In geometrical optics, light is commonly depicted as a ray that travels in a straight line through a homogeneous medium. However, phenomena such as Interference and Diffraction cannot be adequately explained solely by considering light as particles. Instead, these phenomena require an understanding of the wave nature of light. This branch of optics is known as physical optics or wave optics. The wave theory of light was initially proposed by Christian Huygens. It is important to note that Huygens was uncertain about whether light waves were longitudinal or transverse and how they propagated through a vacuum. Subsequently, in the nineteenth century, James Clerk Maxwell elucidated these aspects by introducing the electromagnetic wave theory.

Geometrical optics

Geometrical optics operates under the assumption that light travels in a straight line, a property known as rectilinear propagation. This fundamental characteristic allows for the geometric explanation of various optical phenomena, including laws of reflection, refraction, and total internal reflection. By utilizing the concept of rectilinear propagation, these optical phenomena can be effectively understood and described in a geometric framework.

Physical optics or wave optics:

In the realm of physical optics, light is viewed as a wave. The principles of Huygen's wave and the superposition principle are employed to elucidate phenomena such as interference and diffraction. The electromagnetic wave nature of light is utilized to explain the concept of polarization.

There are specific conditions under which geometrical optics and wave optics are applicable. Geometrical optics can be applied when the size of the object interacting with light is considerably larger than the wavelength of light. Conversely, wave optics can be applied when the wavelength of light is comparable to or smaller than the size of the object involved in light interaction. These conditions dictate the appropriate choice between geometrical and wave optics in analyzing optical phenomena.

If 'b' is the size of the object interacting with light, 'ℓ' is the distance between the object and the screen and 'λ' is the wavelength of light then,

i) The condition for applicability of geometrical optics is $\frac{b^2}{\ell\lambda} >> 1$

ii) The condition for applicability of wave optics is $\frac{b^2}{\ell\lambda} \approx 1$ or $\frac{b^2}{\ell\lambda} << 1$

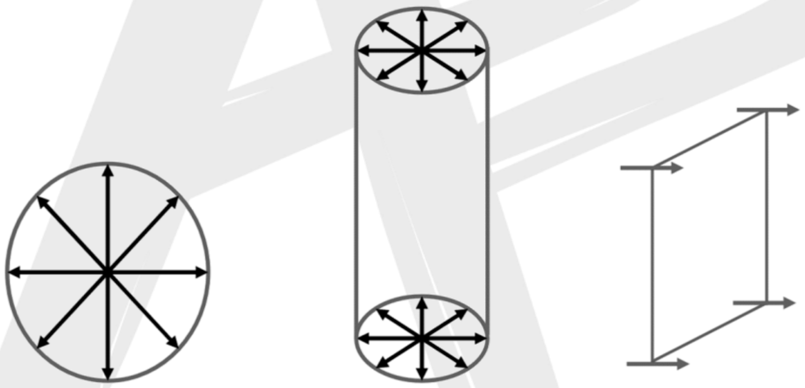
Note: The objects that can interact with light encompass a variety of optical components, including mirrors, lenses, prisms, apertures (such as pinholes), slits, and straight edges. These objects play crucial roles in manipulating and influencing the behaviour of light in various optical systems.

WAVE FRONT

In accordance with the wave theory of light, a light source emits disturbances that propagate in all directions. Within a homogeneous medium, these disturbances reach particles located equidistant from the source, causing them to vibrate in phase with one another at any given moment. The locus of all the particles within the medium that vibrate in the same phase simultaneously is referred to as the wavefront.

Depending upon the shape of the source of light, wavefront can be of the following types

1. **Spherical wavefront:** A point source of light generates a spherical wavefront. This occurs because the locus of points that are equidistant from the point source forms a sphere. Therefore, the wavefront produced by a point source of light takes on a spherical shape.

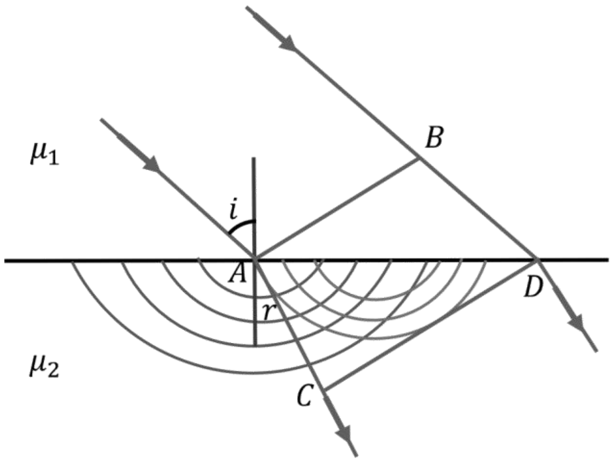


(a) (b) (c)

2. **Cylindrical wavefront:** A linear light source, like a slit, produces a cylindrical wavefront. This is due to the fact that all points equidistant from the linear source lie on the surface of a cylinder. Hence, the wavefront generated by a linear light source exhibits a cylindrical shape. (b).
3. **Plane wavefront:** A small portion of a spherical or cylindrical wavefront that originates from a distant source can appear to be flat or planar, and is therefore referred to as a plane wavefront. (c).

Huygens Principle:

Each point on a wavefront serves as a source of secondary disturbance, emitting wavelets that Propagate through the medium at the speed of light, but only in the forward direction. The collection of these secondary waves forms an envelope that represents the position of the new wavefront at a particular moment in time. It is important to note that the wavefront in a medium is always perpendicular to the direction of wave propagation.



AB is width of incident beam

CD is width of refracted beam

$$\frac{\text{width of incident beam}}{\text{width of refracted beam}} = \frac{\cos i}{\cos r}$$

The Doppler Effect:

(i) When a light-emitting source, such as the sun, moon, a star, or an atom, moves towards or away from an observer, the perceived frequency or wavelength of light undergoes a change. This phenomenon is known as the Doppler effect in light. The Doppler effect refers to the apparent alteration in frequency or wavelength of light as observed by an observer due to the relative motion between the source and the observer.

Blue Shift: When the distance between a light source and an observer decreases, indicating that the source is approaching the observer, the frequency of light appears to increase, while the wavelength appears to decrease. This shift in the spectral line towards the blue end of the electromagnetic spectrum is commonly referred to as a "blue shift." The term "blue shift" is used to describe this phenomenon due to the noticeable shift of the light spectrum towards shorter wavelengths, which are associated with the color blue.

Red Shift: As the distance between a light source and an observer increases, indicating that the source is moving away from the observer, the frequency of light appears to decrease, while the wavelength appears to increase. This displacement of the spectral line towards the red end of the electromagnetic spectrum is commonly referred to as a "red shift." The term "red shift" is used to describe this phenomenon due to the noticeable shift of the light spectrum towards longer wavelengths, which are associated with the color red.

Doppler shift, $\frac{\Delta v}{v} = \frac{V}{C}$ (where V is the speed of source and C is the speed of light)

Principle of superposition of waves:

When multiple waves converge at a specific point in the same medium, the particles within the medium experience displacements caused by each individual wave simultaneously. The resulting wave is determined by the combined displacement of the particles.

The principle of superposition of waves states that when two or more waves simultaneously act on the particles of a medium, the resultant displacement of any particle is equal to the algebraic sum of the displacements caused by each individual wave. In other words, the displacement of a particle at a given point is the sum of the displacements produced by all the waves present at that location.

(or)

When multiple waves intersect or overlap, the resulting displacement at any given point and moment is determined by the vector sum of the instantaneous displacements that would be generated by each individual wave if they were present individually at that point. In essence, the resultant displacement is obtained by adding the individual wave displacements vectorially. If $y_1, y_2, ...y_n$ denote the displacements of 'n' waves meeting at a point, then the resultant displacement is given by $y = y_1 + y_2 + ... + y_n$.

(a) **Superposition of coherent waves:** Consider two waves travelling in space with an angular frequency ω. Let the two waves arrive at some point simultaneously. Let y_1 and y_2 represent the displacements of two waves at this point.

$\therefore y_1 = A_1 \sin(\omega t + \phi_1) \; \& \; y_2 = A_2 \sin(\omega t + \phi_2)$

Then according to the principle of superposition the resultant displacement at the point is given by,

$y = y_1 + y_2$ or $y = A_1 \sin(\omega t + \phi_1) + A_2 \sin(\omega t + \phi_2)$

$= A_1(\sin \omega t \cos \phi_1 + \cos \omega t \sin \phi_1) + A_2(\sin \omega t \cos \phi_2 + \cos \omega t \sin \phi_2)$

$= A \cos \phi . \sin \omega t + A \sin \phi . \cos \omega t$

$= A \sin(\omega t + \phi)$

where $A \cos \phi = A_1 \cos \phi_1 + A_2 \cos \phi_2$ ..... (1)

and $A \sin \phi = A_1 \sin \phi_1 + A_2 \sin \phi_2$.... (2)

Here A and ϕ are respectively the amplitude and initial phase of the resultant displacement

Squaring and adding equations (1) & (2), we get

$A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2 \cos(\phi_1 - \phi_2)}$

$= \sqrt{A_1^2 + A_2^2 + 2A_1A_2 \cos \phi}$ ... (3)

Where $\phi = \phi_1 - \phi_2$, phase difference between the two waves.

Dividing equation (2) by equation (1), we get

$$\tan\phi = \frac{A_1 \sin\phi_1 + A_2 \sin\phi_2}{A_1 \cos\phi_1 + A_2 \cos\phi_2} \quad .....(4)$$

Since the intensity of a wave is proportional to square of the amplitude, the resultant intensity I of the wave from equation (3) may be written as

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi \quad .... (5)$$

Where I_1 and I_2 be the intensities of the two waves. It can be seen that the amplitude (intensity) of the resultant displacement varies with phase difference of the constituent displacements.

Case I: when $\phi = \phi_1 - \phi_2 = 0, 2\pi, 4\pi$ .... $2n\pi$

where $n = 0, 1, 2, ...$

$\Rightarrow \cos\phi = 1$

$\therefore A = A_1 + A_2$ from (3)

and $\sqrt{I} = \sqrt{I_1} + \sqrt{I_2}$ from (5)

Hence the resultant amplitude is the sum of the two individual amplitudes. This condition refers to the constructive interference.

Case II: when $\phi = \phi_1 - \phi_2 = \pi, 3\pi, 5\pi$ .... $(2n - 1)\pi$

Where $n = 1, 2, 3, ...;$ $\Rightarrow \cos\phi = -1$

$\therefore A = |A_1 - A_2|$ and $\sqrt{I} = \left|\sqrt{I_1} - \sqrt{I_2}\right|$

Consequently, when the amplitudes of the individual waves subtract from each other, the resulting amplitude is the difference between the individual amplitudes, leading to what is known as destructive interference.

(b) Superposition of incoherent waves:

Incoherent waves are the waves which do not maintain a constant phase difference. The phase of the waves fluctuates irregularly with time and independently of each other. In case of light waves, the phase fluctuates randomly at a rate of about 10^8 per second. Light detectors such as human eye, photographic film etc, cannot respond to such rapid changes. The detected intensity is always the average intensity, averaged over a time interval which is very much larger than the time of fluctuations. Thus

$I_{av} = I_1 + I_2 + 2\sqrt{I_1 I_2} < \cos\phi >$. The average value of the $\cos\phi$ over a large time interval will be zero and hence $I_{av} = I_1 + I_2$

Consequently, when incoherent waves superpose, it results in a uniform illumination at each point, and the resulting intensity is merely the sum of the intensities of the individual waves.

Interference:

The phenomenon where the total energy of interfering waves is redistributed, leading to variations in intensity, is known as interference. Interference of light is a wave phenomenon, specifically pertaining to the behavior of light waves. When light sources emit waves of the same frequency and travel with either the same phase or a constant phase difference, they are referred to as coherent sources.

Ex: Two virtual sources derived from a single source can be used as Coherent Sources.

- The source producing the light wave travelling with rapid and random phase changes are called Incoherent Sources.

Ex: 1. Light emitted by two candles.

2. Light emitted by two lamps.

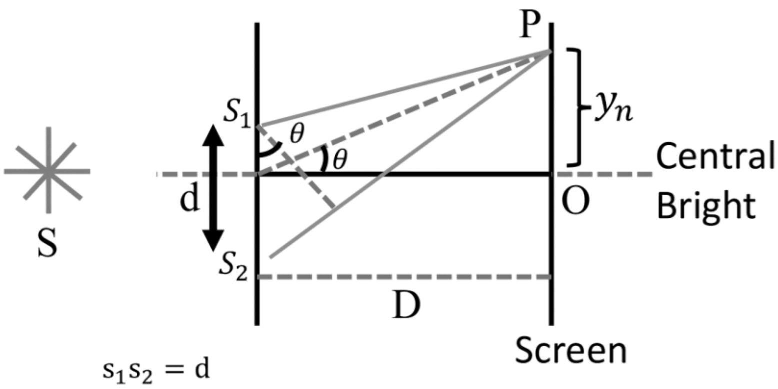
Conditions for Steady Interference

- The two sources must be coherent.
- Two sources must be narrow.
- Two sources must be close together.

NOTE: The two sources must be mono chromatic, otherwise the fringes of different colours overlap and hence interference cannot be observed.

Young's Double Slit Experiment

- Young with his experiment measured the most important characteristic of the light wave i.e wavelength (λ)
- Young's experiment conclusively established the wave nature of light.



$s_1 s_2 = d$

- When source illuminates the two slits, the pattern observed on the screen consists of large number of equally spaced bright and dark bands called "interference fringes"

(a) Bright fringes:

Bright fringes occur whenever the waves from S_1 and S_2 interfere constructively. i.e. on reaching 'P', the waves with crest (or trough) superimpose at the same time and they are said to be in phase. The condition for finding a bright fringe at 'P' is that $S_2P - S_1P = n\lambda$,

Where $n = 0, \pm 1, \pm 2, \pm 3,$ ... and n is called the order of bright fringe. Hence for n^{th} order bright fringe, the path difference is

$$d \sin\theta = n\lambda$$

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

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

Where y_n is the position of n^{th} maximum from O. The bright fringe corresponding to $n = 0$, is called the zero – order fringe or central maximum. It means it is the fringe with zero path difference between two waves on reaching the point P.

The bright fringe corresponding to n=1 is called first order bright fringe i.e., if the path difference between the two waves on reaching 'P' is λ. Similarly, second order bright fringe $n = 2$ is located where the path difference is 2λ and so on.

From $I = 4I_0 \cos^2\left(\frac{\phi}{2}\right)$

For maximum intensity $\cos\frac{\phi}{2} = 1$

i.e. $\frac{\phi}{2} = 0, \pm, \pi, \pm 2\pi$ .....

(or) Phase difference between the waves

$\phi = \pm 2\pi n$ with $n = 0, 1, 2, 3.....$

The corresponding path difference, $\Delta x = n\lambda$

Hence $I_{max} = 4I_0$

(b) Dark fringes:

Dark fringes occur whenever the waves from S_1 and S_2 interfere destructively. i.e., on reaching 'P' one wave with its crest and another wave with its trough superimpose. Then the phase difference between the waves is π and the waves are said to be in opposite phase.

Destructive interference occurs at P, if S_1P and S_2P differ by a odd integral multiple of $\frac{\lambda}{2}$.

Thus, the condition for finding dark fringe at P is that $S_2P - S_1P = (2n-1)\frac{\lambda}{2}$.

Where $n = \pm1, \pm2, \pm3$, ……, and n is called order of dark fringe. Hence for n^{th} order dark.

fringe, the path difference, $d\sin\theta = (2n-1)\frac{\lambda}{2}$

$$\Rightarrow d\left(\frac{y_n}{D}\right) = (2n-1)\frac{\lambda}{2} \therefore y_n = \left(\frac{2n-1}{2}\right)\frac{\lambda D}{d}$$

Where y_n is the position of n^{th} minima from O.

The first dark fringe occurs when

$S_2P - S_1P = \frac{\lambda}{2}$. This is called first order dark (n=1)

fringe and similarly for $S_2P - S_1P = \frac{3\lambda}{2}$ second order dark fringe $(n = 2)$ occurs and so on.

From $I = 4I_0 \cos^2\left(\frac{\phi}{2}\right)$

For minimum intensity $\cos\frac{\phi}{2} = 0$

i.e, $\frac{\phi}{2} = \pm\frac{\pi}{2}, \pm\frac{3\pi}{2}, \pm\frac{5\pi}{2}$.....

(or) $\phi = \pm\pi, \pm3, \pm5\pi$ ....

(or) $\phi = \pm(2n-1)\pi$ with n=1,2,3....

The corresponding path difference,

$\Delta x = (2n-1)\frac{\lambda}{2}$

Hence $I_{min} = O$

(c) Fringe width (β):

The distance between two adjacent bright (or dark) fringes is called the fringe width. It is denoted by β:

The n^{th} order bright fringes occurs from the central maximum at $y_n = \frac{n\lambda D}{d}$

The $(n+1)^{th}$ order bright fringe occurs from the central maximum at $y_{n+1} = \frac{(n+1)\lambda D}{d}$

$\therefore$ The fringe separation, β is given by $\beta = y_{n+1} - y_n = \frac{\lambda D}{d}$

In a similar way, the same result will be obtained for the dark fringes also.

$\therefore$ Fringe width, $\beta = \frac{\lambda D}{d}$

Thus fringe width is same every where on the screen and the width of bright fringe is equal to the width of dark fringe

$\therefore \beta_{bright} = \beta_{dark} = \beta = \frac{\lambda D}{d}$

d) The locus of a point P in the xy-plane, where the path difference $S_2P - S_1P = (\Delta x)$ remains constant, is described by a hyperbola. When the distance D is significantly larger than the fringe width, the fringes will appear as nearly straight lines.

Constructive Interference

(i) (a) If the phase difference is $\phi = (2n)\pi$ (even multiples of π). Where $n = 0,1,2,3,....$ i.e., when $\phi = 0, 2\pi, 4\pi$ .... $2n\pi$

(b) If the path difference $x = 2n\left(\frac{\lambda}{2}\right)$ (even multiples of half wavelength).

i.e., when $x = 0, \lambda, 2\lambda....n\lambda$

The amplitude and intensity are maximum.

$\boxed{A_{max} = (A_1 + A_2)}$

$\boxed{I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2 = (A_1 + A_2)^2}$

Note: If $A_1 = A_2 = a$ then $\boxed{A_{max} = 2a}$

If $I_1 = I_2 = I_0$ then $\boxed{I_{max} = 4I_0}$

Destructive Interference

(ii) a) If the phase difference $\phi = (2n-1)\pi$ (odd multiples of π) where $n = 1,2,3$ ....

i.e., when $\phi = \pi, 3\pi, 5\pi$ ...... $(2n-1)\pi$

b) If the path difference $x = (2n-1)\lambda/2$ (odd multiples of $\lambda/2$)

i.e. when $x = \frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}$ ...... $\frac{(2n-1)\lambda}{2}$

The amplitude and Intensity are minimum.

$\boxed{A_{min} = (A_1 - A_2)}$

$$\boxed{I_{min} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2 = \left(A_1 - A_2\right)^2}$$

Note: If $A_1 = A_2 = a$ then $\boxed{A_{min} = 0}$

If $I_1 = I_2 = I_0$ then $\boxed{I_{min} = 0}$

$$\boxed{\frac{I_{max}}{I_{min}} = \frac{\left(\sqrt{I_1} + \sqrt{I_2}\right)^2}{\left(\sqrt{I_1} - \sqrt{I_2}\right)^2} = \frac{\left(A_1 + A_2\right)^2}{\left(A_1 - A_2\right)^2}}$$

iii) phase difference $= \frac{2\pi}{\lambda}$ (path difference).

$$\boxed{\phi = \frac{2\pi}{\lambda} x}$$

iv) Since $\beta \alpha \lambda$, $\beta_{red} > \beta_{voilet}$, as $\lambda_{red} > \lambda_{voilet}$

v) In YDSE, if blue light is used instead of red light then β decreases $\left(\because \lambda_B < \lambda_R\right)$

vi) If YDSE is conducted in vacuum instead of air, then β increases $\left(\because \lambda_{vacuum} > \lambda_{air}\right)$

vii) In certain field of view on the screen, if n_1 fringes are formed when light of wavelength λ_1 is used and n_2 fringes are formed when light of wavelength λ_2 is used, then

$$y = \frac{n\lambda D}{d} = \text{constant} \Rightarrow n\lambda = \text{constant}$$

$$\therefore n_1\lambda_1 = n_2\lambda_2 \left(\text{or}\right) n_1\beta_1 = n_2\beta_2$$

viii) The distance of n^{th} bright fringe from central maximum is $\left(y_n\right)_{bri} = \frac{n\lambda D}{d} = n\beta$

The distance of m^{th} dark fringe from central maximum is

$$\left(y_m\right)_{dark} = \frac{\left(2m-1\right)}{2}\frac{\lambda D}{d} = \frac{\left(2m-1\right)}{2}\beta$$

$\therefore$ The distance between n^{th} bright and m^{th} dark fringes is

$$\left(y_n\right)_{bri} - \left(y_m\right)_{dark} = n\beta - \frac{\left(2m-1\right)}{2}\beta$$

ix) When white light is used in YDSE the interference patterns due to different component colours of white light overlap (incoherently). The central bright fringes for different colours are at the same position. Therefore, the central fringe is white. For a point P for which $S_2P - S_1P = \frac{\lambda_b}{2}$

where $\lambda_b\left(\approx 4000A^0\right)$ represents the wavelength for the blue colour, the blue component will be absent and the fringe will appear red in colour.

Slightly farther away where $S_2Q - S_1Q = \frac{\lambda_r}{2}$ where $\lambda_r\left(\approx 8000A^0\right)$ is the wavelength for the red colour, the fringe will be predominantly blue.

As we move away from the central white fringe, the fringes closest to it will appear red, while the fringes farthest from it will appear blue. However, as we continue to observe the fringes, the pattern becomes less distinct and eventually becomes difficult to discern.

(x) To know maximum number of possible maxima on the screen.

If $d\sin\theta = n\lambda$ (or) $\sin\theta = \frac{n\lambda}{d}$

As $\sin\theta < 1, \frac{n\lambda}{d} \leq 1$ $\therefore n \leq \frac{d}{\lambda}$

Therefore, the maximum number of complete maxima on the screen will be $2(n)+1$.

Ex: If $d = 3\lambda$ then $\sin\theta = \frac{n\lambda}{3\lambda} = \frac{n}{3}$ As $\sin\theta \leq 1$,

n can takes values -3, -2, -1, 0, 1, 2, 3

$\therefore$ Maximum number of maxima is 7.

(xi) Fringe visibility (or) band visibility (V):

It is the measure of contrast between the bright and dark fringes.

Fringe visibility, $V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$

where $I_{max} = I_1 + I_2 + 2\sqrt{I_1 I_2}$

and $I_{min} = I_1 + I_2 - 2\sqrt{I_1 I_2}$

$$\therefore V = \frac{4\sqrt{I_1 I_2}}{2(I_1 + I_2)} = \frac{2\sqrt{I_1 I_2}}{(I_1 + I_2)}$$

V has no unit and no dimensional formula.

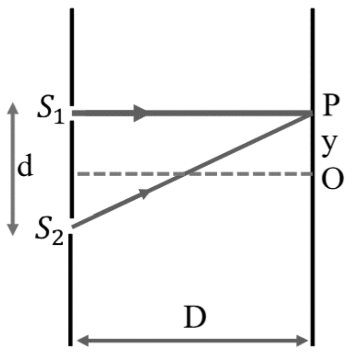
Generally, 0< V < 1.

Fringe visibility is maximum, if $I_{min} = 0$, then $V = 1$.

For poor visibility is maximum, if I_{min} =0, then V = 0 i.e., if $V = 1$, then the fringes are very clear and contrast is maximum and if V=0, then there will be no fringes and there will be uniform illumination i.e., the contrast is poor.

(xii) When one slit is fully open while the other is partially open, the contrast between the fringes diminishes. In other words, if the widths of the slits are unequal, the minima in the interference pattern will not appear completely dark.

(xiii) Missing wavelength in front of one slit in YDSE:



Suppose P is a point of observation in front of slit S_1 as shown in figure. Path difference between the two waves from S_1 and S_2 is

$$\Delta x = S_2P - S_1P = \sqrt{D^2 + d^2} - D$$

$$= D\left(1+\frac{d^2}{D^2}\right)^{1/2} - D = D\left(1+\frac{d^2}{2D^2}\right) - D = \frac{d^2}{2D}$$

$$\therefore \Delta x = \frac{d^2}{2D} \quad \text{........(1)}$$

But for missing wavelengths, intensity will be zero.

i.e., the corresponding path difference,

$$\Delta x = (2n-1)\frac{\lambda}{2} \quad \text{.... (2)}$$

From equations (1) and (2)

$$\frac{d^2}{2D} = (2n-1)\frac{\lambda}{2}$$

$\therefore$ Missing wavelength, $\lambda = \dfrac{d^2}{(2n-1)D}$

By putting $n = 1, 2, 3, \ldots,$ the wavelengths at P are

$$\lambda = \frac{d^2}{D}, \frac{d^2}{3D}, \frac{d^2}{5D} \ldots\ldots$$

In the above case, if bright fringes are to be formed exactly opposite to S_1 then

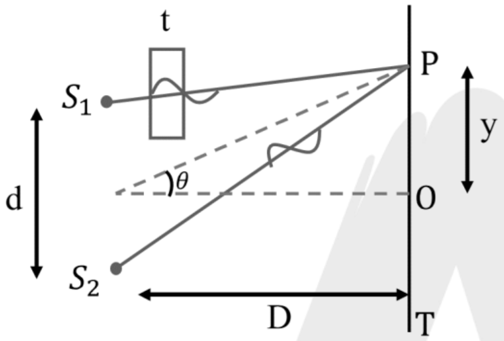
$$\frac{d^2}{2D} = n\lambda \Rightarrow \lambda = \frac{d^2}{2Dn}$$

By putting n=1,2,3, the possible wavelengths at P are

$$\lambda = \frac{d^2}{2D}, \frac{d^2}{4D}, \frac{d^2}{6D}$$

(xiv) Lateral displacement of fringes:

To measure the thickness of a thin transparent material like glass or mica, the material is placed in the path of one of the interfering beams. This introduction of the transparent sheet causes a displacement in the fringe pattern towards the beam where the sheet is inserted. This displacement is referred to as the lateral displacement or lateral shift.



The optical path from S_1 to $P = (S_1P - t) + \mu t$.

The optical path from S_2 to $P = S_2P$.

To get central zero fringe at P, $\Delta_{s_1P} = \Delta_{s_2P}$

$$\Rightarrow S_1P - t + \mu t = S_2P$$

$$\therefore S_2P - S_1P = (\mu - 1)t$$

Since $\mu > 1$, this implies $S_2P > S_1P$ hence the fringe pattern must shift towards the beam from S_1

But $S_2P - S_1P = d\sin\theta = d\frac{y}{D}$, where 'y' is the lateral shift.

$$\therefore (\mu - 1)t = d\frac{y}{D}$$

$\therefore$ Lateral shift (y) = $\frac{D}{d}(\mu - 1)t = \frac{\beta}{\lambda}(\mu - 1)t$

(or) Thickness of sheet

$$t = \frac{yd}{(\mu - 1)D} = \frac{y\lambda}{(\mu - 1)\beta}$$

From the above it is clear that

(a) For a given colour, shift is independent of order of the fringe i.e. shift in zero order maximum = shift in 9th minima (or) shift in 6th maxima = shift in 2nd minima. Since the refractive index depends on wavelength hence lateral shift is different for different colours.

(b) The number of fringes shifted = $\frac{\text{lateral shift}}{\text{fringe width}}$

$$\therefore n = \frac{y}{\beta} = \frac{(\mu-1)t}{\lambda} (\text{or}) n\lambda = (\mu-1)t$$

Therefore, number of fringes shifted is more for shorted wavelength.

(c) If a transparent sheet of thickness 't' and its relative refractive index μ_r (w.r.t surroundings) be introduced in one of the beams of interference, then

(1) the lateral shift $y = \frac{(\mu_r - 1)tD}{d}$

(2) the number of fringes shifted $n = \frac{(\mu_r - 1)t}{\lambda}$

(d) Due to the presence of transparent sheet, the phase difference between the interfering waves at a given point is given by $= \frac{2\pi}{\lambda}(\mu-1)t$.

(e) If YDSE is performed with two different colours of light of wavelengths λ_1 & λ_2 but by placing the same transparent sheet in the path of one of the interfering waves then $n_1\lambda_1 = n_2\lambda_2$ where n_1 and n_2 are the number of fringes shifted with wavelengths λ_1 & λ_2.

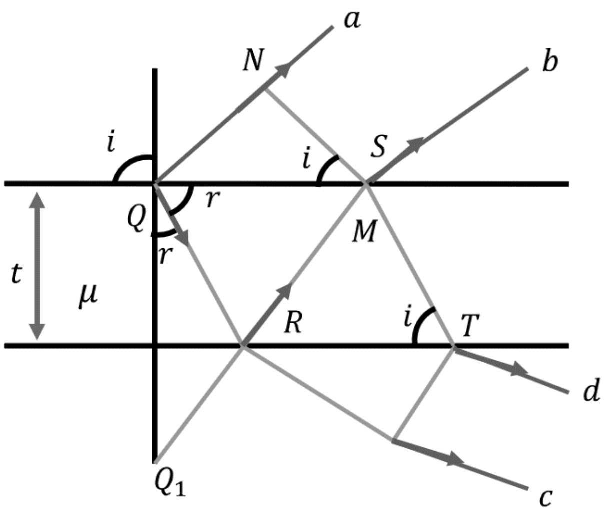
When two different transparent sheets of thickness t_1, t_2 and refractive index μ_1, μ_2 are placed in the paths of two interfering waves in YDSE, if the central bright fringe position is not shifted, then

$(\mu_1 - 1)t_1 = (\mu_2 - 1)t_2$.

Important Concepts:

- Formation of colours in thin films:

a) Interference due to reflected light



Reflected system:

- Path difference between the rays Qa and QRSb.

  (PD) = QRS in medium – QN in air

  $\therefore$ P.D = $2\mu t\cos r$

  This is the path lag due to reflection on film additional path lag of $\lambda/2$ exists. (stoke's theorem)

  Total path difference = $2\mu t\cos r+\frac{\lambda}{2}$

Condition for maximum

- $2\mu t\cos r+\frac{\lambda}{2}=n\lambda$

  OR $\boxed{2\mu t\cos r=(2n-1)\frac{\lambda}{2}}$ For all values of n

  is equal to 1,2,3……..n.

- **Condition for Minimum**

  $2\mu t\cos r+\frac{\lambda}{2}=(2n-1)\frac{\lambda}{2}$

  $\boxed{2\mu t\cos r=n\lambda}$ for values of $n=0,1,2,3\ldots\ n$

  = 0 gives the central minima.

  For normal incident $i=o=r$

  $2\mu t=n\lambda$ for dark; $2\mu t=(2n-1)\frac{\lambda}{2}$ for bright.

Transmitted system

- Interference of two rays Rc and Td. By symmetry it can be concluded that the path difference between the rays in $2\mu t\cos r$.

  But there would not be any extra phase lag because either of the two rays suffers reflection at denser surface.

- **Condition for maxima:** $\boxed{2\mu t\cos r=n\lambda}$

- **Condition for minimum:** $\boxed{2\mu t\cos r=(2n-1)\frac{\lambda}{2}}$

If YDSE is conducted with white light,

- The central fringe of an interference pattern always appears achromatic, meaning it appears as white light.

When the path difference is small, colored fringes can be observed on either side of the central fringe. The outer edge of the fringe appears violet, while the inner edge appears red. It is important to note that the fringe width varies for different colors. Additionally, when compared to a monochromatic light source, the number of fringes obtained is generally fewer.

Diffraction

The phenomenon in which light bends around the edges of an obstacle or enters the geometrically shadowed region is referred to as "diffraction of light." Diffraction is an inherent property of waves and is observed in various wave phenomena, including electromagnetic waves, water waves, and sound waves. Even small particles such as atoms, neutrons, and electrons exhibit diffraction due to their wave-like nature.

When light passes through a narrow aperture, some of it extends into regions that are in the shadow. The extent of this light encroachment is minimal and negligible when the slit width is larger. However, when the slit width becomes comparable to the wavelength of light, the encroachment of light into the shadowed region becomes more prominent. If the size of the obstacle or aperture is similar to the wavelength of light, the light deviates from straight-line propagation near the edges, resulting in light encroaching into the geometrically shadowed area.

Diffraction phenomenon is classified into two types,

(a) Fresnel diffraction (b) Fraunhofer diffraction

Fresnel Diffraction

In the case of Fresnel diffraction, it is important to note that the source, screen, or both are situated at finite distances from the diffracting device, be it an obstacle or an aperture. The observed effect at any point on the screen is influenced by the exposed wavefront, which can possess a spherical or cylindrical shape.

Unlike other forms of diffraction, Fresnel diffraction does not necessitate the presence of a lens to modify the beam. The phenomenon can be elucidated by considering "half-period zones or strips" which play a crucial role in shaping the resulting diffraction pattern.

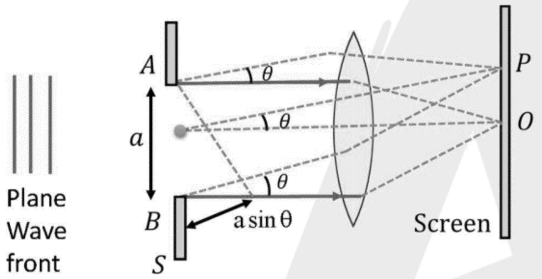
Fraunhofer Diffraction:

In the case of Fraunhofer diffraction, it is assumed that both the source and the screen are situated at an infinite distance from the diffracting device, whether it be an aperture or an obstacle. The wavefront that interacts with the diffracting device is considered to be a plane wavefront. In contrast to Fresnel diffraction, Fraunhofer diffraction often requires the use of lenses or optical components to modify the beam before it reaches the diffracting device and forms the diffraction pattern on the screen.

Diffraction Due to Single Slit

Diffraction is attributed to the interference of secondary wavelets originating from the exposed portion of a wavefront passing through a slit. However, there is a distinction between diffraction and interference in terms of the intensity of the resulting patterns.

In interference, all bright fringes exhibit the same intensity. On the other hand, in diffraction, the intensity of the bright bands tends to decrease as we move away from the central maximum. This variation in intensity is a characteristic feature of diffraction phenomena.



(i) Condition for minimum intensity is

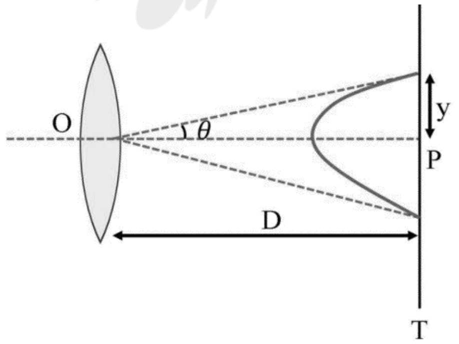
$\boxed{a\sin\theta = n\lambda}\ (n = 1, 2, 3.....)$

Where 'a' is the width of the slit, θ is the angle of diffraction.

(ii) Condition for maximum intensity

$\boxed{a\sin\theta = (2n+1)\frac{\lambda}{2}}\ (n = 1, 2, 3, ...)$

The intensity decreases as we go to successive maxima away from the centre, on either side. The width of central maxima is twice as that of secondary maxima.



For first minima $a\sin\theta = \lambda$

$a\frac{y}{D} = \lambda\ \ (\because \sin\theta \approx \tan\theta)\ \ \therefore y = \frac{\lambda D}{a}$

Width of central maxima $w = 2y = \frac{2\lambda D}{a}$

Note: If lens is placed close to the slit, then D=f. Hence 'f' be the focal length of lens, then width of the central maximum $w = \frac{2f\lambda}{a}$.

Note: If this experiment is performed in liquid other than air, width of diffraction maxima will decrease and becomes $\frac{1}{\mu}$ times. With while light, the central maximum is white and the rest of the diffraction bands are colored.

- **Interference and diffraction bands**

  If N interference bands are contained by the width of the central bright.

  Width $= N\beta = N\left(\frac{D\lambda}{d}\right)$; $\therefore \frac{2D\lambda}{a} = \frac{ND\lambda}{d}$

  Therefore, width of the slit $a = \frac{2d}{N}$

The Validity of Ray Optics:

The distance between the screen and the slit, where the spreading of light caused by diffraction from the center of the screen is equal to the size of the slit, is known as the Fresnel distance (denoted by Z).

When light diffracts from a slit, the resulting diffraction pattern on the screen consists of secondary maxima and minima on both sides of the central maximum. As a result, we can conclude that light spreads on the screen in the form of a central maximum due to diffraction from the slit.

The angular position of first secondary minimum is called half angular width of the central maximum and it is given by

$\theta = \frac{\lambda}{a}$ (provided θ is small)

If the screen is placed at a distance D from the slit, then the linear spread of the central maximum is given by

$y = D\theta = \frac{D\lambda}{a}$

It is, in fact, the distance of first secondary minimum from the centre of the screen. It follows that as the screen is moved away (D is increased), the linear size of the central maximum i.e., spread distance, when $D = Z_F$, $y = a$ (size of the slit)

Setting this condition in the above equation, we have

$$a = \frac{Z_F \lambda}{a} \text{ or } \boxed{Z_F = \frac{a^2}{\lambda}}$$

If the screen is positioned at a distance beyond the Fresnel distance (Z), the spreading of light resulting from diffraction will be significant compared to the size of the slit. The equation mentioned above indicates that the laws of ray optics hold true when the wavelength approaches zero.

Limit of resolution:

The limit of resolution of an optical instrument refers to the smallest linear or angular separation between two point objects at which they can be distinctly observed or resolved.

Resolving Power:

The resolving power of an optical instrument is defined as the reciprocal of the smallest linear or angular separation between two point objects for which their images can be distinctly resolved by the instrument.

$$\text{Resolving power} = \frac{1}{\text{Limit of resoluton}}$$

The resolving power of an optical instrument is inversely proportional to the wavelength of light used.

Diffraction as a limit on resolving power:

Every optical instrument, such as lenses, telescopes, microscopes, and others, acts as an aperture through which light passes. As light traverses these instruments, it undergoes diffraction, which imposes a limitation on their resolving power.

Rayleigh's criterion for resolution:

The images of two-point objects are considered resolved when the central maximum of the diffraction pattern of one object aligns with the first minimum of the diffraction pattern of the other object.

Resolving Power of a Microscope:

The resolving power of a microscope is defined as the reciprocal of the smallest distance d between two-point objects at which they can be just resolved when seen in the microscope.

➢ $\boxed{\text{Resolving power of microscope} = \frac{1}{d} = \frac{2\mu \sin\theta}{1.22\lambda}}$

Clearly, the resolving power of a microscope depends on :

(i) the wavelength (λ) of the light used

(ii) Half the angle (θ) of the cone of light from each point object.

(iii) the refractive index (μ) of the medium between the object and the objective of the microscope.

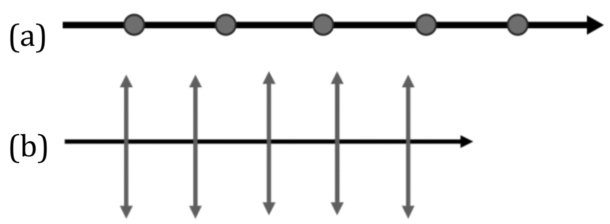
Resolving Power of a Telescope:

- The resolving power of a telescope is defined as the reciprocal of the smallest angular separation 'dθ' between two distant objects whose images can be just resolved by it.
- $\boxed{\text{Resolving power of telescope } \frac{1}{d\theta} = \frac{D}{1.22\lambda}}$

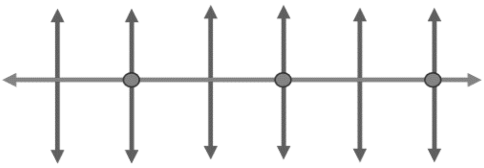
Clearly, the resolving power of telescope depends on: (i) the diameter (D) of the telescope objective (ii) The wavelength (λ) of the light used.

POLARIZATION

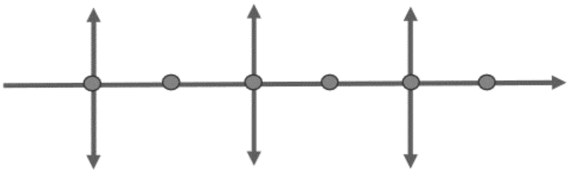
- ✓ Interference and diffraction demonstrate the wave nature of light.
- ✓ Both longitudinal and transverse waves can exhibit interference and diffraction effects.
- ✓ Polarization, however, can only be exhibited by transverse waves.
- ✓ The human eye cannot distinguish between polarized and unpolarized light.
- ✓ As light is an electromagnetic wave, the electric vector is mainly responsible for optical effects.
- ✓ The electric vector of a wave is referred to as the "light vector".
- ✓ Ordinary light is unpolarized, where the electric vector is randomly oriented in all directions perpendicular to the direction of light propagation.
- ✓ The phenomenon of confining the vibrations of the electric vector to a specific direction perpendicular to the direction of light propagation is known as polarization.
- ✓ Polarized light is referred to as linearly polarized or plane polarized light.
- ✓ The plane in which the vibrations occur is called the "plane of polarization."



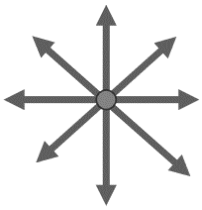
Polarized light

(c) 

Partially Polarized light

(d) 

Partially Polarized light

(e) 

Partially Polarized light

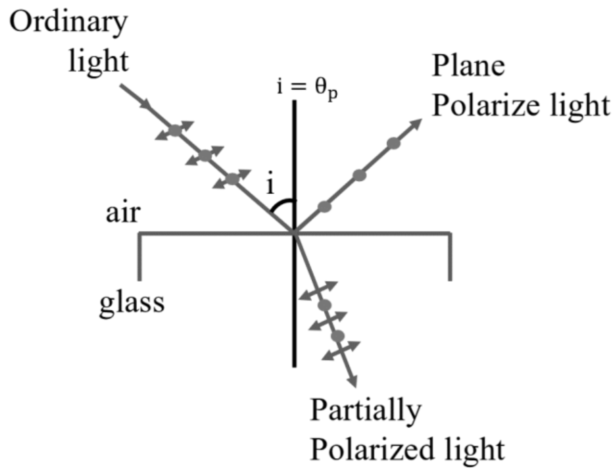
- Plane polarised light can be produced by different method
  i. Reflection ii. Refraction iii. Double refraction iv. Polaroids.
- Plane polarised light can be produced by different methods like
  i. Reflection ii. Refraction
  iii. Double refraction iv. Polaroids

Polarization by Reflection

- ✓ When ordinary light is incident on a transparent surface, such as a glass or water, both the reflected and refracted beams become partially polarized.
- ✓ The degree of polarization varies with the angle of incidence.
- ✓ At a specific angle of incidence known as the "polarizing angle," the reflected beam becomes completely plane polarized.
- ✓ The reflected beam exhibits vibrations of the electric vector perpendicular to the plane of the surface.
- ✓ The polarizing angle is dependent on the nature of the reflecting surface.

Brewster's Law: Brewster's Law states that when the angle of incidence equals the polarizing angle, the reflected and refracted rays will be perpendicular to each other.

- Brewster's law states that "The refractive index of a medium is equal to the tangent of polarising angle θ_p".



- The refractive index of the medium changes with wavelength of incident light and so polarising angle will be different for different wavelengths.
- The complete polarization is possible when incident light in monochromatic.

$$\mu = \frac{\sin\theta_p}{\sin r} = \frac{\sin\theta_p}{\sin\left(90^0 - \theta_p\right)} = \frac{\sin\theta_p}{\cos\theta_p} = \tan\theta_p$$

- From Brewster's law, $\mu = \tan\theta_p$.
- If $i = \theta_p$, the reflected light is completely polarised and the refracted light is partially polarised.
- If $i < \theta_p$ or $i > \theta_p$, both reflected and refracted rays get partially polarised.
- For glass $\theta_P = \tan^{-1}(1.5) \approx 57^o$

  For water $\theta_P = \tan^{-1}(1.33) \approx 53^o$

Polarisation by Refraction

When unpolarized light is incident on a glass plate at an angle equal to the polarizing angle, the reflected light becomes fully plane polarized, while the refracted light remains partially polarized.

If the incident light is allowed to pass through multiple thin glass plates arranged in parallel, the refracted light becomes fully plane polarized. This configuration of glass plates is known as a "pile of plates."

Polarisation by Double Refraction (Additional)

Bartholinus discovered the phenomenon of double refraction or birefringence, where incident light on a calcite crystal produces two refracted rays.

When viewing an ink dot on paper through a calcite crystal, two images are observed due to double refraction. One image remains stationary while the other image rotates around the stationary image. The rotating image follows a circular path around the stationary image.

The stationary image is formed by the ordinary ray, while the revolving image is formed by the extraordinary ray.

The principal section of the crystal refers to a plane that contains the optic axis and is perpendicular to the two opposite faces of the crystal.

The ordinary ray that emerges from the calcite crystal follows the laws of refraction, and its vibrations are perpendicular to the principal section of the crystal.

The extraordinary ray, on the other hand, does not follow the laws of refraction, and its vibrations occur within the plane of the principal section of the crystal.

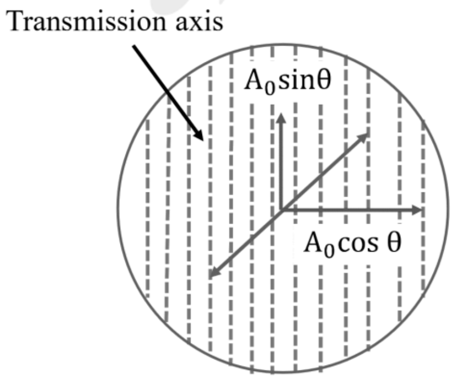
Both the ordinary and extraordinary rays are plane polarized.

Polaroid: Polaroid is an optical device used to produce plane polarised light making use of the phenomenon of "selective absorption".

- More recent type of polaroids are H-polaroids.
- H-polaroid's are prepared by stretching a film of polyvinyl alcohol three to eight times to original length.

Effect of polarizer on natural light:

If one of waves of an unpolarized light of intensity I_0 is incident on a polaroid and its vibration amplitude A_0 makes an angle θ with the transmission axis, then the component of vibration parallel to transmission axis will be $A_0 \cos\theta$ while perpendicular to it $A_0 \sin\theta$. Now as polaroid will pass only those vibrations which are parallel to its transmission axis, the intensity I of emergent light wave will be



$I = KA_0^2 \cos^2\theta$ (or)

$I = I_0 \cos^2\theta \left\lfloor \text{as } I_0 = KA_0^2 \right\rfloor$ In unpolarized light, all values of θ starting from 0 to 2π are equally probable, therefore

$$I = I_0 < \cos^2\theta > \Rightarrow I = \frac{I_0}{2\pi}\int_0^{2\pi} \cos^2\theta d\theta = \frac{I_0}{2}$$

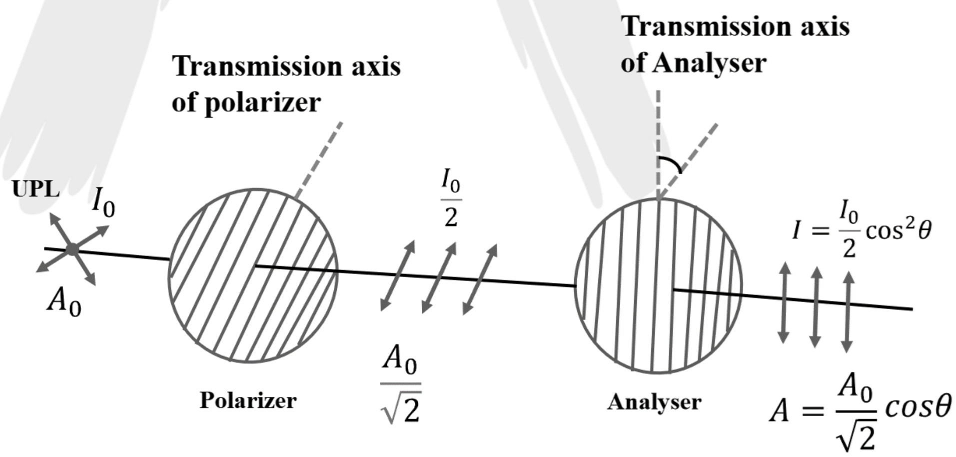
$$\therefore I = \frac{I_0}{2}$$

Thus, if unpolarized light of intensity I_0 is incident on a polarizer, the intensity of light transmitted through the polarizer is $\frac{I_0}{2}$. The amplitude of polarized light is $\frac{A_0}{\sqrt{2}}$.

Effect of Analyser on plane polarized light:

When unpolarized light passes through a polarizer, the transmitted light becomes linearly polarized, meaning its electric field oscillates in a specific direction. If this polarized light then continues through an analyzer, the intensity of the transmitted light varies depending on the angle between the transmission axes of the polarizer and the analyzer.

Malus's Law describes this relationship: "The intensity of the polarized light transmitted through the analyzer is proportional to the cosine squared of the angle between the planes of transmission of the polarizer and the analyzer." According to Malus's Law, when the angle between the transmission axes is 0^0 (parallel orientation), the transmitted intensity is maximum. As the angle increases to 90^0 (perpendicular orientation), the transmitted intensity reduces to zero.



Therefore, the intensity of polarized light after passing through analyser is $\boxed{I = \frac{I_0}{2}\cos^2\theta}$

Where I_0 is the intensity of unpolarized light. The amplitude of polarized light after passing through analyser is $A = \frac{A_0}{\sqrt{2}}\cos\theta$.

Case (i) : If $\theta = 0^0$ axes are parallel then $I = \frac{I_0}{2}$

Case (ii) : If $\theta = 90^0$ axes are perpendicular, then $I = 0$.

Case (iii) : If $\theta = 180^0$ axes are parallel then $I = \frac{I_0}{2}$

Case (iv) : If $\theta = 270^0$ axes are perpendicular then $I = 0$ Thus for linearly polarized light we obtain two position of minimum (zero) intensity, when we rotate the axis of analyser w.r.t. to polarizer by an angle 2π. In the above cases if the polariser is rotated with respected to analiser then there is no change in the outcoming intensity.

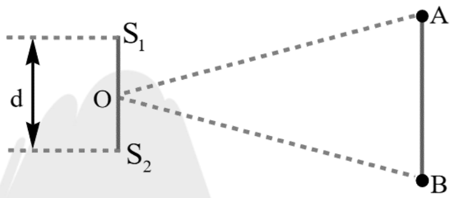
Note: In case of three polarizers P_1, P_2 and P_3 : If θ_1 is the angle between transmission axes of P_1 and P_2, θ_2 is the angle between transmission axes of P_2 and P_3. Then the intensity of emerging light from P_3 is $I = \frac{I_0}{2}\cos^2\theta_1 \cos^2\theta_2$.

EXERCISE – 1

1. The distance of n^{th} bright fringe to the $(n+1)^{th}$ dark fringe in Young's experiment is equal to

(A) $\frac{n\lambda D}{d}$ (B) $\frac{n\lambda D}{2d}$ (C) $\frac{\lambda D}{2d}$ (D) $\frac{\lambda D}{d}$

2. 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?

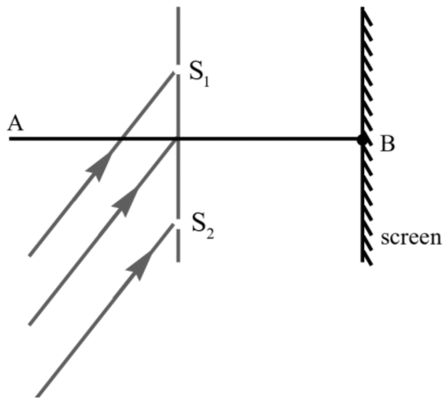


3. In a YDSE, distance between the slits and the screen is 1m, separation between the slits is 1mm and the wavelength of the light used is 5000 nm. The distance of 100th maxima from the central maxima is $\frac{1}{\sqrt{\alpha}}$ m. Find α ?

4. In a Young's double slit experiment the slit is illuminated by a source having two wavelengths of 400nm and 600nm. If distance between slits, d = 1mm, and distance between the plane of the slit and screen, D = 10m then the smallest distance from the central maximum where there is complete darkness is

(A) 2mm (B) 3mm (C) 12mm (D) there is no such point

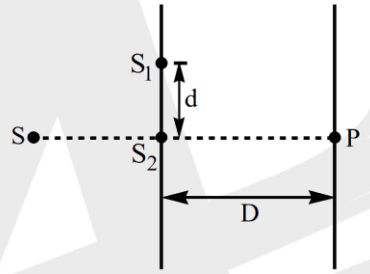
5. A beam of light parallel to central line AB is incident on the plane of slits in a YDSE experiment as shown. The number of minima obtained on the large screen is n_1. Now if the beam is tilted by some angle $(\neq 90°)$ as shown in the figure, then the number of minima obtained is n_2. Then



(A) $n_1 = n_2$ (B) $n_1 > n_2$ (C) $n_2 > n_1$ (D) None of these

6. The central fringe of the interference pattern produced by light of wavelength $6000\,\overset{\circ}{A}$ is found to shift to the position of 4th bright fringe after glass plate of refractive index 1.5 is introduced. The thickness of the glass plate would be $\frac{48}{n}\mu m$. Find n

7. In a YDSE experiment two slits S_1 and S_2 have separation of $d = 2mm$. The distance of the screen is $D = \frac{8}{5}m$. Source S starts moving from a very large distance towards S_2 perpendicular to S_1S_2 as shown in figure. The wavelength of mono-chromatic light is 500 nm. Find the number of maximas observed on the screen at point P as the source moves towards S_2 is



(A) 1000 (B) 2000 (C) 3000 (D) 4000

8. The YDSE apparatus is modified by placing an isotropic transparent plate of high melting point in front of one of the slits. The refractive index of the plate is $\mu r = 1.5$ at room temperature and its thickness is $t = 2\mu m$. The refractive index of plate will increase when temperature increases and temperature coefficient of refractive index of the plate (i.e., the fractional change in refractive index per unit rise in temperature) is $3\times10^{-3}\,/\,°C$. The incident light is having wavelength $\lambda = 6000\,\overset{\circ}{A}$. The separation between the slits is $d = 0.2\,cm$, and separation between the slit and the screen is 2m. If the plate is heated so that it temperature rises by $100\,°C$, then how many fringes will cross a particular point? Give your answer in integer only. (Neglect the thermal expansion of plate)

9. In young's double slit experiment one of the slits 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

(A) $\frac{I_m}{9}(4 + 5\cos\phi)$ (B) $\frac{I_m}{3}(1 + 2\cos^2\phi)$

(C) $\frac{I_m}{5}\left(1 + 4\cos^2\frac{\phi}{2}\right)$ (D) $\frac{I_m}{9}\left(1 + 8\cos^2\frac{\phi}{2}\right)$

10. In Young's double slit experiment, the 10th bright fringe is at a distance x from the central fringe. Then

(a) the 10th dark fringe is at a distance of $\frac{19x}{20}$ from the central fringe

(b) the 10th dark fringe is at a distance of $\frac{21x}{20}$ from the central fringe

(c) the 5th dark fringe is at a distance of $\frac{x}{2}$ from the central fringe.

(d) the 5th dark fringe is at a distance of $\frac{9x}{20}$ from the central fringe.

(A) a, b, c only (B) b, c, d only

(C) a, d only (D) a, b, c, d only

11. In a Young's double slit experiment, the fringes are displaced by a distance x when a glass plate of refractive index 1.5 is introduced in the path of one of the beams. When this plate is replaced by another plate of the same thickness, the shift of fringes is $3/2x$. The refractive index of the second plate is

(A) 2.25 (B) 2.0 (C) 1.75 (D) 1.25

12. A double slit experiment is performed with light of wavelength 500 nm. A thin film of thickness $2\mu m$ 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

13. In Young's double slit experiment, an interference pattern is obtained on a screen by a light of wavelength $6000A^0$ coming from the coherent sources S_1 and S_2 . At certain point p on the screen third dark fringe is formed. Then the path difference $S_1p - S_2p$ in micron is

(A) 0.75 (B) 1.5

(C) 3.0 (D) 4.5

14. 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 light coincide. Further, it is observed that the third bright fringe of known light coincides with the 4th bright fringe of the unknown light. The wavelength of the unknown light is

(A)393.4 nm (B)885.0 nm (C)442.5 nm (D)776.8 nm

15. In Young's experiment using monochromatic light, the fringe pattern shifts by a certain distance on the screen when a mica sheet of refractive index 1.6 and thickness 2 micron is introduced in the path of one of the interfering waves. The mica sheet is then removed and the distance between the slits and the screen is doubled. It is found that the distance between successive maxima now is the same as the observed fringe shift upon the introduction of the mica sheet. The wavelength of light is

(A) $5762\,\mathring{A}$ (B) $5825\,\mathring{A}$ (C) $6000\,\mathring{A}$ (D) $6500\,\mathring{A}$

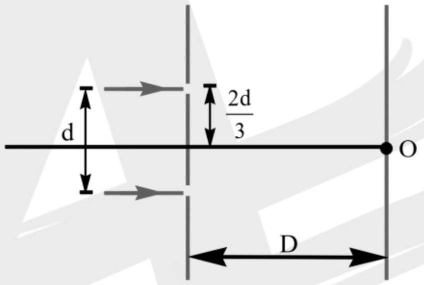
sEXERCISE – 2

1. A double – slit arrangement produces interference fringes that are $0.25°$ apart using wavelength 600nm. If angular separation is increased to $0.3°$ by changing wavelength of the light used, then the new wavelength (in nm) must be Since d is constant.

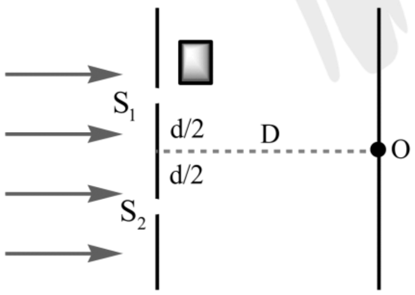
2. In Young's double slit interference experiment if the slit separation is made 3 folds, the fringe width becomes

(A) 6 fold (B) 3 fold (C) $\frac{3}{6}$fold (D) $\frac{1}{3}$fold

3. In the figure shown if a parallel beam of white light is incident on the plane of the slits then the distance of the nearest white spot on the screen from O is $\frac{d}{2\alpha}$. Find α ? [Assume d << D, λ << d]



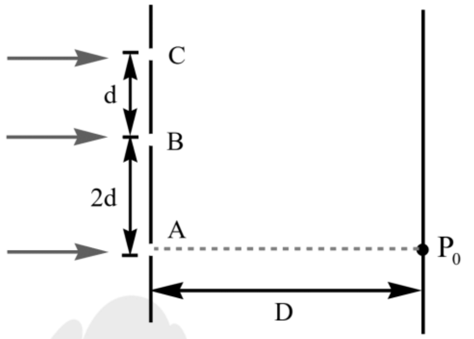
4. When a perfectly transparent glass slab $(\mu = 1.5)$ is introduced in front of upper slit of a usual double slit experiment,the intensity at 'O' reduces to $\frac{1}{2}$ times of its earlier value. Minimum thickness of slab would be $\frac{\alpha\lambda}{\beta}$. Find $\alpha + \beta$? [Assume that slab does not absorb any energy]



5. In Young's double slit experiment, slits are arranged in such a way that besides central bright fringe, there is only one bright fringe on either side of it. Slit separation d for the given condition cannot be (if λ is wavelength of the light used):

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

6. In the figure shown A, B and C are three slits each of them individually producing the same intensity I_0 at P_0 when they are illuminated by parallel beam of light of wavelength 'λ'. It is given that $BP_0 - AP_0 = \frac{\lambda}{2}$. Also given that $d << D$. Find:



(A) λ in terms of d and D is $\frac{4d^2}{D}$

(B) λ in terms of d and D is $\frac{2d^2}{D}$

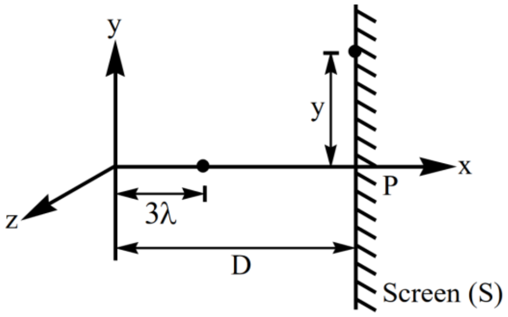
(C) Resultant intensity at P_0 is I_0

(D) Resultant intensity at P_0 is $2I_0$

7. Two monochromatic and coherent point sources of light, S_1 and S_2 of wavelength $4000\,\mathring{A}$, are placed at a distance 4mm from each other. The line joining the two sources is perpendicular to screen. The distance of the midpoint of S_1S_2 from the screen is $D = \sqrt{2}\,m$. Find the radius (non-zero value) of the smallest bright ring on the screen, using valid assumptions.

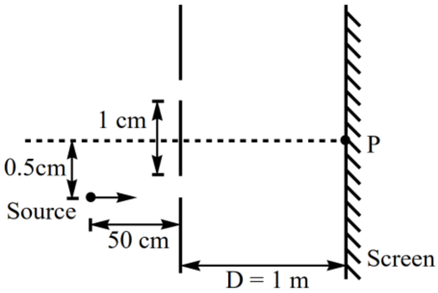
(A) 1cm (B) 2cm (C) 3cm (D) 4cm

8. Two coherent narrow slits emitting wavelength $\lambda = 500\,nm$ in the same phase are placed at (0,0,0) and $(3\lambda, 0, 0)$ in an x-y-z space as shown in the figure. The light from the two slits interfere on a screen S which is parallel to y-z plane and is placed at a distance $D = 2m$ from the origin. The distance of the nearest point on the screen from the centre of the screen P, where intensity is equal to that at P is y m then find the value of y^2.



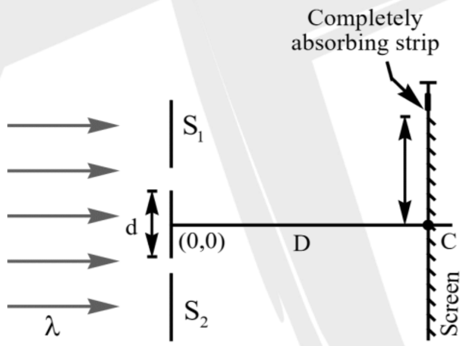
(A) 2.5 (B) 5 (C) 7.5 (D) 10

9. In a typical Young's double slit experiment a point source of monochromatic light is kept as shown in the figure. If the source is given an instantaneous velocity v = 1mm per second towards the screen, then find the instantaneous velocity of central maxima is



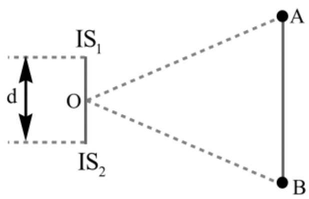
(A) 2 mm/s (B) 0.2 mm/s (C) 0.02 mm/s (D) 20 mm/s

10. Figure shows two identical narrow slits S_1 and S_2. A very small completely absorbing strip is placed at distance 'y' from the point C. 'C' is the point on the screen equidistant from S_1 and S_2. Assume $\lambda << d << D$ where λ,d and D have usual meaning. When S_2 is covered the force due to light acting on strip is 'f' and when both slits are opened the force acting on strip is 2f. Minimum positive 'y' (< D) coordinate of the strip in terms of λ, d and D is $\frac{\lambda D}{2md}$ then m is



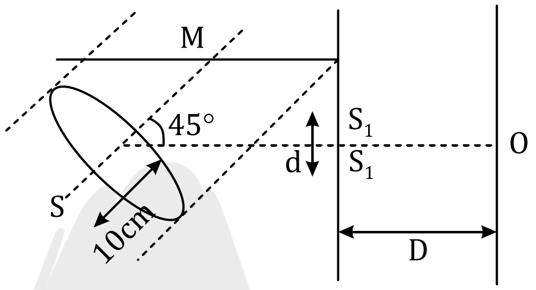
(A) 1 (B) 2 (C) 3 (D) 4

11. Figure shows two coherent sources S_1, S_2 vibrating in same phase. AB is 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.

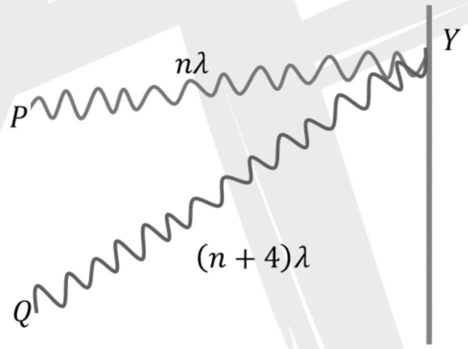


(A) 1 (B) 2 (C) 3 (D) 4

12. In Young's Double slit experiment, distance between the slits is d and that between the slits and screen is D. Angle between principle axis of lens and perpendicular bisector of S_1 and S_2 is 45^o. The point source S is placed at the focus of lens and aperture of lens is much larger than d. Assuming only the reflected light from plane mirror M is incident on slits, distance of central maxima from point O will be X then find 4X/D. Point O is the point where perpendicular bisector of S_1S_2 meets the screen. Assume all rays to be paraxial for lens.

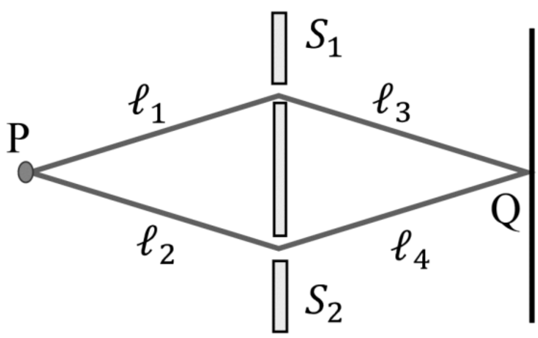


13. Fig shows a double slit experiment, P and Q are the two coherent sources. The path lengths PY and QY are $n\lambda$ and $(n+4)\lambda$ respectively where n is whole number and λ is wavelength. Taking the central bright fringe as zero, what is formed at Y?



(A) First Bright (B) First Dark (C) Fourth Bright (D) Second Dark

14. Two identical narrow slits S_1 and S_2 are illuminated by light of wavelength λ from a point source P. If, as shown in the diagram below, the light is then allowed to fall on a screen, and if n is a positive integer, the condition for destructive interference at Q is that



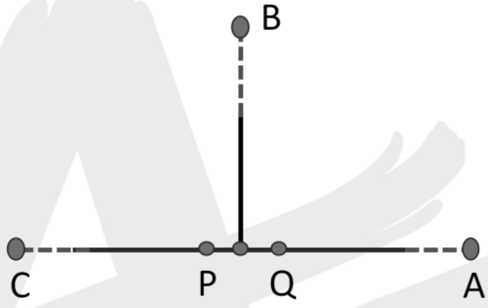
(A) $(\ell_1 - \ell_2) = (2n+1)\lambda/2$

(B) $(\ell_3 - \ell_4) = (2n+1)\lambda/2$

(C) $(\ell_3 + \ell_4) - (\ell_2 + \ell_4) = n\lambda$

(D) $(\ell_1 + \ell_3) - (\ell_2 + \ell_4) = (2n+1)\lambda/2$

15. Figure here shows P and Q as two equally intense coherent sources emitting radiations of wavelength 20 m. The separation PQ is 5m, and phase of P is ahead of the phase of Q by 90°. A, B and C are three distant points of observation equidistant from the mid-point of PQ. The intensity of radiations of A, B, C will bear the ratio



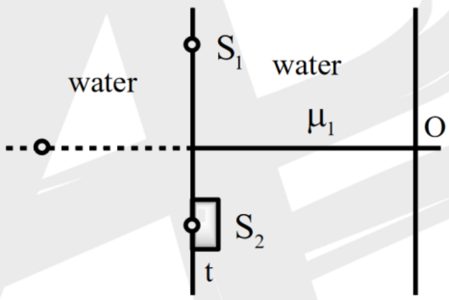
(A) 0 : 1 : 4 (B) 4 : 1 : 0 (C) 0 : 1 : 2 (D) 2 : 1 : 0

EXERCISE – 3

1. In Young's double slit experiment, we get 60 fringes in the field of view of monochromatic light of wavelength $4000\overset{o}{A}$. If we use monochromatic light of wavelength $6000\overset{o}{A}$, then the number of fringes that would be obtained in the same field of view is.

2. If the distance between the first maxima and fifth minima of a double slit pattern is 7mm and the slits are separated by 0.15 mm with the screen 50 cm from the slits, then wavelength (in nm) of the light used is.

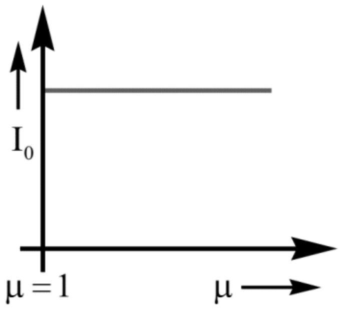
3. A Young' double slit experiment is conducted in water (μ_1) as shown in the figure, and a glass plate of thickness t and refractive index μ_2 is placed in the path of S_2. The magnitude of the phase difference at O is (Assume that 'λ' is the wavelength of light in air). O is symmetrical w.r.t. S_1 and S_2.

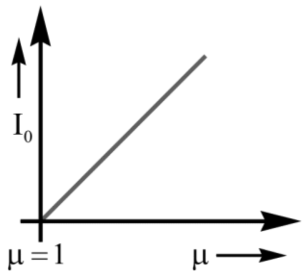


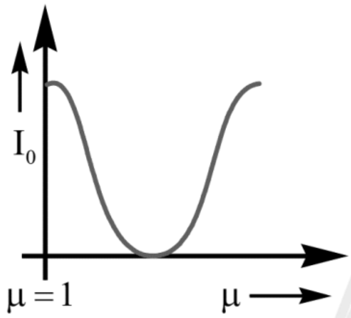
(A) $\left|\left(\frac{\mu_2}{\mu_1}-1\right)t\right|\frac{2\pi}{\lambda}$
(B) $\left|\left(\frac{\mu_1}{\mu_2}-1\right)t\right|\frac{2\pi}{\lambda}$
(C) $\left|(\mu_2-\mu_1)t\right|\frac{2\pi}{\lambda}$
(D) $\left|(\mu_2-1)t\right|\frac{2\pi}{\lambda}$

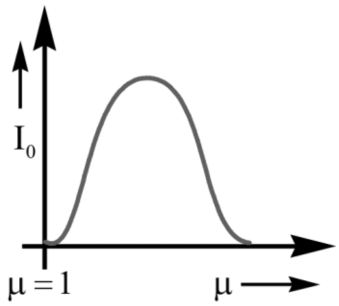
4. Interference fringes were produced using white light in a double slit arrangement. When a mica sheet of uniform thickness of refractive index 1.6 (relative to air) is placed in the path of light from one of the slits, the central fringe moves through some a distance. This distance is equal to the width of 30 interference bands if light of wavelength $4800\overset{o}{A}$ is used. The thickness (in $1\mu m$) of mica is.

5. In a YDSE experiment if a slab whose refractive index can be varied is placed in front of one of the slits then the variation of resultant intensity at mid – point of screen with 'μ' will be best represented by $(\mu \geq 1)$. [Assume slits of equal width and there is no absorption by slab; mid point of screen is the point where waves interfere with zero phase difference in absence of slab]

(A)


(B)


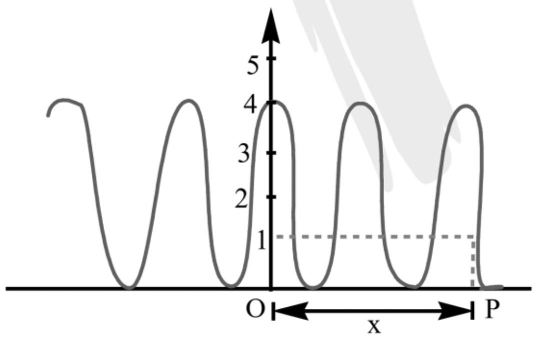
(C)


(D)


6. In the above equestion if the light incident is monochromatic and point O is a maxima, then the wavelength of the light incident cannot be

(A) $\frac{d^2}{3D}$ (B) $\frac{d^2}{6D}$ (C) $\frac{d^2}{12D}$ (D) $\frac{d^2}{18D}$

7. In a YDSE set – up light of wavelength 600 nm is used. The slits separation is 0.6 mm and the screen is at a distance of 180 cm from the plane of the slits. The plot of intensity is mapped across the screen. The value of x is $\frac{36}{n}\text{mm}$. Find n?



8. If one of the slits of a standard Young's double slit experiment is covered by a thin parallel sided glass slab so that it transmits only one half the light intensity of the other, then:

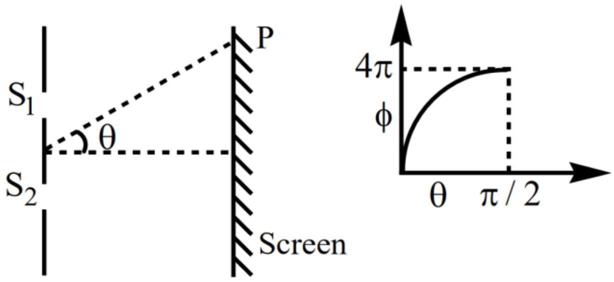
(A) The fringe pattern will get shifted towards the covered slit

(B) The fringe pattern will get shifted away from the covered slit

(C) The bright fringes will become less bright and the dark ones will become more bright

(D) The fringe width will remain unchanged

9. In a YDSE setup, we plot the phase difference (ϕ) between both waves at point P on the screen against the angular position (θ) of point P on the screen. The graph is as shown below.



(A) The distance $S_1S_2 = 2\lambda$

(B) There are a total of 8 minima on the screen

(C) The first maxima above the centre is at $\theta = \frac{\pi}{4}$

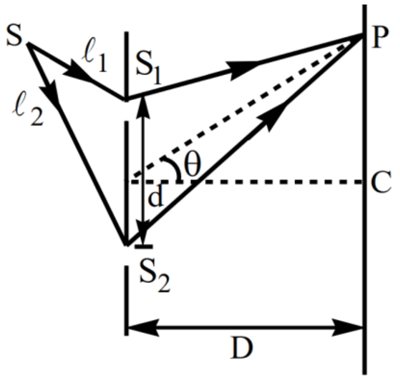
(D) At $\theta = \frac{\pi}{6}$, intensity is maximum

10. In a YDSE arrangement, white light is used to illuminate the slits. At point on the screen directly in front of the slits, which of these wavelengths is/are missing?

(λ = wavelength of light used, d = distance between the slits, D = separation between the slits and the screen, $d << D$):

(A) $\frac{d^2}{D}$ (B) $\frac{d^2}{3D}$ (C) $\frac{d^2}{4D}$ (D) $\frac{d^2}{8D}$

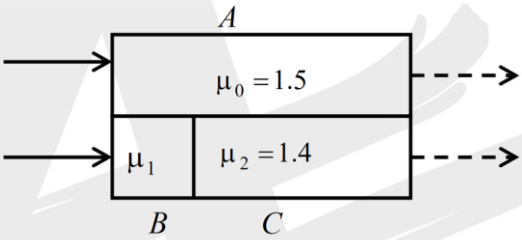
11. In a Young's double slit experiment the light source is at distance $\ell_1 = 5\mu m$ and $\ell_2 = 10\mu m$ from the slits. The light of wavelengths $\lambda = 500 nm$ incident on slits separated at a distance $d = 10\mu m$. A screen is placed at a distance $D = 2m$ way from the slits as shown in the figure. If 10 k maxima appear on the screen, then find the value of k. Round off your answer to the nearest integer, if required.



12. Monochromatic light is used in Young's double slit experiment. When one of the slits is covered by a transparent sheet of thickness $1.8\times10^{-5}m$, made of material of refractive index μ_1 the pattern shifts by 18 fringes. When another sheet of thickness $3.6\times10^{-5}m$, made of material of refractive index μ_2 is used (instead of first sheet), the pattern shifts by 9 fringes. Relation between μ_1 and μ_2 is given by

(A) $4\mu_2-\mu_1=3$ (B) $4\mu_1-\mu_2=3$ (C) $3\mu_2-\mu_1=4$ (D) $2\mu_1-\mu_2=4$

13. A slab of transparent materials is made as shown in the figure. Monochromatic parallel beams of light of same wave length are normally incident on the slabs. The thickness of C is twice the thickness of B. The number of waves in A = the number of waves in the combination of B and C. The refractive index of material A is $\mu_0=1.5$ and that of C is $\mu_2=1.4$



(A) The refractive index of B is 1.6

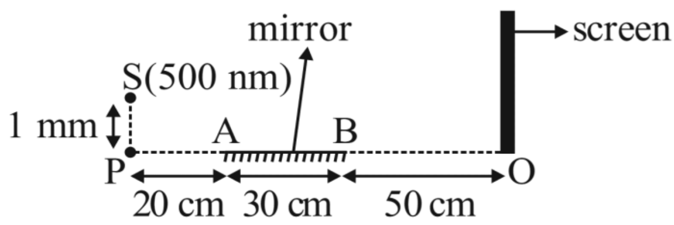
(B) The frequency of light in B is two times the frequency of light in C

(C) The refractive index of B is 1.7

(D) The frequency of light in B is the same as the frequency of light in C

14. In a YDSE bi-chromatic light of wavelengths 400 nm and 560 nm are used. Distance between the slits is 0.1 mm and distance between the plane of the slits and the screen is 1 m. The minimum distance (in millimeter) between two successive regions of complete darkness is equal to 4x. Find x

15. The total number of maxima formed on screen in the Lloyd's mirror arrangement shown is nearly 2*n*. Find *n*?

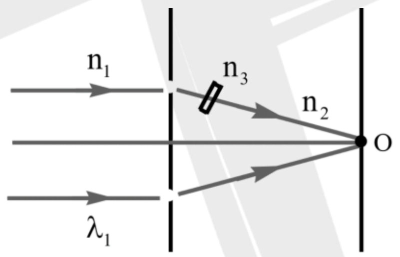


EXERCISE – 4

1. In a Young's double slit experiment, d = 1mm, $\lambda = 6000\,\overset{o}{A}$ and D = 1m (where d, λ and D have usual meaning). Each of slit individually produces same intensity on the screen. The minimum distance between two points on the screen having 75% intensity of the maximum intensity is $\frac{20}{n}\text{mm}$. Find n?

2. The path difference between two interfering waves at a point on the screen is $\frac{\lambda}{6}$. The ratio of intensity at this point and that at the central bright fringe will be $\frac{75}{n}$. Find n? (Assume that intensity due to each slit is same)

3. In the figure shown in a YDSE, a parallel beam of light is incident on the slits from a medium of refractive index n_1. The wavelength of light in this medium is ℓ_1. A transparent slab of thickness 't' and refractive index is put infront of one slit. The medium between the screen and the plane of the slits is n_2. The phase difference between the light waves reaching point 'O' (symmetrical, relative to the slits) is



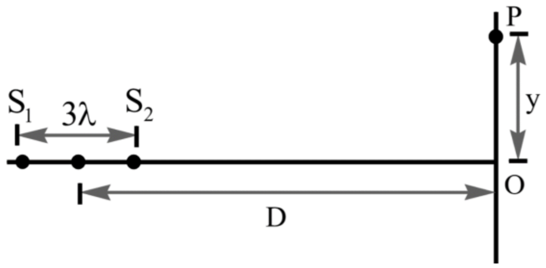
(A) $\frac{2\pi}{n_1\lambda_1}(n_3 - n_2)t$ (B) $\frac{2\pi}{\lambda_1}(n_3 - n_2)t$

(C) $\frac{2\pi n_1}{n_2\lambda_1}\left(\frac{n_3}{n_2} - 1\right)t$ (D) $\frac{2\pi n_1}{\lambda_1}(n_3 - n_2)t$

4. In a YDSE both slits produce equal intensities on the screen. A 100% transparent thin film is placed in front of one of the slits. Now the intensity of the geometrical centre of system on the screen becomes 75% of the previous intensity. The wavelength of the light is $6000\,\overset{o}{A}$ and $\mu_{film} = 1.5$. The thickness of the film cannot be

(A) $0.2\mu m$ (B) $1.0\mu m$ (C) $1.4\mu m$ (D) $1.6\mu m$

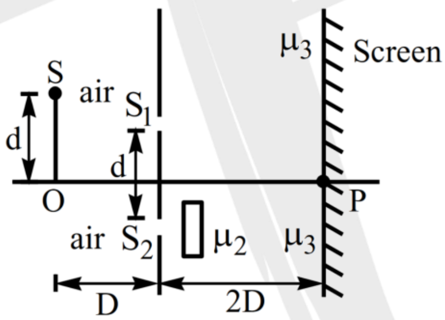
5. Figure shows two coherent microwave source S_1 and S_2 emitting waves of wavelength λ and separated by a distance 3λ. For $\lambda < D$ and $y \neq 0$, the minimum value of y for point P to be an intensity maximum is



(A) $\frac{D\sqrt{5}}{2}$ (B) $\frac{D\sqrt{7}}{2}$ (C) $\frac{D\sqrt{3}}{2}$ (D) $\frac{D\sqrt{15}}{2}$

6. Consider the situation shown in the figure. Two slits S_1 and S_2 are placed symmetrically about the line OP which is perpendicular to screen. The space between screen and slits is filled with a liquid of refractive index μ_3. A plate of thickness t and refractive index μ_2 is placed in front of one of the slit. Choose the correct alternatives.

[(Given that $D = 1m$, $d = 2mm$, $t = 6\times10^{-6}m$, $\mu_2 = 1.2$, $\mu_3 = 1.8$)]



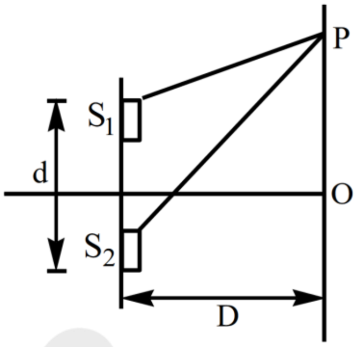
(A) Position of central maxima from point P is 2 mm

(B) Position of central maxima from point P is $\frac{2}{9}$mm

(C) Thickness of glass slab so that central maxima forms at point P is $\frac{20}{3}\times10^{-6}m$

(D) If glass slab is removed, the central maxima shifts by a distance of 2mm

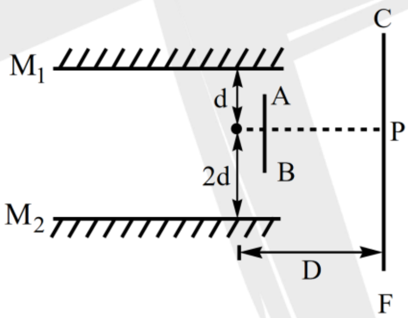
7. In a Young's double slit experiment two thin transparent sheets are used in front of the slits S_1 and S_2. One of thin sheet has refractive index $\mu_1 = 1.6$ and other has $\mu_2 = 1.4$. Both sheets have thickness $\frac{t_1 + t_2}{2}$ the central maxima is observed at a distance of 5mm from centre 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. Now central maxima is observed at a distance 8mm from centre O. Find the thickness of two sheets. Given $d = 1mm$, $D = 1m$. Then



(A) $t_1 = 1.2 \times 10^{-5}m$ (B) $t_1 = 3.3 \times 10^{-5}m$

(C) $t_2 = 1.7 \times 10^{-5}m$ (D) $t_2 = 2 \times 10^{-5}m$

8. M_1 and M_2 are two plane mirror and S is monochromatic source. AB is a 'stop' which stops direct light to reach CF and allows reflected light from M_1 and M_2 to reach CF. P is a point on CF such that SP is parallel to M_1 and M_2 and perpendicular to CF:



(A) Circular fringes will be formed on CF

(B) P will be central maxima

(C) P will be a point of maxima if $\lambda = \frac{6d^2}{D}$

(D) P will be a point of maxima if $\lambda = \frac{d^2}{D}$

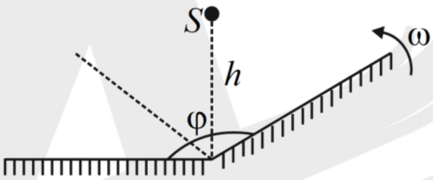
9. A glass sheet 12×10^{-3}mmthick is placed in the path of one of the interfering beams in a Young's double slit interference arrangement using monochromatic light of wavelength $6000\overset{o}{A}$. If the central bright fringe shifts a distance equal to width of 10 bands. What is the thickness of the sheet of diamond of refractive index 2.5 that has to be introduced in the path of second beam to bring the central bright fringe to original position?

(A) 1μm (B) 2μm (C) 3μm (D) 4μm

10. One slit of a Young's experiment is covered by a glass plate $(\mu_1 = 1.4)$ and the other by another glass plate $(\mu_2 = 1.7)$ of the same thickness. The point of central maxima on the screen, before the plates were introduced is now occupied by the third bright fringe. Find the thickness of the plates, when the wavelength of light used is $4000\,\mathring{A}$.

(A) 4 μm (B) 2.5 μm (C) 3 μm (D) 4.5 μm

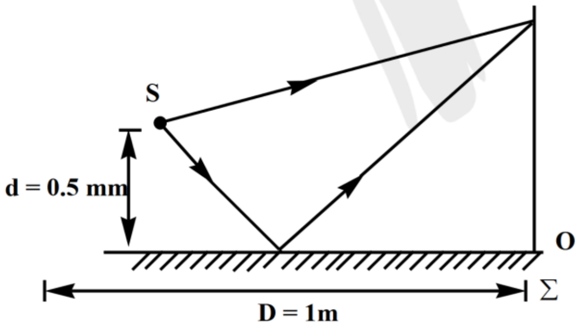
11. The angle between two flat mirrors is changed by rotating one of the mirrors around the edge of another with a constant angular velocity $\omega = 1.5 \deg/\sec$. Source of light S is placed as shown in the figure at a distance $h = 10\,cm$. At the initial moment mirrors were in the same plane $(\varphi = 180^o)$. After what minimum time (in second), 3 images will be formed by the mirrors.



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

12. A narrow slit S transmitting light of wave length λ is placed a distance d above a large plane mirror as shown in the figure. The light coming directly form the slit and that coming after reflection from the plane mirror interfere on a screen Σ placed at a distance D from the slit. Assume that the mirror is 100% reflecting.

(Given $D = 1m$, $d = 0.5mm$ and $\lambda = 500\,nm$)



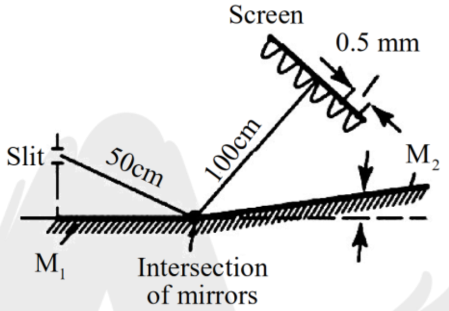
(A) Distance from O, where first interference maximum is formed on the screen is $\frac{1}{4}$ mm.

(B) Distance from O, where closest interference minimum is formed on the screen is zero.

(C) Fringe width of the interference pattern formed on the screen is $\frac{1}{2}$ mm.

(D) Closest point to O on the screen where waves interfere with a phase difference of $\frac{\pi}{2}$ is $\frac{1}{8}$ mm

13. The small angle θ between two plane, adjacent reflecting surfaces is determined by examining the interference fringes produced in a Fresnel mirror experiment. A source slit is parallel to the intersection between the mirrors and 50 cm away. The screen is 1 m from the same intersection, measured along the normal to the screen. When illuminated with sodium light (589.3 nm), fringes appear on the screen with a spacing of 0.5 mm. Now choose the correct statement(s): (The reflected light is incident almost normally on the screen where we are observing the fringes).



(A) The spacing between the fringes is independent of the angle between the mirrors.

(B) The spacing between the fringes will be independent of the distance of the source from the intersection line of the mirrors.

(C) The spacing between the fringes depends on the distance of the screen from the intersection lines.

(D) The angle between the mirrors is about 1.8×10^{-3} radians.

14. In a YDSE experiment, thin films of thickness t_1 and t_2 are placed in front of slits S_1 and S_2 as shown in fig-1 and fig-2. It is observed that first minima and second maxima are produced at point 'O' in first and second experiment respectively. Point 'O' and 'S' are symmetrical with respect to S_1 and S_2. Both the films have same refractive index if $\frac{t_2}{t_1}=\frac{x}{5}$, then calculate 'x'.

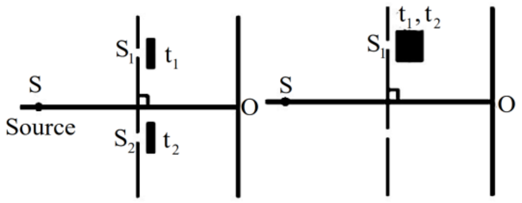
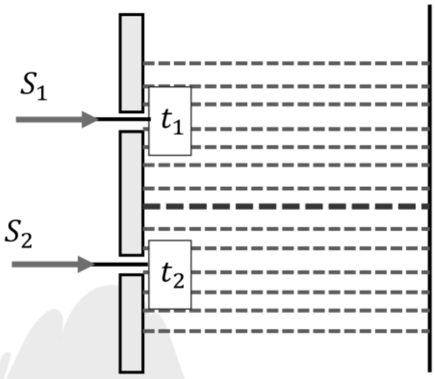


Figure -1 Figure -2

15. A screen is at a distance D = 80cm from a diaphragm having two narrow slits S_1 and S_2 which are $d = 2\text{mm}$ apart. Slit S_1 is covered by a transparent sheet of thickness $t_1 = 2.5\mu\text{m}$ and slit S_2 is covered by another sheet of thickness $t_2 = 1.25\mu\text{m}$ as shown in figure. Both sheets are made of same material having refractive index $\mu = 1.4$. Water is filled in the space between the diaphragm and screen. A monochromatic light beam of wavelength $\lambda = 5000A^0$ is incident normally on the diaphragm. Assuming intensity of beam to be uniform calculate ratio of intensity at C to the maximum intensity of interference pattern obtained on the screen. $[\mu_\omega = 4/3]$.

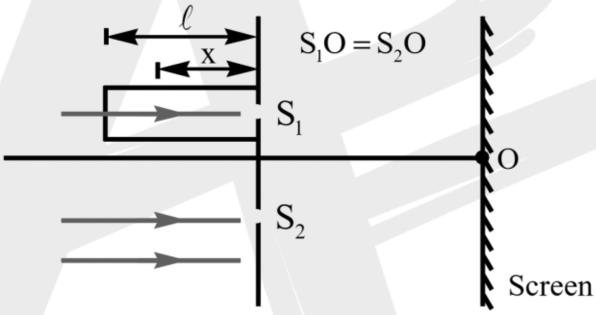


(A) $\frac{3}{4}$ (B) $\frac{2}{3}$ (C) $\frac{8}{9}$ (D) $\frac{5}{7}$

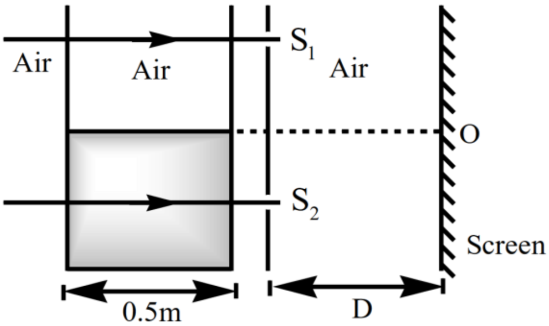
EXERCISE – 5

1. Let S_1 and S_2 be the two slits in Young's double slit experiment. If central maxima is observed at P and angle $\angle S_1PS_2 = \theta$, then the fringe width for the light of wavelength λ will be $\frac{\alpha\lambda}{\beta\theta}$. Find $\alpha+\beta$? (Assume θ to be a small angle)

2. In the figure shown, a parallel beam of light is incident on the plane of the slits of a Young's double slit experiment. Light incident on the slit, S_1 passes through a medium of variable refractive index $\mu = 1 + ax$ (where 'x' is the distance from the plane of slits as shown), upto a distance 'ℓ' before falling on S_1. Rest of the space is filled with air. If at 'O' a minima is formed, then the minimum value of the positive constant a (in terms of ℓ and wavelength 'λ' in air) is $\frac{\alpha\lambda}{\ell^\beta}$. Find $\alpha+\beta$?

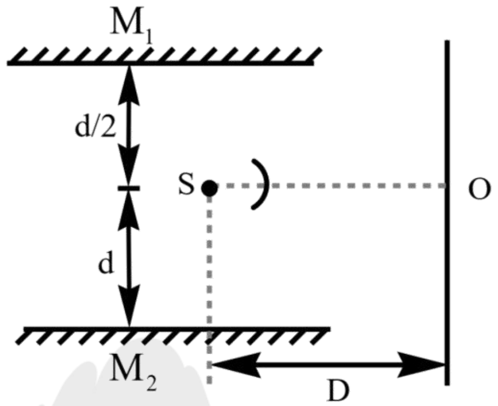


3. In a YDSE, radio waves of wave length $\lambda = 50\text{mm}$ (in air) are used. Two parallel beams are first passed through a glass vessel of base length 0.5m as shown, filled upto some height (shaded region) with a liquid whose refractive index is vaying with distance 'x' (in meters) from the left face as $\mu(x) = \mu_0(a+x)$ where $\mu_0 = \frac{4}{3}\text{m}^{-1}$ and a = 1m. if intensity due to each slit at O (symmetrical with respect to S_1 and S_2) is I. Find the intensity at point O on the screen.



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

4. 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 wave length λ is not reaching directly on the screen. Then λ is $[D >> d,\ d >> \lambda]$

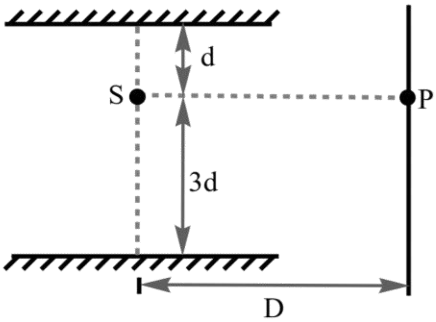


(A) $\frac{3d^2}{D}$ (B) $\frac{3d^2}{2D}$ (C) $\frac{d^2}{D}$ (D) $\frac{2d^2}{D}$

5. Consider an YDSE that has different slits width, as a result, amplitudes of waves from two slits are A and 2A, respectively. If I_0 be the maximum intensity of the interference pattern, then intensity of the pattern at a point where phase difference between waves is ϕ, is $\frac{I_0}{9}(\alpha + \beta\cos\phi)$. Find $\alpha + \beta$

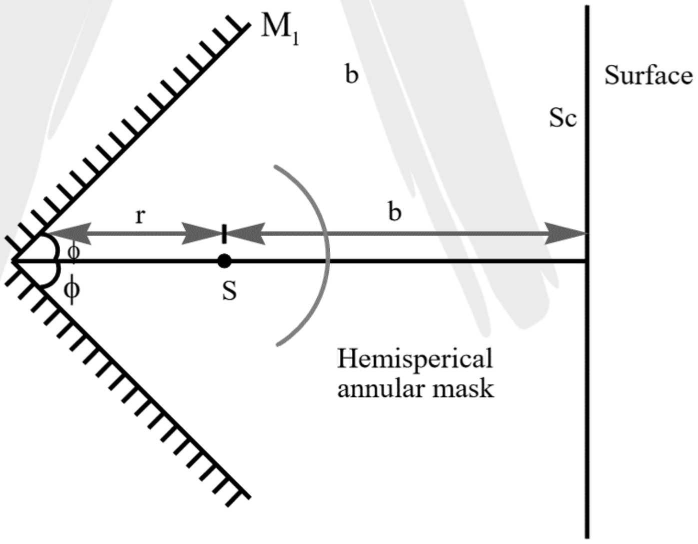
6. A transparent slab of thickness t and refractive index μ is inserted in front of upper slit of YDSE apparatus. The wavelength of light used is λ.
Assume that there is no absorption of light by the slab. Mark the incorrect statement.
(A) The intensity of dark fringes will be zero if slits are identical
(B) The change in optical path due to insertion of plate is μt
(C) For marking intensity maximum at the centre of screen the thickness could be $\frac{5\lambda}{(\mu-1)}$
(D) For marking intensity zero at the centre of screen, the thickness could be $\frac{5\lambda}{2(\mu-1)}$

7. Consider the optical system shown in the figure that follows. The point source of light S is having wavelength equal to λ. The light is reaching screen only after reflection. For point P to be 2nd maxima, the value of λ is $\frac{nd^2}{D}$. Find n $(D >> d$ and $d >> \lambda)$



8. A lens of diameter 5.0 cm and focal length f = 20.0 cm was cut along the diameter into two identical halves. In the process, a thin layer of lens (a = 1.0 mm) is lost. Then the halves were put together to form a composite lens. A source slit is placed 10 cm from the lens, emitting light of wavelength $\lambda = 600\,\text{nm}$. Behind the lens, a screen wall located at a distance b = 80 cm from lens. The fringe width is $\frac{6}{n}\text{mm}$. Find n

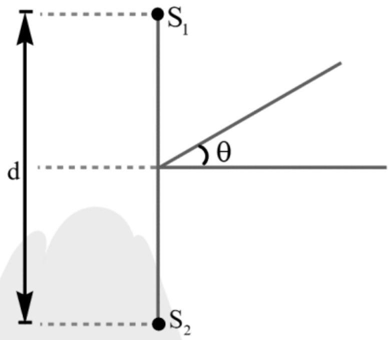
9. Two mirrors M_1 and M_2 make an angle ϕ with line AB. A point source S is kept at a distance r from the point of intersection of mirrors. A small hemispherical annular mask is kept close to S so that no ray emanating from S directly reaches the screen kept at a distance b from the source. Interference pattern of rays reflected from M_1 and M_2 is observed on the screen. Find the fringe width of this interference pattern, λ = wavelength of light being emitted by source.



(A) $\dfrac{\lambda\left(b+2r\sin^2\phi\right)}{2r\sin 2\phi}$ (B) $\dfrac{\lambda\left(b+2r\cos 2\phi\right)}{2r\sin 2\phi}$

(C) $\dfrac{\lambda\left(b+r\cos 2\phi\right)}{2r\sin 2\phi}$ (D) $\dfrac{\lambda\left(b+2r\cos 2\phi\right)}{r\sin 2\phi}$

10. In an interference arrangement, similar to Young's double – slit experiment, the slits S_1 and S_2 are illuminated with coherent microwave sources, each of frequency 10^6Hz. The sources are synchronized to have zero phase difference. The slits are separated by distance $d = 150\text{m}$. The intensity I_θ is measured as a function of θ, where θ is defined as shown in figure. If I_0 is maximum intensity, then $I_{(\theta)}$ for $0 \le \theta \le 90°$ is given by:



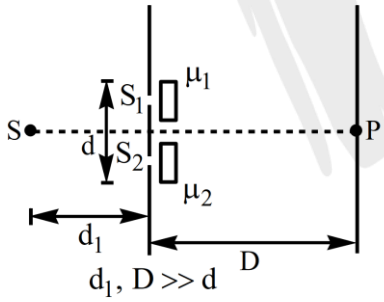
(A) $I_{(\theta)} = I_0$ for $\theta = 0°$

(B) $I_{(\theta)} = \left(\frac{I_0}{2}\right)$ for $\theta = 30°$

(C) $I_{(\theta)} = 0$ for $\theta = 90°$

(D) $I_{(\theta)}$ is constant for all values of θ

11. In Young's experiment, the upper slit is covered by a thin glass plate of refractive index $\frac{4}{3}$ and of thickness 9λ, where λ is the wavelength of light used in the experiment. The lower slit is also covered by another glass plate of thickness 2λ and refractive index $\frac{3}{2}$, as shown in figure. If I_0 is the intensity at point P due to slits S_1 and S_2 each, then:



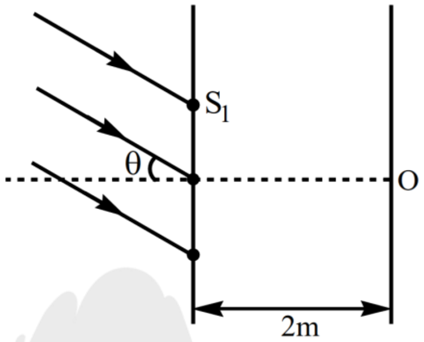
(A) Intensity at point P is $4I_0$

(B) Two fringes have been shifted in upward direction after insertion of both the glass plates together

(C) Optical path difference between the waves from S_1 and S_2 at point P is 2λ

(D) If the source S is shifted upwards by a small distance d_2 then the fringe originally at P after inserting the plates, shifts downward by $D\left(\frac{d_2}{d_1}\right)$

12. A parallel beam of light $\left(\lambda = 5000\,\overset{\circ}{A}\right)$ is incident at an angle $\theta = 30°$ with the normal to the slit plane in a Young's double slit experiment. The intensity due to each slit is I_0. Point O is equidistant from S_1 and S_2. The distance between slits is 1mm, then:



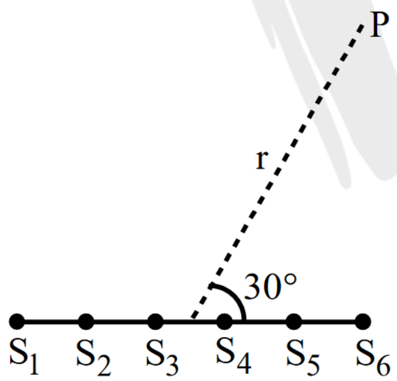
(A) The intensity at O is $4I_0$

(B) The intensity at O is zero

(C) The intensity at a point on the screen 4mm above O is $4I_0$

(D) The intensity at a point on the screen 4mm above O is zero

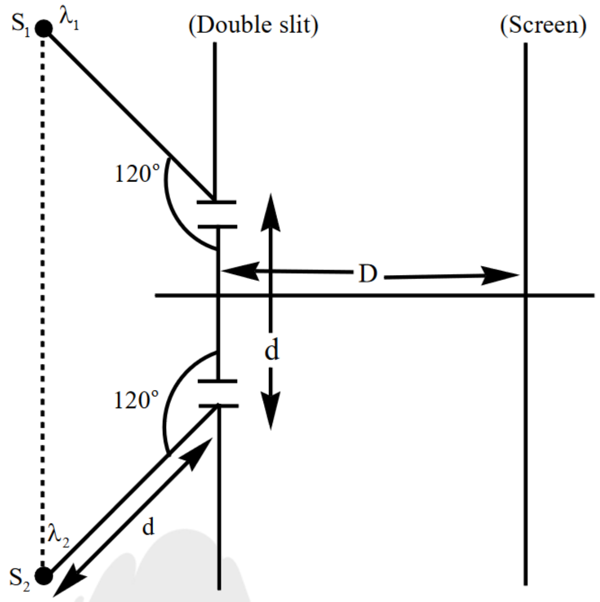
13. Each light source $(S_1, S_2, S_3, S_4, S_5, S_6)$ in a line has same power, same wavelength (λ) and all are in phase. Distance between consecutive sources is a if smallest value of a is a' such that point $P(r >> a)$ has zero light intensity, find the value of $\left(\frac{\lambda}{a'}\right)^2$



(A) 9 (B) 18

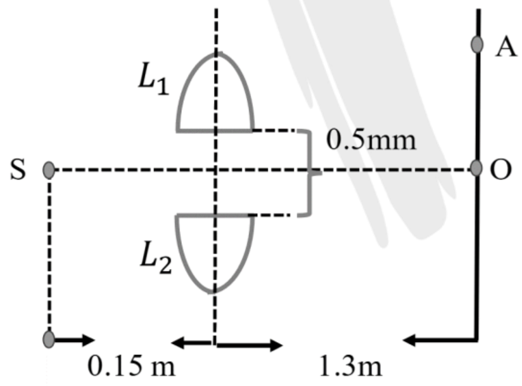
(C) 15 (D) 27

14. Two source S_1 and S_2 emitting wavelengths λ_1 and λ_2 are placed to the left of the double slit in Young's Double slit Experiment. The distance between the central maximas due to two wavelengths on the screen is(given D>>>>d)



(A) $\sqrt{\frac{4-2\sqrt{3}}{2\sqrt{3}-3}}D$ (B) $2\sqrt{\frac{2\sqrt{3}-3}{4-2\sqrt{3}}}D$ (C) $\sqrt{\frac{2\sqrt{3}-3}{4-2\sqrt{3}}}D$ (D) $2\sqrt{\frac{4-2\sqrt{3}}{2\sqrt{3}-3}}D$

15. In the given figure, S is a monochromatic point source emitting light of wavelength $\lambda = 500\text{nm}$ A thin lens of circular shape and focal length 0.1m is cut into two identical halves L_1 and L_2 by a plane passing through diameter. The two halves are symmetrically placed about the central axis SO with gap of 0.5mm. The distance along the axis the from S to L_1 and L_2 is 0.15m, while that from L_1 and L_2 to 'O' is 1.3m. The screen at O is normal to SO. If the third maxima occurs at point A on the screen find the distance OA?



(A) 1 mm (B) 2 mm (C) 1.5 mm (D) 2.5 mm

PROFICIENCY TEST -1

1. In a Young's double slit experiment, the separation between the slits is d, distance between the slit and screen is D $(D >> d)$. In the interference pattern, there is a maxima exactly in front for each slit. Then the possible wavelength used in the experiment are

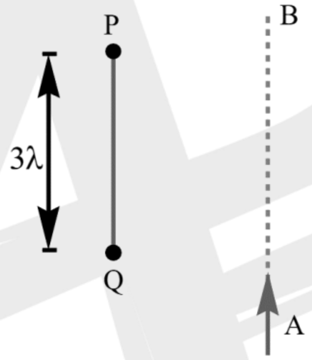
(A) $\frac{d^2}{D}, \frac{d^2}{2D}, \frac{d^2}{3D}$

(B) $\frac{d^2}{D}, \frac{d^2}{3D}, \frac{d^2}{5D}$

(C) $\frac{d^2}{2D}, \frac{d^2}{4D}, \frac{d^2}{6D}$

(D) None of these

2. Two coherent light sources P and Q each of wavelength λ are separated by a distance 3λ as shown. The maximum number of minima formed on line AB which runs from $-\infty$ to $+\infty$ is



3. In Young's double slit experiment, if the widths of the slit are in the ratio 4:9, ratio of intensity of maxima to intensity of minima will be

(A) 25:1 (B) 9:4 (C) 3:2 (D) 81:16

4. In YDSE of equal width slits, if intensity at the centre of screen is I_0, then intensity at a distance of $\frac{\beta}{4}$ from the central maxima is $\frac{I_0}{n}$. Find n (β is the fringe width)

5. A light with wavelength $(\lambda = 550\,\text{nm})$ from a distance source falls normally on the surface of a glass wedge with refractive index 1.5. A fringe pattern whose neighbouring maxima on the wedge are separated by a distance $(\Delta x = 11\,\mu\text{m})$ is observed in reflected light. The angle between the wedge faces is

(A) $\frac{1}{30}$ rad

(B) $\frac{1}{60}$ rad

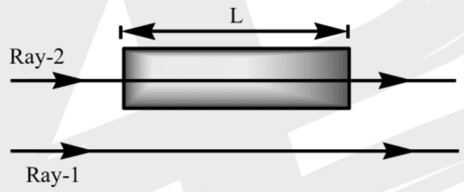
(C) $\frac{1}{90}$ rad

(D) $\frac{1}{45}$ rad

6. In a Young's double slit experiment the intensity at a point where the path difference is $\frac{\lambda}{6}$ (λ being the wavelength of the light used) is I. if I_0 denotes the maximum intensity, $\frac{I_0}{I}$ is equal to

(A) $\sqrt{2}$ (B) $\frac{4}{3}$ (C) 2 (D) $\frac{2}{\sqrt{3}}$

7. As shown in arrangement waves with identical wavelength and amplitudes and that are initially in phase travel through different media. Ray – 1 travels through air and Ray – 2 through a transparent medium for equal length L in four different situations. In each situation the two rays reach a common point on the screen. The number of wavelength in length L is N_1 for Ray – 1 and N_2 for Ray – 2. The order of situation according to the intensity of the light at the common position in descending order



Situation	1	2	3	4
N_1	2.25	1.80	3.00	3.25
N_2	2.75	2.80	3.25	4.00

(A) $I_3 = I_4 > I_2 > I_1$ (B) $I_1 > I_3 = I_4 > I_2$

(C) $I_1 > I_2 > I_3 > I_4$ (D) $I_2 > I_3 = I_4 > I_1$

8. A thin paper of thickness 0.02 mm having refractive index 1.45 is pasted across one of the slits in a Young's double slit experiment. The paper transmits $\frac{4}{9}$ of light falling on it $(\lambda_{light} = 600\,nm)$:

(A) Amplitude of light wave transmitted through the paper will be $\frac{2}{3}$ times that of incident wave

(B) The ratio of maximum and minimum intensity in the fringe pattern will be 25

(C) The total number of fringe crossing the centre if an identical paper is pasted on the other slit is 30

(D) The ratio of maximum and minimum intensity in the pattern will be 5

9. In a particular set up, interference is observed on a screen as shown. Wavelength of light emitted by source is $4000\,\overset{o}{A}$. Out of two coherent sources, one is obtained by reflection with a plane mirror of length 2m. If I_{max} is the maximum intensity in interference pattern, find number of such points in the pattern.

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

10. The outer surface of a transparent glass slab of refractive index $\mu_1 = 1.5$ is coated by a thin layer of transparent medium of refractive index $\mu_2 = 1.6$. Orange light of wave length $6400\,\overset{o}{A}$ fall normally on the coat. The reflected light at the upper surface and the lower surface of the coat interfere destructively. Find the thickness of coat is

(A) $2\times10^{-6}\,m$ (B) $4\times10^{-7}\,m$

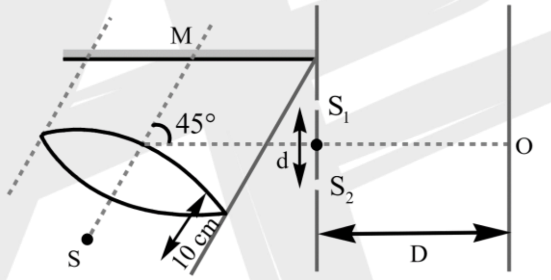
(C) $2\times10^{-7}\,m$ (D) $4\times10^{-6}\,m$

PROFICIENCY TEST -2

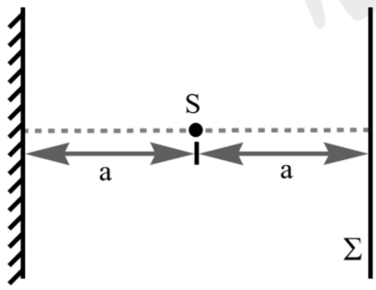
1. If the first minima in a Young's slit experiment occurs directly infront of one of the slits. (distance between slit and screen D = 12 cm and distance between slits d = 5cm) then the wavelength(s) of the radiation used is

(A) 2 cm only
(B) 4 cm only
(C) $2m, \frac{2}{3}cm, \frac{2}{5}cm$
(D) $4cm, \frac{4}{3}cm, \frac{4}{5}cm$

2. In Young's double slit experiment, distance between the slits is d and that between the slits and screen is D. angle between principle axis of lens and perpendicular bisector of S_1 and S_2 is $45°$. The point source S is placed at the focus of lens and aperture of lens is much larger than d. assuming only reflected light from plane mirror M is incident on slits, distance of central maxima from O will be $\frac{D}{\sqrt{\alpha}}$. Find α ?



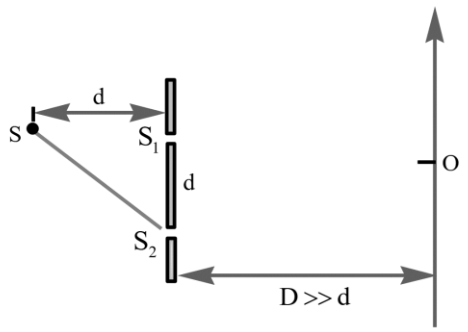
3. A point source of light S is place in front of a perfectly reflecting mirror as shown in the figure. Σ is a screen. The intensity at the centre of screen is found to be I. if the mirror is removed, then the intensity at the centre of screen is $\left(\frac{\alpha I}{5+\beta}\right)$. Find $\alpha + \beta$



4. In standard YDSE setup, the slits are 0.5 mm apart and interference is observed on a screen placed at a distance of 100 cm from the slits. It is found that the 9th bright fringe is at a distance of 8.835 mm from the 2nd dark fringe from the centre of fringe pattern. The wavelength of light used is

(A) $2.945 \times 10^{-7}m$ (B) $5.888 \times 10^{-7}m$ (C) $8.835 \times 10^{-7}m$ (D) $11.78 \times 10^{-7}m$

5. To make the central fringe at the centre O, a mica sheet of refractive index 1.5 is introduced. Choose the correct statement



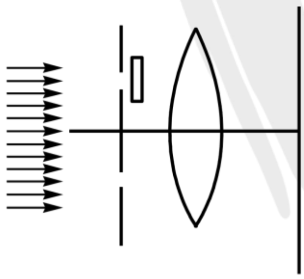
(A) The thickness of sheet is $2(\sqrt{2}-1)d$ infront of S_1

(B) The thickness of sheet is $(\sqrt{2}-1)d$ infront of S_2

(C) The thickness of sheet is $2\sqrt{2}d$ infront of S_1

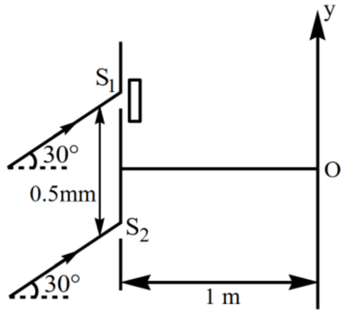
(D) The thickness of sheet is $(2\sqrt{2}-1)d$ infront of S_1

6. The intensity received at the focus of the lens is I when no glass slab has been placed in front of the slit. Both the slits are of the same dimension and the plane wavefront incident perpendicularly on them has wavelength λ. On placing the glass slab, the intensity reduces to $\frac{3I}{4}$ at the focus. Find out the minimum thickness of the glass slab if its refractive index is $\frac{3}{2}$. Given $\lambda = 6000\,\mathring{A}$, $\mu = 1.5$.



(A) $1000\mathring{A}$ (B) $1500\mathring{A}$ (C) $2000\mathring{A}$ (D) $2500\mathring{A}$

7. In Young's double slits experiment parallel monochromatic electromagnetic waves of wavelength $3 \times 10^{-5} m$ fall on the slits at an angle of 30° with the normal to the plane of slits as shown in the figure. A transparent sheet of thickness $5 \times 10^{-5} m$ and refractive index 1.5 is introduced near the slit S_1. The distance between the two slits is 0.5mm and the distance between the plane of slits and the screen is 1m. Find the y – coordinate of the closest maxima to the origin on the positive y – axis.

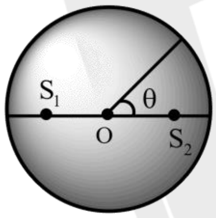


(A) 1m (B) 0.1m (C) 0.01m (D) 0.001m

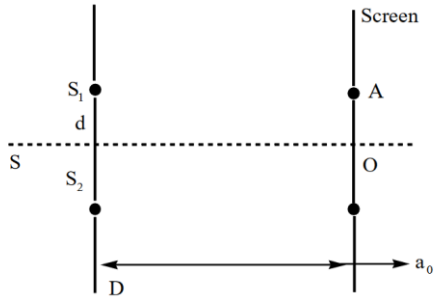
8. White light is incident normally on a thin sheet of plastic film in air. The reflected light has a minima for $\lambda = 512$nm and $\lambda = 640$nmin the visible spectrum. What is the minimum thickness (in μm) of the film? (Given: $\mu = 1.28$)

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

9. Two coherent sources S_1 and S_2 separated by distance 2λemit light of wavelength λin phase as shown in the figure. A circular wire of radius 100λ is placed in such a way that S_1S_2 lies in its plane and the mid – point of $S_1S_2$is at the centre of wire. The angular positions on the wire for which intensity reduces to half of its maximum value for the first time is given as θ. Find the value of $32\cos\theta$.



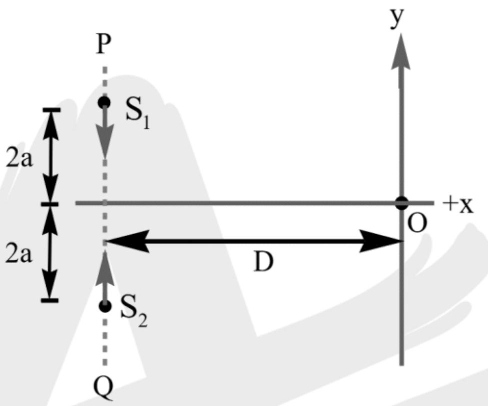
10. In the given YDSE apparatus as shown in figure, wavelength of light used is λ. The initial distance between screen and plane of slits is 'D'. Point A is point on screen where 4th order maxima lies. Now, screen is moved from rest with constant acceleration a_0 towards right. Then find the time after which third order maxima is formed at point A



(A) $\sqrt{\frac{2D}{3a_0}}$ (B) $\sqrt{\frac{D}{a_0}}$ (C) $2\sqrt{\frac{D}{a_0}}$ (D) $\sqrt{\frac{D}{2a_0}}$

PROFICIENCY TEST -3

1. In the figure shown S_1 and S_2 are two coherent sources emitting light of wavelength 'λ' and having no initial phase difference. S_1 and S_2 oscillate simple harmonically with amplitude 'a' each and frequency 'f' each on the line PQ which is perpendicular to the x – axis. The initial position and initial direction of motion of 'S_1' and 'S_2' are shown in the figure. S_1 and S_2 are at their mean position at t = 0 sec. find the y – coordinates of 3rd maxima at time 't' . assume that $\lambda << a$ and $a << D$.



(A) $\frac{3\lambda D}{d}$ (B) $\frac{4\lambda D}{d}$ (C) $\frac{2\lambda D}{d}$ (D) $\frac{\lambda D}{d}$

2. In Young's double slit experiment, the fringes are displaced by a distance x when a glass plate of refractive index 1.5 is introduced in the path of one of the beams. When this plate is replaced by another plate of the same thickness, the shift of fringes is $\left(\frac{3}{2}\right)$x. The refractive index of the second plate is $\frac{175}{n}$. Find n?

3. One of the slits of a double slit system in Young's experiment is wider than the other so that the amplitude of the light reaching the central part of the screen from one slit, acting alone, is twice that from the other slit acting alone. Assume that $\beta = \frac{\pi d \sin\theta}{\lambda}$, where d is the centre to centre distance between the two slits and λ, the wavelength of light used. Then I_θ, the intensity of the resultant interference wave in the direction θ to central maximum on the screen will be correctly given by

(A) $I_\theta = (4I_0)\cos^2\beta$ (B) $I_\theta = \frac{4I_0}{9}(\cos^2\beta)$

(C) $I_\theta = \frac{4I_0}{9}(1+\cos^2\beta)$ (D) $I_\theta = I_0\left[1+8\cos^2\beta\right]$

Where I_0 is the intensity of the individual wave due to the narrow slit alone.

4. At a point on the screen at distance D from the slits in standard YDSE experiment, 3rd maxima is observed at t = 0. Now screen is slowly moved with constant speed away from the slits in such a way that the centre of slits and centre of screen always lie on same line and at t = 1sec, the intensity at that point is observed to be $\left(\frac{3}{4}\right)^{th}$ of maximum intensity in between 2nd and 3rd maxima. The speed of screen is $\frac{nD}{\alpha+6}$. Find $n+\alpha$

5. In a YDSE setup the intensity due to two coherent beams differ from each other by 1%. If one of the beam has intensity I, then intensity of minima is $\frac{1}{n}\left(10^{-4}\right)$. Find n

6. In a regular YDSE, when thin film of refractive index μ is placed in front of the lower slit then it is observed that the intensity at the central point becomes half of the original intensity. It is also observed that the initial 3rd maxima is now below the central point and the initial 4th minima is above the central point. Now, instead, a flim of refractive index μ_1 and thickness same as the above film, is put in the front of the lower slit. If is observed that whole fringe pattern shifts by one fringe width. The value of μ_1 is $\frac{\alpha\mu+\beta}{n+6}$. Find $\alpha+\beta+n$

7. In Young's double slit experiment the slits are 0.5 mm apart and interference is observed on a screen placed at a distance of 100 cm from the slits. It is found that the 9th bright fringe is at a distance of 9.0mm from the second dark fringe from the centre of the fringe pattern. The wavelength of light used is $n\times10^{-7}\,m$. Find n

8. White light is used to illuminate the two slits in Young's slit experiment. The separation between the slits is d and the distance between the screen and the slit is $D(>d)$. At a point on the screen directly in front of one of the slits, certain wavelengths are missing. The missing wavelengths are (Here $m=0,1,2,\ldots\ldots$ is an integer):

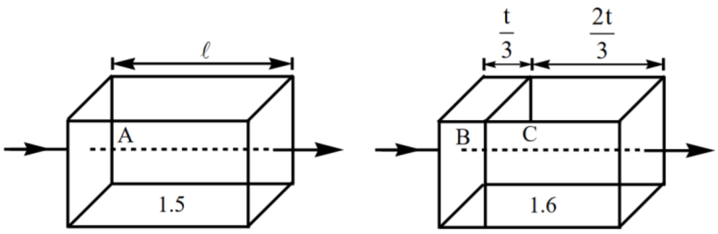
(A) $\lambda=\frac{d^2}{(2m+1)D}$

(B) $\lambda=\frac{(2m+1)d^2}{D}$

(C) $\lambda=\frac{d^2}{(m+1)D}$

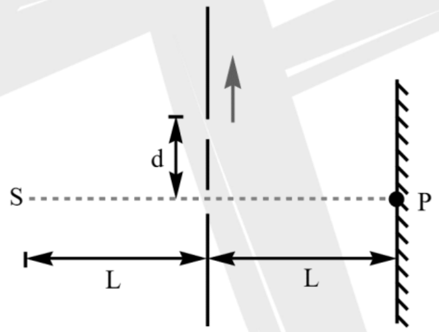
(D) $\lambda=\frac{(m+1)d^2}{D}$

9. Two transparent slabs have the same thickness as shown. One is made of material A of refractive index 1.5. The other is made of two materials B and C with thickness in the ratio 1:2. The refractive index of C is 1.6. If a monochromatic parallel beam passing through the slabs has the same number of wavelengths inside both, the refractive index of B is



(A) 0.3 (B) 0.7 (C) 0.9 (D) 1.3

10. Light from a monochromatic point source S falls on the opaque wall having two slits. Intensity of interference pattern is observed at a point P on the screen. The light source S and point P are at same distance of L = 1m from the wall. By slowly moving only the upper slit and thereby increasing the distance d between the slits, from $200\sqrt{15}\ \mu m$ to $400\sqrt{5}\ \mu m$, the intensity at point P gradually changes from maxima to 25% of maxima. Find the wavelength of light used is



(A) $3000\,\overset{o}{A}$ (B) $4000\,\overset{o}{A}$ (C) $5000\,\overset{o}{A}$ (D) $6000\,\overset{o}{A}$

11. A narrow light beam is incident on a plane – parallel plate having a refractive index of $n = \frac{17}{16}$ at an angle of $30°$ to the normal from air. As a result it is partially reflected and refracted. The refracted beam is reflected by the rear surface of the plate and then undergoes refraction again, emerging from the plate with a displacement of $4\sqrt{3}\,cm$ parallel to the primary reflected beam. Find the thickness of the plate is

(A) 5.5cm (B) 6.5cm (C) 7.5cm (D) 8.5 cm

ANSWER KEY

EXERCISE – 1-KEY

1	2	3	4	5	6	7	8	9	10
C	3	3	D	A	10	D	1	D	C
11	**12**	**13**	**14**	**15**					
C	B	C	C	1					

EXERCISE – 2-KEYS

1	2	3	4	5	6	7	8	9	10
720	D	3	3	AB	AC	B	B	C	B
11	**12**	**13**	**14**	**15**					
C	4	C	D	D					

EXERCISE – 3-KEY

1	2	3	4	5	6	7	8	9	10
40	600	C	24	C	A	10	ACD	AD	AB
11	**12**	**13**	**14**	**15**					
4	A	CD	7	6					

EXERCISE – 4-KEY

1	2	3	4	5	6	7	8	9	10
100	100	A	D	A	BC	BC	CD	D	A
11	**12**	**13**	**14**	**15**					
B	ABCD	CD	3	A					

EXERCISE – 5-KEY

1	2	3	4	5	6	7	8	9	10
2	3	A	B	9	B	8	10	A	ABC
11	**12**	**13**	**14**	**15**					
ABCD	AC	D	D	A					

PROFICIENCY TEST -1-KEY

1	2	3	4	5	6	7	8	9	10
C	6	A	2	B	B	D	AB	B	C

PROFICIENCY TEST -2-KEY

1	2	3	4	5	6	7	8	9	10
C	2	14	B	A	C	C	A	4	A

PROFICIENCY TEST-3-KEY

1	2	3	4	5	6	7	8	9	10	11
A	100	D	12	4	20	6	A	D	D	C