
 - Da/λ
 - $2Da/\lambda$
 - $2D\lambda/a$
 - $D\lambda/a$ [AIPMT 2015]
- In a double slit experiment, the two slits are 1 mm apart and the screen is placed 1 m away. A monochromatic light of 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?
 - 0.5 mm
 - 0.02 mm
 - 0.2 mm
 - 0.1 mm [AIPMT 2015]
- A beam of light of $\lambda = 600\text{ nm}$ 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 :
 - 1.2 cm
 - 1.2 mm
 - 2.4 cm
 - 2.4 mm [AIPMT 2014]
- In the Young's double-slit experiment, the intensity of light at a point on the screen where the path difference is λ is K , (λ being the wave length of light used). The intensity at a point where the path difference is $\lambda/4$, will be :
 - K
 - $K/4$
 - $K/2$
 - Zero [AIPMT 2014]
- A slit of width a is illuminated by white light. For red light ($\lambda = 6500\text{\AA}$), the first minima is obtained at $\theta = 30^\circ$. Then the value of a will :
 - $3250\ \text{\AA}$
 - $6.5 \times 10^{-4}\text{ mm}$
 - 1.24 microns
 - $2.6 \times 10^{-4}\text{ cm}$ [CPMT 2002]
- The bending of beam of light around corners of obstacles is called :
 - Reflection
 - Diffraction
 - Refraction
 - Interference [NCERT 1990; CPMT 1999]
- The penetration of light into the region of geometrical shadow is called
 - Polarization
 - Interference
 - Diffraction
 - Refraction [CPMT 1999]
- 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 clearer (b) Will contract
(c) Will expanded (d) Will not be visualized

[CPMT 2005]

15. Diffraction and interference of light suggest

- (a) Nature of light is electro-magnetic
(b) Wave nature
(c) Nature is quantum
(d) Nature of light is transverse

[CPMT 1995]

16. A polariser is used to

- (a) Reduce intensity of light
(b) Produce polarised light
(c) Increase intensity of light
(d) Produce unpolarised light

[CPMT 1999]

17. Light waves can be polarised as they are

- (a) Transverse (b) of high frequency
(c) Longitudinal (d) Reflected

[CBSE PMT 1993; CPMT 2005]

18. Through which character we can distinguish the light waves from sound waves

- (a) Interference (b) Refraction
(c) Polarisation (d) Reflection

[CBSE PMT 1990]

19. Out of the following statements which is not correct?

- (a) When unpolarised light passes through a Nicol's prism, the emergent light is elliptically polarized
(b) Nicol's prism works on the principle of double refraction and total internal reflection
(c) Nicol's prism can be used to produce and analyze polarized light
(d) Calcite and Quartz are both doubly refracting crystals

[CPMT 1991]

20. The idea of the quantum nature of light has emerged in an attempt to explain

- (a) Interference
(b) Diffraction
(c) Radiation spectrum of a black body
(d) Polarisation

[CPMT 1990]

21. By Huygen's wave theory of light, we cannot explain the phenomenon of

- (a) Interference (b) Diffraction
(c) Photoelectric effect (d) Polarisation

[CPMT 1989]

Answer Key

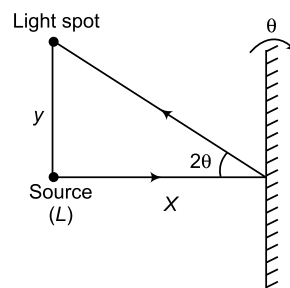
1.	(b)	2.	(b)	3.	(d)	4.	(b)	5.	(b)	6.	(d)
7.	(c)	8.	(c)	9.	(d)	10.	(c)	11.	(c)	12.	(b)
13.	(c)	14.	(b)	15.	(b)	16.	(b)	17.	(a)	18.	(c)
19.	(a)	20.	(c)	21.	(c)						

Answers with Explanation

1. (b) If reflected and refracted light rays are perpendicular, reflected light gets polarised with electric field vector perpendicular to the plane of incidence.
2. (b) Angular Width = $\lambda/d = 0.20^\circ = \lambda/2 \text{ mm}$
 $\lambda = 0.20^\circ \times 2$
As $\lambda/d = 0.21^\circ$, so using value of λ , we have
 $d = (0.20^\circ \times 2 \text{ mm})/0.21^\circ = 1.9 \text{ mm}$

3. (d) As the mirror is rotated θ , the reflected ray rotates 2θ .

Using trigonometry, $\tan 2\theta = y/x$
 θ being small, $2\theta = y/x$
or $\theta = y/2x$



4. (b) Applying Malus' Law,
Intensity of light from first polaroid $P_1, I_1 = I_0/2$

Intensity of light from second polaroid $P_2,$

$$I_2 = I_0/2 \cos^2 45^\circ$$

$$I_2 = I_0/2 \times (1/2) = I_0/4$$

$$I_3 = (I_0/4) \cos^2 45^\circ$$

$$I_3 = (I_0/4) \times (1/2) = I_0/8$$

5. (b) Maximum Intensity is given as $I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$

Minimum intensity is given as $I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$

Now, $I_1 / I_2 = n$

$$I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2 = (n^{1/2} + 1)^2 \times I_2$$

$$I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2 = (n^{1/2} - 1)^2 \times I_2$$

Now, $(I_{max} - I_{min}) / (I_{max} + I_{min}) = 2\sqrt{n} / (n + 1)$

6. (d) Phase difference $\theta = \lambda/a$

Path difference $a = 2\pi\Delta x$

Hence, $\theta = \lambda/a = Y/f$

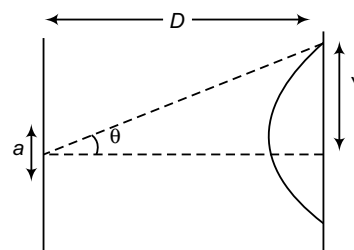
Now, $Y = f\lambda/a$

$$= 5 \times 10^{-5} \times 10^{-2} \times 60 \times 10^{-2} / 2 \times 10^{-4}$$

$$150 \times 10^{-5} = 1.5 \times 10^{-3} = 0.15 \text{ cm}$$

7. (c) $\theta = \lambda/a$

From the figure geometry



$$\sin \theta = Y/D$$

$$\theta = \frac{Y}{D}$$

or, $Y = \lambda D/a$

Width of centre maxima $2Y = 2\lambda D/a$

8. (c) $d = 1 \text{ mm}$

$$D = 1 \text{ m}$$

width of central maxima = $2(\lambda/a)D$

$$\lambda = 500 \times 10^{-9}$$

Putting formula, $10(D\lambda/d) = 2\lambda D/a$

$$a = d/5 = 0.2 \text{ mm}$$

9. (d) $\lambda = 600 \times 10^{-9} \text{ m}$

$$D = 2 \text{ m}$$

$$d = 1 \text{ mm} = 10^{-3} \text{ m}$$

Now, width of central maxima is given as:

$$W_0 = 2\lambda D/d = 2 \times 600 \times 10^{-9} \times 2/10^{-3}$$

$$= 2.4 \times 10^{-3} \text{ m} = 2.4 \text{ mm}$$

10. (c) Now $\Delta\phi = 2\pi/\lambda \times (\Delta x)$

$$= (2\pi/\lambda) \times (\lambda) = 2\pi$$

Further Intensity, $I = I_0 + I_0 + 2\sqrt{I_0 I_0} \cos 2\pi$

$$I = 4I_0 = K$$

$$\Delta\phi = (2\pi/\lambda)(\lambda/4) = \pi/2$$

$$I = I_0 + I_0 + 2\sqrt{I_0 I_0} \cos \pi/2 = 2I_0 = K/2$$

11. (c) For first minima

$$\theta = \lambda/a \Rightarrow a = \lambda/\theta \quad \left(\because \theta = \frac{\pi}{6} = 30^\circ \right)$$

$$\begin{aligned} \text{Now, } a &= 6500 \times 10^{-8} \times 6/\pi \\ &= 1.24 \times 10^{-4} \text{ cm} = 1.24 \text{ microns} \end{aligned}$$

12. (b) Diffraction is the bending of light waves around obstacles or edges, causing them to spread out and interfere with each other. This phenomenon occurs when the size of the obstacle or opening is comparable to the wavelength of the light.
13. (c) The penetration of light into the region of geometrical shadow results to turning of light around corners is known as Diffraction.
14. (b) If $\lambda_{\text{Blue}} < \lambda_{\text{Red}}$, hence the fringe pattern will contract as fringe width $\propto \lambda$
15. (b) Diffraction and interference of light are phenomena that demonstrate the wave-like behavior of light. Diffraction occurs when light waves bend around obstacles or pass through small openings, while

interference occurs when two or more light waves overlap and either reinforce or cancel each other.

16. (b) Polariser is used in producing polarised light.
17. (a) It is observed that only transverse waves can be polarised.
18. (c) Interference, Refraction and Reflection are shown by both light and sound waves while polarisation is shown by light wave only.
19. (a) Nicol prism is made from a double refracting calcite crystal which works on principle of double refraction and total internal reflection and is used to produce and analyse polarised light.
Also, in Nicol prism there is no light on refraction so (a) is not correct.
20. (c) A theory that explains blackbody radiation over the broad spectrum requires that light be emitted in energy quanta, which turns out to be the photon. A wave theory allows for energy to be emitted in a continuous range of values. Models that allows this to happen are only valid for specific cases of the spectrum. So, as per Planck's hypothesis, black bodies emits radiations in form of photons.
21. (c) Huygen's wave theory of light is not able to explain particle nature of light (photoelectric effect) but describes rectilinear propagation, reflection, refraction, interference, diffraction and polarization.

